Cyclopath Edinburgh

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Abstract

Cycling can be a part of a healthier lifestyle and is beneficial for the environment. However, deterrent factors such as lack of bike lane information can discourage people from cycling. In this project, we investigated the challenges faced by cyclists in Edinburgh and developed a cycling app to elevate their daily cycling experiences. We collected the needs and requirements of cyclists through several stages of data gathering. Based on their feedback, we built the app using the Cyclopath implemented by the University of Minnesota. We evaluated the app's usability and potential impact on cyclists in Edinburgh by conducting interviews with both cyclists and HCI experts at the University of Edinburgh. As a result, Cyclopath Edinburgh achieved a mean score of 94.8 out of 100 in the SUS evaluation, which measures the app's usability in the Summative Evaluation. This suggests that cyclists like Cyclopath Edinburgh and are likely to recommend it to their friends. Based on the Summative Evaluation, we also found that Cyclopath Edinburgh improves cyclists' cycling experiences and supports their daily cycling trips.

The link to the source code on Github can be found here:
`https://github.com/Cyclopath-Edinburgh/Cyclopath`

Research Ethics Approval

This project obtained approval from the Informatics Research Ethics committee.
First ethics application number: RT2022/454672 (rt#7162)
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The participants' information sheet (Appendix L) and consent form (Appendix M) are included in the appendix.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Chang Shian Goh*)

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To my partner. Thank you for the encouragement throughout the year.

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Chapter 1

Introduction

Disclaimer: Throughout this dissertation, the proverb 'we' is used when the step is carried out collaboratively by my partner and I, whereas the proverb 'I' is used when the step is carried out by myself.

1.1 Motivation

Bicycle is a popular form of transportation for commuting and leisure activities. In 2021, people in the UK cycled a total of 0.9 billion trips (Department for Transport GOV UK, 31 August 2022). The number of cycling trips has remained stable for the past 20 years since 2002. According to Bike Life, 26% of residents in Edinburgh cycle at least once a week, which shows that a significant number of people still consider cycling an important aspect of their lives (The City of Edinburgh Council, 2022).

Cycling enhances our cardiovascular system, relaxes our mind, and relieves our stress (Bike Radar, 1 February 2023). Cycling is also environment-friendly, as it reduces pollution and gas emissions. However, there are a few reasons that deter people from taking up cycling. Safety concern is the primary factor among them. People feel apprehensive to cycle on the road in the cities, as busy streets filled with vehicles pose immense dangers (Ma, 7 July 2019). Besides, people easily get bored when they cycle along the same route repeatedly (Cycling Today, 29 November 2017).

Edinburgh was rated as one of the top 20 best cities in the world to explore historic landmarks in 2022 (Bloom, 27 July 2022). Apart from historical tourist attractions, Edinburgh is famous for its natural features such as Arthur Seat, The Meadows, and Holyrood Park, providing nature lovers with opportunities to experience the beauty of nature on a relaxing weekend. Although cycling is one of the best commuting modes to travel around the city, the limited bike lane infrastructure might stop people from cycling (Akar and Clifton, 2009).

Cyclopath was an Android application operated by GroupLens Research at the University of Minnesota (Cyclopath, 2013). It was a research platform that facilitated Computer Science education at the University of Minnesota and was actively being used between 2006 and 2013. It used an open-source web mapping known as MapServer

that was originally developed by University of Minnesota as its base mapping (Open Source Geospatial Foundation, 5 October 2022). The codebase can be found in Github and has not been updated since almost eight years ago as the application is shut down (Cyclopath Developers, 19 July 2016). The main purpose of the app was to help users find and navigate routes in the state of Minnesota, as well as save and share their own routes. It also allowed users to view and follow routes created by other users, and record the tracks of their own cycling journeys.

As a Computer Science student at the University of Edinburgh who is experienced in Android app development, I think that it will be a great idea to adapt Cyclopath for use in Edinburgh. With the codebase, it can be redeveloped to suit the needs of cyclists in Edinburgh. I believe that an app designed specifically for cyclists in Edinburgh will support them to tour and travel around this fascinating city by cycling.

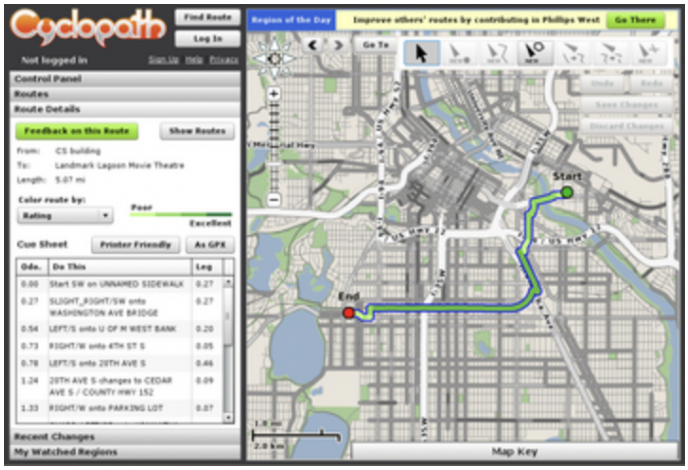


Figure 1.1: The user interface of Cyclopath in 2013 (Cyclopath, 2013)

1.2 Overview

The aim of this project is to establish and promote a Cyclopath instance for the city of Edinburgh. The project is being undertaken by my partner and I, who implement different features on the same Android app. I am responsible for adapting and updating the existing codebase of the Cyclopath available on Github for use in Edinburgh. I have migrated the database of the Cyclopath and converted the map available in the app from a map in Minnesota to a map in Edinburgh. The newly updated Android app allows cyclists in Edinburgh to search for cycling routes and record their cycling tracks, just like how it worked in the original Cyclopath. Furthermore, the user interface of Cyclopath has been redesigned to be more user-friendly. In order to facilitate the project, we have carried out three rounds of data gathering processes. Firstly, we conducted a Requirement Gathering to collect feedback on the original Cyclopath and decided the parts needed to be redeveloped and reimplemented. We then conducted Formative Evaluation and Summative Evaluation to seek advice on our implementation of the Cyclopath Edinburgh for further improvement. Chengyu Kang, a student in the School of Informatics is my partner for this project. He is responsible for Route Sharing and the Library. We received a mean score of 94.8 in the SUS Evaluation (an

app usability scale mentioned in Chapter 3) in the Summative Evaluation which proved that Cyclopath Edinburgh is highly acceptable by cyclists in Edinburgh. However, we missed the opportunity to publish the app due to unexpected delay of implementation.

1.3 Research Questions

The dissertation's objectives can be broken down into the following research questions:

RQ1: How can we adapt the existing codebase of Cyclopath for Edinburgh?

RQ2: Does the original Cyclopath meet the user requirement in Edinburgh?

RQ3: How can we develop an app that is suitable for cyclists in Edinburgh?

RQ4: How does the experts in the field of design and human computer interaction and cyclists perceive the usability of Cyclopath Edinburgh?

RQ5: Based on how the usability is perceived, how can we improve it by changing the design considerations that have been taken?

RQ6: What is the potential impact of Cyclopath Edinburgh for cyclists, in terms of:
(a) supporting their daily cycles?
(b) discovering and exploring new routes?
(c) improving the experience of their cycling trip?

1.4 Summary

The remainder of this dissertation is divided into nine chapters:

Chapter 2: I will introduce the background of the project on the benefits and challenges of cycling, along with a review of other existing apps.

Chapter 3: I will introduce the data collection methods used for each stage of data gathering.

Chapter 4: I will discuss the updates and adaptation of the original Cyclopath to make it workable, providing answers to RQ1.

Chapter 5: I will discuss the Requirement Gathering including the process and the feedback received, providing answers to RQ2.

Chapter 6: I will discuss the first iteration of implementation made from functionalities and design perspectives, providing answers to RQ3.

Chapter 7: I will discuss the Formative Evaluation collected from HCI experts and cyclists, providing insights to RQ4.

Chapter 8: I will discuss the second iteration of implementation made based on the results from Formative Evaluation, providing answers to RQ5.

Chapter 9: I will discuss the Summative Evaluation collected from HCI experts and cyclists, providing answers to RQ4 and RQ6.

Chapter 10: I will discuss the implementation and future work of Cyclopath Edinburgh, providing a conclusion to this project.

Chapter 2

Background

2.1 Advantages of Cycling

Outdoor activities are one of the favourite pastimes on weekends for people to relax their body and mind (Boyarsky, 12 August 2022). A study shows that cycling stayed popular even during the Covid-19 pandemic and the trend increased over time in recent years (Buehler and Pucher, 2021). According to recent reports suggesting exponential growth in e-bike sales, we can infer that cycling is growing in popularity amongst members of the public (Toll, 3 July 2022).

Regular cycling stimulates and strengthens your heart, lungs and circulation, lowering the risk of cardiovascular diseases associated with a sedentary lifestyle (Bike Radar, 1 February 2023). A five-year study conducted by the University of Glasgow over 260,000 individuals found that cycling to work reduces the chance of developing heart disease by 50% (Celis-Morales et al., 2017; Stern, 21 April 2017). Another study conducted over 28 years with 30,640 participants aged 20 to 93 years old found that cycling to work reduces the risk of all-cause mortality by 28% (Troelsen, 2018; Jepsen et al., 2019). This evidence further proves that cycling minimises the chances of acquiring cardiovascular diseases.

Cyclists can burn 400 to 1000 calories by cycling for an hour based on their weight and cycling speed (Cycling Weekly, 17 April 2020). A research from Harvard University shows that cycling at a speed of 12 to 13.9 miles per hour can help a 70kg person burn 298 calories in 30 minutes (Harvard Medical School, 8 March 2021). This proves that cycling is an effective method to control your weight, as it increases your metabolism, builds muscle and burns body fat. Furthermore, cycling increases your stamina, strength and aerobic fitness as it involves using all of the major muscle groups when you pedal (BetterHealth Channel, 30 November 2013).

Cycling is beneficial for the environment, as it reduces noise, air pollution, and greenhouse gas emissions, which contribute to global warming (sustrans, 10 December 2020). According to the European Cyclist's Federation (ECF), riding a bike produces only 21g of carbon dioxide per km, which is ten times less than driving a car (European Cyclists' Federation, 11 July 2013). This promotes a cleaner and greener environment,

leading to a better living standard.

Considering that cycling is one of the most time-efficient ways to incorporate regular exercise into your daily routine, it seems wise to adopt the habit of cycling as a means to travel. Additionally, a study in 2019 found that cycling improves executive functions, such as planning, focus, and observation (Leyland et al., 2019). Cycling alone can improve your mood, alleviating symptoms of certain mental health conditions such as depression and anxiety, while cycling in groups broadens your social circle (Arthurs-Brennan, 16 August 2022; Ballinger, 28 January 2020).

In conclusion, it is evident that cycling carries an abundance of benefits ranging from improving personal health and preserving the environment. People are thus highly encouraged to take up the habit of cycling to enjoy its benefits.

2.2 Challenges for Cycling

While cycling is popular in almost every age group, challenges do exist and have deterred some people from taking up the habit of cycling. According to a recent survey, the main reason for people to avoid cycling is due to an overall negative perception of road safety (Department of Transport, 5 August 2020; Ipsos, 24 May 2022). People are hesitant to cycle due to their impression of bad driving habits of drivers on the road (Walsh, 31 March 2014). Besides, roads in the cities are mainly designed for cars, thus it could be dangerous for cyclists to pedal on roads.

Since many pick up the habit of cycling for the reward of enjoying scenic views along the route, it is thus natural for them to develop interest in exploring new routes. However, people will get bored if they cycle using the same route every day (Arthurs-Brennan, 9 June 2017). Hence, it will be useful to have an online platform which provides information and resources on cycling route map.

Apart from that, it is inevitable that cyclists might face bad weather while cycling (Ma, 7 July 2019). As cycling is mainly an outdoor activity, cyclists are not shielded from scorching sun and relentless rain. Compared to vehicles, riders are directly exposed to the outdoor environment and therefore, the dangers of it. It would not be uncommon for cycling journeys to terminate earlier due to sudden weather changes. People might start abandoning the habit of cycling due to such troubles.

On the other hand, there is a lack of facilities and infrastructures that support cyclists in most countries (Hughes, 9 June 2022; Akar and Clifton, 2009). In an unfortunate case of a bicycle breaking down during the middle of a journey, it could be difficult to seek help. There is also inadequate supply of public toilets and benches for cyclists to take breaks (Pitane.Blue, 18 September 2022).

2.3 Previous Work

2.3.1 Software Engineering Background

I am a final year BSc Computer Science student in the University of Edinburgh. Across the four years degree, I learnt software engineering, app development and user design. The modules related are Software Engineering and Professional Practices (SEPP), Software Design and Modelling (SDM) and Software Testing (ST). I learnt the basics of software engineering from SEPP like the fundamentals of software requirement, software design and testing (Sommerville, 2016, 2020). This built my basic knowledge and sparks my curiosity in software development. Following this, I learnt how to develop an Android app from scratch. My knowledge in software design is reinforced after I took SDM. In this module, I learnt the design principles and design patterns in more-detailed as well as the model driven development (Object Management Group, February 2014; Debnath et al., 2005). To further improve my testing technique, I took ST and learnt different techniques of testing such as test driven development (Pezzè, 2008). As our goal was to create an app for public use, I learnt the basics of Human-Computer Interaction technique (Sharp et al., 2019). This ensures that Cyclopath Edinburgh has high usability and is user-friendly for our target audience.

2.3.2 Edinburgh Cycling Clubs and Events

Edinburgh was the first UK city to sign the Charter of Brussels and is currently committing 10% of the city's transport budget to cycling (Edinburgh Festival of Cycling, n.d.). Following this, the Edinburgh Festival of Cycling was launched in 2013 and became one of the top ten cycling festivals in Europe. It aims to celebrate all aspects of cycling, as well as recognize cycling as one of the ways to reduce ill health and pollution. Additionally, there are many cycling clubs in Edinburgh (The City of Edinburgh Council, n.d.; mattlamy, 7 July 2017). The most well-known cycling campaign is Spokes, the Lothian Cycling Campaign founded in 1977 which aims to promote cycling (Spokes, n.d.). Besides, the Edinburgh Road Club, established in 1925, and the Ronde Cycling Club, founded in 2011 (Edinburgh Road Club, n.d.; Ronde Cycling Club, n.d.) aim to develop cycling habits in the community in Edinburgh. From this, we can conclude that people in Edinburgh like to cycle in their daily lives.

Figure 2.1: Edinburgh Festival of Cycling (Edinburgh Festival of Cycling, n.d.)

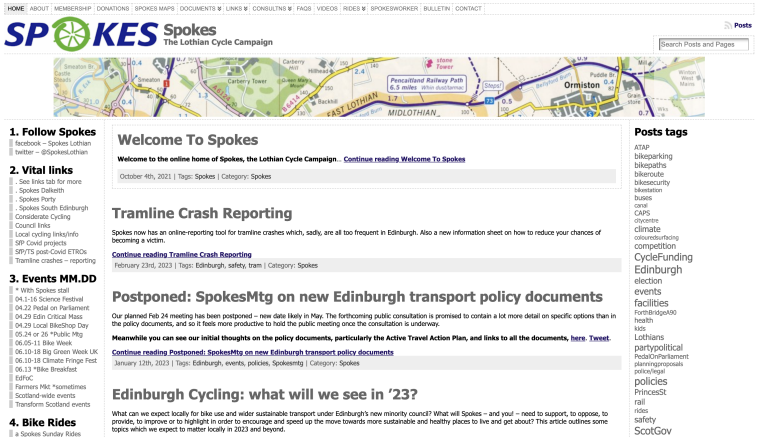


Figure 2.2: Spokes (Spokes, n.d.)

2.3.3 Other Related Apps

There are a few apps that are related to our project (bikeradar, 5 June 2022). In this section, I will describe a few examples and the pros and cons of the app.

2.3.3.1 Komoot (Figure 2.3a)

Komoot is an app that provides navigation and route planning features for users to create and follow routes according to their riding style (Portus, 27 July 2021). It is available on desktop and mobile apps in both Android and iOS as well as in cycling computers such as Garmin (Cyclist Magazine, 12 August 2019). It provides routing and navigation for cycling, hiking and also running. When planning for a cycling journey, users can select routes according to several parameters including distance, elevation, road surface, fitness level required, difficulty and estimated time of arrival. It is equipped with audible navigation features which allow users to follow the route without looking at a phone. It also has a community for users to upload their completed tracks together with pictures of the destination to share with other cyclists. However, certain features such as offline navigation and access to global routes require a subscription fee. This may be a barrier for some cyclists who cannot afford the additional cost, especially since cycling is often seen as a cost-effective means of transportation.

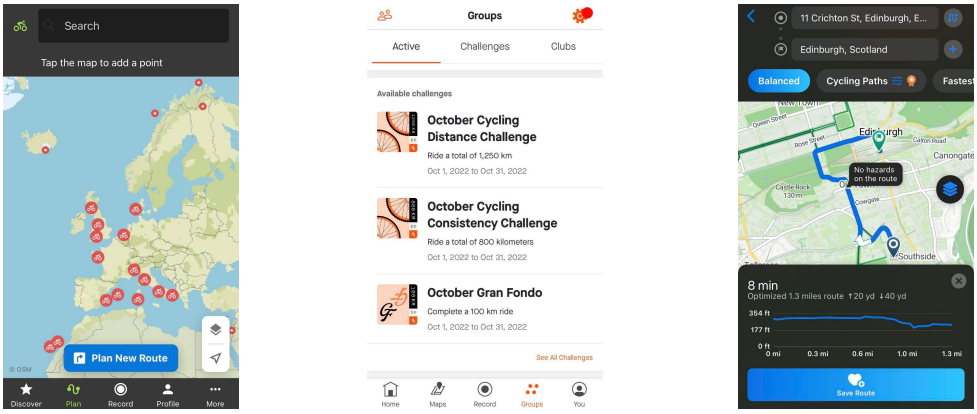
2.3.3.2 Strava (Figure 2.3b)

Strava is an American internet service that helps track physical exercise and incorporates social network features (Strava, n.d.). It is mainly used for cycling and running with features of routing, navigating and socialising. Besides the normal functionality as other apps, it can be used as a fitness app. It records your weekly and monthly progress as well as stores a record of your training logs. It has an interesting feature which allows the user to set up goals that they aim to achieve. This will motivate the user to work harder and exercise more in order to reach the target (Hakulinen et al., 2013). It can be connected to social media such as Facebook to see the activities of friends. It is also equipped with a personal heatmap where users can view the body area that they have exercised the most (Luke, 26 January 2021). It is further combined to

a 3D map which makes the graphic of the app more interesting and attracting (Portus, 24 February 2022). Despite fantastic features and layouts, it has similar issues with Komoot as it requires users to subscribe in order to enjoy the premium features such as trip planner.

2.3.3.3 Bikemap (Figure 2.3c)

Bikemap is a cycling app for cyclists to plan their journey, as well as referring to navigation and realtime update (Bikemap, n.d.*b*). It is a good alternative to Komoot and Strava because it provides more features in the free version. It stands out from other cycling apps as it offers real-time updates for cyclists. Cyclists can alert others of sudden emergency or road issues on a specific route, or even use it to seek help if they face problems in the midst of a journey. This could potentially reduce risks of accidents and make cycling in urban environments more appealing.



