Politecnico di Milano
AY 2017/2018

Travlendar+

Requirement Analysis and Specification Document

Mirko Salaris, Piervincenzo Ventrella, Pietro Cassarino

October 29, 2017

Deliverable:	RASD
Title:	Requirement Analysis and Verification Document
Authors:	Mirko Salaris, Piervincenzo Ventrella, Pietro Cassarino
Version:	1.0
Date:	27-October-2017
Download page:	https://github.com/mirkosalaris/CassarinoSalarisVentrella/
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1 Introduction

1.1 Purpose

This document is the Requirement Analysis and Specification Document for the Travlendar+ application. Its aim is to inform about what the application offers, about requirements and goals that the system must present. This document offers also an analysis of the world and of the shared phenomena regarding Travlendar+. RASD contains class diagram to show domain model and other diagrams which illustrate, with more details, transactions of the functionalities of the application.

1.2 Scope

Travlendar+ is an application that allows people to organize and to track their appointments and meeting by registering them into the application. A person becomes a User of Travlendar+ by registering himself to the app. After this phase, users can start to use basic functionalities of the app (e.g. register appointments and organize meetings).
The app allows users to create appointments, eventually inviting other users of the app, facilitating communication issues. The goal of Travlendar+ is to organize in the best way all daily commitments of its users considering all the possible problems that can influence travels and trips (e.g. weather conditions, strikes, etc.).
When a User creates an event, he can add, for the travel, eventual passengers or baggage, so that the app can suggest better trip choices. Travlendar+ allows users to visualize their planned schedule too.
The dynamicity of the software allows users to set some personal preferences, for example, to set a flexible break window time for having free time or lunch, to choose eco-friendly solutions for his trips, to deactivate some transportation means.
The system interfaces with other firms (e.g. transportation companies, territory maps companies, sharing transportation companies) to offer a more comprehensive user experience. In this way, a User has the possibility to buy tickets and passes for transportation means. Moreover, the system offers a localization service for vehicles of affiliated shared transport companies but to proceed with the renting the User is redirected to the company's app.

1.2.1 Goals

[G1] a Person should be able to have his/her own Travlendar+ agenda

[G2] a User should be able to customize the offered service

- [G2]#1 specify his/her preference for eco-friendly solution
- [G2]#2 define break time windows, either flexible or fixed
- [G2]#3 define time slot in which the use of specific transportation means should be avoided
- [G2]#4 define a minimum distance below which a specific transportation mean should be avoided
- [G2]#5 define a maximum distance beyond which a specific transportation mean should be avoided
- [G2]#6 disable permanently specific transportation means

[G3] a User should be able to take note of all his/her appointments and their details

[G4] a User should be able to manage his/her appointments

[G5] for each appointment, the User should be assisted in the choice of the travel solution

- [G5]#1 travel solution suggestions must take into account traffic, weather conditions/forecast, strikes, type of appointment, baggage, passengers

[G6] a User should be able to invite other persons to his/her appointment

[G7] a User is assisted in the purchase of a ticket when it is required

[G8] a User should be able to locate the nearest vehicle of a vehicle sharing system, if that is the transportation mean of choice of an incoming appointment

[G9] a User should be able to rent a shared vehicle, if that is the transportation mean of choice of an incoming appointment

[G10] a User should always be aware of the incoming appointments and how to reach them

[G10]#1 the User should be aware of eventual complications (bad weather, traffic, strikes)

1.3 Definitions, Acronyms, Abbreviations

1.3.1 Definitions

Here we provide a list of definitions of words and expression used in the documents. Every time such words or expressions will be used they will be preceded by the symbol "(↑)" that will be a link to this section.

- ***affiliated company*:** a company (transportation company or vehicle sharing company) that has deals with the S2B.

- ***appointment details*:** time, date, type of appointment, location, number of passengers and presence of baggage.

- ***break window*:** it is a time slot in which the User specifies he/she wants to be absolutely free. In this time slot he does not want to have any appointment nor to be travelling. This is a fixed break window. A flexible break window is a time slot in which the User specifies he/she wants to have some free time, but not the full window free.

- ***incoming appointment*:** the next scheduled appointment for which the S2B send a reminder to the user. The reminder is sent a certain amount of time before the appointment starts, to allow the user to get on time in the location.

- ***personal preferences*:** with this term we mean that here the user can:
  - specify break time windows;
  - specify the interest or not for eco-friendly solutions;
  - specify constraints, such as avoiding bike, on the travel means solutions.

- ***supported languages*:** the set of languages that the S2B will be able to use to communicate with its users. English and Italian are included.

- ***valid credentials*:** Name, surname, personal email address and password.

  Name: it should be non empty and it should contain only alphabetical characters

  Surname: it should be non empty and it should contain only alphabetical characters

  Email: It should be a valid email address, with an alphanumerical string followed by a '@', followed by an alphanumerical string, a dot, and a domain name

  Password: It should be a string with at least 8 characters

- ***welcome page*:** the page where the user is redirected after completing the sign-up process and logging in for the first time. In this page, the app sequentially asks the user to insert credit-card data and set his preferences. The user can skip any of this phases and complete them at a later time. After this process, the initial settings configuration is completed.

1.3.2 Acronyms

- ***S2B*:** System to Be;

- ***API*:** Application Programming Interface.

1.3.3 Abbreviations

- ***[Gn]*:** nth goal. Apart when it is actually defined, it is always a reference to the definition of the goal

- ***[Dn]*:** nth domain assumption. Apart when it is actually defined, it is always a reference to the definition of the domain assumption

- ***[Rn]*:** nth requirement

1.4 Revision history

1.5 Document Structure

After purpose and scope, used to briefly introduce the topic, we delineated the goals that the S2B should achieve coupled with a list of useful definitions and acronyms. Subsequently, the text proceeds with an analysis of the functions that the app should provide. The analysis starts with a general exposition of the scenarios and becomes gradually more detailed passing through the analysis of the actors that will interact with the S2B and the statement of the domain assumptions. After that, the specific requirements are exposed focusing firstly on the external interfaces and then providing the models used to highlight the relations between actors and S2B and describe the internal structure of the latter. After that, Functional and non-Functional requirements are sequentially discussed. Before ending with the effort spent and the references we provide a formal analysis performed with alloy.

2 Overall Description

2.1 Product perspective

The system will be developed from scratch and it will use a lot of external services including Google services and the services provided by the (↑)*affiliated companies*. This is because the services provided by Google are of high quality and there is no point in trying to redevelop them. The services of affiliated companies are needed to interface with them and to have information on tickets and vehicles *(for Sharing Transportation Companies)*.

2.2 Product functions

Here we provide several scenarios to better delineate the purposes for which the app should be designed, the situations the S2B will deal with and more generally to have a better comprehension of the associated environment.

2.2.1 Scenario 1

Mario is the director of his company and he has seen an ad of Travlendar+, so he wants to try it to organize the weekly meetings with his employees. After the installation, he has to register to the app. The first thing he creates is his weekly program. He works from Monday to Friday, from 8 am to 16 pm. There is an actual meeting coming up on Friday at 8 pm, so he creates a new meeting in the app. After setting the time and the day, he invites his employees to join the meeting. He will remain in his office, so he will not need to use any travel means.
Giovanni is one of Mario's employee and he is registered to Travlendar+. He receives a notification and accepts the invitation to the meeting. He chooses to reach the location by walk because he will already be nearby.
Alex is another employee and does not have an account on Travlendar. He receives an email with an invitation link to register to the app. After the registration, the app redirects him to the meeting's invitation and he will proceed by accepting it and choosing to go by car. Then he explores the app and decides to add his weekly program. The app finds out that he will be in the cafe near the metro at 6:40 pm, so it suggests Alex takes the metro instead of the car. He accepts the suggestion.

2.2.2 Scenario 2

Paolo, a resident of Bergamo, has recently registered to Travlendar+ and during the initial setup has specified a flexible launch break from 11:00 am to 13:00 am, with at least 40 minutes of break.
Tomorrow he is going to have an audition at 12:30 pm, in Monza. He inserts the event in the app and after having specified that the audition will end at about 13:30pm, he looks at the suggestions of the app on the travel means to take: the app suggests him some travel solutions, but he does not specify which he's going to take because he wants to think about it overnight.
The next morning, the app sends Paolo a reminder with two travel solutions:

- go by car, leaving at about 11.45am, arriving at 12.27 pm;
- take the bus, passing at 10:49 am and arriving at 11:38 am.

He chooses the second option to avoid being late at the audition.

2.2.3 Scenario 3

Alex is a professor of Bologna University, he has a short memory and is very badly organized, so he decides to rely on Travlendar+. Alex downloads it on occasion of a work trip. He signs up and decides to insert his credit card data for an eventual purchase from the app.
He needs to reach the University of Parma to hold a conference. Alex sets up the app to arrive in Parma by train. Travlendar+ asks Alex the kind of event and he specifies it is a formal work meeting. The app asks him which transport means he wants to take in order to get to the university from the railway station. Alex opts to go by bicycle, although the app suggests not to, because of the formal type of meeting.
The departure day Alex is in a shopping center with his family, he has completely forgotten that he has a train to take, but Travlendar+ solves the problem by notifying him of the appointment. At that point, Alex has no more time and chooses to buy the train tickets using the app. While he is on the

train, Travlendar+ suggests him to choose another transport means (instead of a bike) because of the bad weather conditions. Alex accepts the advice and decides to take a bus.

