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RASD

Requirement Analysis and Specification Document

Best Bike Paths

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1.0
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Contents

1 Introduction

1.1 Purpose

The growing interest in cycling, whether as a recreational activity, a means of transportation, or a sport, brings with it a significant challenge: finding routes that are not only efficient, but also safe and well-maintained. Cyclists often lack reliable and up-to-date information on trail conditions, such as the presence of potholes, obstacles, or roads with little traffic. At the same time, many cyclists meticulously log their trips to monitor their performance, collecting valuable data that, however, remains siloed. This creates a gap where vital community knowledge about trail quality is not easily shared or accessible. "Best Bike Paths" (BBP) aims to provide a solution. Commissioned by a cyclists' association, BBP will be a software system designed to create and manage a community-driven inventory of cycling routes. The platform will help bridge this information gap by allowing registered users to track their trips while simultaneously submitting detailed information on the condition of their routes. Other users, registered or not, will then be able to use this collective data to find and display the best possible cycling routes between two points, ranked by a quality score.

1.1.1 Goals

- **G1:** A registered user wants to track their personal cycling activities and related performance statistics.
- **G2:** A registered user wants to contribute to the community inventory by sharing reliable information on the condition of the trails (e.g. quality, obstacles, potholes).
- **G3:** Any user (registered or not) wants to find and view the best cycling route between an origin and a destination, based on up-to-date and relevant data.
- **G4:** The cycling association aims to provide the community with a tool to create, consult, and maintain a reliable and centralized inventory of cycling routes.

1.2 Scope

The project scope covers users interacting with the system, user-generated actions that influence the system, and system-generated actions that impact the outside world.

For this project, the following users interacting with the system have been identified:

- **Registered User**
- **Any User**

A Registered User will be able to use the application to log and store their trips, tracking their cycling activities and related statistics. When available, this data can be enriched with weather information retrieved from external services. Furthermore, this user is the primary contributor to the inventory. They can enter route information in two ways:

1. In **manual mode**, by actively specifying the route status (e.g., optimal, requires maintenance) and the presence of obstacles (e.g., potholes).
2. In **automatic mode**, by allowing the app to acquire data from GPS and mobile device sensors while cycling, in order to automatically detect potential problems such as potholes.

For automatically collected data, the system will ask the user to confirm or correct the information before making it available to the community. Once confirmed or manually entered, this information becomes publishable.

Any user, whether registered or not, can benefit from the collected information. This user can specify a starting point and a destination and ask the system to display available cycling routes on a map. If multiple routes exist, BBP will present them based on a score, calculated based on the route status derived from the data confirmed by users.

1.2.1 World phenomena

- **WP1:** A registered user starts a cycling activity.
- **WP2:** Any user searches for a cycling route between two places.
- **WP3:** A registered user contributes contribute to the BBP inventory.
- **WP4:** While pedaling a registred user ecounters some kind of problem on the route.

1.2.2 Shared phenomena

World controlled

- **SP_WC1:** The registered user launches starts to register the trip with the application.
- **SP_WC2:** The registered user stops to register the trip with the application.
- **SP_WC3:** The registered user opens the interface for manually entering route information.
- **SP_WC4:** The registered user enters the data (e.g. ”optimal” status, ”hole” presence) and sends the manual entry form.
- **SP_WC5:** The registered user selects a notification or confirmation request for automatically detected data.

- **SP_WC6:** The registered user confirms to validate automatically the detected data (e.g. a pothole).
- **SP_WC7:** The registered user deletes to invalidate an automatically detected data (false positive).
- **SP_WC8:** The registered user modifies an automatically detected piece of data (e.g. corrects the position of the hole on the map) and saves the change.
- **SP_WC9:** Any user enters a source and destination address.
- **SP_WC10:** Any user starts the route search.

Machine controlled

- **SP_MC1:** The system shows the statistics of the completed trip to the registered user.
- **SP_MC2:** The system shows the weather data associated with the trip to the registered user.
- **SP_MC3:** The system presents the Registered User with a confirmation request for automatically detected data.
- **SP_MC4:** The system shows the user a map with the cycling routes found between the origin and the destination.
- **SP_MC5:** The system displays the details of a route, including its score and confirmed obstacles.
- **SP_MC6:** The system displays an error message (e.g., "Weather service unavailable").

1.3 Definitions, Acronyms, Abbreviations

This section contains the definitions for people that may not know what a specific concept is, acronyms and abbreviations used throughout the document.

1.3.1 Definitions

- **Bike Path:** a route deemed suitable for cycling. This includes paths with a proper bike track or roads where cars are rare and speed limits are compatible with the average speed of a bike.
- **Trip:** a personal record of a user's cycling activity, stored by the system to track performance metrics like distance and speed.
- **Publishable Information:** data about a bike path (e.g., status, obstacles) that a registered user has either entered making it available to the wider community.

- **Path Score:** a metric computed by BBP to rank route options. It is based on the status of the path and its effectiveness in getting the user from their origin to their destination.
- **Obstacle:** any significant element or condition on a cycle path that may represent a danger or hindrance to the cyclist (e.g. pothole).

1.3.2 Acronyms

- **BBP:** Best Bike Paths.
- **GPS:** Global Positioning System.
- **API:** Application Programming Interface.

1.3.3 Abbreviations

- **G*:** Goal.
- **WP*:** World Phenomenon.
- **SP*:** Shared Phenomenon.
- **R*:** Requirement.
- **UC*:** Use Case.
- **D*:** Domain Assumption.

Note: asterisks are intended as a replacement for the number.

1.4 Revision history

- **Version 1.0 (17/11/2025)**

1.5 Reference documents

This document is based on the following materials:

- The specification of the RASD and DD assignment of the Software Engineering II course a.y. 2025/26.
- Course slides shared on WeBeep.
- Past Requirement Analysis and Specification Documents.

1.6 Document structure

1. **Introduction:** a brief description of the project. It contains the main goals and objectives that the final system wants to achieve.
2. **Overall description:** this section is a high-level representation of the system and of the interactions of the system with the other actors.

3. **Specific requirements:** a detailed list of all the requirements needed for the system to achieve the goals. It contains valuable information for developers.

4. **Formal analysis using Alloy:** a formal description of the model of the system with Alloy.

5. **Effort spent:** the time spent on each section of the document, for each member of the group.

6. **References:** reference to documents or tools used for writing this document..

2 Overall description

2.1 Product perspective

2.1.1 Scenarios

[SC1] Registering a new user

User "Zoe" has just downloaded the BBP app in order to monitor her activities with the bicycle, and wants to create a profile. So she creates an account by entering name, surname, email, birth date, gender, and accepting the privacy policy. Once her information is verified, she receives an email to confirm **her** email address. She confirms it, and the account is then created.