(a) (b) (c)

Figure 2.3: (a) Komoot - the map and the available plan nearby (Komoot, n.d.), (b) Strava - the challenges that cyclists can join (Strava, n.d.), (c) Bikemap - the condition on the route (Bikemap, n.d.*b*)

I reviewed some user statistics and feedback among the cycling apps. Komoot was founded in 2010 in Berlin and has reached 30 million users to date. A Komoot user commented that it is the most intuitive route planning app in the market, saving him time and making it easy to explore new adventures (Komoot, n.d.). This shows that Komoot is one of the popular cycling app that is widely used by cyclists. Strava was launched in July 2009 and has 95 million active users as of January 2022, with an increase of two million users every month (Curry, 9 January 2023). Almost two billion activities were completed on Strava in 2021. We can conclude that Strava has become increasingly popular recently, as evidenced by its strong support among cyclists. Bikemap was founded in 2014 and currently has 7.5 million active users worldwide (Bikemap, n.d.*a*). A UK Bikemap user commented that the app provided clear step-by-step directions and GPS, resulting in a perfect route to work. Although it has less users than Komoot and Strava, it offers the functionalities that we plan to implement in Cyclopath Edinburgh. Therefore, all these apps can serve as references for my project.

Chapter 3

Data Collection Methods

There are two different types of data collection methods which are suitable for my project: user-centered design and participatory design (Enerson, 16 August 2013).

User-centered design is a method to design and develop software products, such as websites and mobile applications, where a professional team puts users' needs front and centre by following an iterative design process throughout the product life cycle (Browne, 15 September 2021; Abras et al., 2004). The entire professional team typically comprises designers, developers, and project managers who work together to strategize, plan, create, and implement a project. Users' behaviours, values, and expectations are prioritised throughout the entire design process, and the final software product is usually owned by the developer team.

Participatory design (also known as co-design) is an approach to designing and developing software products where all stakeholders, such as employees, partners, customers, citizens, and end-users, are actively involved throughout the product life cycle to ensure that the result meets their needs (Olga Elizarova, 14 December 2017; Muller and Kuhn, 1993). Users 'own' the end product as they not only participate in decision-making but also in idea generation, which usually does not happen in traditional user-centered design approaches. They are allowed to decide on functionality and create the entire software product from scratch, and they usually own the final software product.

Research has found that involvement of end-users throughout the design process and working in a co-design environment can lead to more innovative concepts and ideas (Mitchell et al., 2015). Since my project aims to provide a user-friendly app for users, it will be great to involve all stakeholders in my design process. In this project, we recruited Human-Computer Interaction (HCI) experts and cyclists at the University as end-users for the app. We utilised several methods in applying participatory design for the data collection.

The Data Collection Methods are as follows (Bella Martin, 2012; Dix et al., 2003; Bruce Hanington, 2019):

Questionnaire
A research tool that comprises a list of questions that aims to gather information from respondents about their attitudes, experiences, or opinions (Bhat, n.d.; Graham, 2007). It is normally conducted via an online form and comprises a mix of closed-ended and open-ended questions. Questionnaires are effective for a large number of respondents, and the collected data can then be used to carry out quantitative and qualitative analysis.

Focus Group Study
A type of qualitative research that involves a group of 6-10 people who are carefully selected to represent the large population they are targeting to contribute to an open discussion on the research topic (Fleetwood, n.d.; George, 4 May 2022*b*; O.Nyumba et al., 2018). It is a type of group interview that capitalises on communication between research participants and utilizes group dynamics to gather shared experiences from people with similar characteristics (Kitzinger, 1995; Office for Health Improvement and Disparities, 30 January 2020). Participants are encouraged to talk to each other, exchange their ideas, and comment on each other's points of view (Citizens Advice, 2015).

Think Aloud Protocol
A technique used to collect data during usability testing in product design and development (Nielsen, 15 January 2012; Blummer and Kenton, 2014). Participants are required to perform a set of specific tasks using the software product implemented. They are then asked to verbalise what they think, feel, and expect when performing those tasks (Office for Health Improvement and Disparities, 8 September 2021). It aims to understand the user experience of the software product through the perspective of complete strangers to further improve the UI and UX of the software product.

Interview
A type of qualitative research that involves two or more people, one of whom is the interviewer who asks the questions (George, 4 May 2022*a*). It aims to investigate the perspectives, experiences, and motivations of individuals on the software product to collect qualitative data (DeCarlo, August 2018). It can be structured or unstructured, depending on the purposes and the formality of the session (Gill et al., 2008).

Stakeholder Walkthrough
A technique that brings the representative end-users, developer team, and project stakeholders to perform a list of tasks from the end-users' perspective (Bella Martin, 2012). It aims to identify usability problems in the early stage to do further improvement in order to fulfil the needs of end-users.

System Usability Scale (SUS)
A reliable tool to measure the usability of software products (Brooke, 1995; Sauro, 3 February 2011). It consists of ten questions, each consisting of five response choices ranging from 'Strongly Agree' to 'Strongly Disagree' (Thomas, n.d.). It is effective and valid to evaluate and differentiate usable and unusable software products (Aaron Bangor and Miller, 2009).

Padlet, Audio and Screen Recording
Technologies that are suitable to record the qualitative data from respondents.

Chapter 4

Updates and Adaptation of Cyclopath

The aim of this chapter is to answer research question **RQ1**. Screenshots illustrating the original design of Cyclopath can be found in Appendix A, and the updated version can be found in Appendix B. The overall adaptation took 20 hours to complete, with 5 hours on the research of map API and 15 hours on the implementation.

4.1 Updates on Old Codebase

The original Cyclopath has not been maintained for more than eight years. In order to reuse the original codebase for Edinburgh, I need to run it in Android Studio. Android Studio is the official Integrated Development Environment (IDE) for Android app development (Android Studio, 22 February 2023*b*). It is built on IntelliJ IDEA, a Java IDE for software development, and includes its developer tools and code editing capabilities (TechTarget Network, January 2023). To facilitate application development for the Android operating system, Android Studio uses a Gradle-based build system, an Android Emulator, code templates, and Github integration. Gradle is an open-source build automation tool known for its flexibility in building software (Gradle, 2022; Gaba, 24 February 2023). Android Studio uses Gradle to automate and manage the build process while providing flexibility for defining custom tasks, dependencies, plugins, and other build configurations (Android Studio, 22 February 2023*a*). The build process includes compiling, linking, and packaging code. The defined configurations are stored in the build script in the project's root directory.

The original codebase does not contain a build script in the project's root directory. This means that it does not use a Gradle-based build system and cannot be run using Android Studio. Therefore, I created a new project in Android Studio and moved the Java files into it. These files include settings, source codes for each activity, and resources such as layouts and drawables.

Additionally, to run some specific packages, the SDK version of the Android app should be a newer version. SDK stands for Software Development Kit, which consists of a set of tools that enable the programming of mobile apps (AT INTERNET, n.d.). Thus, to keep up with the latest technology, the minimum SDK version of Cyclopath

Edinburgh is set to be 26, and the targeted SDK version is set to be 32.

After moving all the files into the newly created project, the app is still not runnable. From the project's build script, I found that some dependencies and packages are outdated and unavailable. There are also some bugs because of deprecated functions in the current SDK version. For those that are outdated, I searched for the documentation online and updated them with the latest version. For those that are deprecated, I searched for an alternative package to keep the original method working. For example, Junit dependency is added in the build.gradle to import the Assert packages in the file.

After fixing the bugs and updating the version, the project is now runnable. As of mid of November 2022, I was able to view and run the original Cyclopath.

4.2 Adaptation of Cyclopath in Edinburgh

4.2.1 Mapbox

The original Cyclopath is only available in Minnesota and will detect your current location if you are in Minnesota. It only contain a series of static maps of Minnesota from 1991 to 2012. As I am outside Minnesota, I am unable to access the map, search for routes or record tracks. The main page shows empty tiles with an error message.

The original map is powered by MapServer, an open-source platform for publishing spatial data and interactive mapping app to the web (Open Source Geospatial Foundation, 5 October 2022). It is originally developed in the mid-1990s at the University of Minnesota and is still being updated today. The source code can be found on GitHub (MapServer Developers, 21 February 2023). While MapServer provides live maps, it is written in C language and is less well-known compared to other online map services. It is harder to integrate into a Java-written Android app and poses a higher risk of maintenance issues.

There are many online map packages that can be integrated into an Android app. Google Maps is the most popular online mapping service, but it requires a subscription to integrate it into an app (Google Maps Platform, 2 March 2023). As my project is not sponsored, I need to select a free mapping service. From my previous work, I found that every app is either integrated with Mapbox or OpenStreetMap. OpenStreetMap is a free, open geographic database updated and maintained by a community of volunteers via open collaboration (OpenStreetMap, n.d.). It is suitable for Cyclopath Edinburgh but lacks documentation compared to Mapbox. Mapbox is known as the free alternative to Google Maps (Voroshylov, 25 August 2021). It has almost everything that a Google Maps API has, such as the Matrix API for showing the length and duration of the fastest route, the GeoCoding API for translating the coordinates to names of locations, and Directions for showing turn-by-turn navigation. It has a free quota for every user and provides a map profile for cycling routes, which is suitable for Cyclopath Edinburgh. It has well-written documentation and is easy to integrate into mobile apps.

Out of the four choices listed above, I chose to integrate Mapbox into Cyclopath Edin-

burgh. As we aimed to receive feedback on the original Cyclopath during the Requirement Gathering, I decided to only implement the map of Edinburgh. Without a map, it will be difficult for users to provide feedback. I applied the Map SDK for Android into Cyclopath Edinburgh (Mapbox, n.d.*b*). The Map SDK involves the map of the world and has a nicer design compared to MapServer.

4.2.2 Migration of Database

The original Cyclopath used HTTPClient package to send HTTP requests and retrieve HTTP responses to access the database (Microsoft, n.d.*a*). As we are not its creator, we cannot access the database. Therefore, I need to migrate the database to a new one.

I opted to use cloud databases over local databases as they provide a centralised location that can be easily accessed by anyone from anywhere. Local databases are only accessible to the device owner and cannot be transferred to another user. As Cyclopath Edinburgh has a login system and a route sharing library, using cloud databases makes it easier to have a centralised library and user data.

Regarding SQL and NoSQL databases, I chose to use NoSQL databases (Benjamin Anderson, 12 June 2022). SQL is a programming language commonly used for managing data, primarily for querying relational databases where data is stored and linked in tables through different ways. On the other hand, NoSQL is a non-relational database that offers more flexibility, allowing for different structures and formats that best fit the data. My project is cycling-based and involves storing data such as tracks and routes in GeoJson format. Besides, we need to retrieve a specific field such as start date and email of a user from a certain document. Therefore, NoSQL is a better fit for making the process of accessing and retrieving data more efficient.

Firebase is a NoSQL cloud database fully maintained and operated by Google (Stevenson, 24 August 2018). It consists of various tools that developers would normally have to build themselves, such as authentication, databases, and file storage and offers real-time service that allow users to access their data at any time. All of these services fulfil the requirements of my project, including authentication for the login system, databases to store user data, and file storage for keeping track and route history.

Migrating databases to Firebase is easy since it is well-documented, and I will only need to add a few endpoints in the activity that requires a connection to Firebase. Since participants are not required to use the app during the Requirement Gathering, I just created a project in the Firebase console and linked Cyclopath Edinburgh to it.

4.3 Summary

This chapter addressed research question **RQ1**. The rebuilding of the original Cyclopath codebase involved several key changes to make the app runnable and workable. This included updating old and deprecated packages, switching the map API of Cyclopath Edinburgh to Mapbox so that it could be used in Edinburgh, as well as migrating the database to Firebase. As the features and databases in the original Cyclopath cannot be used, I will need to implement features myself from scratch.

Chapter 5

Requirement Gathering

The scripts and results of Requirement Gathering can be found in Appendix C and Appendix D. The Requirement Gathering took 10 hours to complete, with 5 hours on the focus group study and questionnaire and 5 hours on the analysis.

5.1 Aims

The aim of this chapter is to answer research question **RQ2**. I wanted to figure out how the original Cyclopath meets the needs of cyclists in Edinburgh. The data collection methods in the Requirement Gathering are designed to answer this research question.

5.2 Data Collection Methods

We launched an online questionnaire with the assistance of our supervisor. The questionnaire is distributed to all staff and students in the School of Informatics at the University of Edinburgh. With this questionnaire, we collected 86 responses which enabled us to gain a broad insight of cyclists' thoughts.

To perform Requirement Gathering, we used Microsoft Forms for the questionnaire. Microsoft Forms is suitable for providing a list of questions in different sections and provides statistics and net promoter scores for rating questions (Microsoft, n.d.*b*). The net promoter score is a commonly used metric in market research that asks respondents to rate how likely they are to recommend a software product based on a single survey question (NICE, n.d.). The rating, Likert, and multiple-choice questions in the questionnaire are suitable for quantitative analysis. The open-ended questions in the questionnaire are designed to be non-compulsory, and this resulted in a limited number of responses to these questions, with most answers being short. As a result, it was difficult to conduct qualitative analysis based on these results as they lacked detail.

To gather more in-depth qualitative data, we conducted a focus group study. The focus group study is divided into two sessions and conducted in person at the University of Edinburgh. This is aimed at collecting more detailed feedback on the original Cyclopath directly from potential users. We used Microsoft Teams to record the sessions,

which generated automatic transcripts that can be used as backup in the analysis. To ensure that ideas are well-noted, we used Padlet as a platform for participants to answer questions. Padlet is well-documented and easy to use, allowing us to separate different types of questions into different sections (Edwards, 9 May 2022).

5.3 Participants

86 respondents who are either staff or students in the School of Informatics at the University of Edinburgh and cycle routinely completed the questionnaire. From these respondents, we invited eight students to participate in the focus group study, all of whom had expressed a willingness to be involved in further study.

5.4 Materials

As the Requirement Gathering involves data collection from participants, we prepared an Ethics Form for this data collection. This process is to ensure that ethical considerations are taken into account in any research done in the school. We have also prepared a Participant Information Sheet (PIS) and a Participant Consent Form (PCF) for each data collection method. The PIS describes the purpose of the study, the process of the study, data protection, and other relevant information. The PCF serves as an agreement to be signed by participants before the study to inform them about the data that needs to be collected during the study, including the agreement of data usage and recordings. The PIS and PCF are uploaded to OneDrive so that they are visible to the participants.

5.4.1 Questionnaire

The Microsoft Forms contains a brief description of Cyclopath Edinburgh and it is divided into five sections:

Section 1: Agreement to the PCF. Participants are required to read the PIS and agree to the PCF in order to continue with the questionnaire.

Section 2: Personal Cycling Habits. Participants are asked to choose the most relevant choice according to their previous cycling experience. This includes whether they refer to a map when cycling, whether they plan before cycling, and where they often obtain information about cycling.

Section 3: Feedback on Original Cyclopath. Participants are asked to rate the design aspect of the user interface of each page of the original Cyclopath. They are also allowed to provide comments on the overall user interface of the original Cyclopath.

Section 4: Feedback on Current and Future Features. Participants are asked to rate how likely they will use a feature. This includes basic features in the original Cyclopath as well as additional features that we would like to add in the Cyclopath Edinburgh.

Section 5: Involvement in Future Study. Participants are asked if they are willing to join the focus group study in the future.

5.4.2 Focus Group Study

The Focus Group Study is divided into five sections:

Section 1: Agreement to the PCF. Participants are required to read the PIS and agree to the PCF in order to continue with the study.

Section 2: Desired Functionalities. Participants are asked to express and comment on their desirable functionalities in Cyclopath Edinburgh.

Section 3: Voting on Additional Features. Participants are asked to vote on the list of additional features that we would like to add to the Cyclopath Edinburgh.

Section 4: Desired User Interface. Participants are asked to draw their desirable user interface of Cyclopath Edinburgh.

Section 5: Feedback on Original Cyclopath. Participants are asked to comment on the design and user interface of the original Cyclopath.

5.5 Procedure

The questionnaire is sent via a link to staff and students through mailing lists. To proceed with the questionnaire, participants must agree to the statements listed in the first question. Most questions are compulsory, except for text questions. The questionnaire typically takes around ten minutes to complete.

The link to the Padlet for the Focus Group Study is sent to the participants via email once they arrived. They are given five minutes to review the PIS, agree with the PCF, and read the brief introduction on the original Cyclopath. Recording begins once participants agreed to start. A brief verbal introduction is given to the participants, after which they are required to comment and vote based on the questions in the Padlet. Participants are encouraged to provide feedback on other participants' ideas. They are given a pen and paper to draw their desired app design and describe their design to other participants. To prevent the original Cyclopath from influencing participants' design ideas, feedback on the original Cyclopath is left until the end of the focus group study. Participants then provide comments on the available user interface on the Padlet, both verbally and in writing. The focus group study typically takes around an hour.

5.6 Result of Quantitative and Qualitative Analysis

Quantitative analysis is done on rating and multiple-choice questions in the questionnaire and focus group study. Microsoft Forms display statistics for each question in the questionnaire, using pie-charts for multiple-choice, box-plots for Likert, and bar-charts for rating questions. Net promoter score questions are categorized into promoters, passives, and detractors, and scores are calculated by subtracting detractor percentage from promoter percentage. The quantitative analysis for focus group study is done manually as the amount of data collected is small.

Qualitative analysis is achieved by conducting thematic analysis using NVivo. Thematic analysis is a technique used to analyse qualitative data, such as text, which involves identifying recurring patterns and themes throughout a dataset (Braun and Clarke, 2006; Kiger and Varpio, 2020). It is a way to interpret and describe qualitative data by selecting relevant codes and constructing themes. NVivo is a software program specifically used for analyzing unstructured text, audio, and video, including interviews and focus groups in qualitative research (Kent State University, n.d.). Qualitative analysis is performed on text questions with comments in the questionnaire and focus group study. The results of the questionnaire are exported as Microsoft Excel files from Microsoft Forms. The data is then analysed through thematic analysis using NVivo. The results collected from the focus group study are analysed manually.

5.6.1 Questionnaire

The final interpretable data collected is 82 sheets out of 86 responses received initially as four respondents did not agree to the PCF.

5.6.1.1 Quantitative Analysis

Among the 82 responses, 59 cyclists (72%) referred to a map or GPS when cycling. 33 (40.2%) planned out their route before each trip, while 41 (50%) did so sometimes. From this, we can conclude that there is a large number of cyclists in Edinburgh who use maps or GPS and are likely to plan their route before each trip.

Among the resources they used to work out their cycling plan, search engines were the most popular, with 58 respondents (70.7%) stating that they often used them to plan their cycling route. Other resources such as biking websites, biking apps, asking friends and social media are less popular among cyclists in Edinburgh.

Among the four questions on user interface, the main page received the lowest mean rating at 2.46 out of 4. 45 respondents (54.9%) felt that the main page needs significant improvement in design. This suggests that the main page should be prioritised when redesigning the app's user interface. However, none of the mean ratings exceeded 3, indicating that we need to redesign the user interface of the entire app.

Among the eight questions on features, only Find Route (4) and Live Map (13) received a positive net promoter score, suggesting that these features should be included in Cyclopath Edinburgh. The other six features received a negative net promoter score, with Communities (-58) and Inclusive of Other Activities (-53) receiving the lowest marks. This suggests that these features are less likely to be used by cyclists in Cyclopath Edinburgh.

5.6.1.2 Qualitative Analysis

Among 82 valid respondents, 42 (51.2%) of them provided an overall feedback on the functionalities and user interface of the original Cyclopath. I classified the response into four themes, which are Positive Feedback (33%), Negative Feedback on UI (29%), Feature Recommendations (22%) and Irrelevant (16%).