2.2.4 Scenario 4

Luca is a meteorologist who works for a laboratory in Venice. He knows very well all the climatic problem that humans are creating in their Country. Luca finds Travlendar+ very appropriate to help in solving this problematic. He likes to opt for an Eco-friendly solution by setting up this preference in the app settings. In this way he can avoid, at least in this aspect, further damaging the environment. His favorite functionality is bike sharing because of its innovative localization system and its low environmental impact.

2.2.5 Scenario 5

Mark, son of Lucas, asks his father to bring him to the basketball tournament of Sunday morning.
Lucas checks the daily schedule for Sunday and he notices he already has an appointment with the hairdresser but, of course, spending time with his son is more important, so he decides to delete the previous event on the agenda and set a new one.
Mark asks the father whether also his teammate Mike can come. Of course, Mark and Mike have to bring with them the bags with the jersey and the basketball shoes, so Lucas, creating the event on Travlendar+, after specifying the location of the basketball court, specifies also that he will bring baggage and there will be passengers.
Unfortunately, his car is broken, so Lucas uses the app to look for alternative solutions.
Travlendar+, taking into account the constraints previously settled by the man, suggests to him to use Enjoy or SmartToGo, two well-known car sharing companies that will solve his problem.
Lucas accepts the suggested solution and proceeds with the creation of the event.

2.2.6 Scenario 6

Mary, John's wife, one week ago, asked her husband to pick the children up to school on Monday at 13.00 and, knowing John, forced him to take note of that with Travlendar+.
So John planned this event on the app specifying that he will use the car to do it. He specified also the location of the school.
On Monday morning, as usual, Travlendar+ shows to John his daily program reminding him about his children and showing the previous travel mean planned.
John, still intentioned to pick the children up with the car, does not modify the plan, closes the app and goes to work on the other side of Milan.
At 12.00 Travlendar+, according to the GPS position of the man, suggests him to leave in 15 minutes. Travlendar+ also suggests avoiding to go through Viale Gioia because of the traffic and take the SS1.
Thanks to Travlendar+ John manages to be on time, collect the children and make his wife proud of him.

2.3 User characteristics

2.3.1 Actors

- Person: a person that does not have a registered account. The only thing that he/she can do is to proceed with the Sign Up process;
- User: a person passed through a successful registration process and now able to use all the Travlendar+ services. He/she can login to the system and, after that, use all the platform's functionalities.
- Credit Institution: the institution that checks the credit-card validity and reports it to the S2B;
- Google: the system with whom the S2B retrieves the maps and related information about routes, real-time traffic situations, estimated travel time and weather conditions;
- Transport Company System: the system of the affiliated companies with whom the S2B interacts to allow the user to buy the tickets for the associated travel mean;

- Shared Vehicle Company System: the system with whom the S2B interacts to allow the user to visualize the map of the available vehicles to rent and locate the nearest one. Vehicle Company System provides the GPS locations of the vehicles. To proceed with the renting the user is redirected to the vehicle Company System/App.

2.4 Assumptions, dependencies and constraints

2.4.1 Text Assumptions

- credit cards do not have an expiration date

2.4.2 Domain Assumptions

[D1] the User's device should allow the app to retrieve the language settings

[D2] when the registration process begin, the Person always inserts his/her credentials

[D3] when the S2B sends an email, it is always received by the receiver

[D4] every Person has an email address

[D5] the User shall remember his password

[D6] the User knows only his password

[D7] the User's device has a working GPS installed, to which the app has access

[D8] the affiliated shared vehicle companies provide a localization service APIs

[D9] Google Maps services take traffic into consideration

3 Specific Requirements

3.1 External Interface Requirements

3.1.1 User Interfaces

Here we provide some basic mockups to show how the interface should appear to the user:

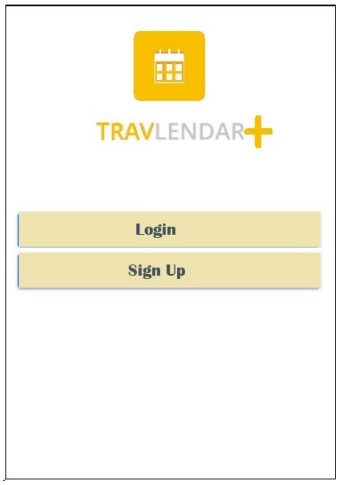


Figure 1: Login

Figure 2: Select solution

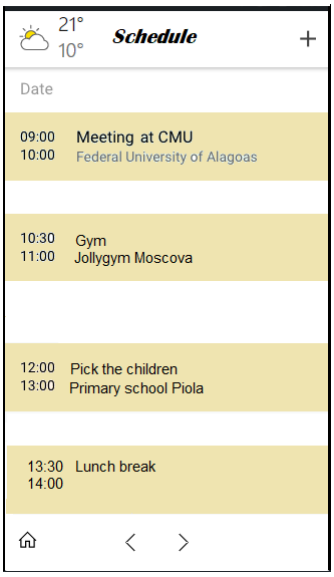


Figure 3: Visualize schedule

3.1.2 Hardware Interfaces

The main hardware interface of the system consists in the access to the GPS data in the mobile application. The application also requires Internet connectivity and internal storage access.

3.1.3 Software Interfaces

The mobile application must support Android, iOS and the remaining main OSs (further details are discussed in paragraph 3.6.5 Portability). The web application works on any web server that supports Java. The back-end stores its data in a DBMS and can run on every platform that supports the JVM.

3.1.4 Communication Interfaces

The communication between clients and server should be HTTP requests/responses based.

3.2 UML modeling

In this section, we formalize the S2B in terms of UML models.
We divided the Use Case Diagrams into parts to slightly improve the readability of the Diagrams. After the Diagrams, descriptions of the main Use Cases are provided.
After that we provide a Class Diagram of the whole system and then some Activity Diagrams, to better explain the structure of the S2B and its behavior.
Other types of diagrams have been considered, but we eventually realized them to not provide, at this stage, any other notable information about the system.