[SC2] Intelligent route planning (General user)

The tourist "Diana" wants to explore the city by bike but is worried about traffic and poor roads. She accesses the BBP website without logging in and enters "Hotel Plaza" as the origin and "Museo della Scienza" as the destination, receving two possible paths as response. Diana notices that the shortest route (3 km) has a low "Path Score", with several "Pothole" icons along the way. The alternative, slightly longer route (3.5 km) has an excellent "Path Score" and it's marked with excellent conditions. Diana chooses the green route, starts the trip activity and follows the instructions.

[SC3] Intelligent route planning (Registred user)

The athlete "Giorgio" is planning his daily cycling training. He opens the BBP app, logs in and searches for bike paths with a starting point near his home and a length of 30 km. He receives three paths: the first one, which has a high "Path Score" but that crosses his ex-wife's house, the second which has a decent "Path score" and no problem marked, and the third one with low "Path Score" and several potholes marked on the map. Given these options, he choose the second one and starts the activity. Once he finishes his training, he stops the activity and checks whether the activity has been registred on his trip history or not.

[SC4] Automatic activity monitoring and trip data enrichment

Registered user "Alessandro" is preparing for his weekly training session. He wants to track his performance, including correlation with the weather. He launches the BBP app, logs in, and starts recording his trip allowing the automatic collection of data, both to check path and weather conditions. Once he has finished his trip, he stops the recording and after little bit he watches the app his trip summary: the path map; the total distance traveled; the average, maximum and minimum speed; maximum, average and minimum altitude excursion; weather conditions.

[SC5] Manual path information update 1

Registered user "Bianca" is riding a popular bike path when she notices that a stretch, previously marked as "Optimal", is now blocked by unreported construction. She decides to alert the community: so she stops and reports the problem on the BBP app: she specifies the bike path, the type of problem, the problem position and adds also an optional textual note to be more detailed, then submits the report, receiving an acknowledgement

[SC6] Manual path information update 2

Registred user "Edoardo" is riding along a path where a pothole had been reported the previous week. He notices that the pothole has been fixed, so he selects the pothole mark on the map and switches its status as resolved. After a few hours, he decides to control if the mark on the map has been removed, and finds out that the pothole mark disappeared.

[SC7] Automatic path information update

Registered user "Carlo" goes to work by bike, he logs in the app and starts the trip activity, giving permission to the app for automatically record the ride. Almost at the end of the ride he goes over a pothole, so when he arrives at work he checks the BBP app to see whether the pothole has been detected or not. He notices that there are two potholes detected: one approximately in the middle of the path, and another one near his work building. Since he never encountered a pothole in the middle of the path, he selects it and discards it as a false positive. Then he selects the pothole near his work building, confirms it and adds an optional note to be more detailed.

[SC8] Historical performance analysis

Registered User "Alessandra", after months of using BBP, wants to analyze her performance progress. She opens the BBP app, logs in, opens the relative section and looks at the list of all her saved trips. She filters the list by "Last month" and looks at the aggregated graph showing her average speed during the whole month and the total distance traveled. Then she searches for a specific trip she did two months ago to understand if she improved.

2.1.2 Domain Class Diagram

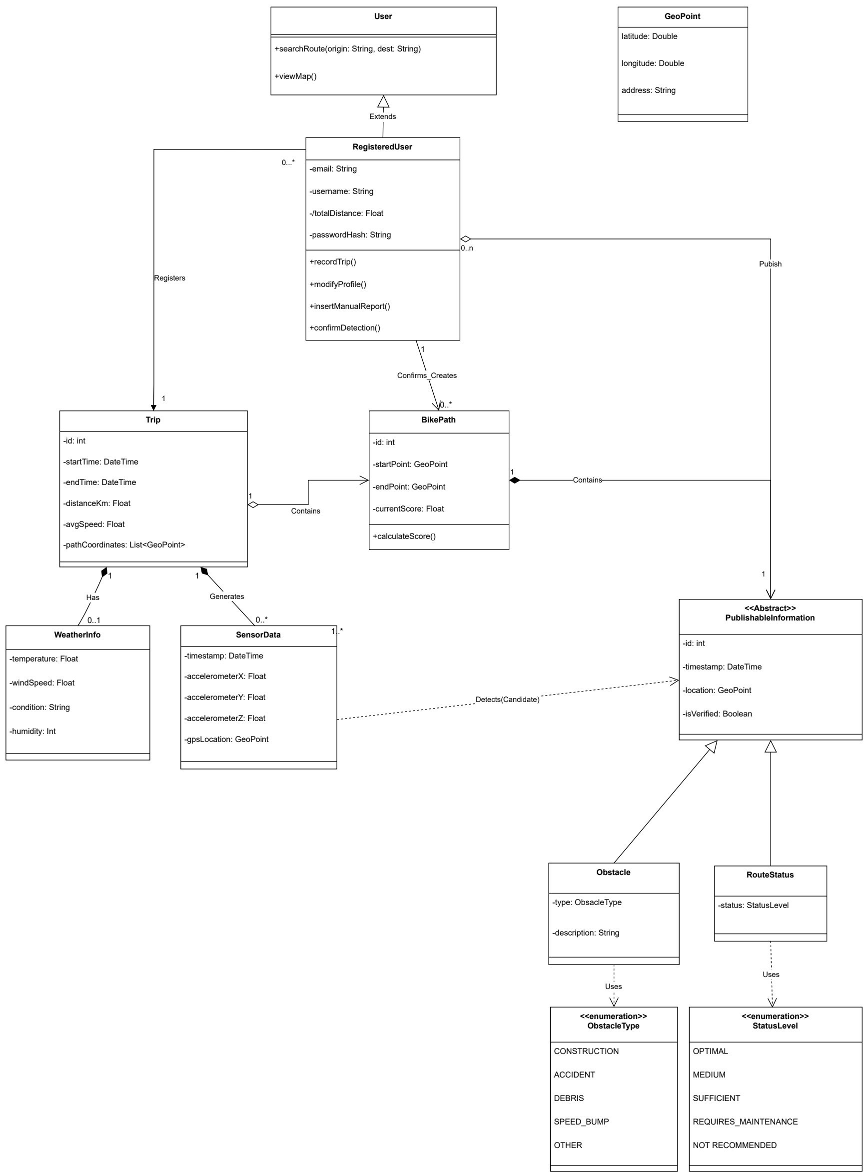

Figure 1: Domain Class Diagram of the BBP system

Figure 1 shows the domain class diagram. The main architectural choices are explained below:

- **User Generalization:** To avoid duplication and facilitate future scalability, the `User` superclass has been introduced. It encapsulates basic functionality accessible to everyone, such as route search and map viewing. The `RegisteredUser` class extends this foundation, adding authentication data and the main writing functionality: `recordTrip()`, `insertManualReport()`, and `confirmDetection()`. This structure allows for easy extension to future roles such as "Administrator" or "Moderator."
- **Information Abstraction and Scoring:** The abstract `PublishableInformation` class was created to logically group all alerts (whether `RouteStatus` or `Obstacle`). This polymorphic approach greatly simplifies the calculation of the Path Score: the system can iterate over a generic list of confirmed information associated with a trip to calculate its score, without having to use separate logic for each type of alert.
- **Sensor Scalability:** Although the assignment specifically mentions potholes, the model correctly links the raw `SensorData` data to the generic `Obstacle` class via the "Detects (Candidate)" dependency. This design ensures that the system can evolve to detect other types of anomalies in the future without changing the core data model.
- **Trip Composition and Data Lifecycle:** There is a composition relationship between `Trip` and its internal data: `WeatherInfo` and `SensorData`. This indicates that this data is closely tied to the trip lifecycle: if a user decides to delete a trip from their history, the associated weather data and raw sensor data will also be automatically removed, preventing data fragmentation and ensuring database cleanliness.

2.1.3 State Diagrams

User Session Lifecycle

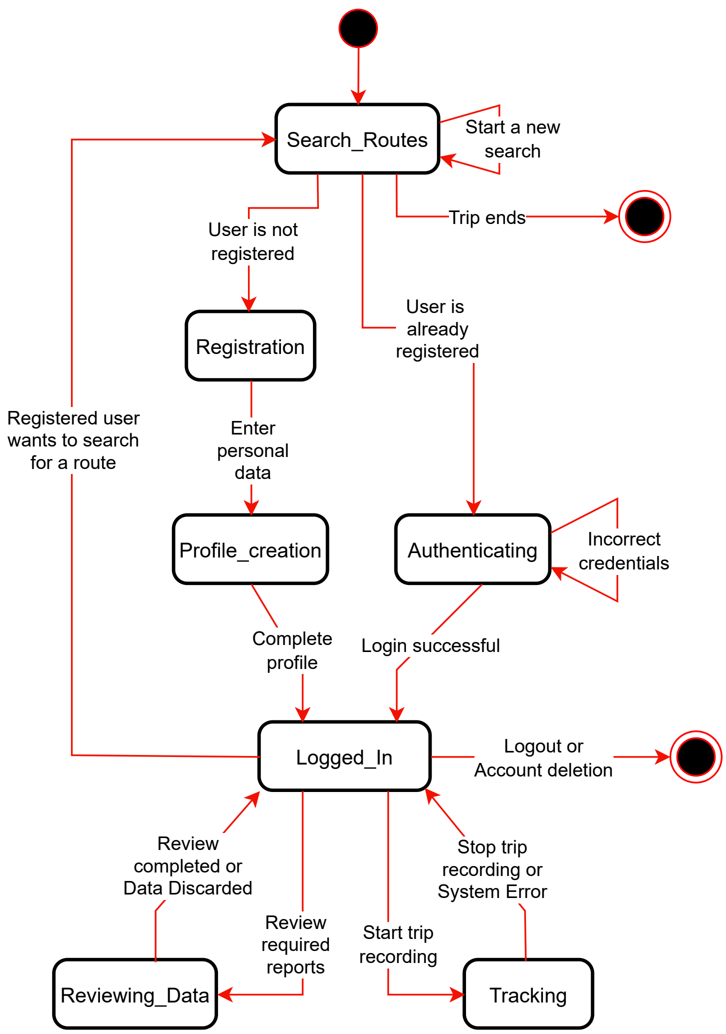

Figure 2: State diagram of a BBP system user's lifecycle

The finite state diagram in Figure 2 models the **user session lifecycle** within the BBP system, defining how the user transitions from the anonymous browsing state to the fully operational one. The system is designed to ensure that all basic functionality, such as route search and map viewing, is immediately accessible, with a single initial state that converges on `Search_Routes`, the universal entry point. From this anonymous browsing state, the user can choose to authenticate whether they are already logged in or not. Once the `Logged_In` state is reached, the user unlocks the contribution capabilities, which are critical to the system's value. This state serves as a hub, allowing the user to initiate trip tracking by moving to the `Tracking` state (when sensors are active) or to proceed to `Reviewing_Data`. Both contribution states are separated to reflect their high impact on resources (tracking) or data consistency (auditing). The session can end by exiting `Search_Routes` (for both anonymous and registered users) or by `Logout` from the operational state for the registered user.

Trip Lifecycle

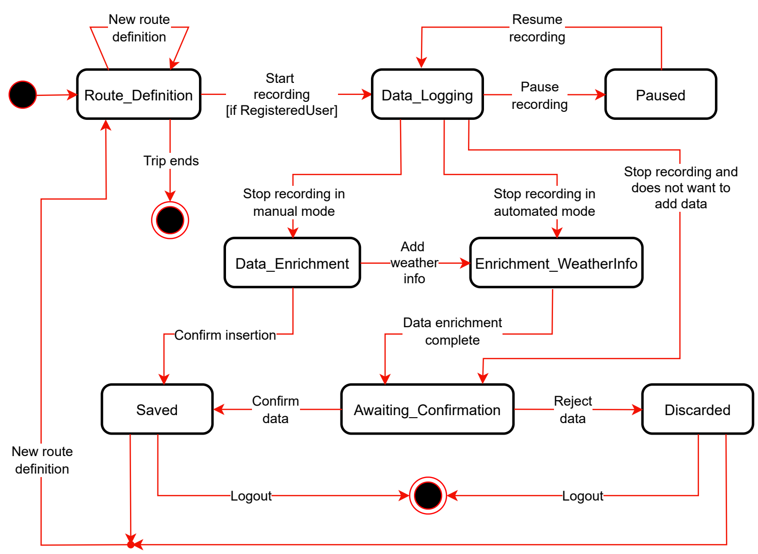

Figure 3: State Diagram of the Lifecycle of a Trip in the BBP System

The diagram in Figure 3 models the complete lifecycle of a `Trip`, from its inception to its final storage or discard. The process begins in the initial `Route_Definition` state, which represents the hub where a new route can be defined or an existing one can be used. The fundamental transition to data acquisition occurs only if the `[if RegisteredUser]` guard condition is satisfied, ensuring that only authenticated users can initiate tracking, based on the system's contribution requirements. Once in the `Data_Logging` state, the system actively logs raw sensor data (GPS, accelerometer) if in automatic mode. This state offers flexibility, allowing data acquisition to be paused and resumed via transitions. The system manages three distinct transitions when recording is stopped, resulting in separate processing paths:

- **Stop in manual mode**: This transition allows the user to actively add non-sensor data to the route.
- **Stop in automated mode**: Indicates that the route has ended, starting the automatic processing cycle.
- **Stop without data**: If the user does not wish to add any data, they go directly to the confirmation to save or delete the collected data (if collected).