Positive Feedback mostly consists of comments on the existing functionalities, with only a few on the user design. Negative Feedback on UI highlights the map and the outdated design. Feature recommendations refer to functionalities that respondents believe would be useful to add or further improve upon the existing features. Irrelevant consists of comments which do not provide workable feedback.

Selected feedback for this question is presented below, one for each theme:

"Functionalities are clear, good idea to provide different routes between the same two points based on the mentioned criteria."

"The UI doesn't is not appealing and inviting to use, seems a bit outdated."

"Clear information about dedicated bike lanes."

"It's difficult to judge as it is a small screenshot and hard to see what it actually does."

20 (24.4%) respondents provided suggestions for additional features they would like to see in the app. These responses are categorized into three main themes: Map Improvements (55%), Additional Features (25%), Other App Suggestions (20%).

The majority of respondents in the Map Improvements category suggested adding new features to the map to provide cycling-related information. This theme is further broken down into several sub-themes based on functions, including bike lanes, facilities, navigation, offline maps, record tracking, and route search. The Additional Features category includes suggestions for specific new features that respondents would like to add. In the Other App Suggestions category, respondents provided feedback on features or recommendations for other available apps that we could refer to.

Selected feedback for this question is presented below, one for each theme:

"An indication of steepness/elevation of a route."

"Fitness tracker of sorts."

"Strava does all of this well and has a well-established user-base."

5.6.2 Focus Group Study

5.6.2.1 Quantitative Analysis

There are some voting questions about additional functionalities that we would like to add into the app. Based on the results, the majority of participants strongly support most of the proposed functionalities. However, some features, such as those related to other activities and communities, are deemed unnecessary by most of the cyclists. Thus, we will need to consider whether or not to implement these features in the future.

5.6.2.2 Qualitative Analysis

Among the functions that would prompt cyclists to use a cycling app over Google Maps, the most supported answers were elevations, anti-theft systems, and fitness trackers. These features are mentioned and supported by multiple participants.

As the ‘Communities’ functionality is supported by four participants and opposed by four others, we asked for their opinions and the types of communities they would like to have. From the results, we found that cyclists would like to have an interactive forum with rating and comment which will act as a route library.

Among the design of the participants, we found that most of the participants like to have a bottom bar in the app. Most of them would like to have the map as the main page and the library, history and profile as other fragments. They want the ‘Search Route’ function in the main page as this is the main function of the app.

From the feedback of the original Cyclopath, all of the cyclists think that a bike lane is very important and should be shown when navigation. For the login system, all of the cyclists would like to have alternative login e.g. with Google. They think that the ‘Login’ page should be located in the first page instead of sidebar.

Overall, respondents think that the original Cyclopath comprises the basic functionalities of a cycling app. However, they suggested adding more features to make Cyclopath Edinburgh more tailor-made to cyclists such as fitness tracker and elevation of the routes. It is useful for cyclists as they need to keep track of their activities and consider the difficulty of the route when selecting a route. For the user interface, they suggested redesigning the overall user interface because it appears too old-fashioned.

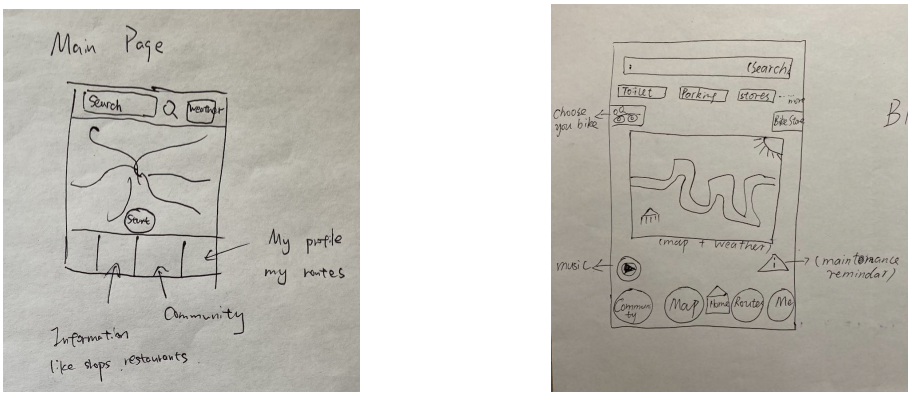


Figure 5.1: Desired main page with bottom app bar by participants

5.7 Summary

The Requirement Gathering addressed research question **RQ2**. Based on the results, I found that cyclists think the original Cyclopath includes most of the basic features that cyclists need. Nevertheless, they would like some additional features to make the app more useful. Also, they think that the user interface (UI) is outdated and need a massive redesign.

Based on these conclusions, I believe that the most important thing is to ensure that the available basic functionalities work well. This will ensure that Cyclopath Edinburgh fulfils the fundamental needs of cyclists. Additionally, I prioritised the UI design since it received a lot of negative feedback from the cyclists. Finally, I planned to add additional features to the app based on the suggestions from the cyclists.

Chapter 6

First Iteration of Implementation

The aim of this chapter is to answer research question **RQ3**. Screenshot illustrating the first version of Cyclopath Edinburgh can be found in Appendix E while the test cases can be found in Appendix F. The first iteration of implementation took 70 hours to complete, with 20 hours on the login system, 35 hours on the map system, 5 hours on the history, 5 hours on the profile and 5 hours on the UI design.

6.1 Tools Used

6.1.1 Github

My partner and I needed a repository for our code to support version control and collaboration. We decided on Github as it is a widely used online platform (Github Developers, n.d.; Juviler, 31 October 2022). If we were working with documents, we would have chosen Google Docs instead. Github allows us to store, track, and work together on software projects independently in different branches from anywhere. We can easily retrieve the latest version by looking up the main branch in our project. All history is then recorded in Github, and it is easy for us to return to the previous step at any time. These features in Github make collaboration smooth and workflow transparent.

6.1.2 Firebase

As mentioned in the Chapter 4.2.2, I used Firebase as my cloud storage. I mainly used three of its functions in my project, namely Authentication, Cloud Firestore, and Storage. Authentication is used to verify the email addresses of newly signed-up users, ensuring that they are valid and exist. Additionally, Authentication supports alternative login options, such as Facebook, Google, and Github, which make the sign-up process faster and more convenient. Cloud Firestore is used to store user information. It's a good choice for storing hierarchical information, as it allows for collections which contain documents with multiple fields. This makes retrieving and updating user information more efficient and streamlined. Storage is used to store the Geojson and text files for each user as it doesn't restrict the file format uploaded. This provides a great platform for my app to store Geojson data.

6.1.3 Android Studio

As mentioned in the Chapter 4.1, Android Studio was the main tool that I used for my project. It provided a great platform for me to code and run my application simultaneously. Android Studio can be connected to an Android phone (with debug mode switched on) to run the app, and it can also generate an APK file for the app that can be downloaded and installed on any Android phone that meets the minimum SDK version. This makes the process of implementation faster and more efficient.

6.2 Implementation

We divided our implementation according to the features. As I began to research and implement the map for Edinburgh before the Requirement Gathering, I continued with the map functions such as search route, navigation, and record track. Since I am familiar with Firebase and had made some changes to the database before the Requirement Gathering, I continued with the implementation of a login system for the app. All of these form the basic functionalities of Cyclopath Edinburgh that meet the basic requirements of cyclists, as determined through the Requirement Gathering, and align with the aims of this project - 'Create a Cyclopath Instance for Edinburgh'. Additionally, I chose to implement a fitness tracker that will collect data and create a report-like statistics for the user. Generally, I focused on the main functionalities of Cyclopath Edinburgh, which include the login system for login, sign up, and log out; the map system for searching routes, navigation, and recording tracks; and the profile, which displays users' statistics and serves as a fitness tracker. My partner mainly worked on the library, which allows users to share their routes with the public, view others' routes, and additional features such as weather forecasts and elevation of routes.

6.2.1 Login System

6.2.1.1 Sign Up (Figure 6.1a)

Users need to create an account on the app for storing their information and access to public routes. They can do this by pressing the 'Sign up' button on the 'Login' page and entering their desired username, email, and password. Usernames and passwords must each contain 6-20 characters. For security purposes, passwords need to include a combination of numbers and letters and are not visible in the input bar. To view the password, users can press the 'Eye' button located to the right of the input bar. Users must agree to the app's terms and conditions for data protection purposes as our app will require location services and store user data.

After entering their information, the system checks if the chosen username and email are available. Once the information is validated, a verification email is sent to the user's email address. To complete the registration process, users must click on the verification link in the email. After verification, the system creates a new document in the Cloud Firestore, using the username as the document name and email, password, and start date as fields. Users can now log in to their account in the 'Login' page. To exit the 'Sign Up' page, a popup will be shown to confirm with the user if they would

like to exit the current page. This is designed as the 'Sign Up' page will provide a button for the users who signed up to choose to resend the verification email. This can prevent the users from accidentally exiting the 'Sign Up' page.

6.2.1.2 Login (Figure 6.1b)

To prevent users from having to log in every time they use the app, I save their logged-in status in the Shared Preferences. When the user opens the app, I check if the Shared Preferences contains their data and navigate them to the main page if it does.

Login with Username and Password
Users can log in using the username and password they created during sign-up. After entering their username and password, the system checks if both are valid, as well as if the email address corresponding to the username has been verified. Once the check is passed, users are navigated to the main page of the app.

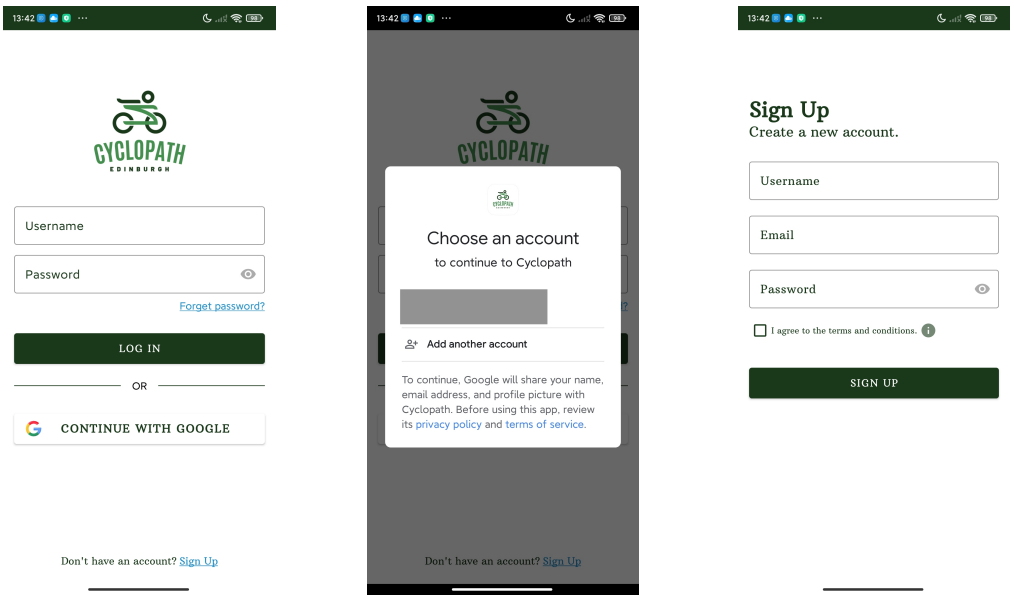
Login with Google (Figure 6.1c)
Following the feedback from the Requirement Gathering, cyclists are happy to have an alternative login method in the app. Thus, I chose to implement 'Login with Google' in the app. To achieve this, I added the API to the dependencies in the Gradle file (Firebase, 3 March 2023). I then followed the documentation in Firebase to link with the Google API Console. To work with Google Login, I created an account that linked my project ID in Firebase with the Google API Console. Then I specified that my app supports Google Login with the ID in the Firebase Authentication.

A 'One-Tap Sign In' popup is shown when users press the 'Continue with Google' button. This directs users to the interface supported by Google. Users can choose their Google account in the popup, as well as adding their Google account to the choices. Once selected, they need to accept the terms and conditions and verify. All these processes are implemented and provided in the Google API. Once the process succeeds, users are directed to the main page of the app automatically.

Forgot Password
As the user accounts are authenticated by Firebase's Authentication, the passwords of the users are stored in secret by Firebase. Therefore, the process of resetting the password is handled by Firebase. If users forget their password when trying to log in, they can press on the 'Forgot Password' word on the 'Login' page. They will need to provide the email address that they registered with Cyclopath Edinburgh and they will receive an email which provides a link that directs them to a website to reset their password. The password will then be updated in the Firebase system.

6.2.1.3 Log Out

A Log out function is needed to allow users to switch accounts on the same mobile device. A 'Log Out' button is located at the end of the scrollable view in the 'Profile' fragment. When the user presses the 'Log Out' button, a popup appears to confirm the action to prevent accidental actions. After confirmation, users are directed to the 'Login' page, and the user data is deleted from the Shared Preferences.



(a) (b) (c)

Figure 6.1: (a) Login Page, (b) Login with Google, (c) Sign Up Page

6.2.2 Map System

6.2.2.1 Search Route (Figure 6.2a)

The main function of Cyclopath Edinburgh is route searching. Therefore, the main page of the app features a map and a route search function. The map is powered by Mapbox and is integrated into the app through the Map SDK for Android API (Mapbox, n.d.*b*). The map is clear and simple as it shows road names and building names, which is suitable for a navigation app.

Users can view their current location on the map by allowing location permissions and turning on location services on their phone. Users are allowed to swipe along the map to view other locations, and they can press the 'Recenter' button to immediately bring the map to their current location. Users can enter their origin and destination in the input bar. As they type, the system provides auto-fill suggestions for locations sorted by their distance from the user. This is achieved by the Search SDK for Android by Mapbox (Mapbox, n.d.*e*,n). To set the current location as the origin or destination, users can press the 'Focus' button located to the right of the input bar. They can also long-press on any location on the map to specify the origin and destination. The 'Swap' button next to the input bar allows users to switch the origin and destination. Once the origin and destination are specified, the fastest route will be shown on the map with the origin and destination marked. The distance and estimated time of arrival for the route are displayed below the input bar. Alternative routes generated by MapboxNavigationRequestRoute function can be selected from the dropdown list.

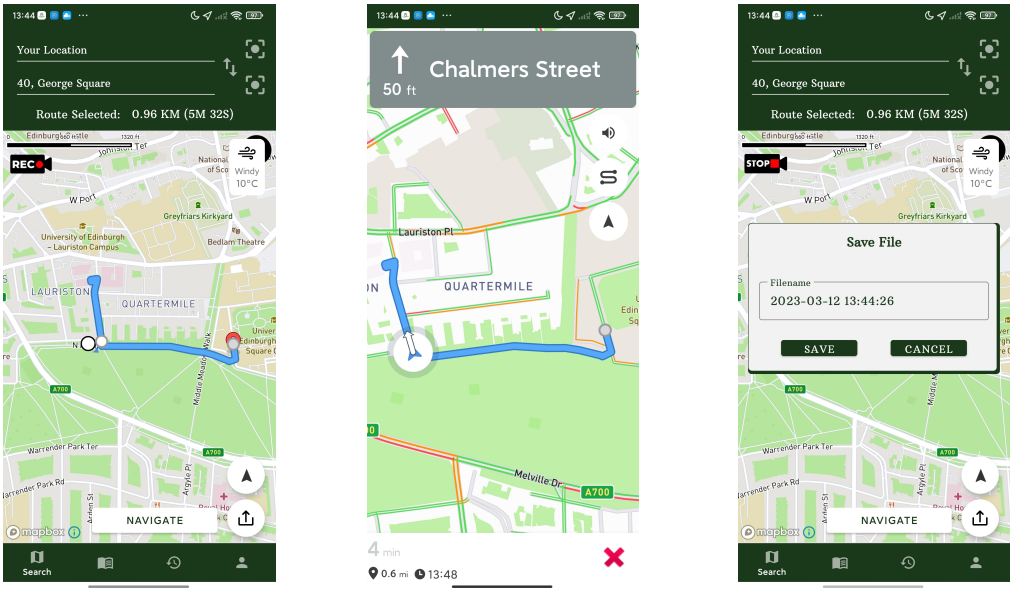
6.2.2.2 Navigation (Figure 6.2b)

Once users have selected a route, they can start their navigation by pressing the 'Navigate' button. Mapbox Navigation will take the DirectionRoute object, display it on the

map, and start the navigation. 'Navigation' page supports audio navigation, and shows bike lane on the map. The distance, estimated time of arrival, and time left until arrival are displayed at the bottom of the page. Additionally, step-by-step navigation is shown at the top of the page. The navigation is supported by the Navigation SDK for Android by Mapbox (Mapbox, n.d.*c*).

6.2.2.3 Record Track (Figure 6.2c)

To record a track, users can press the 'REC' button. The timer starts, the button changes to 'STOP' and the user's location is tracked and saved. The distance travelled is also recorded. When users press the 'STOP' button, a popup appears which allows users to save the track. The default filename is the start time of the recording but users can change the filename as long as it is different from the previous recordings. If the users would like to continue with the recording, they can press the 'Cancel' button. Otherwise, pressing 'Save' button will stop the recording and convert the list of coordinates to a Geojson file. The start time, end time, total duration, and total distance are recorded and saved as a text file. Both files are uploaded to the Firebase Storage and stored in the users' sub-folder in the history folder. Besides, the total duration and total distance are updated to the user data file in the historyData folder.



(a) (b) (c)

Figure 6.2: (a) Main Page, (b) Navigation Page, (c) Record Track

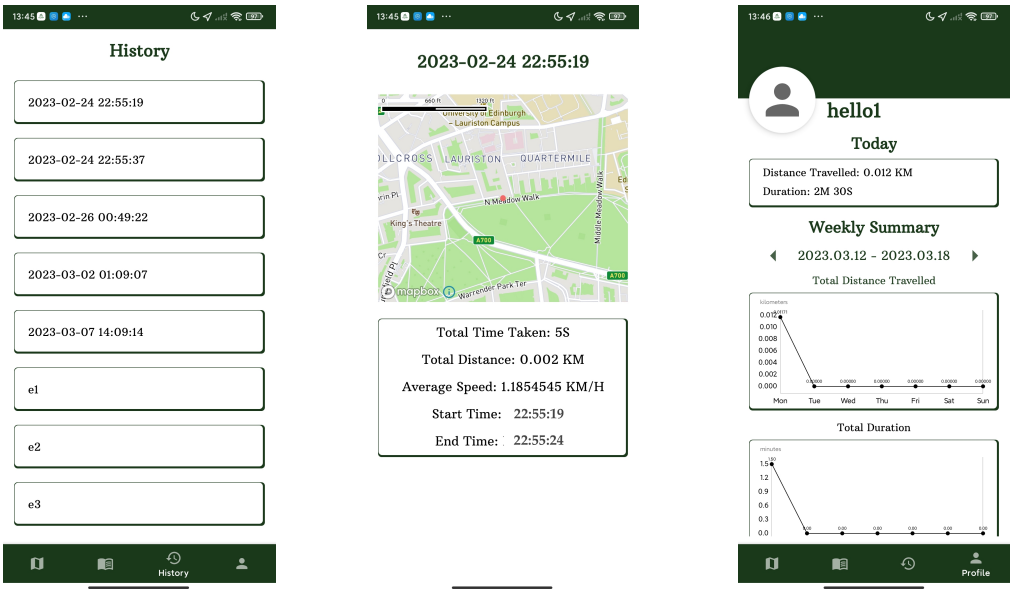
6.2.3 History (Figure 6.3a & Figure 6.3b)

All of the recorded tracks can be viewed in the 'History' fragment. These recordings are retrieved from the user's folder in Firebase Storage. The fragment consists of a scrollable view with different entries named after the filename of the respective recordings. The history tracks are displayed by the RecyclerView which enables a dynamic amount of content. Upon pressing on an entry, the system retrieves data from the Geojson and text file of the corresponding track. The Geojson file is used to display the

route on the map, while the text file is used to display the track information, including start and end coordinates, start and end times, total duration, and total distance.