3.2.1 Use Case diagram

Figure 4: Person Use Case Diagram

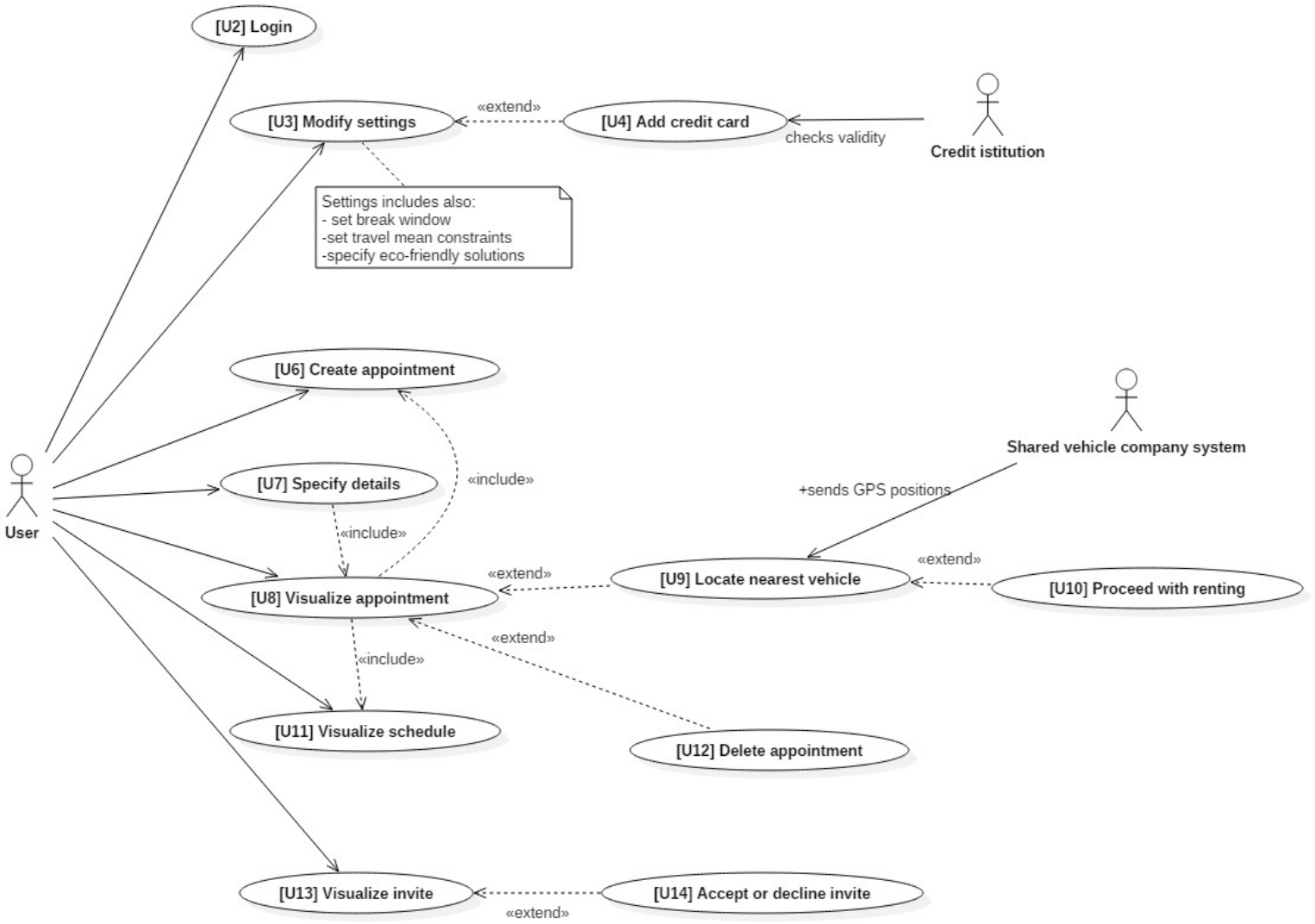


Figure 5: User Use Case Diagram

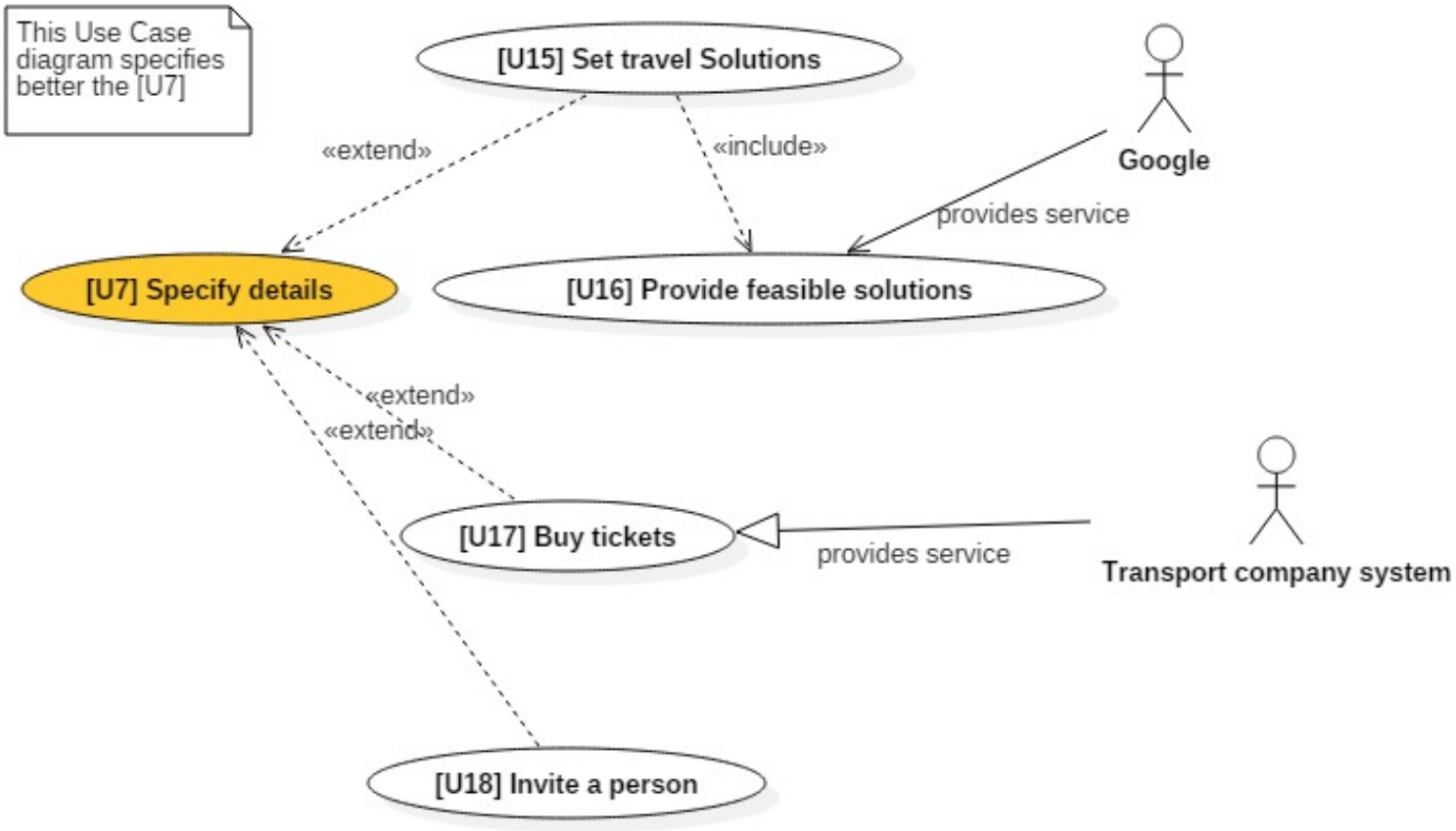


Figure 6: "Specify Details" Use Case

User creates appointment

Use case:	User creates an appointment
Actors:	User
Entry condition:	The user must be logged
Flow of events:	The user creates an appointment giving it a name; User specifies the time and date of the appointment; User specifies the location of the appointment; User specifies the type of the appointment; User specifies details such as passengers or baggage; User selects a travel mean taking into account app's suggestions; The app takes note of the settings and send a confirmation; The app redirects the User to the main page.
Secondary flows:	User does not specify a travel mean and let it blank; The app takes anyway note of the setting and alert the user of the missing information; The app redirects the user to the main page.
Exceptions:	Warnings messages are created in the following cases: • User creates an appointment that overlaps with another appointment; • User creates an appointment with a location that is unreachable in the allocated time; • User creates an appointment that violates the set constraints about the break windows.
Post conditions:	The user is successfully redirected to the main page.

Sign Up

Use case:	Sign Up
Actors:	Person
Entry condition:	none;
Flow of events:	the Person inserts (↑)*valid credentials*; the app sends an email with the confirmation link; the Person gives the confirmation through the link on the mail; the app shows the (↑)*welcome page* to the new User.
Secondary flows:	none.
Exceptions:	the person inserts non (↑)*valid credentials*; the sign-up cannot proceed.
Post conditions:	the person is successfully signed up and become an actual User.

Initial settings configuration

Use case:	Initial settings configuration
Actors:	User
Entry condition:	the User has just completed the sign up process; User must be logged.
Flow of events:	User inserts sequentially the following information: • Credit card; • Break time windows; • Interest for Eco-friendly solutions on the travel means. • Constraints on travel means. The app, for each step, checks the info and sends a confirmation; The app redirects the User to the main page.
Secondary flows:	User skips specifying one or more information that could be specified later in the settings. The app notifies the user about the missing information and redirects anyway the user to the main page.
Exceptions:	user inserts inconsistent information (incorrect credit-card information, break time shorter than 30 minutes); The app alerts the user and asks him to insert again the info.
Post conditions:	the set (↑)*preferences* are successfully saved and the user is redirected to the main page.

User specifies the appointment

Use case:	User specifies appointment's details.
Actors:	User
Entry condition:	User must be logged; the appointment must exist;
Description:	User specifies or modifies basic details (time, date, location, type of appointment, number of passengers and the presence of baggage) and eventually: • If not specified yet, sets a transportation mean; • Modifies the previous transportation mean; • Buys a ticket for the transportation mean; • Invites a person.

User buy travel ticket

Use case:	User buys travel ticket
Actors:	User
Entry condition:	User must be logged; User must have added a payment card.
Flow of events:	User selects an appointment; User, through the app, searches for tickets for the specified transportation mean; User selects the ticket's option and picks one; User proceeds with the payment; The payment operation ends successfully; The app sends a confirmation and redirects the User to the main page;
Secondary flows:	none
Exceptions:	The payment is rejected (not enough credit, expired card, ..); The app notifies the User; The app redirects the User to the main page;
Post conditions:	User successfully books the tickets and is redirected to the main page.