The automated processing cycle begins with `Enrichment_WeatherInfo`, where the system enriches the trip with weather data retrieved from external services. Once enrichment is complete, the flow moves to `Awaiting_Confirmation`. This state is crucial for data quality: here, the user must decide whether to validate the anomalies detected by the sensors (e.g., potholes) or discard them. The cycle closes by returning to the `Route_Definition` state or definitively exiting the system, demonstrating how data only goes from ephemeral to persistent information through a rigorous validation process.

Data Lifecycle

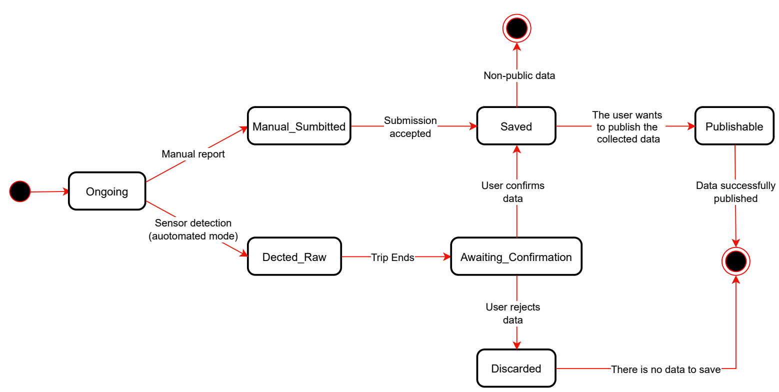

Figure 4: Data lifecycle state diagram in BBP system

The diagram in Figure 4 models the complete data lifecycle, from its origin to its final state. The process rigorously distinguishes data based on its source to direct it to the correct validation path. The flow forks immediately from the initial state:

- **Manual Path:** The user generates a `Manual report` that transitions to the `Manual_Submission` state. The data, being the result of an explicit action, is initially saved and can be published if the user wishes.

- **Automatic Path:** The data passively detected by the sensors transitions to the `Dected_Raw` state. This raw data must pass through the `Awaiting_Confirmation` state at the end of its journey.

The pending confirmation state is the critical checkpoint: the user is responsible for validating the discovery to allow it to move to `Publishable`, or discarding it, moving it to `Discarded`. Only data in the `Publishable` state is integrated and can influence the `Path Score`. The cycle ends with final publication or discard.

Bike Path Status Lifecycle

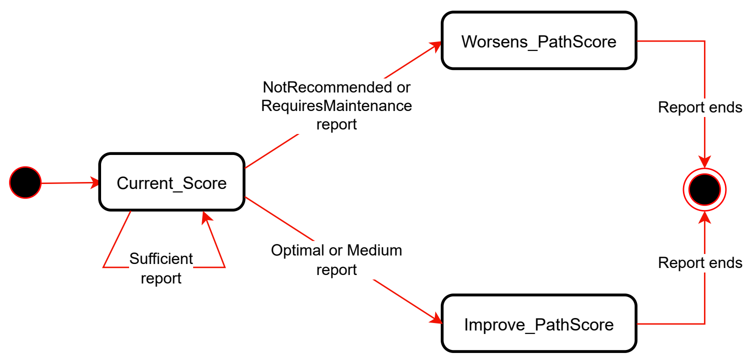

Figure 5: BBP Path State Lifecycle State Diagram

The diagram in Figure 5 models the evolution of a Bike Path's Quality Score in response to user contributions. The entry point is the `Current_Score` state, which represents the value of the path at the time of consultation. This value is dynamic and subject to change based on active reports:

- A hazard or maintenance report (`NotRecommended or Requires Maintenance report`) triggers the `Worsens_PathScore` state. This indicates an immediate degradation in quality.
- Conversely, an `Optimal or Medium report` triggers the `Improve_PathScore` state, indicating an improvement in the path's quality.
- A `Sufficient report` acts as a validation of the current score, maintaining its status and contributing to the data's freshness without drastically altering its perceived quality.

The diagram emphasizes that the score is a dynamic value, constantly recalculated based on the validity and freshness of the active reports in the BBP inventory.

2.2 Product functions

Sign up & Login

This feature is the entry point for any user wishing to actively contribute to the inventory. A visitor can register by providing their information and credentials, and the system creates a `RegisteredUser` profile, enabling write permissions. Once the account is created the user can log in to access their reserved area, view their travel history, and use the tracking features. Without authentication, the user remains in "read-only" mode, without access or all the features expected of a registered user.

User Profile Management

Registered users have access to a dedicated section for managing their personal data. Here they can update their contact information and personal details, change their password, or delete their account. These actions ensure that the user maintains full control over their digital identity within the system.

Trip Recording

This is a core feature available exclusively to authenticated users. Users can start a recording session at the beginning of their activity. During the trip, the system tracks their geographic location via GPS in real time. Users have the flexibility to pause and resume recording (for example, during a rest stop). Upon completion, the trip is stored in the user's personal database.

Statistics Calculation and Data Enrichment

Upon completion of a trip, the system processes the raw data to provide detailed statistics, such as total distance traveled and average speed. Additionally, BBP automatically queries external services, if available, to retrieve weather information (temperature, wind, and weather conditions) for the area and time of the trip. This data is integrated into the trip record, providing the user with richer context for analyzing their performance.

Manual Data Entry

Registered users can actively contribute to the quality of the inventory by entering manual reports. Through a dedicated interface, users can specify the status of a road segment (e.g., "Optimal," "Requires Maintenance") or report the presence of specific obstacles. The system associates this information with the current GPS coordinates (or those selected on the map) and makes it immediately available to the community.

Automatic Detection via Sensors

If the registered user enables "Automatic Mode" while driving, the system uses the mobile device's accelerometer and gyroscope to monitor vibrations and sudden movements. Internal algorithms analyze this data to identify potential road surface anomalies, such as potholes. This process occurs in the background so as not to distract the user while driving.

Review and Confirmation of Detections

To ensure data reliability and filter out false positives, automatic detections are not published immediately. At the end of the journey, the system presents the user with a list of detected anomalies. The registered user must explicitly confirm the presence of the obstacle (validation) or discard the detection (if incorrect). Only confirmed data is promoted to publishable information. The published route data is then used to calculate the Path Score.

Route Search

This function is accessible to all users, regardless of registration. The user enters a point of origin and a destination in the search interface. The system processes the request and calculates one or more possible cycling routes connecting the two points.

Display and Path Score

The routes found are displayed on an interactive map. For each route, the system calculates and displays a `Path Score`. This summary score aggregates information about the route's status and the presence of confirmed obstacles, allowing the user to quickly assess not only the distance, but also the safety and quality of the proposed route.