6.2.4 Profile (Figure 6.3c)

The 'Profile' fragment displays user statistics, which are retrieved from the history-Data folder in Firebase Storage. Each user has a text file in the folder that records their total duration and distance travelled for each day. The top of the page shows the total duration and distance travelled for the current day. The previous records are summarised in two separate line charts, allowing users to view their weekly statistics for duration and distance. The line chart is implemented by using the MPAndroidChart API (MPAndroidChart Developers, n.d.). This feature acts as a simple fitness tracker, enabling users to monitor their cycling intensity on a weekly basis from the start date.



(a) (b) (c)

Figure 6.3: (a) History Fragment, (b) History Details, (c) Profile Fragment

6.2.5 User Interface Design

6.2.5.1 Bottom App Bar

Following the feedback from the Requirement Gathering, most people preferred the bottom app bar instead of the sidebar. They believed that the app's functionality would be more apparent if it is displayed on the bottom app bar. Therefore, I redesigned the sidebar as the bottom app bar. When selecting the fragments for the bottom app bar, I focused on the primary functions of our app and referred to other cycling apps for inspiration. As a result, the bottom app bar includes four fragments: Search, Library, History, and Profile.

6.2.5.2 Colour and Logo

Green is always the best color to demonstrate the natural environment (Gremillion, 2019; Cunningham, 2017). Since Cyclopath Edinburgh is designed to make exploring cycling routes easier and more convenient, the green theme is a perfect fit. The color green helps people easily associate Cyclopath Edinburgh with natural and outdoor activities, which makes them feel optimistic and refreshed. Additionally, by using green as the theme color, the app feels more lively and symbolizes health. To create a calming and relaxing user interface, I chose a dark green color for Cyclopath Edinburgh, as it suits the app's functional nature (London Image Institute, 22 October 2020).

The logo shows a person cycling, representing the energetic and motivated nature of cyclists in the green theme colour. This symbolises that Cyclopath Edinburgh encourages people to cycle in their daily lives. This matches the aim for this project, which is to provide a user-friendly cycling app for cyclists in Edinburgh, supporting and improving the cycling experience for cyclists in Edinburgh.

6.2.5.3 General Design

The overall user interface is designed according to the formal standard design pattern, namely Material Design. Material Design is a guide for creating visual, motion, and interaction designs that work well on different platforms and devices (Android Developers, 25 August 2022; Google, n.d.). It provides full specifications for designs, as well as support for components and styles libraries. This includes the spacing methods between two components, navigation between pages, and widget components such as input bars. This makes the overall user interface of Cyclopath Edinburgh more user-friendly and the navigation smoother, further improving the user experience of the app.

6.2.6 Deployment

After completing the implementation of Cyclopath Edinburgh, I tested its functionality on an Android device. To do this, I pushed the final version of my code to Github and retrieved the latest combined version of both my partner's and my implementations. Using Android Studio, I built the apk file, which can be easily installed on any Android phone. I then tested the app on an Android device including the navigation between pages, data storage and functionalities. All test cases passed and all the functions worked as expected.

6.3 Summary

This chapter addressed research question **RQ3**. Throughout the project, I used technologies like Github, Firebase, Android Studio, and Gradle to build the app. The implementation of basic features involved search route, navigation, record track, and login system. To tailor to the needs of Edinburgh cyclists, I also added a fitness tracker, bike lane information, and alternative login options. The redesign of the user interface involved revamping the icons, logo, font, and colour theme of the app, and switching the sidebar to a bottom app bar.

Chapter 7

Formative Evaluation

The scripts and results of the Formative Evaluation can be found in Appendix G. The Formative Evaluation took 10 hours to complete, with 5 hours on the think aloud protocol and stakeholder walkthrough and 5 hours on the analysis.

7.1 Aims

The aim of this chapter is to provide insights to research question **RQ4**. I wanted to determine the usability of Cyclopath Edinburgh based on feedback from both HCI experts and cyclists. The data collection methods used in the Formative Evaluation have been specifically designed to answer this research question.

7.2 Data Collection Methods

To gather data on the usability of Cyclopath Edinburgh, we used different methods for HCI experts and cyclists. HCI experts are asked to participate in a think aloud protocol followed by an interview, while cyclists are asked to attend a stakeholder walkthrough followed by a questionnaire. The feedback obtained from each session is used for qualitative analysis. Both sessions are followed by an SUS evaluation in the form of a questionnaire, which is used for quantitative analysis.

Each session is conducted individually so that participants can express their thoughts without being influenced by others. Most sessions are held in person at the University of Edinburgh, while others are conducted online. We invited HCI experts to verbal sessions since they are familiar with the data gathering process and more confident in providing feedback. We invited cyclists to structured sessions using predefined questions to provide feedback from both functional and user design perspectives. These sessions offered insight into potential improvements to usability and user experience.

Both sessions are recorded using Microsoft Teams to generate transcripts for future analysis. In addition, notes are taken in text files throughout the sessions. The SUS evaluation and questionnaire are conducted via Microsoft Forms, which facilitates the automatic generation of charts and graphs for quantitative questions.

7.3 Participants

We invited two HCI experts for the think aloud protocol and eight cyclists for the stakeholder walkthrough. They are all from the University of Edinburgh.

7.4 Materials

Similar to Requirement Gathering, we prepared an Ethics Form for an ethics application for this data collection. We have also prepared two PISs and PCFs for think aloud protocol and stakeholder walkthrough. The PIS and PCF for both sessions are uploaded to OneDrive so that they are visible to the participants. As users are required to use Cyclopath Edinburgh and provide feedback according to their user experience, I prepared an Android phone with preinstalled Cyclopath Edinburgh for them. One of the HCI experts was willing to use her mobile phone to download Cyclopath Edinburgh. Thus, I generated an apk file from the codes and sent the apk to her during the session.

At this stage, I have completed all of the implementation for my part, which includes the login system, search and navigation routes, record tracking, and fitness tracking. Unfortunately, my partner has not finished his part yet and is not able to show the full functionality.

7.4.1 Think Aloud Protocol

There is no additional material needed.

7.4.2 Stakeholder Walkthrough

After each task, we have prepared a set of general questions to ask participants. The questions are consistent across all tasks to ensure consistency in analysis, and they focus mainly on the navigation, usability, and design of the specific task.

7.4.3 Interview and Questionnaire

The scripts for the interview and questionnaire are the same, but the interview is verbal, while the questionnaire is done via a Microsoft Forms. In order to assess the usability of Cyclopath Edinburgh, the script mainly focuses on gathering feedback on the user design, such as what participants like and dislike, what features they would like to see added or removed, and their feedback on the font and icons. These questions provide an overall evaluation of Cyclopath Edinburgh from a usability perspective.

7.4.4 SUS Evaluation

The scripts for the SUS evaluation are obtained online and follow a standard format. They consist of ten questions that mainly focus on the usability of Cyclopath Edinburgh. Each question has a range of answers from 1 to 5.

7.5 Procedure

Participants are provided with an Android phone to use Cyclopath Edinburgh during the session. Before the session begins, participants are given five minutes to review the PIS and PCF. The recording starts once the participant has agreed to participate.

During the think aloud protocol, HCI experts are given several predetermined tasks to perform on the prototype. They are encouraged to verbalize their thoughts throughout the whole session and provide feedback informally. The think aloud protocol takes approximately 30 minutes. Afterward, HCI experts are interviewed for about ten minutes to ask follow-up questions from the think aloud protocol. In this interview, they can detail any usability issues they have identified while interacting with Cyclopath Edinburgh, and provide their opinions on Cyclopath Edinburgh.

Cyclists are given the same set of tasks as HCI experts during the stakeholder walkthrough. However, after they finish each task, they are asked three questions regarding navigation, usability, and design of Cyclopath Edinburgh. The stakeholder walkthrough takes around 30 minutes. Afterward, cyclists are asked to fill out a questionnaire with the same questions as the interview for HCI experts, conducted via Microsoft Forms. The questionnaire takes around ten minutes to complete.

Both HCI experts and cyclists are asked to complete the SUS evaluation after they complete the sessions. The SUS evaluation takes less than five minutes to complete.

7.6 Results of Quantitative and Qualitative Analysis

As both data gathering from HCI experts and cyclists have similar scripts, I combined the results and carry out the analysis together. I used SUS evaluations for quantitative analysis and others for qualitative analysis. Since the number of responses is small, I performed the analysis manually. In the analysis, I focused on the parts implemented by me, rather than providing an overall analysis.

7.6.1 Quantitative Analysis

The SUS evaluation score is calculated using the formula in Appendix K. The results of SUS evaluation are summarised in the tables below:

Participants	**E1**	**E2**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
SUS Scores	77.5	95	82.5	95	95	90	92.5	72.5	80	90

Table 7.1: SUS Evaluation Score for HCI Experts (E1-E2) and Cyclists (P1-P8)

Participants	**Samples**	**Mean**	**Median**	**Standard Deviation**	**Min**	**Max**
All	10	87	90	7.5	72.5	95
HCI Experts	2	86.3	-	8.8	77.5	95
Cyclists	8	87.2	90	7.1	72.5	95

Table 7.2: Statistics for the SUS Evaluation Score

From the tables above, we can see that the mean for each category is considered to be an A, as it is higher than 80.3 (Thomas, n.d.). This means that they like Cyclopath Edinburgh and highly likely to recommend it to their friends. All of the statistics, including mean, median, standard deviation, minimum, and maximum for each category, are similar. This shows that the usability of Cyclopath Edinburgh is acceptable, from both HCI and user's perspective.

7.6.2 Qualitative Analysis

7.6.2.1 Think Aloud Protocol and Stakeholder Walkthrough

Every participant in the think aloud protocol and stakeholder walkthrough was able to complete all the predetermined tasks. We found that most of the cyclists will provide feedback on the usability whereas the HCI experts will mainly comment on the navigation and design. Thus, I discuss the feedback based on navigation, usability and design.

Navigation
Most participants found it troublesome to login using their username and password again after signing up. The popup could lead to confusion. Similarly, the 'Cross' button in the 'Navigation' page is confusing too.

Selected feedback for this question is presented below:

"The popup in the Sign Up page is misleading. It should redirect to the main page."

"The cross button in the Navigation page should exit the navigation."

Other navigation and popup functions worked well and received good feedback. They found them intuitive and smooth.

Usability
For newly logged-in participants, they are required to provide permission to access location service and enable it. However, after enabling location service, they would prefer the map to automatically re-center to their current location.

Some respondents suggested that it would be more helpful to have a location address instead of coordinates when long-pressed a location as they need to know the exact name of the location so that it is more convenient for them to remember.

In addition, they feel that the 'Sign Up' page could be improved for better security and usability. It would also be better to use email addresses to log in instead of usernames, as it is hard to remember the username of the account.

Apart from displaying weekly reports for distance travelled and duration, they suggested that it would be great to have estimated calories consumed recorded. It could be a rough estimate as this is not a fitness app.

Selected feedback for this question is presented below:

"It should automatically recenter the current location after enables location services."

"The name displays when pressing a location should be address not coordinate."

"Retype the password and add more requirement such as symbol and uppercase letter."

"Estimated calories consumed for the history tracks and in the weekly report."

Some users provided additional features that would be useful for cyclists, such as expanding the weekly report to a monthly report, searching for addresses using postcodes, and including additional layers of maps such as heatmaps to provide more information. One user suggested adding Tactons to Cyclopath Edinburgh. Tactons are touch messages that can be employed in mobile apps to convey intricate information to users without relying on visual cues (Brewster and Brown, 2004). They can be useful for people with visual impairments or during nighttime cycling.

They are satisfied with the current version of Cyclopath Edinburgh as it fulfills the basic needs for cyclists in Edinburgh. All the functionalities work as expected.

Design
Some participants mentioned that certain icons and input fields in Cyclopath Edinburgh are not completely intuitive.

Selected feedback for this question is presented below:

"The icon for the recenter and indicating current location are not intuitive."

"The requirement of input field in the Sign Up page should be display beforehand to prevent users from retyping."

However, they found that all other user interfaces, including font size and colour, were user-friendly. Overall, they are satisfied with the user interface.

7.6.2.2 Interview and Questionnaire

The overall feedback was positive. The participants like the idea of recording their cycling tracks and keeping track of their previous routes. Most of the functionalities and designs are good enough, except for a few areas of improvement that are mentioned above. The participants think that the colour theme, font type, and font size for the entire app are consistent and pleasant. Most of the icons are good, except for some that are less intuitive. The participants do not think that anything should be removed from Cyclopath Edinburgh as they find the existing features to be useful. The current version of Cyclopath Edinburgh can be further improved by providing additional features that are specifically for cyclists, as mentioned in the suggestions above.

7.7 Summary

The Formative Evaluation provided insights to research question **RQ4**. Cyclopath Edinburgh obtained a mean score of 87 in the SUS evaluation. I found that all HCI experts and cyclists are satisfied with the design and usability of Cyclopath Edinburgh and found it to be highly useful for their daily cycling trips. Not only the app met their basic requirements, it also offers a range of additional features such as bike lane information, and a fitness tracker. Nevertheless, they have suggested some minor improvements that could further enhance the user experience.

Chapter 8

Second Iteration of Implementation

The aim of this chapter is to answer research question **RQ5**. Screenshot illustrating the final version of Cyclopath Edinburgh can be found in Appendix H while the test cases for this version of Cyclopath Edinburgh can be found in Appendix I. The second iteration of implementation took around 10 hours to complete.

8.1 Implementation

Based on the feedback we received from the Formative Evaluation, I made several small changes to the existing features of the app to make it more user-friendly.

1. Sign Up (Figure 8.2)
I added a small text below each input field to show the required format for that input. This prevents the user from having to re-enter their username and password after receiving the Toast error message. In order to provide a more secure password system, I changed the password requirements to include at least one uppercase letter, one lowercase letter, one number, and one symbol. To confirm their password, users now have a new input field to retype their password. After successfully signing up, the 'Sign Up' button is changed to the 'Login' button so that users can directly log in after they verified their email.

2. Login
I changed the username field to an email field in the 'Login' page so that it is easier for users to remember.

3. Recenter Current Location
I added a listener to track the status of the location services and update the map to the current location automatically. Additionally, I implemented an animation to smoothly ease the camera to the current location, providing a more seamless transition.

4. Record Track (Figure 8.1a & Figure 8.3)
I added a timer below the record track icon, making it more obvious to the user how long they have been recording. I also changed the label of the 'Cancel' button to 'Discard', allowing users to easily discard their recordings.

5. Selecting Origin and Destination by Pressing on the Map
The original feature displays the coordinate of the location after users long-pressed a location on the map instead of the address. Therefore, I used the Forward Geocoding API in Mapbox to translate the coordinate of the selected location to an address and display it in the field (Mapbox, n.d.*d*).

6. Navigate
I restricted the navigation to routes that start from the user's current location only. This prevents the navigation from misleading the user by using an incorrect starting point. Additionally, I implemented an 'Overview' button, allowing users to see the whole route at a glance, and a 'Recenter' button, which centres the map on the user's current location. To avoid confusion, I removed the 'Cross' button from the bottom bar.

7. History Details (Figure 8.4)
I added several new information to the details of a history track, which include the addresses of both the origin and destination, as well as the estimated calories consumed during the trip. All of these details are now saved in the historyData folder in Firebase Storage, along with other relevant information.

8. Estimated Calories Consumed (Figure 8.5)
I implemented a feature that calculates the estimated calories consumed for every trip. This data is displayed as text in the 'Today' field and as a line chart in the weekly fitness report in the 'Profile' fragment. To calculate the estimated calories consumed, I used the value of 32 calories per kilometer, which is the estimated amount for an adult weighing 80kg cycling at a speed of 12mph (Burned CALORIES.com, n.d.). This value is then saved using the same method as distance travelled and duration.

9. Icons (Figure 8.1b)
To improve the design consistency of the app, I used the same icon for the 'Recenter' button and the 'Select the current location as origin or destination' button.

10. Remove Pointer of Bearing
Due to ongoing issues with the bearing feature in the Mapbox API, which was causing continuous misinterpretation of the user's direction, I decided to temporarily remove the pointer indicating the bearing of the current location as well as the rotation of the map according to the bearing (Mapbox Developers, 26 May 2022). This will remain in effect until the issues with the bearing feature are fully resolved.

11. Keeps the Autofill Suggestion
To improve the app's autofill feature, I conducted some research on available options and found that the Google API offered the most promising solution. However, this API requires a paid subscription and does not provide any free quota. Thus, I will keep this as the future work for this project.

(a) (b)

Figure 8.1: Icons: (a) Record button, (b) Recenter button

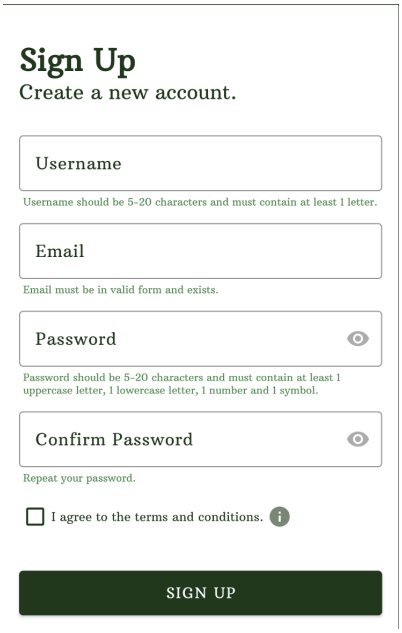


Figure 8.2: Sign Up Page

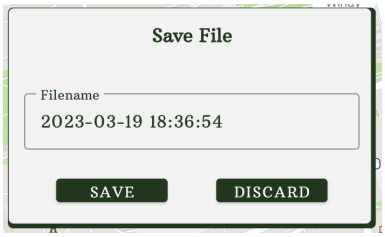


Figure 8.3: Record Track - Change the button from 'Cancel' to 'Discard'

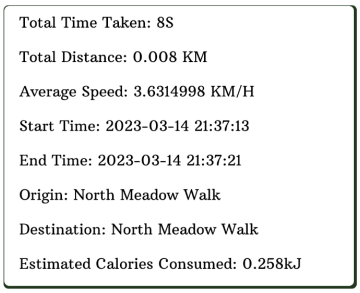


Figure 8.4: History Details - Address and estimated calories consumed

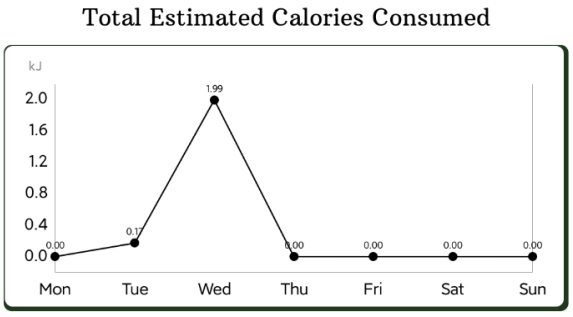


Figure 8.5: Estimated Calories Consumed - Line chart

8.2 Summary

This chapter addressed research question **RQ5**. I made several improvements to the features developed in the first iteration based on the feedback received during the Formative Evaluation. These improvements includes changing icons, adding new features, and improving navigation to enhance the overall user experience.