3.2.2 Class diagram

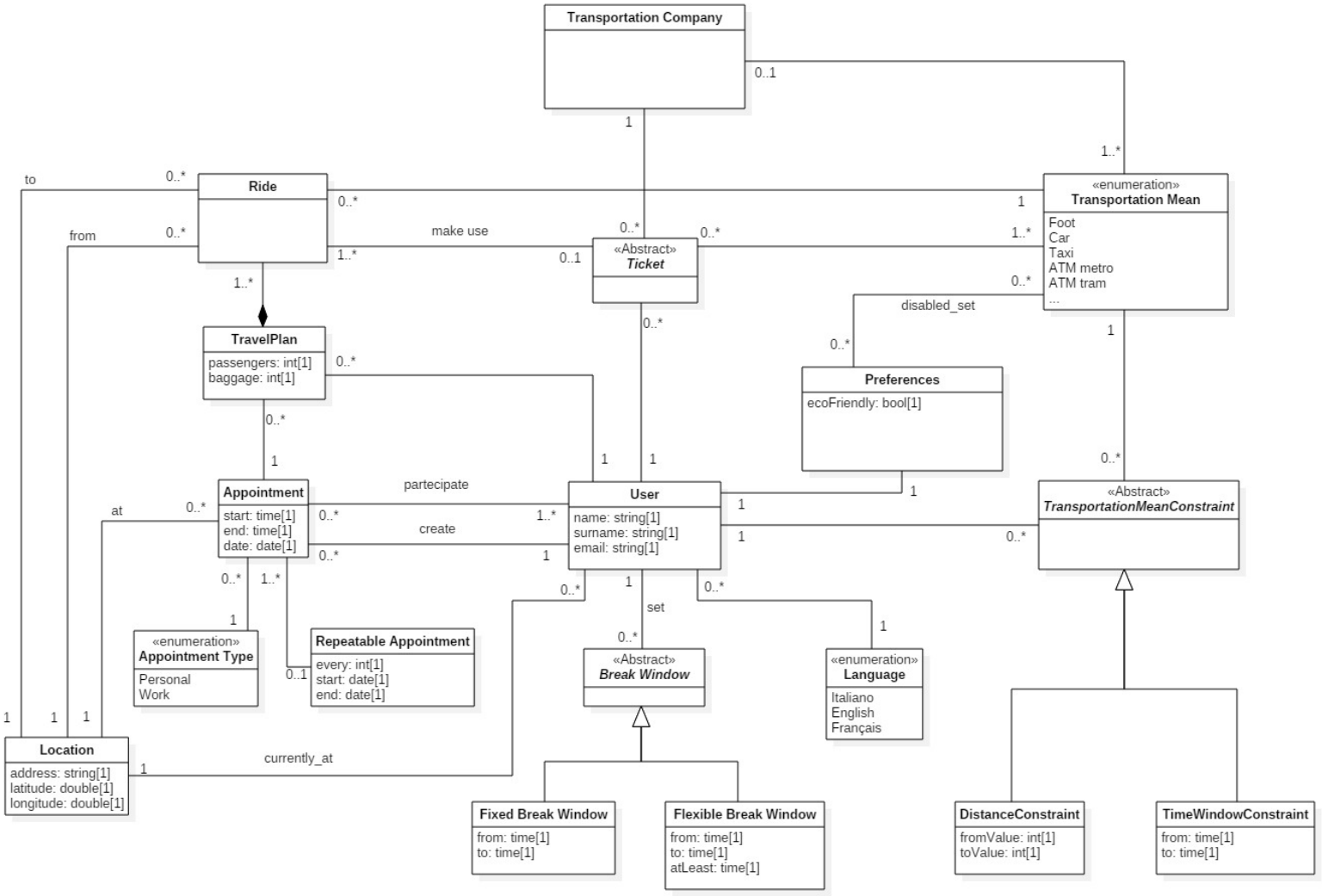


Figure 7: General Class Diagram

3.2.3 Activity diagrams

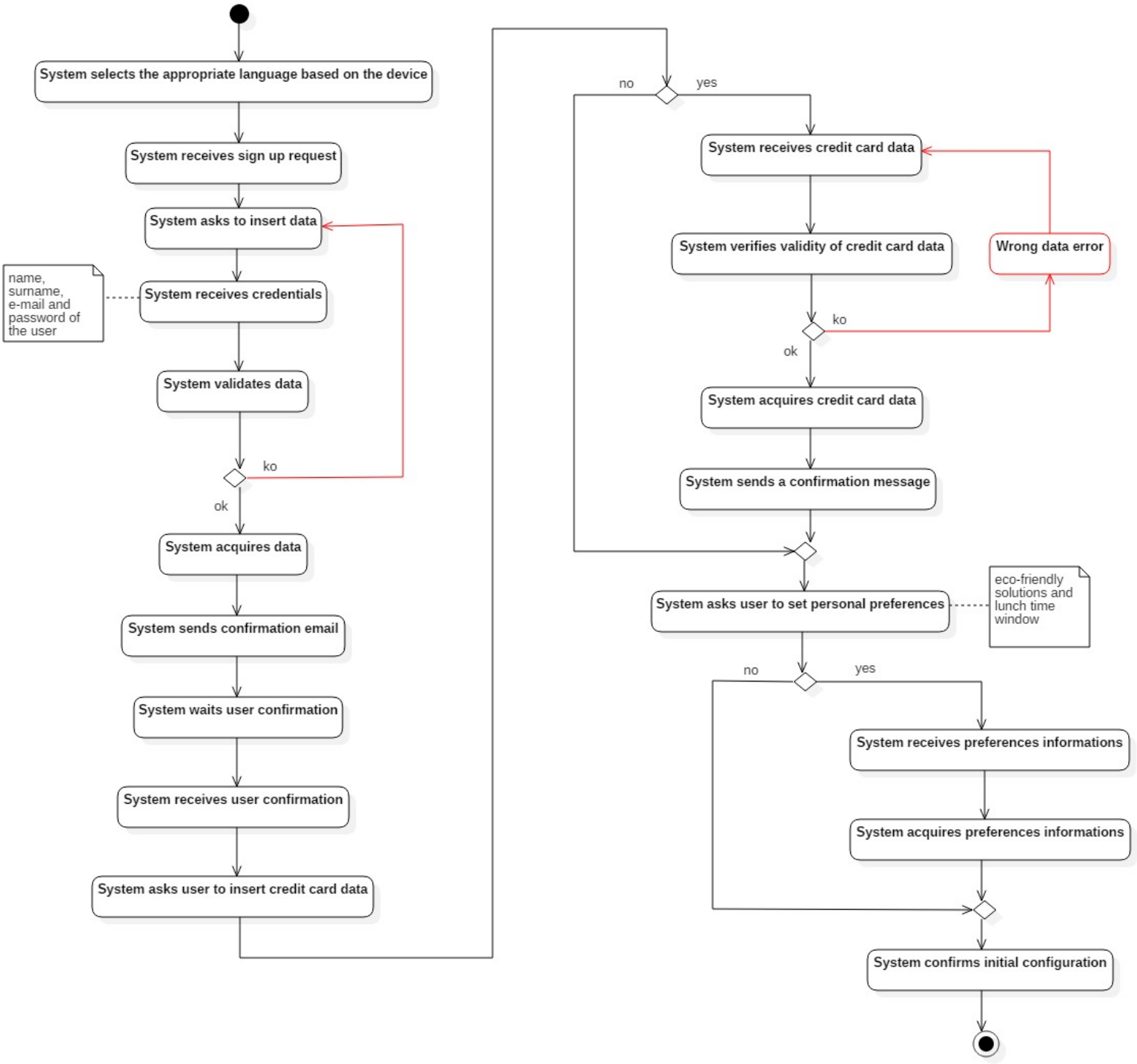


Figure 8: Registration Activity Diagram

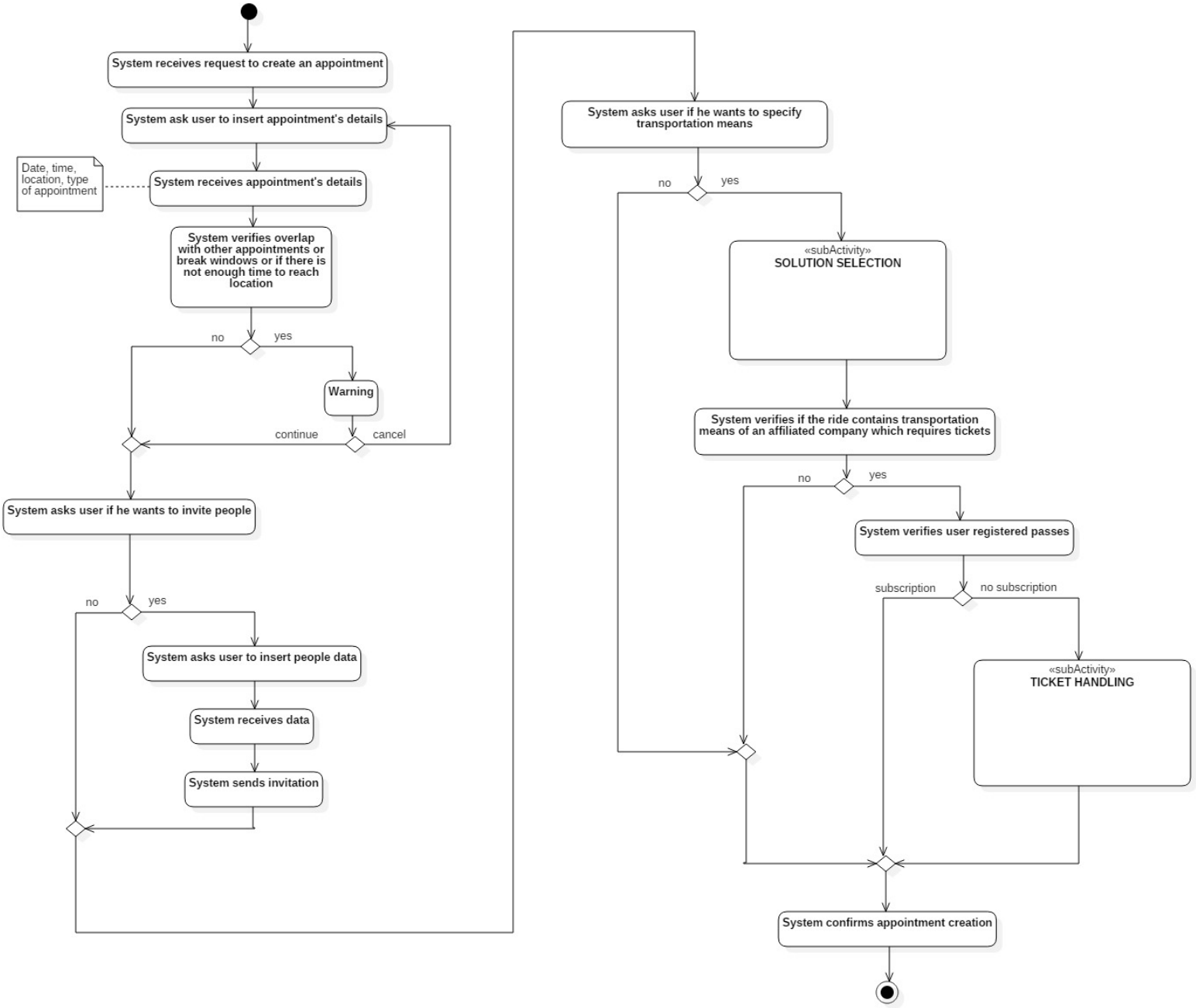


Figure 9: Creation appointment Activity Diagram

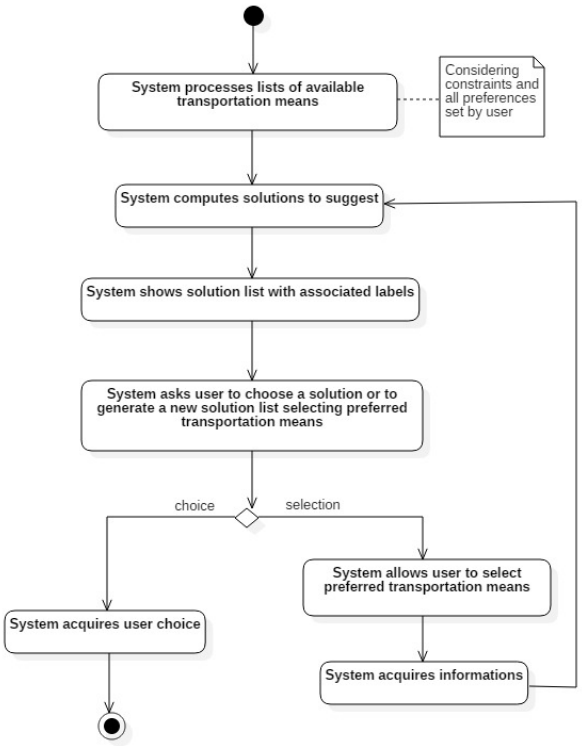


Figure 10: Solution selection Sub-Activity Diagram

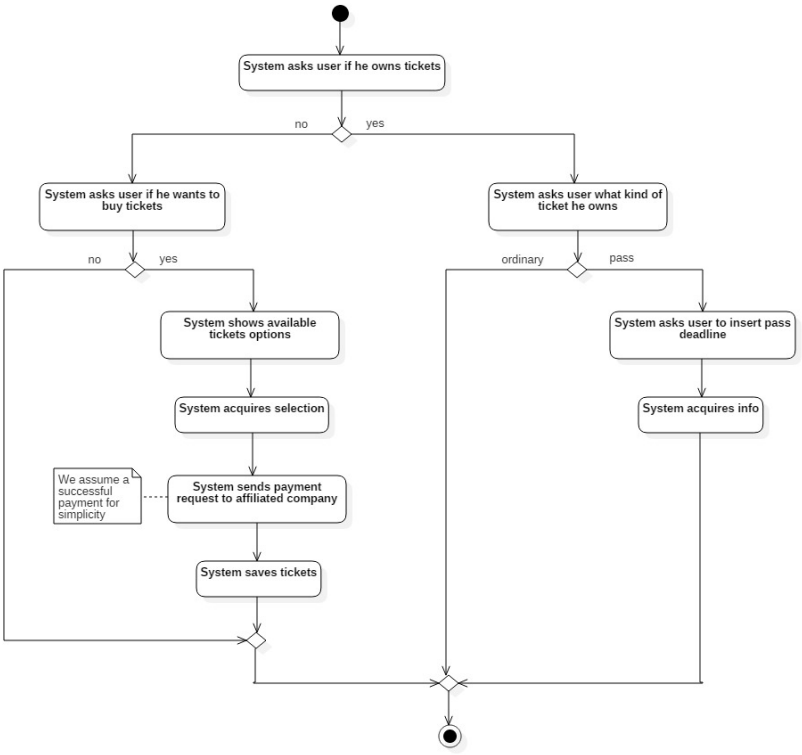


Figure 11: Ticket handling Sub-Activity Diagram

3.3 Functional Requirements

[G1] a Person should be able to have his/her own Travlendar+ agenda

[R1] the S2B must provide to every Person a way to begin the registration process

[R2] after the insertion of the credentials and their (↑)*validation*, the S2B has to send to the provided address an email with an activation link

[R3] the registration fails if the inserted email is already associated to an account

[R4] when the Person confirms through the activation link, he/she becomes a User

[R5] in the case of non (↑)*valid credentials*, the system must reject them and restart the registration process

[R6] the S2B must grant access to the User if and only if the User inserts an existing email and the associated password

[D2] when the registration process begin, the Person always inserts his/her credentials

[D3] when the S2B sends an email, it is always received by the receiver

[D4] every Person has an email address

[D5] the User shall remember his password

[D6] the User knows only his password

[G2] a User should be able to customize the offered service

[R7] for each type of (↑)*preference*, the S2B must provide the User the possibility to set or change the value(s)

[R8] for each type of (↑)*preference*, the S2B must store the preference value(s)

[G3] a User should be able to take note of all his/her appointments and their details

[R9] the system must provide a way to start the creation of a new appointment

[R10] during the process the user shall insert the (↑)*appointment details*

[G4] a User should be able to manage his/her appointments

[R11] existing appointments can be viewed together as a schedule view

[R12] the schedule can be daily or weekly

[R13] from the schedule view, the system provides a way to visualize a single appointment and its details

[R14] after visualizing an appointment, the User who created it, can choose to edit its details

[R15] in the schedule view the User can select one or more appointments

[R16] in the schedule view, selected appointments can be deleted

[G5] for each appointment, the User should be assisted in the choice of the travel solution

[R17] when time and location of the current appointment are set, the S2B produces a list of travel solutions with associated suggestions

[R18] the S2B provide the user the possibility to choose one of the suggested travel solutions or leave the travel plan unspecified

[R19] the S2B also provides the possibility to choose a preferred transportation mean

[R20] when a new preferred transportation mean is selected the S2B has to recompute the list of solutions according to the new preference

[R21] if weather forecast are bad: foot, bicycle motorbike are discouraged

[R22] if strikes have been announced, public transport is discouraged

[R23] in case of baggage or passengers a car is recommended

[R24] in case of a work appointment, bicycle is discouraged

[D9] Google Maps services take traffic into consideration

[G6] a User should be able to invite other persons to his/her appointment

[R25] when time and location of the current appointment are set, the S2B offers the possibility to invite other Users or Persons, through their emails

[R26] when a User or a Person is invited, the S2B will inform him/her sending an email