2.3 User Characteristics

This section describes the general characteristics of users who interact with the BBP system. There are two main categories of users: Registered Users (the active contributors) and General Users (the passive users).

2.3.1 Registered Users

The Registered User represents the core of the BBP ecosystem. This profile typically corresponds to a regular cyclist (commuter or recreational) who wishes to monitor their performance and actively contribute to community safety.

Profile and Skills

The user must have a personal account with login credentials. It is assumed that they have moderate familiarity with the use of smartphones and GPS technology. Since the app is used in mobile contexts, the user requires a clear interface that minimizes distractions.

Needs and Interactions:

- **Tracking:** The user wants to track their trips to analyze statistics such as speed and distance, contextualized with weather data if available.
- **Active Contribution:** The user wants to report obstacles or assess road conditions to help other cyclists. They can do this manually or by activating automatic mode.
- **Validation:** The user is responsible for data quality. The system relies on them to confirm or discard automatic sensor detections (e.g., potholes) at the end of the trip, ensuring that only truthful information influences the Path Score.
- **Privacy:** The user wants sensitive data (such as personal travel history) to remain private, while agreeing to share anonymized road condition data publicly.

2.3.2 Generic User

The Generic User includes anyone who accesses the platform without authenticating. This profile includes tourists, occasional cyclists, or route planners who need quick and reliable information without the commitment of registration.

Profile and Skills

They do not have a persistent profile in the system. Minimum proficiency in using digital maps and web/mobile interfaces is required. Interaction is sporadic and aimed at an immediate goal: reaching a destination.

Needs and Interactions:

- **Safety and Planning:** The primary need is to find the safest or most efficient route between two points. The user relies on the system to avoid poor or dangerous roads.
- **Immediacy:** They want to view routes and their Path Score immediately. It's not interested in contributing data or saving history, but only in consuming aggregated information generated by the community.
- **Reliability:** It expects the obstacle reports (e.g., potholes) displayed on the map to be up-to-date and verified, so it can plan its trip with confidence.

2.4 Assumptions, dependecies and constraints

2.4.1 Domain Assumptions

The following assumptions describe real-world conditions that the system considers true and necessary for the correct functioning of the intended features:

- **D1 - Hardware Equipment:** It is assumed that the user's mobile device is equipped with functioning and calibrated hardware, specifically: GPS receiver, accelerometer, and gyroscope. The system cannot compensate for physical hardware failures of the device.
- **D2 - Accuracy of User Data:** It is assumed that the information entered by users is correct and truthful. This includes:
  - Registration data.
  - Manual reports.
  - Confirmation of automatic detections (the user does not intentionally confirm false positives).
- **D3 - Accuracy of Basemaps:** It is assumed that third-party mapping services provide a correct topological representation of reality. If a road exists on the map, it is assumed that it physically exists and is drivable (unless otherwise reported on BBP).
- **D4 - GPS Signal Availability:** It is assumed that, for most of the duration of an outdoor trip, satellite coverage is sufficient to ensure useful location accuracy.
- **D5 - Distinguishable Movement Patterns:** It is assumed that the physical characteristics of cycling are sufficiently distinct from those of other modes of transport or walking, allowing classification algorithms to operate with an acceptable level of accuracy.
- **D6 - Compliance with Highway Codes:** It is assumed that users use the application in compliance with applicable laws (e.g., not looking at the screen in dangerous situations), absolving the system from liability for accidents caused by distraction.

2.4.2 System Dependencies

The BBP system is not an island; it relies on external services to provide added value. Failure of these services degrades the system's functionality as follows:

- **External Weather Service:** BBP depends on third-party APIs to retrieve weather data (temperature, wind). If this service is unavailable, the system will continue to record trips, but the "Weather Enrichment" feature will not be performed, and the trips will be saved without this metadata.

- **Mapping Services:** Route visualization and address geocoding depend on external map providers. If these are unavailable, the "Route Search" and "Map View" features will be compromised.

2.4.3 System Constraints

- **GDPR and Privacy:** Since the system tracks users' physical movements (sensitive data), the management, storage, and sharing of GPS data must strictly comply with the GDPR regulation. Personal travel data must not be accessible to other users without explicit consent.
- **Energy Consumption:** The automatic detection algorithm must be optimized to avoid draining the mobile device's battery quickly, ensuring coverage of medium-duration trips (e.g., 2-3 hours).
- **Intermittent Connectivity:** Since cycling routes can pass through areas with poor network coverage, the mobile application must be able to store sensor data locally and synchronize it with the server as soon as the connection is re-established.

3 Specific requirements

3.1 External interface requirements

3.1.1 User interfaces

This section presents mockups of the BBP mobile application's user interface. The images illustrate the main interaction flows defined in the scenarios, demonstrating how the system meets usability and functionality requirements.