Chapter 9

Summative Evaluation

The scripts and results of the Summative Evaluation can be found in Appendix J. The Summative Evaluation took around 10 hours to complete, with 5 hours on the think aloud protocol and stakeholder walkthrough and 5 hours on the analysis.

9.1 Aims

The aim of this chapter is to answer research questions **RQ4** and **RQ6**. I wanted to figure out the usability of Cyclopath Edinburgh based on the feedback we received from HCI experts and cyclists. The data collections in this Summative Evaluation have been designed to solve and answer these research questions.

9.2 Data Collection Methods, Participants, Materials, and Procedure

The data collection methods are the same as Formative Evaluation in Chapter 7.2. The participants are the same as Formative Evaluation in Chapter 7.3. The materials are the same as Formative Evaluation in Chapter 7.4. However, in the Summative Evaluation, we added an extra question to figure out the potential impacts of Cyclopath Edinburgh on cyclists in Edinburgh. Based on this, we can conclude the main outcome of Cyclopath Edinburgh for the public. The procedure are the same as Formative Evaluation in Chapter 7.5 with an extra question at the end of both sessions.

9.3 Results of Quantitative and Qualitative Analysis

Similar to Formative Evaluation, I combined the results obtained from HCI experts and cyclists and carry out the analysis together. I used SUS evaluations for quantitative analysis and all verbalised and text responses for qualitative analysis. Since the number of responses is small, I performed the analysis manually. Again, I focused on the parts implemented by me, rather than providing an overall analysis.

9.3.1 Quantitative Analysis

9.3.1.1 Potential Impacts of Cyclopath Edinburgh for cyclists in Edinburgh

The potential impacts of Cyclopath Edinburgh for cyclists in Edinburgh, RQ6 mentioned in Chapter 1.3 are listed below:

Participants	HCI Experts	Cyclists
Supporting their daily cycles	2	6
Discovering and exploring new routes	2	4
Improving the experience of their cycling trip	2	7

Table 9.1: Number of participants agreed to the potential impacts of Cyclopath Edinburgh for cyclists in Edinburgh

From the table above, we can see that the main potential impact of Cyclopath Edinburgh is improving cyclists' experience during their cycling trip. This suggests that Cyclopath Edinburgh could enhance the quality and attractiveness of cycling. Additionally, Cyclopath Edinburgh can support cyclists' daily rides, helping them when they are cycling. However, participants suggested that more information could be provided in Cyclopath Edinburgh such as facilities information and anti-theft system when selecting routes to help cyclists discover and explore new routes. Therefore, we have to take it into account in the future work.

9.3.1.2 SUS Evaluation

The SUS Evaluation Score is calculated using the formula in Appendix K. The results of SUS evaluation are summarised in the tables below:

Participants	E1	E2	P1	P2	P3	P4	P5	P6	P7	P8
SUS Scores	92.5	95	92.5	97.5	100	97.5	92.5	95	100	85

Table 9.2: SUS Evaluation Score for HCI Experts (E1-E2) and Cyclists (P1-P8)

Participants	Samples	Mean	Median	Standard Deviation	Min	Max
All	10	94.8	95	4.3	85	100
HCI Experts	2	93.8	-	1.3	92.5	95
Cyclists	8	95	96.3	4.7	85	100

Table 9.3: Statistics for the SUS Evaluation Score

From the tables above, we can see that the mean for each category is higher than that of the Formative Evaluation, which is considered a high A. This shows that the changes we made in the second iteration of implementation improved the usability of Cyclopath Edinburgh. Users found Cyclopath Edinburgh to be useful and are more likely to use and recommend it to their friends. In addition, the mean and median for all 10 participants is 94.8 and 95 respectively with a standard deviation of 4.3. This further proves that both HCI experts and cyclists are satisfied with Cyclopath Edinburgh.

9.3.2 Qualitative Analysis

9.3.2.1 Think Aloud Protocol and Stakeholder Walkthrough

Similar to Formative Evaluation, every participant managed to complete all of the predetermined tasks. I divide the feedback into three sections: navigation, usability, and design.

Navigation
Most participants found the improvement in navigation on the 'Sign Up' page to be extremely convenient and useful. They appreciated not having to re-enter their email and password to login, as they are automatically directed to the main page after pressing the 'Login' button on the 'Sign Up' page.

The navigation when pressing the buttons worked smoothly. For example, the camera eased smoothly when users pressed the 'Recenter' button on the main page, as well as when they used the buttons on the 'Navigation' page. Each button worked smoothly with animation, transitioning seamlessly from the previous state to the new state.

Selected feedback for this question is presented below:

"It is good to direct navigate to the main page after signing up since I no need to reenter the information."

"The recenter button works smoothly with slow animation."

"The sound, overview and recenter buttons in the Navigation page work smoothly."

Usability
One of the participants tried the alternative login with Google and found it to be very convenient. All of the login and sign-up functions worked perfectly.

The long-press feature for indicating the origin and destination is one of the best features based on the feedback from the participants. They found it to be very convenient for cyclists to indicate any location on the map without having to type the address. The address detected by the app was accurate, clear, and precise.

All of the participants liked the three buttons on the 'Navigation' page: 'Sound', 'Overview', and 'Recenter'. The 'Sound' button allowed them to receive directions without having to look at their phone, the 'Overview' button provided them with an overall idea of the distance remaining, and the 'Recenter' button allowed them to see the upcoming and nearby situations.

The fitness tracker, especially the estimated calories consumed, is highly supported by the participants. They think that this feature motivates them to cycle more and allows them to keep track of their weekly cycling trips.

Selected feedback for this question is presented below:

"Google login is extremely good, convenient and smooth."

"I like the long-press feature which allows me to press on any location on the map to search for a route."

"The overview and sound buttons are useful for cyclists."

"The estimated calories consumed encourage me to cycle more."

Design
All of the participants think that the user interface of Cyclopath Edinburgh is clean, simple, and nice. There is clear guidance such as the format in the 'Sign Up' page, and none of the information provided is redundant. All of the icons are intuitive, and even some of them come with labels.

Selected feedback for this question is presented below:

"Clean UI, clear guidance and secure."

"I like the label comes with button as this makes the functionality of a button more obvious."

9.3.2.2 Interview and Questionnaire

The overall feedback for Cyclopath Edinburgh is extremely positive, even better than the Formative Evaluation. Participants particularly like the main page and record track functionalities. They have no complaints about the user interface or functionalities they would like to remove. The energetic green color theme fits the cycling theme well, and the font type and size are consistent. All icons are intuitive and easy to understand. Although the current version of Cyclopath Edinburgh fulfils the needs of cyclists, some recommended features can be added in the future work to make it more tailored to their needs, as mentioned above.

9.4 Summary

The Summative Evaluation addressed research questions **RQ4** and **RQ6**. Based on the results, all participants found that the current version of Cyclopath Edinburgh is much better than the previous version. The icons are more intuitive, the navigation is smoother, and more functionalities have been added. They are satisfied with Cyclopath Edinburgh, which is evident from the high mean marks of 94.8 in the SUS evaluation. The participants also agreed that Cyclopath Edinburgh has the potential to enhance the cycling experience and support cyclists in their daily routines. The app offers a combination of navigation and community features that are tailored to the needs of cyclists. However, Cyclopath Edinburgh is less likely in helping cyclists to discover new routes. Therefore, some additional features could be added in the future work to prompt users to explore new routes.

In conclusion, the current version of Cyclopath Edinburgh is highly acceptable to cyclists in Edinburgh. The improvements made in the second iteration of implementation have further enhanced the user experience and made the app even more user-friendly. These changes have made Cyclopath Edinburgh into an app that cyclists in Edinburgh can use for their daily cycling trip.

Chapter 10

Conclusion

10.1 Reflection

I really enjoyed this project and learned a lot throughout it. This project provided me with a complete full-stack development experience as it aimed to provide a workable, runnable, and user-friendly Android app that cyclists in Edinburgh could use. It was my first time being involved in user studies and data gathering to collect feedback from stakeholders. From this project, I become more familiar with the process of promoting an app to the public and experience a more real-world project.

As this was a group project, we did the data collections together to receive feedback on our progress and we split our job so that we could work independently to achieve more targets. We discussed the job division and timeline to ensure that the project could be completed on time. Throughout this project, I found that it is more challenging when working in a group as discussion takes time. It is important to set the deadline earlier to preserve extra time for communication. As different people have different working habits, I managed to experience the agile process in software development.

I spent approximately 120 hours on this project and finally, we successfully built a Cyclopath instance for cyclists in Edinburgh. We conducted several rounds of data collection in order to continuously gather suggestions from HCI experts and cyclists. From the Summative Evaluation, we received an extremely positive result from both HCI experts and cyclists, with a mean of 94.8. They like the Cyclopath Edinburgh very much and are willing to introduce it to their friends. I am happy with the outcomes since I put in a lot of effort to make this happen. My hard work has paid off, and our aims have been achieved. We managed to promote a Cyclopath instance for cyclists in Edinburgh and create a user-friendly interface for the public.

10.2 Limitation

The initial goal was to adapt Cyclopath for use in Edinburgh and collect user feedback, focusing on data gathering and improvement rather than adding large amounts of new code. However, the original Cyclopath is unexpectedly not maintained outside Min-

nesota and its user interface were outdated, resulting in the need to reimplement the app to make it usable in Edinburgh.

The process of implementing the original features took a lot of time. We focused on adding basic features to the app and keeping more advanced features for future development. Unfortunately, this meant that Cyclopath Edinburgh has fewer additional features than originally expected, with only fitness tracker, elevation of routes and weather forecast added to the original Cyclopath. Furthermore, some features are not implemented due to the project's lack of funding. We chose to use Mapbox API instead of Google API, which provides a free quota for every feature but results in inaccurate bearing and underperformed autofill suggestions.

The prolonged and delayed implementation caused us to miss the opportunity to publish our app on the Google Play store. We finished the implementation just before the Summative Evaluation, leaving us no time to seek advice on publishing Cyclopath Edinburgh. Additionally, our efforts to reach out to the Cycling Club outside the University for a wider user base are either rejected or unresponded, resulting in missed opportunities to promote Cyclopath Edinburgh to the public.

10.3 Future Work

Additional features tailored for cyclists in Edinburgh can be implemented based on the suggestions in the data gathering. As mentioned in the Chapter 9.3.1.1, we could implement features such as attraction suggestion, anti-theft system and facilities information to help cyclists discover new routes. Cyclopath Edinburgh could be extended to include more accessibility features such as consideration for color blindness, and Tactons to aid elderly or visually impaired cyclists, particularly during night cycling. Additionally, Cyclopath Edinburgh could be expanded to include other outdoor activities, making it more accessible to people with disabilities.

In addition, we can improve the existing features of Cyclopath Edinburgh. We can enhance the fitness tracker feature by allowing users to fill in a more detailed profile with information such as weight, height, age, and other related information to calculate a personalized and accurate estimate of calories consumed. A goal system can be added to the profile, motivating users to cycle and achieve their fitness targets, potentially making Cyclopath Edinburgh a multifunctional app instead of just a navigation app.

If we have a budget, we could upgrade the API from Mapbox to Google, as Google has better organization and implementation, which would improve the overall usability and user experience of Cyclopath Edinburgh. Furthermore, if Cyclopath Edinburgh meets the requirements for publication, publishing the app on the Google Play Store could expand its user base and increase its chances of being promoted to potential users.

During my further research, I discovered that the password requirement on the 'Sign Up' page is less secure (Adams et al., 1997) (xkcd, n.d.). The current password format restrictions make the process of guessing the password faster, which poses a potential security risk. Therefore, if we plan to publish our app to the public, it would be better to revise the password requirements to enhance security.

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Appendix A

Original Design of Cyclopath

Figure A.1: Original Cyclopath - Main Page (Cyclopath, 2013)

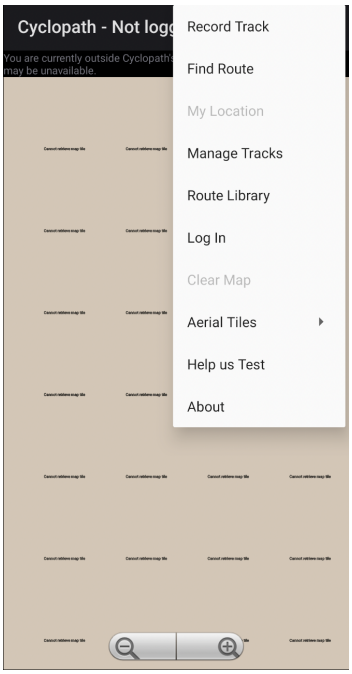


Figure A.2: Original Cyclopath - Side Bar (Cyclopath, 2013)

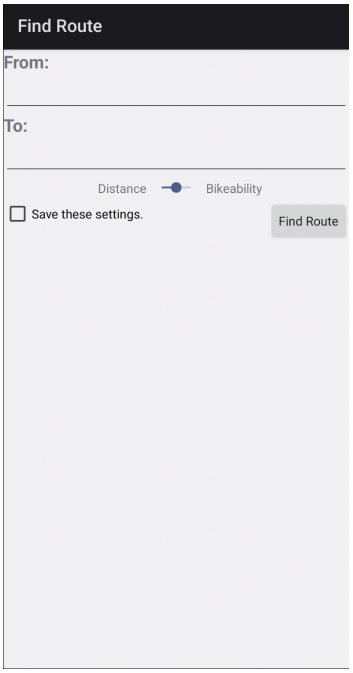


Figure A.3: Original Cyclopath - Find Route (Cyclopath, 2013)

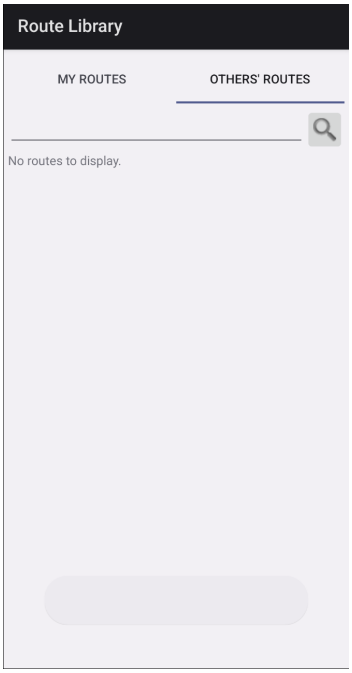


Figure A.4: Original Cyclopath - Route Library (Cyclopath, 2013)

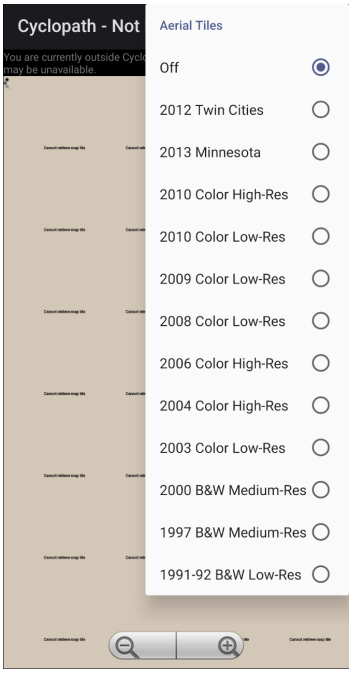


Figure A.5: Original Cyclopath - Map Tile Selection (Cyclopath, 2013)

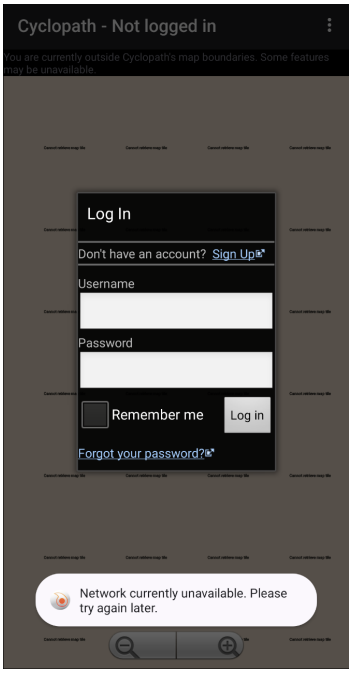


Figure A.6: Original Cyclopath - Login (Cyclopath, 2013)

Appendix B

Cyclopath User Interface after Adaptation

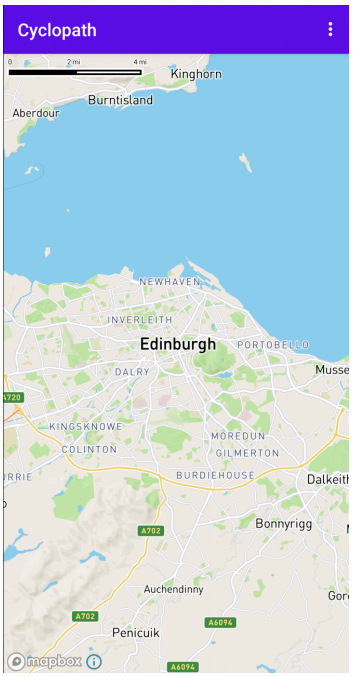


Figure B.1: Cyclopath User Interface after Adaptation - Main Page

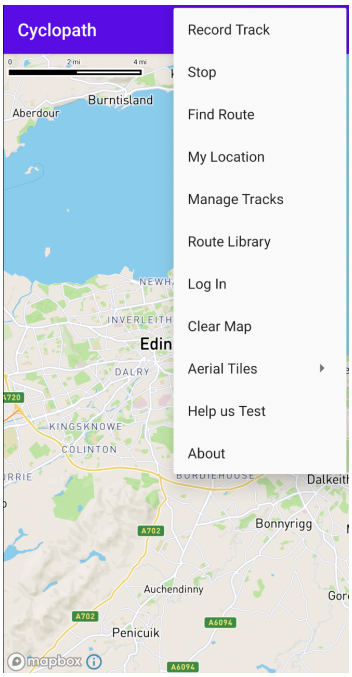


Figure B.2: Cyclopath User Interface after Adaptation - Side Bar

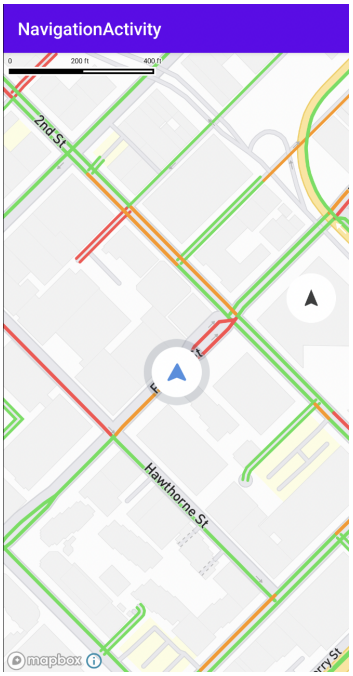


Figure B.3: Cyclopath User Interface after Adaptation - Search Route

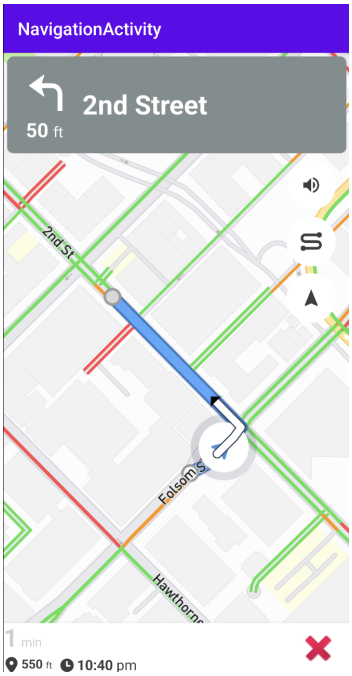


Figure B.4: Cyclopath User Interface after Adaptation - Search Route

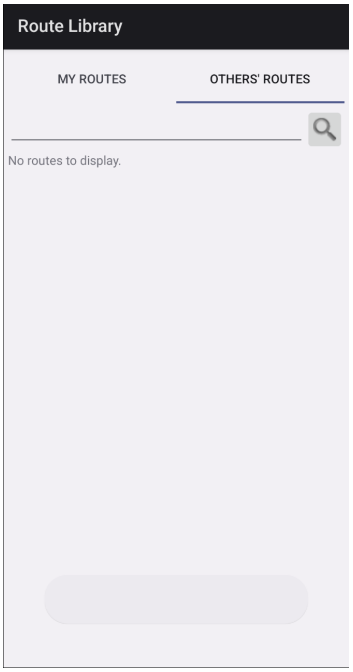


Figure B.5: Cyclopath User Interface after Adaptation - Route Library

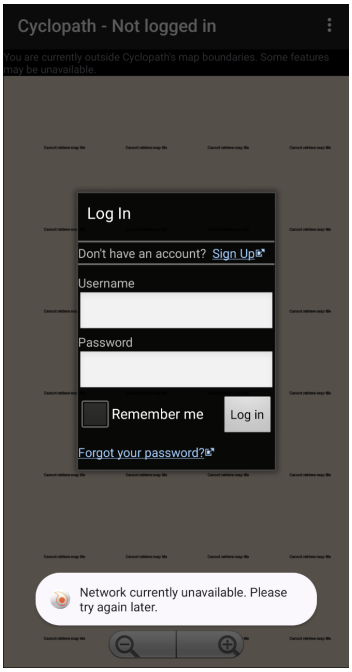


Figure B.6: Cyclopath User Interface after Adaptation - Login

Appendix C

Requirement Gathering - Questionnaire

C.1 Questions

Question labelled with * indicates it is required to answer.