[D3] when the S2B sends an email, it is always received by the receiver

[G7] a User is assisted in the purchase of a ticket when it is required

[R27] the S2B must accept credit card data from the User

[R28] the S2B must forward the credit card data to a credit institution to validate them

[R29] the S2B must let the User use the credit card if and only if the inserted credit card data are valid

[R30] when the user selects a travel solution for which a ticket is expected, the S2B asks the User to specify if he/she owns a ticket (either ordinary or a pass, in which case the deadline has to be inserted)

[R31] if the user has selected a travel solution for which a ticket is expected and the User said to not own a ticket, the S2B asks him/her to buy a ticket (options available only for transportation means of (↑)*affiliated companies*)

[G8] a User should be able to locate the nearest vehicle of a vehicle sharing system, if that is the transportation mean of choice of an incoming appointment

[R32] when a user visualizes an incoming appointment for which a shared vehicle of an affiliated company has to be used, the S2B provides a localization service

[D7] the User's device has a working GPS installed, to which the app has access

[D8] the affiliated shared vehicle companies provide a localization service APIs

[G9] a User should be able to rent a shared vehicle, if that is the transportation mean of choice of an incoming appointment

[R33] after the User has localized a vehicle, the S2B offers the possibility to rent it

[R34] when the User selects the vehicle to rent, the app redirects him/her to the right company's app or site

[G10] a User should always be aware of the incoming appointments and how to reach them

[R35] when an appointment becomes incoming, the S2B sends a notification to the User

[R36] if a travel plan has not already been set by the User, the notification suggests one

[R37] if a travel plan has already been chosen but some complications (bad weather, traffic, strikes) have arisen the User is informed and a new feasible solution is suggested

3.4 Performance Requirements

The system has to be able to respond to a possibly great number of simultaneous requests and more generally to a great number of request throughout the day. The S2B, at least for the start, will only be available for the Lombardy region. Based on demographic analysis (number of inhabitants, number of people under the age of 60, number of smartphones sold over the past 2 years), it was decided to design the S2B to support 100,000 users simultaneously, but scalability needs to be guaranteed.

3.5 Design Constraints

3.5.1 Standard compliance

To ensure interoperability the S2B will follow the W3C web standard and will be as adherent as possible to code practices in relation to the use of HTML/XHTML, CSS and Java programming language. Moreover, the use of non-opensource libraries will be avoided.

3.5.2 Hardware limitations

- Mobile App:
  * 3G connection
  * GPS
  * Space for app package
- Web App:
  * Modern browser able to retrieve User's location

3.5.3 Any other constraint

Regulatory policies
The system will ask for users' payment information and obviously, in addition to store them safely, will use them only for fees and rides payments. Moreover, the system will have to ask for users' permission in order to retrieve and use their positions. Email addresses will not be used for commercial uses.

3.6 Software System Attributes

3.6.1 Reliability

The system must guarantee a 24/7 service. Very small deviations from this requirement will be obviously acceptable.

3.6.2 Availability

The S2B must guarantees a 3-nines availability (99.9 percent) with a downtime not greater than 8 hours per year.