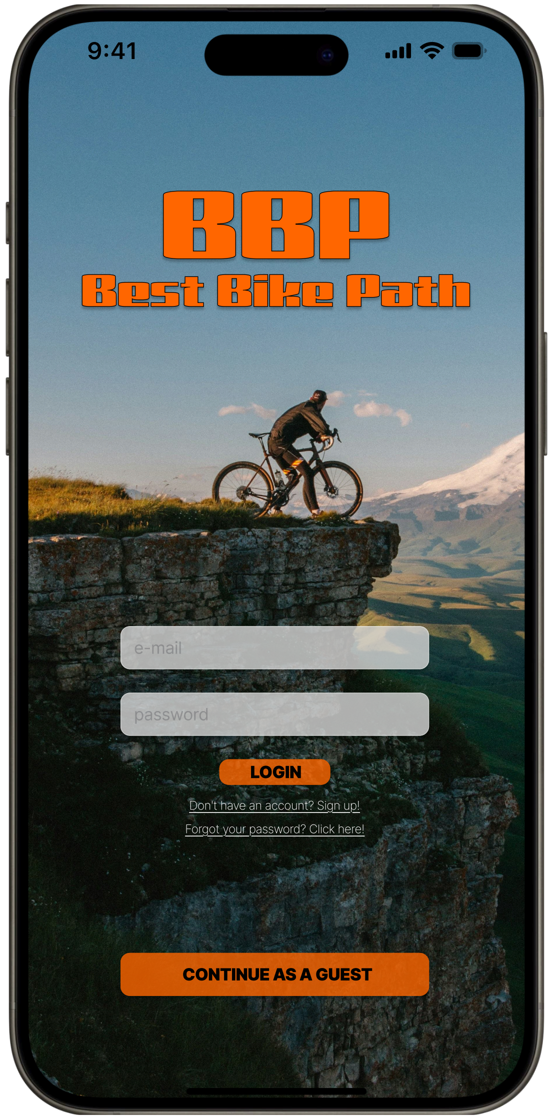

Figure 6: Login and Registration Screen

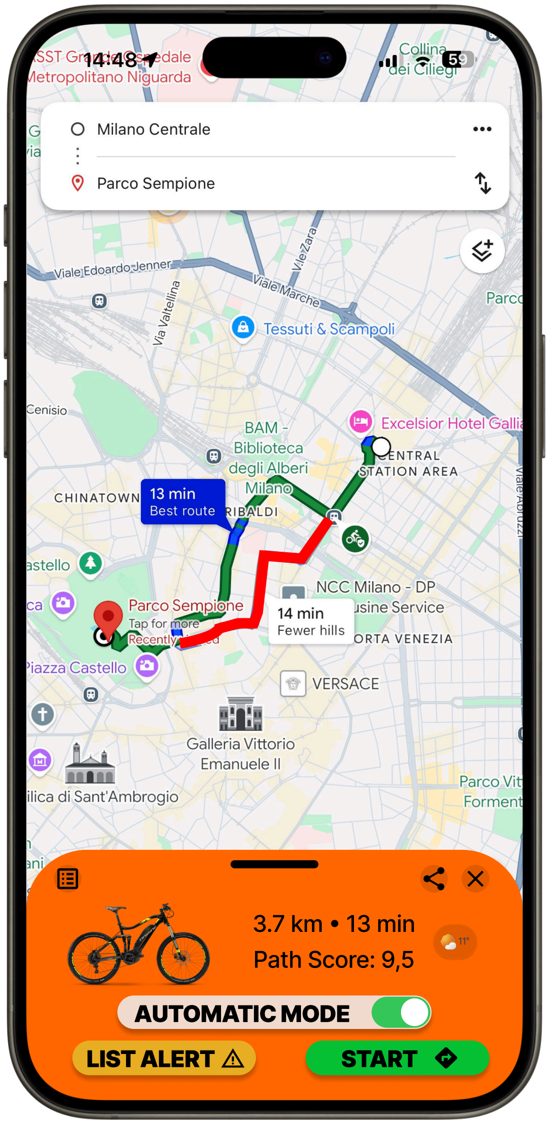

Figure 7: Route Selection Screen

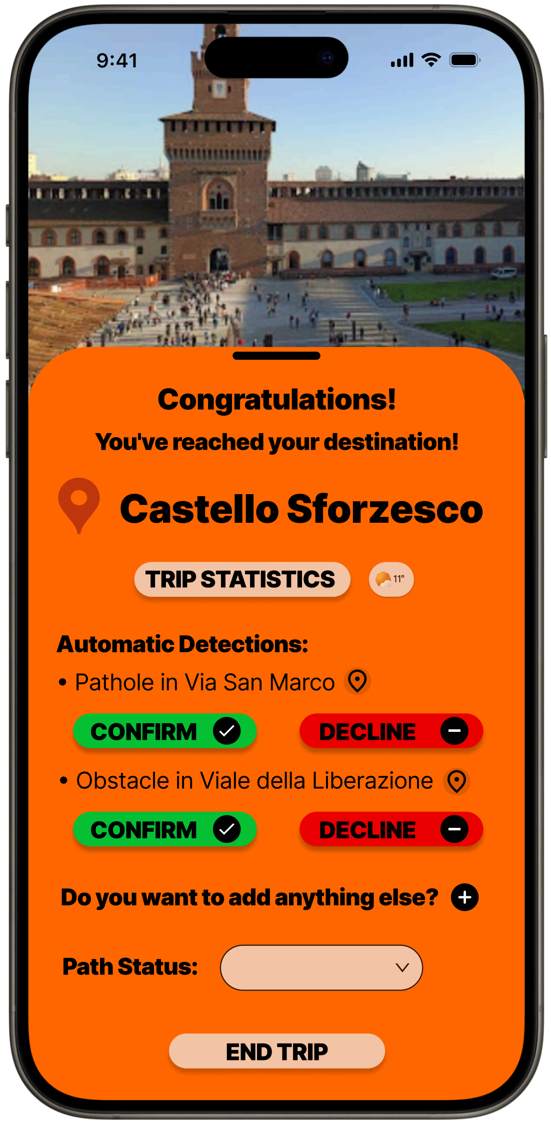

Figure 8: Post-Trip Confirmation Screen

Figure 9: Trip History Screen

3.1.2 Hardware interfaces

Since BBP is a mobile application focused on automatic tracking and detection, hardware interfaces are critical to the system's operation.

- **GPS:** The system requires access to the mobile device's GPS receiver to track the user's location in real time during travel and to geolocate alerts.

- **Inertial Sensors:** For the "Automatic Mode" feature, the application needs to interface directly with the device's motion sensors to detect vibrations and road surface anomalies.
- **Network Connectivity:** The device must have a network interface (4G/5G/Wi-Fi) to send data to the server and download maps.

3.1.3 Software interfaces

The system interacts with external software components to enhance its functionality.

- **External Weather Service API:** The system interfaces with a weather data provider to retrieve historical weather conditions for the time and location of the completed trip.
- **Mapping Service API:** The application uses mapping services for map rendering, route calculation, and address geocoding.
- **Mobile OS APIs:** The app interacts with native Android and iOS APIs for managing permissions and push notifications.

3.1.4 Communication interfaces

- **Network Protocols:** All communications between the mobile application and the backend server are via the **HTTPS** protocol to ensure the security and encryption of data in transit, especially for authentication information and sensitive location data.
- **Data Format:** Structured data exchange typically occurs in **JSON** format via RESTful APIs.

3.2 Functional requirements

Authentication and Account Management

- [**R1**] The system shall allow any user to create an account.
- [**R2**] The system shall allow registered user to log in using their credentials.
- [**R3**] The system shall allow registered user to update their personal profile information.
- [**R4**] The system shall allow registered user to delete their account.

Trip Recording and Monitoring

- [**R5**] The system shall allow registered user to start the recording of a new trip.

- **[R6]** The system shall allow registered user to pause and resume the recording of an active trip.
- **[R7]** The system shall allow registered user to save a trip.
- **[R8]** During the recording, the system shall track the user's position and its performance statistics.
- **[R9]** Upon completion of a trip, the system shall automatically retrieve weather data from an external service, if available, and associate it with the saved trip.

Data Contribution and Governance

- **[R10]** The system shall allow registered user to insert manual reports regarding the status of a path.
- **[R11]** The system shall allow registered user to insert a personal rating of a path.
- **[R12]** The system shall allow registered user to insert manual reports regarding problems on the path.
- **[R13]** The system shall allow registered user to enable automatic detection for a trip.
- **[R14]** When automatic detection is active, the system shall analyze data from the device's sensors to detect potential anomalies.
- **[R15]** The system shall present the list of automatically detected anomalies to the registered user at the end of the recorded trip for review.
- **[R16]** The system shall allow the registered user to confirm or discard a detected anomaly.