Section 1: Agreement to the PCF
1. I agree with all of the statements above. * (Yes/No)

Section 2: Personal Cycling Habits
2. Do you refer to a map or GPS when you cycle? * (Yes/No)
3. While cycling, do you plan out your route before each travel? * (Yes/No/Sometimes)
4. Where do you usually obtain information to work out your cycling plan? * (Choose between 'Very often', 'Often', 'Sometimes', 'Seldom' and 'Never' for every choice)

1. Search engine (Google, Safari, etc.)
2. Biking website
3. Biking app
4. Asking friends
5. Social media

Section 3: Feedback on Original Cyclopath
For Q5-Q8, participants are required to rate from 1 to 4 based on the design aspect (layout, efficient to use, aesthetics). 1 indicates 'Need to redesign', 2 indicates 'Need a bit of improvements on the current design', 3 indicates 'Need little improvement on the current design' and 4 indicates 'I am happy with the current design'.
5. Main Page A.1 - Display a map of the current location (It only contains a static map but not a live traffic map. This picture has been edited to show the map of Minnesota.). *
6. Find Route A.3 - Search routes by providing the starting point and destination. Options provided according to the level of distance and bikeability selected by the user. *
7. Route library A.4 - Display your saved routes and others' saved routes. You can

search your previous saved routes in the library. *
8. Login/Sign Up A.6 *
9. Please provide an overall feedback on the functionalities and user interface of the original Cyclopath.

Section 4: Feedback on Current and Future Features
For Q10-17, participants are required to rate from 1 to 10 based on how likely they will use the feature. 1 indicates 'Not at all likely' and 10 indicates 'Extremely likely'.
10. Find routes (Provides available paths between starting point and destination) *
11. Save routes (Saves the path that you found in your history record) *
12. Record tracks (Record tracks that you have been through including starting point, destination and time taken) *
13. Save tracks (Save the track that you have been through in your history record) *
14. Communities (Forum for route sharing between users, users can post their routes and view other's post) *
15. Live map (Show the live traffic map of a city, including road block, road diversion and traffic) *
16. Inclusive of other outdoor activities (Include other outdoor activities sucha s jogging or hiking in the app) *
17. Weather forecase (Display the weather forecast of the current location) *
18. Please provide any other features that you would like to have in the app.

Section 5: Involvement in Future Study
19. Are you willing to participate in a follow-up focus group study to share your experiences and feedback? * (Yes/No)
20. If you chose yes in the previous question, please leave your email.

C.2 Quantitative Analysis

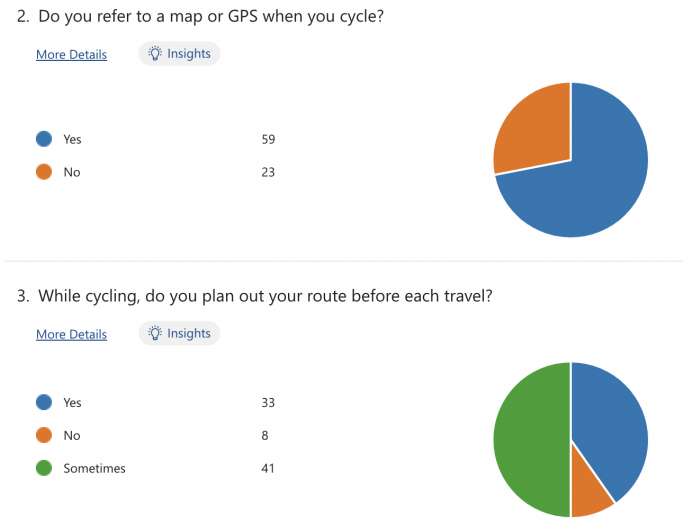


Figure C.1: Questionnaire Quantitative Analysis - Q2 & Q3

Resources	Very Often	Often	Sometimes	Seldom	Never
Search Engine	43	15	17	2	5
Biking Website	4	4	10	11	53
Biking App	6	4	10	10	52
Asking Friends	9	14	27	14	18
Social Media	2	3	8	12	57

Table C.1: Questionnaire Quantitative Analysis - Q4

Page	1	2	3	4	Average Rating
Main Page	12	33	24	13	2.46
Search Route	5	24	39	14	2.76
Route Library	4	20	36	22	2.93
Login/Sign Up	5	20	31	26	2.95

Table C.2: Questionnaire Quantitative Analysis - Q5-Q8

Feature	Promoters	Passives	Detractors	Net Promoter Score
Find Routes	28	28	25	4
Save Routes	19	25	38	-23
Record Tracks	20	21	41	-26
Save Tracks	16	18	48	-39
Communities	10	15	57	-58
Live Map	34	25	23	13
Other Activities	10	19	53	-53
Weather Forecast	22	15	45	-28

Table C.3: Questionnaire Quantitative Analysis - Q11-Q17

C.3 Qualitative Analysis

C.3.1 Quesiton 1 - Overall Feedback on the Functionalities and User Interface of the Original Cyclopath App

Positive Feedback on Functionalities

Everything that's needed seems to be there.

Functionalities are clear, good idea to provide different routes between the same two points based on the mentioned criteria.

Positive Feedback on User Interface

Straightforward interface, which is a huge plus.

Negative Feedback on Map

Need to redesign the map since it is really hard for user to recognize.

The map itself is not clear at all.

The main map should clearly show: road surface (asphalt, gravel), type of road/path (large road, small street, cycling path, shared cycling path).

Negative Feedback on Overall Design

The overall design is like a web page from the 90s.

Looks quite old and clunky not very nice to look at. A cleaner and more modern look would work better.

The UI doesn't is not appealing and inviting to use, seems a bit outdated.

Feature Recommendations

Clear information about dedicated bike lanes.

More cycling-specific info than eg. google maps.

Amenities like bike shops and bike parking would be helpful.

Irrelevant

Never heard of this one before, so it's difficult to give a judgment.

It's difficult to judge as it is a small screenshot and hard to see what it actually does.

It's difficult to evaluate the Cyclopath app without having used it.

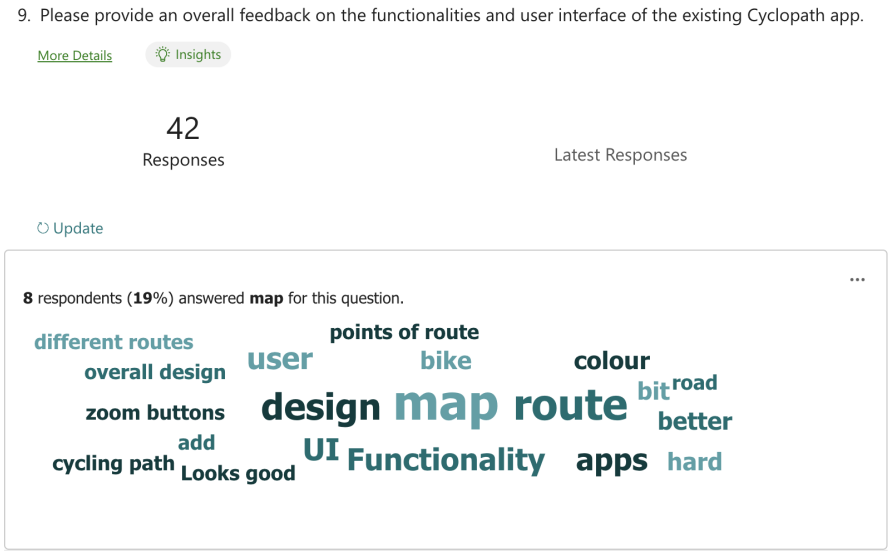


Figure C.2: Requirement Gathering - Questionnaire Qualitative Analysis

C.3.2 Question 2 - Suggestions for Additional Features they would Like to See in the App

Map Improvement

Clear information about dedicated bike lanes.

Important facilities such as toilets, water collection points, shops and even train stations are important.

Directions without looking at phone (eg. vibrate before turn).

Download maps and saved routes because sometimes there's no internet.

Save track automatically once a trip is finished.

An indication of steepness/elevation of a route.

Additional Features

If other outdoor activities are included then there should be an option for wheelchair/step-free access.

Fitness tracker of sorts.

Some chatbot.

Other App Suggestions

Strava does all of this well and has a well-established user-base.

My preferred navigational tool in Edinburgh and environs are the paper-based maps produced by Spokes.

You need to compare it to the already existing apps that do this e.g. Strava, Outdooractive, etc. they're the benchmarks.

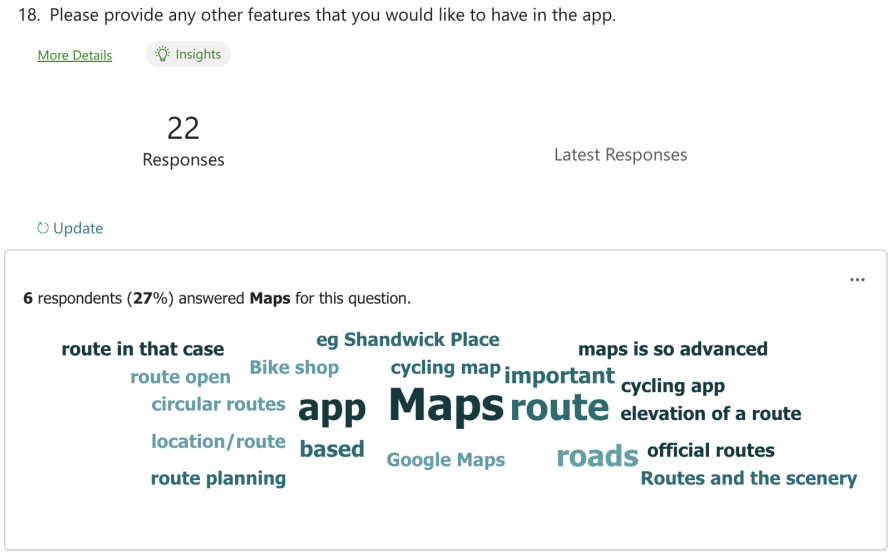


Figure C.3: Requirement Gathering - Questionnaire Qualitative Analysis

Appendix D

Requirement Gathering - Focus Group Study

D.1 Scripts

(3 mins) - Introduction on the basic Functionalities of the App

The app has the following functions (They can be an interface or a button):

- Main Page - a map with your current location
- Search Route - a page that you can search for a route and navigate
- Record Track - a function that allow you to track your route and save
- Route Library - your saved routes
- Login and Profiles - a login system

(10 mins) - Give some examples for the participant to review

Q1 - As a cyclist in Edinburgh, with the basic functions above, what other functions will switch you from Google map to a cycling app? For example application functions, location information and etc. It can be an interface or a button. (4 mins)

We also thought about some functions that might help you: (select those you like, you don't need to select all of them). (3 mins)

Application Functions:

- Weather forecast
- Save map offline
- Elevation
- Fitness tracker
- Bike lane information

- Route sharing community (with/without comment, like, image, rating) it can be an interactive forum/ a search engine
- Cycling route mode change (easy/hard/quickest/mountain bike/road bike)
- Other activities (jogging, running if user need)
- Reminder for maintenance

Location Information:

- Bike shop/maintenance
- Bike parking
- Shops, toilets, water point
- Public transportation (between cities)

You can give your opinions on those functions, and rate them. (3 mins)

(30 mins) - Draw the Design of User Interface

Q2 - Route sharing community (with/without comment, like, image, rating) it can be an interactive forum or just a search engine, which do you want? Discuss then draw it as you like! (7 mins)

Q3 - Now you are able to design the UI with the functions provided, you can design the app in the way you like, on main page only. For example, sidebar/bottom bar and etc. Try to put all the functions you need in the app. (7 mins)

Q4 - Draw the other pages as you wish. For example navigation, community, and user profiles. (16 mins)

(15 mins) - Give Brief Ideas on the Available App

1. Main Page

- What else would you like to have on the main page?

- Do you think bike lane is very important? In which form it should be shown to the user? navigation page or search page

2. Search Route

- Do you have any suggestions for the search route?

- Do you like the user interface of the search route?

3. Record Track

- Do you think this function is useful?

- Do you have any suggestions for the record track?

4. Login and User Profile

- Do you think alternative login (via Google) is useful?

- What do you want to have in the user profiles?

5. UI Design

- Which design do you like? Sidebar, bottom bar, or any others.

- Do you like the user interface of the sidebar?

D.2 Quantitative Analysis

Application Functions	Like	Dislike
Weather Forecast	8	0
Save Map Offline	7	1
Elevation	8	0
Fitness Tracker	7	1
Bike Lane Information	8	0
Route Sharing Community	4	4
Cycling Mode Change	8	0
Other Activities	1	7
Reminder for Maintenance	7	1

Table D.1: Voting on the Additional Application Functions

Location Information	Like	Dislike
Bike Shop/Maintenance	8	0
Bike Parking/Storage	8	0
Shops, Toilets, Water Point	6	2
Public Transportation	6	2

Table D.2: Voting on the Additional Location Information

D.3 Qualitative Analysis

Question 1 - Which functions would prompt you to use a cycling app over Google Maps?

I think that it will be great to have elevation when I search for a route so that I am able to decide the route according to the inclination.

It is special if there is a heatmap that shows the spread of location that has high risk in bike stealing.

If we are able to view our history and statistics (total distance, calories), it is attractive and really useful.

Question 2 - Feedback on the Additional Features that we would like to add.

I like bank lane information the most because it gives me a more clear picture of the cycling route.

Fitness tracker can extends to generating health report and exercise suggestion to the user.

Cycling mode change is the most useful function, as people may cycle for different reason, this function can help people choose the most suitable route.

Question 3 - Feedback on the Location Information that we would like to add.

May be add a heat map of bike stolen frequency, so users can try to avoid to park their bike on dangerous place.

Accurate bike parking information is very useful.

Question 4 - What type of community you would like to see in a biking app?

I think that there will be no privacy if I share my route to other people that I don't know.

I don't think there is a need to have a full community as this is a cycling app for navigation. Route library would be enough.

Search engine, I believe the most Useful function of community is help users find hidden cycle path, with search engine function users can find the cycle path they like the most.

Question 5 - Draw your desired user interface.

Mentioned in the next section D.4.

Question 6 - What would you like to add on the main page?

Almost all of the participants would like to have weather information in the main page as they think it is useful for a cyclist.

Question 7 - Do you think the bike lane is important?

Where do you want to have the bike lane? This is supported by every participant. They think that a bike lane is very important in a biking app and it will be great if it shows in the navigation page.

Question 8 - What do you like to have in the search route page?

The most supported answer is elevation and calories consumed when choosing the route.

Question 9 - Do you think an alternative login (e.g. Google) is useful?

This is supported by every participant as they think that it is more convenient to have alternative login in an app since it is hard to remember the password for every app.

Question 10 - What do you want to have in the profile page?

Most of the participants would like to have a health report which is a kind of statistics of their cycling trip per week.

Question 11 - Do you think it is better to have login in the first page or as a page in the sidebar?

Every participant thinks that the login page should be at the first page.

Question 12 - Do you like the current sidebar or you would like a bottom bar?

Every participant thinks that the current sidebar is too complex and hard to navigate since every function is put in the sidebar. They prefer a bottom bar for the app with less functions.

Question 13 - Overall feedback on the Functionalities.

Most of the basic function is implemented, but it will be great to have some additional features.

Question 14 - Overall feedback on the User Interface.

The UI needs to be redesigned.

The current user interface is ancient.