3.6.3 Security

User credentials and payment information will be stored. Data confidentiality is a primary concern. In addition, when the user wants to buy tickets or rent a shared vehicle, the stored information must be sent to affiliated transport Company systems or shared vehicle Company systems. To ensure the security and the confidentiality of this information, the S2B must be able to adopt access management protocols and communication protocols able to prevent not granted access and/or Sniffing/Spoofing activities performed by thirds.

3.6.4 Maintainability

The S2B must be designed in a way to easily correct defects or their cause, repair or replace faulty or worn out components without having to replace still working parts, prevent unexpected working condition, maximize its useful life, maximize efficiency, reliability, and safety, meet new requirements, make future maintenance and cope with a changed environment.

3.6.5 Portability

The S2B must be able to run in all main mobile OS *Android, iOS, Windows-Phone OS)* and to be supported by all the main Web Browser *(Google Chrome, Safari, Firefox, Microsoft Edge)*.

4 Formal Analysis Using Alloy

4.1 Alloy Code

```
// ============================================== PRIMITIVE SIGNATURES
sig Name {}

sig Surname {}

sig Email {}

sig Address {}

sig Double {}

enum Bool {
        True,
        False
        }

// ============================================== SIGNATURES
sig Time {
        value: Int
        } { value ≥ 0 }

sig Date {
        value: Int
        } { value ≥ 0 }

sig Ride {
        makeUseTicket: lone Ticket,
        byTranMean: TransportationMean,
        fromLocation: Location,
        toLocation: Location
        }       { fromLocation ≠ toLocation }

sig TransportationCompany {}

abstract sig Ticket {
        usedFor: some TransportationMean,
        providedByCompany: TransportationCompany
        }

sig User {
        name: Name,
        surname: Surname,
        email: Email,
        ownsTicket: set Ticket,
        hasPreferences: Preferences,
        hasConstraints: set TransportationMeanConstraint,
        speaksLanguage: Language,
        setBreakWindows: set BreakWindow,
        createsAppointment: set Appointment,
        participatesToAppointment: set Appointment,
        hasTravelPlan: set TravelPlan,
```

```
54          currentlyAtLoc: Location
55          }
56
57  sig Appointment {
58          id: Int,
59          start: Time,
60          end: Time,
61          atLocation: Location,
62          hasType: AppointmentType,
63          isRepeatable: lone RepeatableAppointment,
64          isModified: Bool,
65          isIncoming: Bool
66          } { start.value < end.value }
67
68  sig Location {
69          address: Address,
70          latitude: Double,
71          longitude: Double
72          }
73
74  enum AppointmentType {
75          Personal,
76          Work
77          }
78
79  sig RepeatableAppointment {
80          every: Int,
81          start: Date,
82          end: Date
83          } { every > 0
84                      start.value < end.value }
85
86  sig TravelPlan {
87          passengers: Int,
88          baggage: Int,
89          startRide: Ride,
90          intermediateRides: set Ride,
91          endRide: Ride,
92          forAppointment: Appointment
93          } {
94                  passengers ≥ 0
95                  baggage ≥ 0
96
97                  // structural constraints on start, intermediate and end
                        ↪ Rides
98                  no ir: intermediateRides | startRide = ir or endRide = ir
99                  lone ir: intermediateRides | startRide.toLocation = ir.
                        ↪ fromLocation
100                 lone ir: intermediateRides | endRide.fromLocation = ir.
                        ↪ toLocation
101                 no ir: intermediateRides | startRide.fromLocation = ir.
                        ↪ toLocation
102                 no ir: intermediateRides | endRide.toLocation = ir.
                        ↪ fromLocation
103                 all ir: intermediateRides | ir.toLocation = endRide.
                        ↪ fromLocation or
```

```
104                         one ir1: intermediateRides | ir.toLocation = ir1.
                               ↪ fromLocation
105                 all ir: intermediateRides | ir.fromLocation = startRide.
                       ↪ toLocation or
106                         one ir1: intermediateRides | ir.fromLocation =
                               ↪ ir1.toLocation
107                 #intermediateRides = 0 implies
108                         (startRide = endRide or startRide.toLocation =
                               ↪ endRide.fromLocation)
109                 }
110
111 // retrieves the whole set of Rides of a travel plan
112 fun travelPlanRides[t: TravelPlan] : some Ride {
113         t.startRide + t.intermediateRides + t.endRide
114 }
115
116 abstract sig BreakWindow {}
117
118 sig FixedBreakWindow extends BreakWindow {
119         from: Time,
120         to: Time
121         } { from.value < to.value }
122
123 sig FlexibleBreakWindow extends BreakWindow {
124         from: Time,
125         to: Time,
126         atLeast: Time
127         } { from.value < to.value
128                   (atLeast.value > 0 and atLeast.value < minus[to.@value,
                          ↪  from.@value]) }
129
130 enum Language {
131         Italiano,
132         English,
133         Francais
134         }
135
136 abstract sig TransportationMean {
137         belongsToCompany: lone TransportationCompany
138         }
139
140 one sig Foot, MoBike, PersonalCar, EnjoyCar, Metro, Tram extends
       ↪ TransportationMean {}
141
142 sig Preferences {
143         ecoFriendly: Bool,
144         disabledTranMean: set TransportationMean
145         }
146
147 abstract sig TransportationMeanConstraint {
148         associatedToTranMean: TransportationMean
149         }
150
151 sig DistanceConstraint extends TransportationMeanConstraint {
152         fromValue: Int,
153         toValue: Int
154         } { fromValue ≥ 0
```

```
155                     toValue ≥ 0
156                     fromValue < toValue }
157
158 sig TimeWindowConstraint extends TransportationMeanConstraint{
159         from: Time,
160         to: Time
161         } { from.value < to.value }
162
163 // ================================================
164 // ========================= ADDITIONAL SIGNATURES
165 sig SuggestedSolution {
166         suggestsTo: User,
167         containsTravelPlan: TravelPlan
168         }
169
170 sig Device {
171         belongsTo: User,
172         language: Language
173 }
174
175 sig AppInstance{
176         installedOn: Device,
177         displayLanguage: Language
178 }{ let d = installedOn |
179                         ( d.language not in SupportedLanguages.
                                ↪ setOfLanguages implies ( displayLanguage =
                                ↪ English )
180                         else (displayLanguage = d.language) )
181                         }
182
183
184 one sig SupportedLanguages {
185         setOfLanguages: set Language
186 }
187
188 sig Person {
189         name: Name,
190         surname: Surname,
191         email: Email,
192         isUser: lone User
193 }
194
195 sig Invitation {
196         fromUser: User,
197         toEmail: Email,
198         forAppointment: Appointment
199 }{
200         forAppointment in fromUser.createsAppointment
201         fromUser.email ≠ toEmail
202 }
203
204 sig Notification {
205         toUser: User,
206         incomingAppointment: Appointment
207 }
208
209 // ================================================
```

```
// ========================== FACTS
fact EmailsAreUnique {
        all disjoint u1, u2: User | u1.email ≠ u2.email
        }

fact NoOverlappingLocations {
        all disjoint l1, l2: Location | (l1.latitude ≠ l2.latitude) ∨ (l1
            ↪ .longitude ≠ l2.longitude)
        }

fact TimeIsUnique {
        all disjoint t1, t2: Time | t1.value ≠ t2.value
        }

fact ATicketBelongsOnlyToOneUser {
        all disjoint u1, u2: User | u1.ownsTicket & u2.ownsTicket = none
        }

fact TicketMustBeAssociatedToRides {
        all t: Ticket | some r: Ride | t in r.makeUseTicket
        }

fact APreferenceBelongsOnlyToOneUser {
        all disjoint u1, u2: User | u1.hasPreferences & u2.hasPreferences
            ↪  = none
        }

fact TranMeanConstraintsRefersOnlyToOneUser {
        all disjoint u1, u2: User | u1.hasConstraints & u2.hasConstraints
            ↪  = none
        }

fact ABreakWindowIsSetOnlyByOneUser {
        all disjoint u1, u2: User | u1.setBreakWindows & u2.
            ↪ setBreakWindows = none
        }

fact AnAppointmentIsCreatedOnlyByOneUser {
        all disjoint u1, u2: User | u1.createsAppointment & u2.
            ↪ createsAppointment = none
        }

fact AppointmentsMustBeCreatedOnlyByUsers {
        all a: Appointment | some u: User | a in u.createsAppointment
        }

fact ATravelPlanBelongsOnlyToOneUser {
        all disjoint u1, u2: User | u1.hasTravelPlan & u2.hasTravelPlan =
            ↪  none
        }

// if an appointment is associated to a travel plan of a User, the User
    ↪ must participate to the appointment
fact ConsistentUserTravelPlanAppointment {
        all u: User, a: Appointment, tp: TravelPlan |
        (tp.forAppointment = a and tp in u.hasTravelPlan) implies (a in u
            ↪ .participatesToAppointment)
```

```
259         }
260
261 fact AppointmentCreationImpliesParticipation {
262         all u: User, a: Appointment |
263         (a in u.createsAppointment) implies (a in u.
                ↪ participatesToAppointment)
264         }
265
266 fact AllNameMustBelongToUsers {
267         all n: Name | some u: User | u.name = n
268         }
269
270 fact AllSurnameMustBelongToUsers {
271         all s: Surname | some u: User | u.surname = s
272         }
273
274 fact AllEmailMustBelongToPersons {
275         all e: Email | some p: Person | p.email = e
276         }
277
278 fact AllAddressesMustBelongToLocations {
279         all a: Address | some loc: Location | loc.address = a
280         }
281
282 fact TicketMustBelongToUsers {
283         all t: Ticket | some u: User | t in u.ownsTicket
284         }
285
286 fact AllTicketsMustBeProvidedByTranCompany {
287         all t: Ticket | some tc: TransportationCompany | t.
                ↪ providedByCompany = tc
288 }
289
290 fact TranCompanyMustBeAssociatedWithTranMean {
291         all tc: TransportationCompany | some tm: TransportationMean | tm.
                ↪ belongsToCompany = tc
292         }
293
294 // no tickets for personal and shared transportation means
295 fact TicketsUsedOnlyIfNecessary {
296         all t: Ticket | (Foot & t.usedFor = none) and
297         (MoBike & t.usedFor = none) and
298         (PersonalCar & t.usedFor = none) and
299         (EnjoyCar & t.usedFor = none)
300         }
301
302 fact NoTranCompanyForPersonalTranMeans  {
303         (Foot.belongsToCompany = none) and
304         (PersonalCar.belongsToCompany= none)
305         }
306
307 fact PreferenceMustBelongToUser {
308         all p: Preferences | some u: User | u.hasPreferences = p
309 }
310
311 fact TranMeanConstraintsMustBelongToUsers {
```

```
312         all tmc: TransportationMeanConstraint | some u: User | tmc in u.
                ↪ hasConstraints
313         }
314
315 fact BreakWindowMustBeSetByUsers {
316         all bw: BreakWindow | some u: User | bw in u.setBreakWindows
317         }
318
319 fact RideMustBelongToTravelPlans {
320         all r: Ride | some tp: TravelPlan | r in travelPlanRides[tp]
321         }
322
323 fact RideBelongsToOnlyOneTravelPlan {
324         all disjoint tp1, tp2: TravelPlan | travelPlanRides[tp1] &
                ↪ travelPlanRides[tp2] = none
325 }
326
327 fact TravelPlanMustBelongToUsers {
328         all tp: TravelPlan | some u: User | tp in u.hasTravelPlan
329         }
330
331 fact LocationAssociatedToRideAppointmentOrUser {
332         all l: Location | some r: Ride, a: Appointment, u: User |
333         l in (r.fromLocation + r.toLocation + a.atLocation + u.
                ↪ currentlyAtLoc)
334         }
335
336 fact RepeatableAppointmentIsAnAppointment {
337         all ra: RepeatableAppointment | some a: Appointment | ra in a.
                ↪ isRepeatable
338         }
339
340 fact RepeatableAppointmentsAtTheSameTime {
341         all a1, a2: Appointment | (a1.isRepeatable = a2.isRepeatable)
                ↪ implies
342         (a1.start = a2.start and a1.end = a2.end)
343         }
344
345 fact NoStartRideFromAppointmentLocation {
346         all tp: TravelPlan | tp.startRide.fromLocation ≠ tp.
                ↪ forAppointment.atLocation
347 }
348
349 // before registraion we have a person, after registration we have
        ↪ another person who is a User;
350 //person associated with User and person before registration have the
        ↪ same data (email, name, surname)
351 fact EveryUserHasA2Person {
352         all u: User | some disjoint p1, p2: Person | p1.isUser = u and
                ↪ samePerson[p1, p2]
353 }
354
355 fact SameEmailImpliesSamePerson {
356         all p1, p2: Person | p1.email = p2.email implies (samePerson[p1,
                ↪ p2])
357 }
358
```

```
// if two persons are the same, they represent the person before and after registration
fact SamePersonImpliesOldAndNew {
        all disjoint p1, p2: Person | samePerson[p1, p2] implies
                ((p1.isUser = none and p2.isUser ≠ none) or (p1.isUser ≠ none and p2.isUser = none))
}

fact UserAndPersonSameData {
        all p: Person | p.isUser ≠ none implies
                let u = p.isUser |
                p.email = u.email and
                p.name = u.name and
                p.surname = u.surname
}

fact IsModifiedImpliesAnotherAppointment {
        all apOld: Appointment | some apNew: Appointment |
                apOld.isModified = True implies
                apOld.id = apNew.id and apOld ≠ apNew and apNew.isModified = False
}

fact SameAppointmentIdSameUser {
        all disjoint ap1, ap2: Appointment | all u: User |
                ap1.id = ap2.id and
                (ap1 in u.participatesToAppointment implies (ap2 in u.participatesToAppointment))
                and
                (ap1 in u.createsAppointment implies (ap2 in u.createsAppointment))
}

fact AllUsersMustBeCreatorOrInvited {
        all a: Appointment, u: User | a in u.participatesToAppointment implies
        (a in u.createsAppointment or invitedToAppointment[u, a])
}

fact NotificationOnlyIfAppointmentIsIncoming {
        all n: Notification | n.incomingAppointment.isIncoming = True
}

fact NotificationForAllIncomingAppointment {
        all a: Appointment, u: User |
        (a.isIncoming = True and a in u.participatesToAppointment)
        implies
        (one n1: Notification | n1.incomingAppointment = a and n1.toUser = u)
}

fact UserReceivesNotificationOfOwnedAppointments {
        all n: Notification, u: User |
                n.toUser = u implies n.incomingAppointment in u.participatesToAppointment
}