Path Planning and Visualization

- **[R17]** The system shall allow any user to search for cycling paths between starting point and a destination.
- **[R18]** The system shall compute and visualize one or more valid routes between the specified points on a map.
- **[R19]** The system shall calculate a Path Score for each route.
- **[R20]** The system shall display confirmed obstacles on the map with visual markers.
- **[R21]** The system shall allow the user to filter the search on Path properties.

Trip History

- **[R22]** The system shall allow registered user to view the list of its past trips.
- **[R23]** The system shall allow registered user to view the details of a specific past trip, including the route on the map, statistics, and weather data (if they exist).
- **[R24]** The system shall allow registered users to delete a specific trip from their history.
- **[R25]** The system shall allow the user to search a specific trip in its history.
- **[R26]** The system shall allow the user to filter the view of its history.

3.2.1 Use cases

[UC1] Account creation

Name	**Account creation**
Actors	Any person
Entry Condition	True
Event Flow	1. The person downloads the BBP and opens it 2. The system asks to fill out a form with the following personal information: name, surname, age, birth date, geneder, email, password; the form ask also to flag for privacy accpetance 3. The person fills out the questionare and submits it 4. The system verifies that the email exists and sends a verification email containing a link to verify the email address 5. The person receives the email and opens the link
Exit Condition	The account is successfully created
Exception	• Email address is not valid, therefore a warnigs is displayed in point *2.* and the form can't be submitted • Email inserted during registration has been already used, therefore the account is not created and in the point *4.* instead of a link an informative message is sent

We highlight that the same person can create multiple accounts, but with different emails.
Refers to 2.1.1.

[UC2] Route planning

Name	**Route planing**
Actors	Any user
Entry Condition	BPP app installed on personal device
Event Flow	1. The user opens the search page and inserts the starting point and the destination 2. The system retrive from it's archive all paths near the startint point specified by the user, ordered by "Path Score" and send them to the user 3. The user explore the choices given by the system and selects one of them
Exit Condition	A path is displayed to the user
Exception	• No path between starting point and destination is found, threrefore a message of "No route found" is displayed

Refers to 2.1.1, 2.1.1.

[UC3] Automatic trip monitoring

Name	**Automatic trip monitoring**
Actors	Registred user
Entry Condition	The BBP app is installed and the user has already an account
Event Flow	1. The user selects the route he wants to ride on, selects the option to automatically collect data and starts the activity 2. The user's personal device collects user position and sends it to the system 3. Once finised the user stops the activity 4. The system calculates some metrics about the user performances (total sistance traveled, average speed, maximum speed, minumum speed, maximum altitude excursion, average altitude excursion) 5. The system retrives the weather conditions during the activty from a third party weather API 6. The system send the computed informations mentioned in *4.* and *5.* plus the maps showing the path traveled
Exit Condition	The user sees a resume of the activity just finished
Exception	• Weather conditions can't be retrived from the third party API, therefore only the metrics about user performances are shown to the user • User's device loses GPS signal during the activity, therefore the system is not able to compute all the metrics about user performances and shows only the ones that can be computed with the available data

Refers to 2.1.1.

[UC4] Report route prolem

Name	**Manual route status update**
Actors	Registred user
Entry Condition	True
Event Flow	1. The user after noticing a problem along a route open the report issue page 2. The user searches for the route, then specifies the issue type, the issue position along the route and adds a description, and submits it 3. The system receives the issue report and send an acknowledgement 4. The system checks if this issue has been already reported, in that case it increments the number of reports for that issue, and if the number is greater than a certain treshold the issue is marked as True
Exit Condition	The system updates the path status
Exception	

[UC5] Report route problem fixup

Name	**Report route problem fixup**
Actors	Registred user
Entry Condition	The user has already an account
Event Flow	1. The user open the app, selects the problem icon on the route and marks it as fixed 2. The system receives the fixup report and send an acknowledgement 3. The system incrementes the number of reports for that issue, and if the number is greater than a certain treshold the issue is marked as Fixed
Exit Condition	The system updates the path status
Exception	

Refers to 2.1.1.

[UC6] Automatic route error detection

Name	**Automatic route error detection**
Actors	Registred user
Entry Condition	True
Event Flow	1. The user starts an activity with automatic issue detection enabled 2. The BBP app collects data from the user's device sensors and analyzes them in real time to detect potential issues along the route 3. When the user finished the activity, the BBP app shows it a list of all problems detected and their location, asking the user confirmation for each one of them 4. The user confirmes wheteher the problems detected are real issues or false positives 5. The BPP app sends to the system the confirmed issues
Exit Condition	The system updates the path status
Exception	

Refers to 2.1.1.

[UC7] User's activity history consultation

Name	**User's activity history consultation**
Actors	Registred user
Entry Condition	True
Event Flow	1. The user opens the relative page on the app and searches for specific activity over its history, optionally applying filters, and sends the request to the system 2. The system run the query and retrives the activities matching the request, then sends the result to the user
Exit Condition	The user consults the result
Exception	

Refers to 2.1.1.

3.2.2 Requirement Mapping

This section maps the Goals identified in Section 1 to the Functional Requirements and Domain Assumptions. This mapping demonstrates that the set of requirements, supported by the assumptions, is sufficient to satisfy the system goals ($R \wedge D \models G$).

G1: A registered user wants to track their personal cycling activities and related performance statistics.	
Requirements	**Domain Assumptions**
[**R1**] The system shall allow any user to create an account. [**R2**] The system shall allow registered user to log in using their credentials. [**R5**] The system shall allow registered user to start the recording of a new trip. [**R6**] The system shall allow registered user to pause and resume the recording of an active trip. [**R7**] The system shall allow registered user to save a trip. [**R8**] During the recording, the system shall track the user's position and its performance statistics. [**R9**] Upon completion of a trip, the system shall automatically retrieve weather data from an external service, if available, and associate it with the saved trip. [**R22**] The system shall allow registered user to view the list of its past trips. [**R23**] The system shall allow registered user to view the details of a specific past trip, including the route on the map, statistics, and weather data (if they exist). [**R24**] The system shall allow registered users to delete a specific trip from their history. [**R25**] The system shall allow the user to search a specific trip in its history. [**R26**] The system shall allow the user to filter the view of its history.	**D1 - Hardware Equipment:** It is assumed that the user's mobile device is equipped with functioning and calibrated hardware, specifically: GPS receiver, accelerometer, and gyroscope. **D5 - GPS Signal Availability:** It is assumed that, for most of the duration of an outdoor trip, satellite coverage is sufficient to ensure useful location accuracy.