D.4 Desired User Interfaces of Participants

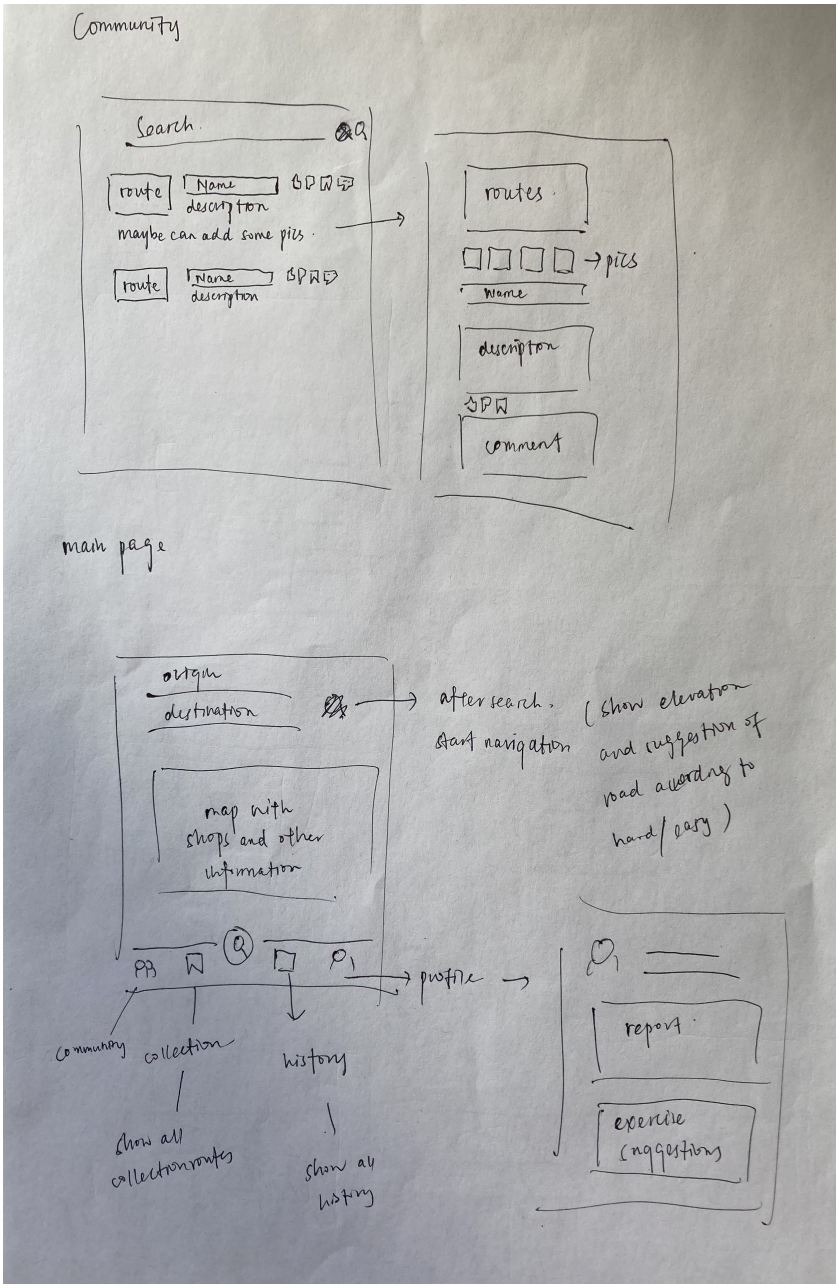


Figure D.1: Requirement Gathering - Focus Group Study - Draw Your Design

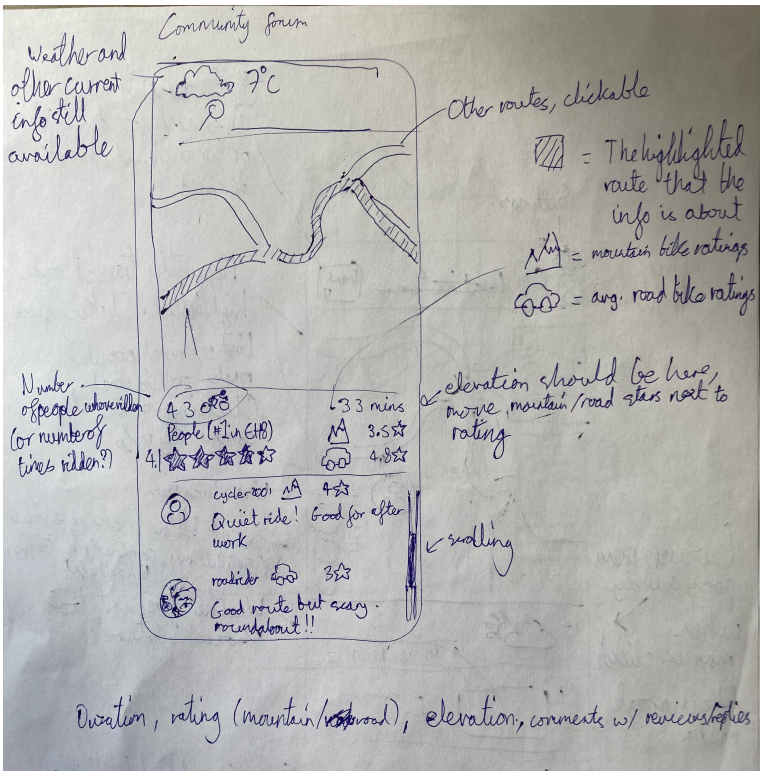


Figure D.2: Requirement Gathering - Focus Group Study - Draw Your Design

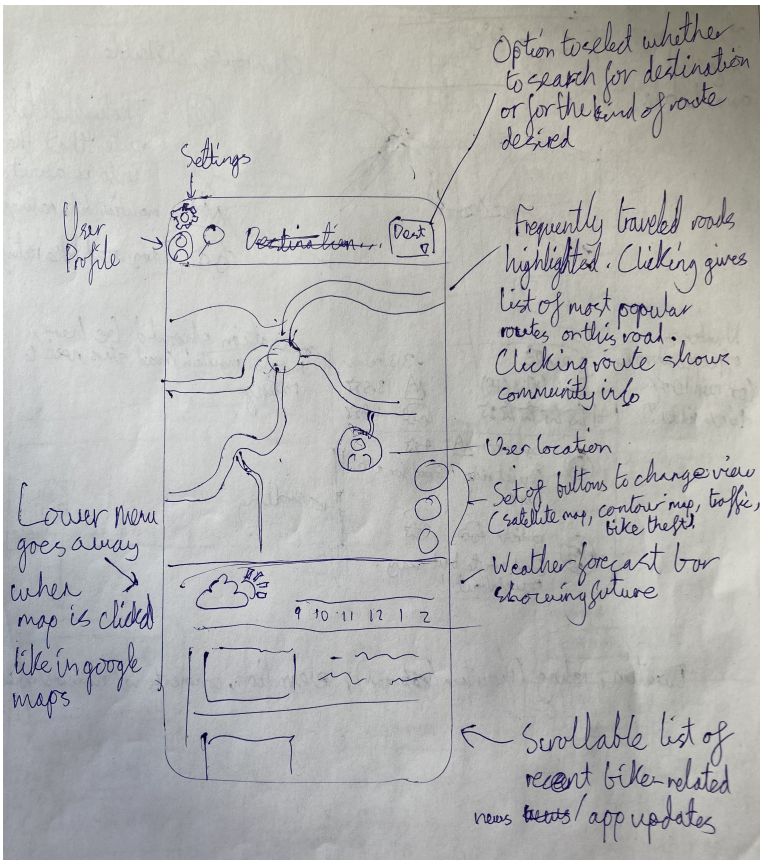


Figure D.3: Requirement Gathering - Focus Group Study - Draw Your Design

D.5 Requirement List

Requirement	Priority
Find Route	High
Live Map	High
Record Track	High
Save Routes	High
Route Library	High
Login	High
Profile	High
Weather Forecast	High
Elevation	High
Bike Lane Information	High
Cycling Mode Change	High
Bike Shop/Maintenance	High
Bike Parking/Storage	High
Save Map Offline	Medium
Fitness Tracker	Medium
Reminder for Maintenance	Medium
Shops, Toilets, Water Point	Medium
Public Transportation	Medium
Route Sharing Community	Low
Other Activities	Low

Table D.3: Priority for the Implementation of each Functionality

Requirement	Priority
Main Page	High
Find Route	High
Record Track	High
Save Routes	High
Route Library	High
Login	High
Profile	High
Side Bar	High

Table D.4: Priority for the Redesign of each User Interface

Appendix E

Cyclopath Edinburgh after First Iteration of Implementation

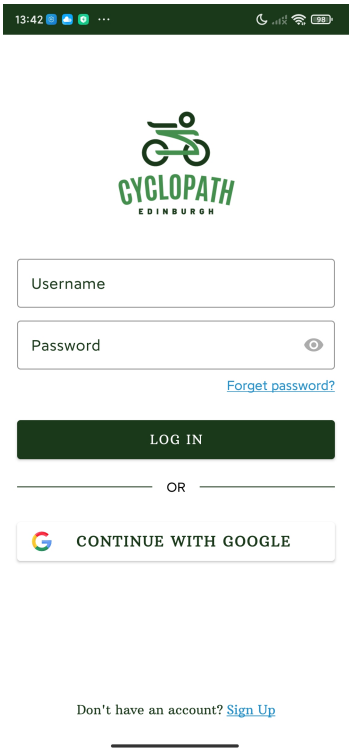


Figure E.1: Cyclopath Edinburgh after First Iteration- Login

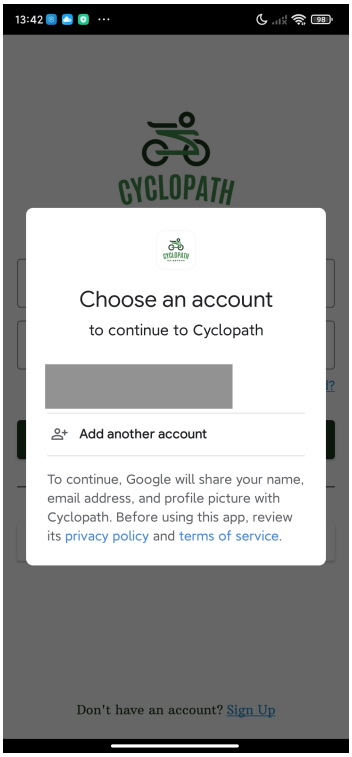


Figure E.2: Cyclopath Edinburgh after First Iteration - Login with Google

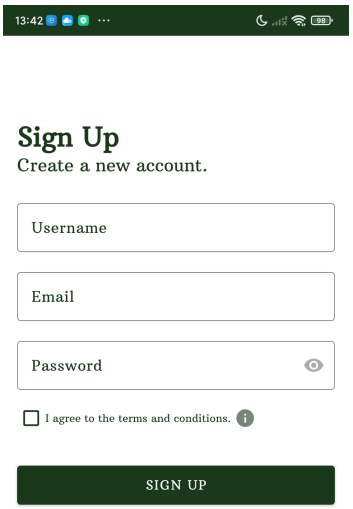


Figure E.3: Cyclopath Edinburgh after First Iteration - Sign Up.

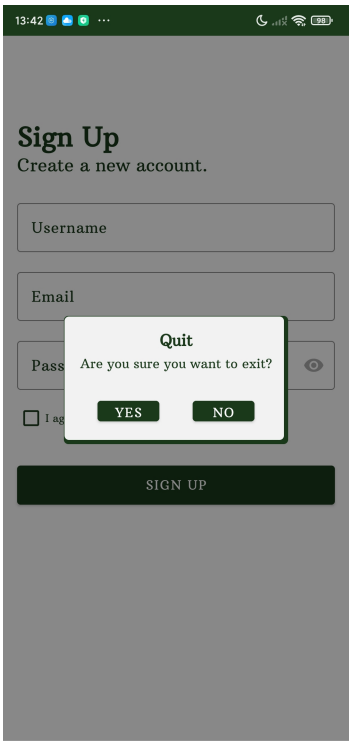


Figure E.4: Cyclopath Edinburgh after First Iteration - Sign Up Popup.