```

```
408 fact EachDeviceHasMaxOneAppInstance {
409         all d: Device | lone a: AppInstance | a.installedOn = d
410 }
411
412 fact EveryUserHasAtLeastOneAppInstance {
413         all u: User | some a: AppInstance | a.installedOn.belongsTo = u
414 }
415
416 fact TravelPlanAppointmentLocationConsistency {
417         all tp: TravelPlan, ap:Appointment  | ap=tp.forAppointment
            ↪ implies (ap.atLocation=tp.endRide.toLocation)
418  }
419
420 fact OneConstraintPerTravelMean {
421         all u:User, tc1, tc2:TransportationMeanConstraint | ( tc1  in u.
            ↪ hasConstraints and tc2 in u.hasConstraints
422         and  tc1.associatedToTranMean = tc2.associatedToTranMean )
            ↪ implies (tc1 = tc2)
423 }
424
425 fact TicketWithOneUser{
426         all t:Ticket | one u:User | t in u.ownsTicket
427 }
428
429 fact TicketWithAtLeastOneRide{
430         all t:Ticket | some r:Ride | r.makeUseTicket = t
431 }
432
433 fact TicketConsistency{
434         all t:Ticket, r:Ride, u:User, tp:TravelPlan | ( r in (tp.
            ↪ startRide + tp.intermediateRides + tp.endRide)
435         and tp in u.hasTravelPlan and r.makeUseTicket = t ) implies t in
            ↪ u.ownsTicket
436 }
437
438 // if a User has disabled a transportation mean, it should never be
    ↪ suggested to him/her
439 fact DisabledTranMeansAreNotSuggested {
440         all u: User, s: SuggestedSolution, tp: TravelPlan |
441                 (u = s.suggestsTo and (tp in u.hasTravelPlan) and tp = s.
                    ↪ containsTravelPlan) implies (
442                 (u.hasPreferences.disabledTranMean & s.containsTravelPlan
                    ↪ .startRide.byTranMean = none) and
443                 (u.hasPreferences.disabledTranMean & s.containsTravelPlan
                    ↪ .intermediateRides.byTranMean = none) and
444                 (u.hasPreferences.disabledTranMean & s.containsTravelPlan
                    ↪ .endRide.byTranMean = none)
445                 )
446         }
447
448 fact UserTravelPlanSolutionConsistency {
449         all s: SuggestedSolution | s.containsTravelPlan in s.suggestsTo.
            ↪ hasTravelPlan
450         }
451
452 fact TravelPlanMustBeSuggested {
```