Table 1: Requirement Mapping for Goal G1

G2: A registered user wants to contribute to the community inventory by sharing reliable information on the condition of the trails (e.g. quality, obstacles, potholes).	
Requirements	**Domain Assumptions**
[**R2**] The system shall allow registered user to log in using their credentials. [**R10**] The system shall allow registered user to insert manual reports regarding the status of a path. [**R11**] The system shall allow registered user to insert a personal rating of a path. [**R12**] The system shall allow registered user to insert manual reports regarding problems on the path. [**R13**] The system shall allow registered user to enable automatic detection for a trip. [**R14**] When automatic detection is active, the system shall analyze data from the device's sensors to detect potential anomalies. [**R15**] The system shall present the list of automatically detected anomalies to the registered user at the end of the recorded trip for review. [**R16**] The system shall allow the registered user to confirm or discard a detected anomaly.	**D1 - Hardware Equipment:** It is assumed that the user's mobile device is equipped with functioning and calibrated hardware, specifically: GPS receiver, accelerometer, and gyroscope. **D3 - Accuracy of route feedbacks:** It is assumed that the user's feedbacks about routes problems (either manual or automatically detected) are correct and truthful. **D6 - Distinguishable Movement Patterns:** It is assumed that the physical characteristics of cycling are sufficiently distinct from those of other modes of transport or walking in order to allow classification algorithms to operate with an acceptable level of accuracy.

Table 2: Requirement Mapping for Goal G2

G3: Any user (registered or not) wants to find and view the best cycling route between an origin and a destination, based on up-to-date and relevant data.	
Requirements	**Domain Assumptions**
[R17] The system shall allow any user to search for cycling paths between starting point and a destination. **[R18]** The system shall compute and visualize one or more valid routes between the specified points on a map. **[R19]** The system shall calculate a Path Score for each route. **[R20]** The system shall display confirmed obstacles on the map with visual markers. **[R21]** The system shall allow the user to filter the search on Path properties.	**D4 - Accuracy of Basemaps:** It is assumed that third-party mapping services provide a correct topological representation of reality, that is if a road exists on the map then it's assumed that physically exists and that it'is drivable safely by bycicles (unless otherwise reported on BBP). **D1 - Hardware Equipment:** It is assumed that the user's mobile device is equipped with functioning and calibrated hardware.

Table 3: Requirement Mapping for Goal G3

G4: The cycling association aims to provide the community with a tool to create, consult, and maintain a reliable and centralized inventory of cycling routes.	
Requirements	**Domain Assumptions**
[R1] The system shall allow any user to create an account. **[R3]** The system shall allow registered user to update their personal profile information. **[R4]** The system shall allow registered user to delete their account. **[R16]** The system shall allow the registered user to confirm or discard a detected anomaly.	**D2 - Accuracy of user registration data:** It is assumed that the information entered by users during registration phase is correct and truthful. **D3 - Accuracy of route feedbacks:** It is assumed that the user's feedbacks about routes problems (either manual or automatically detected) are correct and truthful.

Table 4: Requirement Mapping for Goal G4

3.3 Performance requirements

Given the nature of BBP as a mobile application that also operates in active mobility contexts, performance is critical not only for the user experience, but also for the security and reliability of the collected data.

- **Interface Responsiveness:** The system must ensure immediate response times for critical interactions during cycling, with a latency of less than 200 ms, to avoid dangerous distractions for the user.
- **Real-Time Data Processing:** During "Automatic Detection" mode, the local algorithm on the device must process sensor data in real time without causing interface crashes or delays in recording the GPS track.
- **Routing:** The route search functionality must return results, complete with *Path Score*, within 3 seconds for requests in a standard urban environment (10 km radius), ensuring smooth planning.
- **Backend Scalability:** The system must be able to handle simultaneous load peaks (e.g., weekends or cycling events), scaling horizontally to support thousands of simultaneous trip uploads without data loss.
- **Reliability:** The backend service must guarantee 99.9% uptime on a monthly basis, ensuring that users can always sync their trips and access maps.

3.4 Design Constraints

3.4.1 Standards Compliance

The BBP system adheres to rigorous international standards to ensure interoperability, security, and regulatory compliance.

Standard	Description
GDPR (EU 2016/679)	The system manages sensitive geolocation and user profiling data. All processing must comply with the General Data Protection Regulation, guaranteeing the right to be forgotten and data minimization.
WGS 84	Geodetic reference standard for the GPS system. All stored and exchanged coordinates must comply with this standard to ensure compatibility with global maps.
GPX (GPS Exchange)	The system should support the export of trip data in the standard XML format for GPS data, facilitating interoperability with other sports platforms.
ISO/IEC 27001	Standard for information security management, applied to protect the backend infrastructure and user data from unauthorized access.

Table 5: Compliance standards adopted by BBP

3.4.2 Hardware Limitations

The mobile application must operate in a resource-constrained environment, typical of mobile devices during extended outdoor use.

- **Power Consumption:** The automatic detection algorithm (GPS + Sensors) must be optimized to consume no more than 10-15% battery power per hour of use on an average device, ensuring the user does not run out of battery power while traveling.
- **Required Sensors:** Full use of the app is contingent on the physical presence of a calibrated accelerometer and gyroscope. Older or low-end devices without these sensors will only be able to use the app in limited mode (without automatic detection).
- **Intermittent Connectivity:** The design must include an "offline-first" mode for data recording. Upload to the server must occur asynchronously when the connection is stable, handling any timeouts without losing local data.

3.4.3 Any Other Constraint

- **GPS Accuracy:** The accuracy of obstacle detection is limited by the accuracy of the device's civilian GPS. The system must include clustering or manual correction mechanisms to handle inherent hardware inaccuracy.
- **Operating System:** The application must be compatible with Android and iOS versions released in the last 3 years to ensure access to the latest APIs for efficient background sensor management.

3.5 Software system attributes

3.5.1 Reliability

3.5.2 Availability

3.5.3 Security

3.5.4 Maintainability

3.5.5 Portability

4 Formal anlaysis using Alloy

5 Effort spent

Guglielmi Leonardo

- 11/11/2025 1h (RASD document structure)
- 19/11/2025 1h 30m (Section 1 review)
- 21/11/2025 1h (class diagram review)
- 20/11/2025 1h (Scenarios review)
- 24/11/2025 2h (Scenario update)
- 26/11/2025 2h (Use Cases)

Lo Conte Francesco

- 17/11/2025 4h (Completing Section 1 (Introduction))
- 18/11/2025 7h (Section 2 - StateDiagrams, DomainClassDiagram, Scenarios)
- 19/11/2025 1h (Completing Section 2)
- 25/11/2025 5h (User Interfaces and some subsections of section 3)

6 References