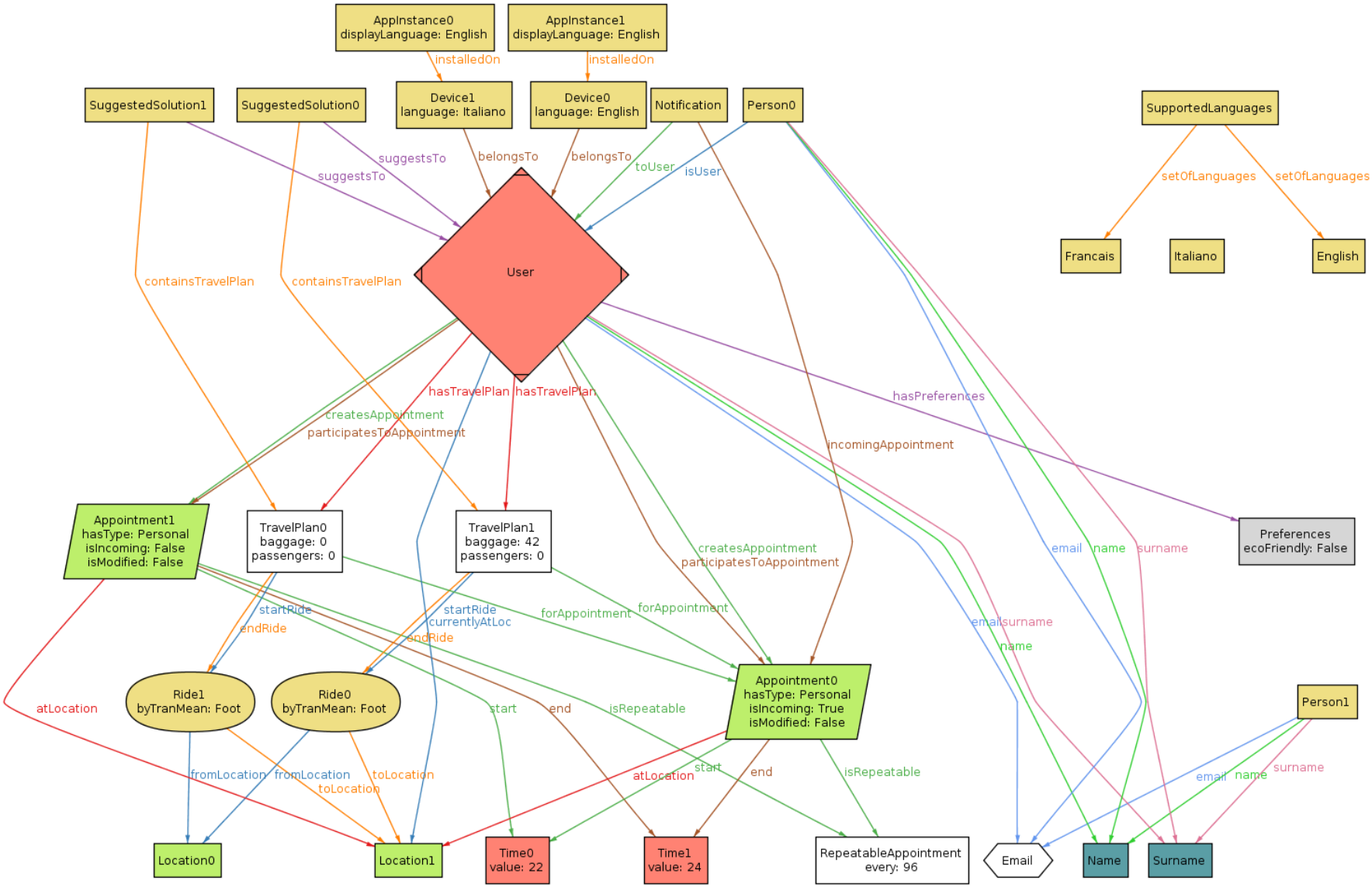
```
453         all tp: TravelPlan | some s: SuggestedSolution | s.
                ↪ containsTravelPlan = tp
454         }
455
456 fact AppointmentWithSameIdAreEqualsIfNotModified {
457         all ap1, ap2: Appointment |
458         (ap1.id = ap2.id and ap1.isModified = False and ap2.isModified =
                ↪ False)
459         implies appointmentsAreEquals[ap1, ap2]
460 }
461
462 fact EnglishAlwaysSupported {
463         English in SupportedLanguages.setOfLanguages
464 }
465
466 // ================================================
467 //  ========================= UTILITY PREDICATES
468 pred samePerson[p1, p2: Person] {
469         p1.email = p2.email and p1.name=p2.name and p1.surname = p2.
                ↪ surname
470 }
471
472 pred invitedToAppointment[u: User, a: Appointment] {
473         some i: Invitation | i.forAppointment = a and i.toEmail = u.email
474 }
475
476 pred appointmentsAreEquals[ap1, ap2: Appointment] {
477         ap1.id = ap2.id and
478         ap1.start = ap2.start and
479         ap1.end = ap2.end and
480         ap1.atLocation = ap2.atLocation and
481         ap1.hasType = ap2.hasType and
482         ap1.isRepeatable = ap2.isRepeatable
483         // no reason to check isModified
484         // isIncoming can be different!
485 }
486
487 // ================================================
488 // ========================= ASSERTIONS
489 assert CanDisplayInAllSupportedLanguages {
490         no l: AppInstance.installedOn.language |
491                 l in SupportedLanguages.setOfLanguages and
492                 no ap: AppInstance | ap.displayLanguage = l
493 }
494 check CanDisplayInAllSupportedLanguages
495
496 assert EveryPersonShouldBeAbleToHaveAnAccount {
497         #User > 0
498         implies
499         some p1, p2: Person, u: User |
500                 p1.email = p2.email and p1.isUser = none and p2.isUser =
                        ↪ u
501 }
502 check EveryPersonShouldBeAbleToHaveAnAccount
503
504 assert UserAlwaysNotified {
505         all a: Appointment, u: User |
```

```
506                     (a.isIncoming = True and a in u.participatesToAppointment
                            ↪ )
507                     implies
508                     (one n: Notification | n.toUser = u and n.
                            ↪ incomingAppointment = a)
509 }
510 check UserAlwaysNotified for 2
511
512 // ==========================================================
513 // ========================== RUNNABLE PREDICATES
514
515 pred showSomeAppointmentModified {
516         some ap: Appointment | ap.isModified = True
517 }
518 run showSomeAppointmentModified
519
520 pred showSomeMeeting {
521         some a: Appointment, disjoint u1, u2: User |
522                  a in u1.participatesToAppointment and a in u2.
                        ↪ participatesToAppointment
523 }
524 run showSomeMeeting for 4
525
526 pred show {
527         #Appointment = 2 and
528         #User = 1 and
529         #Notification > 0 and
530         #TravelPlan = 2 and
531         #SupportedLanguages.setOfLanguages > 1 and
532         #Person = 2 and
533         #Device = 2 and
534         some d: Device | d.language not in SupportedLanguages.
              ↪ setOfLanguages
535 }
536
537 run show for 3 but 4 Notification, 8 Int
```

4.2 Results of Alloy Analysis

```
Executing "Check CanDisplayInAllSupportedLanguages"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   21897 vars. 1278 primary vars. 54318 clauses. 28ms.
   No counterexample found. Assertion may be valid. 12ms.

Executing "Check EveryPersonShouldBeAbleToHaveAnAccount"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   21933 vars. 1275 primary vars. 54347 clauses. 31ms.
   No counterexample found. Assertion may be valid. 18ms.

Executing "Check UserAlwaysNotified for 2"
   Solver=sat4j Bitwidth=4 MaxSeq=2 SkolemDepth=1 Symmetry=20
   11778 vars. 715 primary vars. 30418 clauses. 18ms.
   No counterexample found. Assertion may be valid. 2ms.

Executing "Run showSomeAppointmentModified"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   21854 vars. 1278 primary vars. 54246 clauses. 30ms.
   Instance found. Predicate is consistent. 67ms.

Executing "Run showSomeMeeting for 4"
   Solver=sat4j Bitwidth=4 MaxSeq=4 SkolemDepth=1 Symmetry=20
   35186 vars. 1991 primary vars. 85225 clauses. 49ms.
   Instance found. Predicate is consistent. 109ms.

Executing "Run show for 5 but 8 int, 4 Notification"
   Solver=sat4j Bitwidth=8 MaxSeq=5 SkolemDepth=1 Symmetry=20
   515871 vars. 12412 primary vars. 1848742 clauses. 857ms.
   Instance found. Predicate is consistent. 3527ms.

6 commands were executed. The results are:
   #1: No counterexample found. CanDisplayInAllSupportedLanguages may be valid.
   #2: No counterexample found. EveryPersonShouldBeAbleToHaveAnAccount may be valid.
   #3: No counterexample found. UserAlwaysNotified may be valid.
   #4: Instance found. showSomeAppointmentModified is consistent.
   #5: Instance found. showSomeMeeting is consistent.
   #6: Instance found. show is consistent.
```

4.3 Alloy Model



5 Effort Spent and Team Work

We worked together most of the time, more than 30 hours. This is because in the beginning we struggled to find a way to divide responsibilities so we worked together and when we managed to work separately we still needed to discuss and to cross-check our work.
Below, for each component of the team, we provide his list of main responsibilities, but it is important to say that we have absolutely collaborated on everything as said before.

Cassarino Pietro produced Purpose and Scope of the Introduction section and 2 of the six scenarios. He created Activity Diagrams and collaborated in Goals and Requirements development. He produced part of the alloy modeling, in particular signatures and facts.
Total hours: 61 hours, **Hours working alone:** 28 hours

Salaris Mirko organized the work on LaTeX delineating the document structure and improving it later on. He produced 2 of the six scenarios and created the Class Diagram. Moreover, he delineated the first stub of Goals and Requirements. A part of the alloy modeling was his responsibility.
Total hours: 65 hours, **Hours working alone:** 32 hours

Ventrella Piervincenzo produced 2 of the six scenarios and compiled several sections of the RASD such as Definitions' section , User characteristics' section, Specific Requirements, Performance and Design Constraints. He also took care of the Use Case UML modeling (diagrams and analysis of them). Lastly, he provided some mockups.
Total hours: 53 hours, **Hours working alone:** 20 hours

6 References

6.1 Software and Tools

- LaTeX for typesetting document
- TeXstudio as LaTeX IDE
- GitHub for version control and team work
- Alloy latex highlighting package: https://github.com/Angtrim/alloy-latex-highlighting
- StarUML for UML models

6.2 Reference Documents

- Alloy reference: http://alloy.mit.edu/alloy/documentation/book-chapters/alloy-language-reference.pdf
- 29148-2011 - ISO/IEC/IEEE International Standard - Systems and software engineering – Life cycle processes –Requirements engineering: http://ieeexplore.ieee.org/document/6146379/