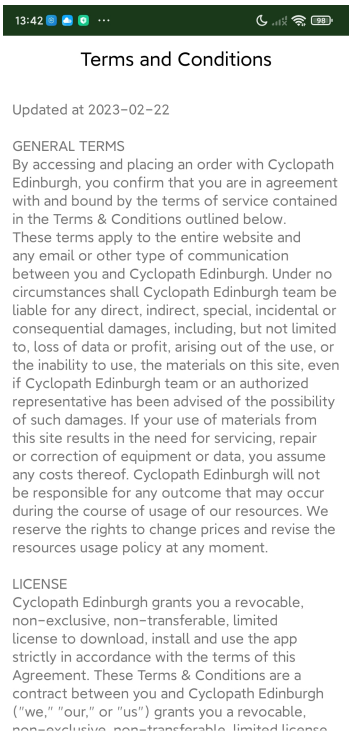


Figure E.5: Cyclopath Edinburgh after First Iteration - Terms & Conditions

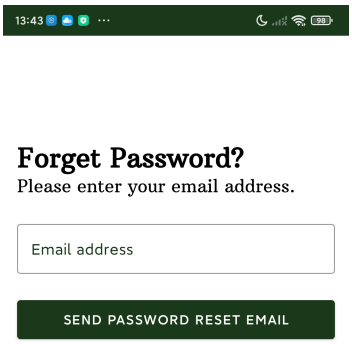


Figure E.6: Cyclopath Edinburgh after First Iteration - Forgot Password

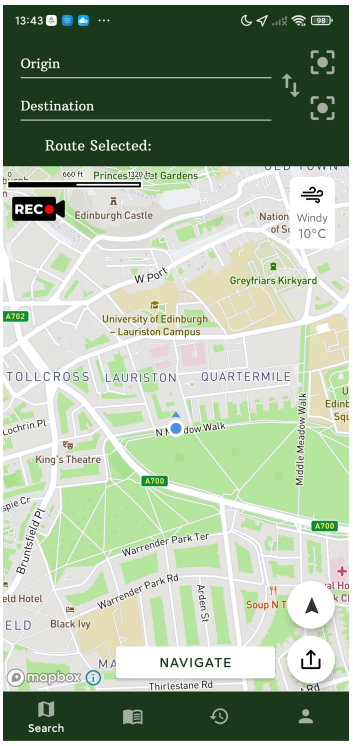


Figure E.7: Cyclopath Edinburgh after First Iteration - Main Page

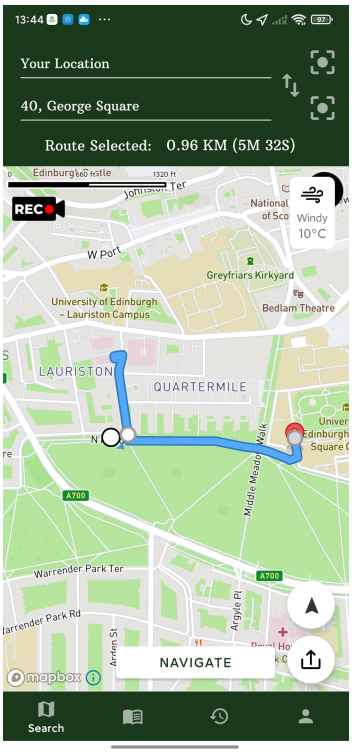


Figure E.8: Cyclopath Edinburgh after First Iteration - Search Route

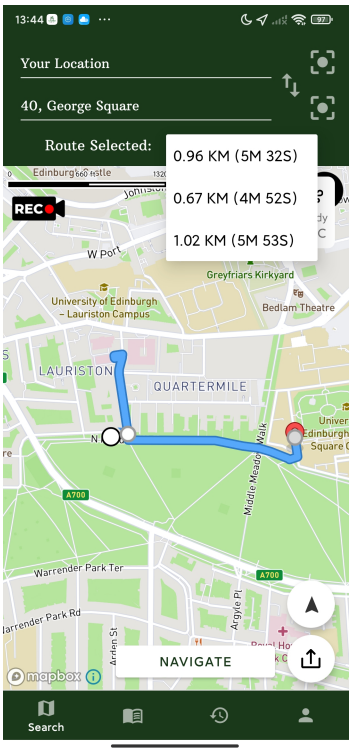


Figure E.9: Cyclopath Edinburgh after First Iteration - Route Selection

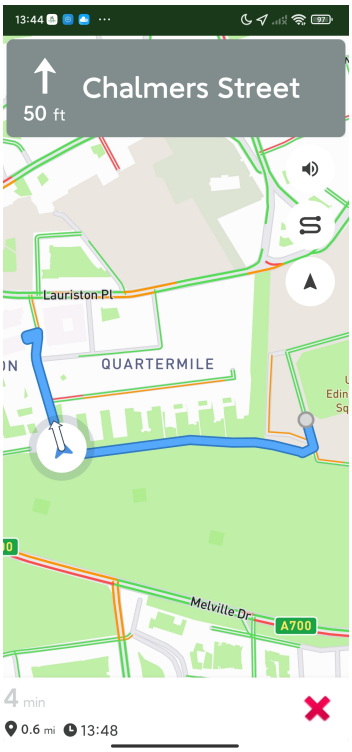


Figure E.10: Cyclopath Edinburgh after First Iteration - Navigation

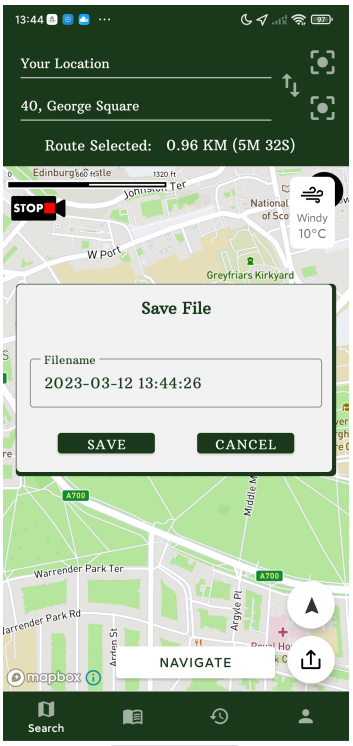


Figure E.11: Cyclopath Edinburgh after First Iteration - Record Track Popup

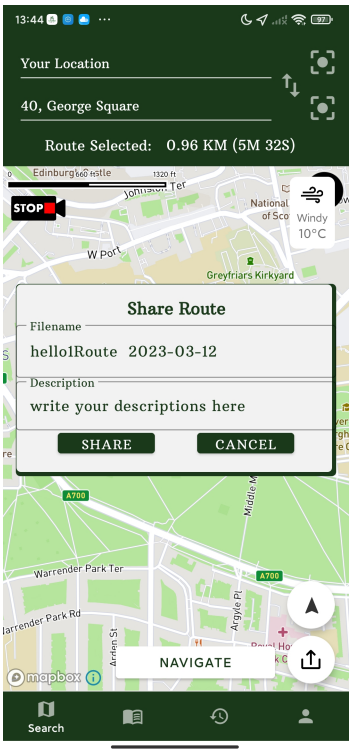


Figure E.12: Cyclopath Edinburgh after First Iteration - Share Route Popup

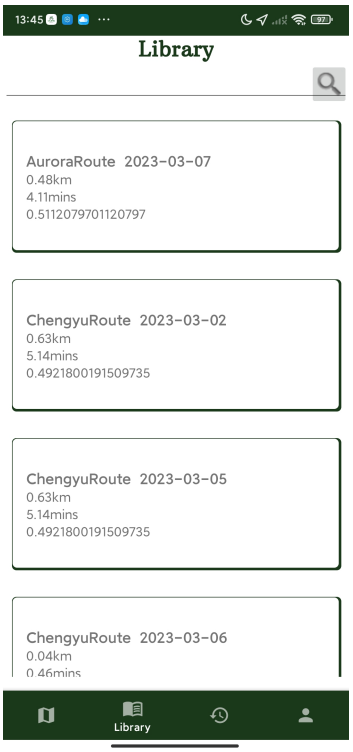


Figure E.13: Cyclopath Edinburgh after First Iteration - Route Library

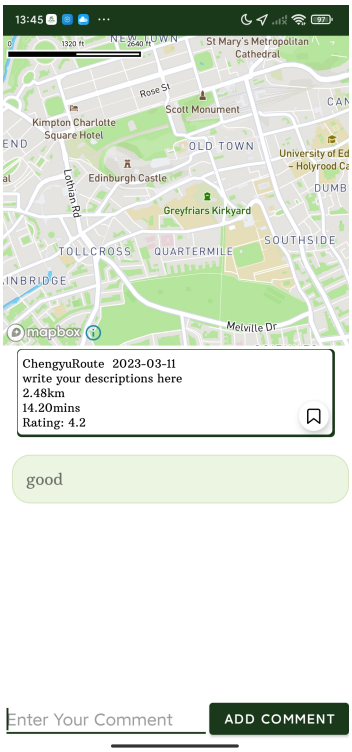


Figure E.14: Cyclopath Edinburgh after First Iteration - Route Details

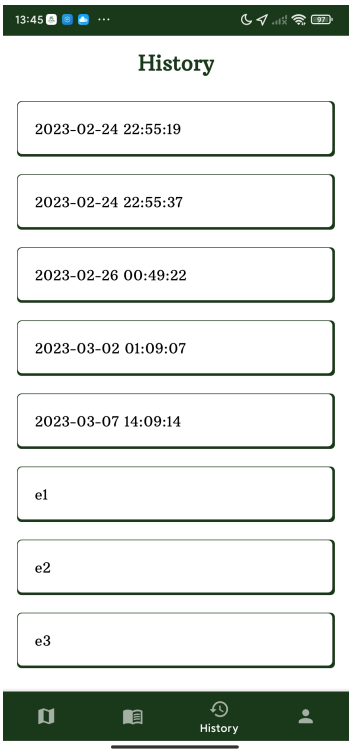


Figure E.15: Cyclopath Edinburgh after First Iteration - History Tracks

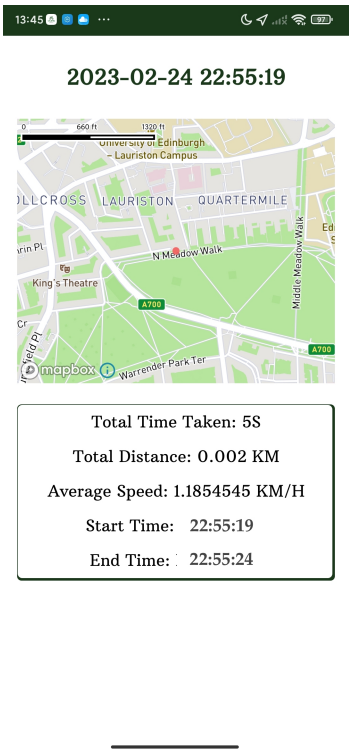


Figure E.16: Cyclopath Edinburgh after First Iteration - History Track Details

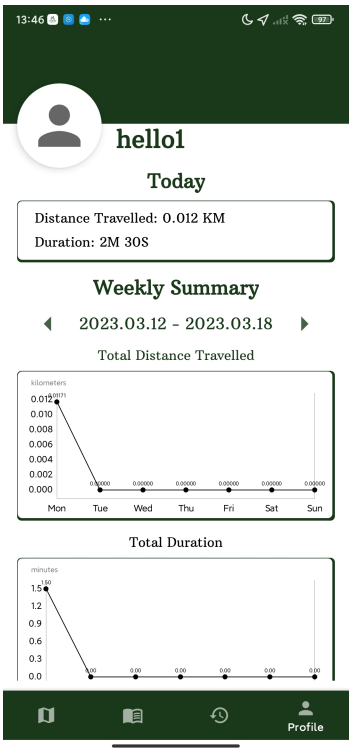


Figure E.17: Cyclopath Edinburgh after First Iteration - Profile

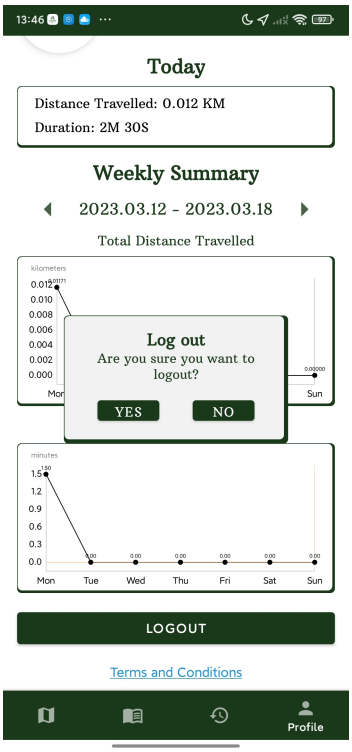


Figure E.18: Cyclopath Edinburgh after First Iteration - Logout Popup

Appendix F

Test Cases for First Iteration of Implementation

F.1 Navigation between Pages

I switched between pages by pressing the button and back as well as switching between both segments. All these navigation works well without any bugs.

Test Scenario	Preconditions	Expected Result	Status
Enter the app	Press the app icon.	Enter the 'Login' page.	Success
Enter the 'Login' page	Enter the app.	Display 'Login' page for users to login.	Success
Navigate from 'Login' page to 'Sign Up' page	Press the 'Sign Up' word in the 'Login' page.	Display 'Sign Up' page for users to sign up.	Success
Navigate from 'Sign Up' page to 'Login' page	Press the back button in your mobile phone.	Display the popup to exit the 'Sign Up' page.	Success
Navigate from 'Sign Up' page to 'Terms & Conditions' page	Press the 'Terms & Conditions' icon in the 'Sign Up' page.	Display the 'Terms & Conditions' page.	Success
Navigate from 'Terms & Conditions' page to 'Sign Up' page	Press the back button in your mobile phone.	Display the previous state of the 'Sign Up' page.	Success
Navigate from 'Login' page to 'Forgot Password' page	Press the 'Forgot Password?' word in the 'Login' page.	Display the 'Forgot Password' page.	Success

Table F.1: Test Scenario for the Navigation between Pages

Test Scenario	Preconditions	Expected Result	Status
Navigate from 'Forgot Password' page to 'Login' page	Press the back button in your mobile phone.	Enter the 'Login' page.	Success
Navigate from 'Login' page to main page	Successful login after pressing the button.	Display the default fragment - 'Search' fragment.	Success
Navigate from 'Search' fragment to 'Navigation' page	Press the 'Navigate' button in the 'Search' fragment.	Enter the 'Navigation' page.	Success
Navigate from 'Navigation' page to 'Search' fragment	Press the back button in your mobile phone.	Display the previous state of the 'Search' fragment.	Success
Navigate between fragments	Press the button in the bottom navigation bar.	Display the fragment according to the button.	Success
Navigate from 'History' fragment to 'Historic Detail' page	Press any of the history tracks.	Display the 'Historic Detail' page.	Success
Navigate from 'Historic Detail' page to 'History' fragment	Press the back button in your mobile phone.	Display the previous state of the 'History' page.	Success
Show the 'Log Out' popup	Press the 'Log Out' button in the 'Profile' fragment.	Show the log out popup.	Success
Exit the 'Log Out' popup	Press the 'No' button in the popup.	Display the previous state of the 'Predict' fragment.	Success
Navigate from 'Log Out' popup to 'Login' page	Press the 'Yes' button in the popup.	Display 'Login' page for users to login.	Success
Exit the app	Press the back button in your mobile phone.	Close the app.	Success

Table F.2: Test Scenario for the Navigation between Pages

F.2 Data Storage

The user data are stored correctly in the Firebase Cloud Firestore. The historic data are stored correctly in the Firebase Storage. The login system (with email and password or with Google) is authenticated using Authentication.

Test Scenario	Preconditions	Expected Result	Status
New user sign up	Enter the username and password and press the 'Sign Up' button.	Checks the cloud database and add the user to the database.	Success
Resend activation email	Press the 'Resend Activation Email' button.	Send a new activation email to the user's email address.	Success
User login	Enter the username and password and press the 'Login' button.	Checks the cloud database and the user exists.	Success
Forgot password	Enter the email and press the 'Send Password Reset Email' button	Send a password reset email to the user's email address.	Success
Login with Google	Press the 'Login with Google' icon.	Enter a 'One-tap Sign In' page to continue with Google login.	Success
Record track	Save the track recorded.	Update the total distance travelled and total duration in the cloud storage.	Success
History tracks	Enter 'History' fragment.	Retrieve the history tracks from the cloud storage.	Success
History track's details	Press any of the history track.	Retrieve the history track's details from the cloud storage.	Success
Total distance travelled	Enter 'Profile' fragment.	Retrieve the total distance travelled from the cloud storage.	Success
Total duration	Enter 'Profile' fragment.	Retrieve the total duration from the cloud storage.	Success
Weekly total distance travelled	Enter 'Profile' fragment.	Retrieve the total distance travelled from the cloud storage.	Success
Weekly total duration	Enter 'Profile' fragment.	Retrieve the total duration from the cloud storage.	Success

Table F.3: Test Scenario for the Data Storage

F.3 Functionalities

Every function in every page works correctly and smoothly. It works as what it is expected.

Test Scenario	Preconditions	Expected Result	Status
Valid new user sign up	Enter the username and password correctly and press the 'Sign Up' button.	Enables the user to enter to the main page.	Success
Invalid new user sign up	Username given used before by other user.	Show a toast message and prevent the user from entering the main page.	Success
Invalid new user sign up	Username given does not contains 6-20 characters.	Show a toast message and prevent the user from successfully sign up.	Success
Invalid new user sign up	Email given used before by other user.	Show a toast message and prevent the user from successfully sign up.	Success
Invalid new user sign up	Email given is not in the correct format.	Show a toast message and prevent the user from successfully sign up.	Success
Invalid new user sign up	Password given does not contains 6-20 characters, letters or numbers.	Show a toast message and prevent the user from successfully sign up.	Success
Invalid new user sign up	User does not tick the 'Terms & Conditions' icon.	Show a toast message and prevent the user from successfully sign up.	Success
Valid user login	Enter the username and password correctly and press the 'Login' button.	Enables the user to enter to the main page.	Success
Invalid user login	Username given does not exist in the cloud database.	Show a toast message and prevent the user from entering the main page.	Success
Invalid user login	Password given is incorrect.	Show a toast message and prevent the user from entering the main page.	Success
Invalid user login	The user's email address is not activated.	Show a toast message and prevent the user from entering the main page.	Success

Table F.4: Test Scenario for the Functionalities

Test Scenario	Preconditions	Expected Result	Status
View my current location	User enables location permissions and location services.	Current location is shown with a blue icon.	Success
Recenter my current location	Press the 'Recenter' button.	Center the map to the current location.	Success
Get autofill suggestion for origin	Enter the origin.	List top ten address suggestion according to the distance.	Success
Get autofill suggestion for destination	Enter the destination.	List top ten address suggestion according to the distance.	Success
Set current location as origin	Press the 'Focus' icon besides origin.	Origin is set to be current location.	Success
Set current location as destination	Press the 'Focus' icon besides destination.	Origin is set to be current location.	Success
Swap origin and destination	Press the 'Swap' icon beside the origin and destination.	Origin and destination are swapped.	Success
Show the route selected	Entered the origin and destination.	Display the route selected with distance and duration.	Success
Change the route	Entered the origin and destination and press the route selected.	Display the route selection available.	Success
Show the route selected on map	Entered the origin and destination.	Display the route selected on map with red line.	Success
Change the route on map	Entered the origin and destination and press the route selected.	Display the route selected on map with red line.	Success
Drag the map	-	Map can be easily dragged to view other location.	Success
Navigate a route	Route is selected	Show the navigation of the route.	Success
Record a track	Press the 'Record Track' icon	Start the recording.	Success
Show the Save Track popup	Press the 'Stop Track' icon	Display the 'Save Track' popup in the center.	Success
Save a track	Press the 'Yes' button in the popup	Stop and save the recording.	Success
Continue a track	Press the 'No' button in the popup or click any place outside the popup.	Continue with the recording.	Success
Change the name of a track	-	The saved track has the given name.	Success

Table F.5: Test Scenario for the Functionalities

Test Scenario	Preconditions	Expected Result	Status
Show history tracks	Enter the 'History' fragment	Display the history tracks.	Success
Show history track's details	Press any history track	Display the history details with a map.	Success
Show today's total distance travelled	-	Display today's total distance travelled at the top of the 'Profile' fragment.	Success
Show today's total duration	-	Display today's total duration at the top of the 'Profile' fragment.	Success
Updates today's total distance travelled	Save a track.	The total distance travelled is updated every time when the user reenters the 'Profile' fragment.	Success
Updates today's total duration	Save a track.	The total duration is updated every time when the user reenters the 'Profile' fragment.	Success
Display the line chart of the weekly total distance travelled	-	The line chart of the weekly total distance travelled of specific period is displayed in the 'Profile' fragment.	Success
Display the line chart of the weekly total duration	-	The line chart of the weekly total duration of specific period is displayed in the 'Profile' fragment.	Success
Change the period of the weekly report.	Have the data of previous weeks and press the 'Left' or 'Right' button beside the date.	Display the weekly data according to the period specified.	Success
Display the 'Log Out' popup	Press the 'Log Out' button in the 'Profile' fragment	The 'Log Out' popup is showed up in the center.	Success
Log out the app	Press the 'Yes' button in the log out popup	Directs the user to the 'Login' page.	Success
Close the 'Log Out' popup	Press the 'No' button or click any place outside the popup.	The 'Log Out' popup is closed and return to the previous state.	Success

Table F.6: Test Scenario for the Functionalities

Appendix G

Formative Evaluation

G.1 Tasks - Think Aloud Protocol & Stakeholder Walkthrough

1. Sign up an account using email and password.
2. Login to your account.
3. View and recenter your current location.
4. Search a route between two points.
5. Start navigation of your selected route.
6. Share a route.
7. View the library.
8. Select a route from the route library and see the details.
9. Record a track.
10. View your history and see the details.
11. View your profile and see the statistics.
12. Log out from your account.

G.2 Script - Stakeholder Walkthrough

Questions asked after every task.

1. What is your opinion on the navigation for this task?
2. Do you have any comments on usability for this task?
3. How did you find the user interface of this task?

G.3 Interview - Think Aloud Protocol & Questionnaire - Stakeholder Walkthrough

1. What did you like most about the user interface?
2. What did you like least about the user interface?
3. What is your opinion of the colors and theme used across the whole application?
4. What is your opinion of the fonts used across the whole application, including the font type and size?
5. What is your opinion of the icons used across the whole application?
6. Is there anything that you would add to the design?
7. Is there anything that you would remove from the design?

G.4 SUS Evaluation - Think Aloud Protocol & Stakeholder Walkthrough

All of the question is rated from 1 to 5.

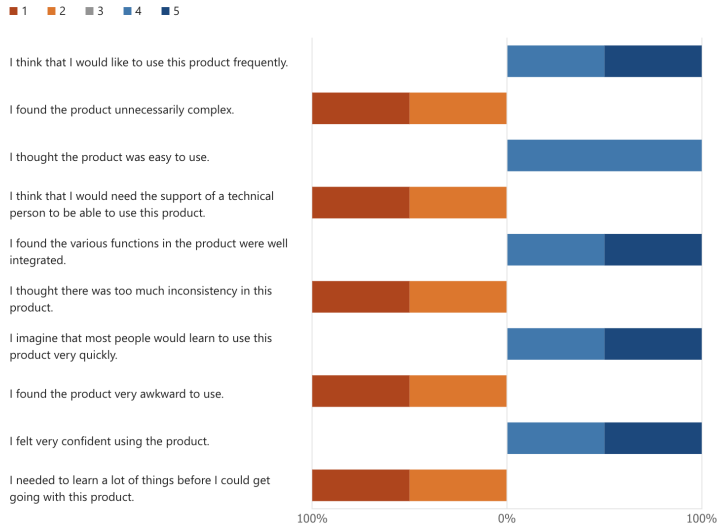
1. I think that I would like to use this product frequently.
2. I found the product unnecessarily complex.
3. I thought the product was easy to use.
4. I think that I would need the support of a technical person to be able to use this product.
5. I found the various functions in the product were well integrated.
6. I thought there was too much inconsistency in this product.
7. I imagine that most people would learn to use this product very quickly.
8. I found the product very awkward to use.
9. I felt very confident using the product.
10. I needed to learn a lot of things before I could get going with this product.

G.5 Quantitative Analysis

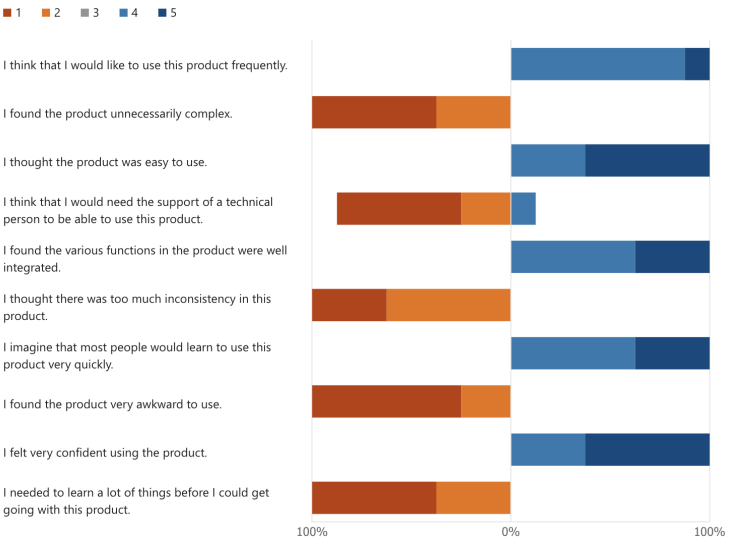
G.5.1 Results of SUS Evaluation by HCI Experts

2. **Rate on a range of 1 to 5.** (0 point)
   1 - Strongly Disagree
   2 - Disagree
   3 - Neutral
   4 - Agree
   5 - Strongly Agree

More Details



G.5.2 Results of SUS Evaluation by Cyclists



G.6 Qualitative Analysis

G.6.1 Think Aloud Protocol and Stakeholder Walkthrough

Task	Navigation	Usability	User Interface
G.1.1	• It should direct the user to the main page after verification. • The popup is misleading. It should direct the user to the main page.	• Add more requirement for the password such as symbols and uppercase letter. • Retype the password to prevent unaware of password mistyping.	• Display the requirement of the input field. • Toast message too fast disappear.
G.1.2	• The overall navigation is good.	• Use email to login instead of username.	• Hide the keyboard after typing the password.
G.1.3	• Show the animation in the map when ease the camera to the current location.	• Automatically recenter your current location after enables location services. • The direction of bearing is not accurate.	• The icon for recenter is not intuitive. • The colour can be change to the theme colour.
G.1.4	• The overall navigation is good.	• The name displays when pressing a location should be address not coordinate. • The suggestion comes out slightly slower. Search the address using postcode. • Add elevation when selecting the route.	• Route selection is not clear enough.
G.1.5	• The 'Cross' icon should exit the current page.	• The direction of the bearing is not accurate.	• The overall user interface is nice.
G.1.9	• The overall navigation is good.	• Add a 'Discard' and 'Pause' button to delete and stop the recording.	• Have a toast message or a timer when the recording starts. • The record button can be bigger as it is not obvious enough.
G.1.10	• The overall navigation is good.	• Share the track and add comments. Show elevation and estimated calories consumed. • Use video replayer to replay the track.	• The history icon is not intuitive. The map should zoom in to the track
G.1.11	• The overall navigation is good.	• Show the total distance travelled from the start.	• Change the graph to show the statistics in monthly basis.
G.1.12	• The overall navigation is good.	• The overall usability works well.	• Not intuitive to have 'Log Out' button in the 'Profile' fragment

G.6.2 Interview and Questionnaire

G.6.2.1 What did you like most about the user interface?

I like the bottom navigation bar and the idea of having record track.

I like the weekly report in the 'Profile' fragment.

The overall design is nice and I like the theme colour.

G.6.2.2 What did you like least about the user interface?

The camera does not zoom in to the route.

It is hard to navigate sometimes.

Some icons will overlap and blocking each other.

G.6.2.3 What is your opinion of the colors and theme used across the whole application?

Very nice and user-friendly.

Looks positive.

G.6.2.4 What is your opinion of the fonts used across the whole application, including the font type and size?

The font type and size is nice.

Very nice and clear.

The font is a good choice, albeit not usually seen in other apps.

G.6.2.5 What is your opinion of the icons used across the whole application?

Some icons are not intuitive, such as recenter and history icons.

G.6.2.6 Is there anything that you would add to the design?

Accessibility for low vision or colour blind and add Tactons.

Some confirmation buttons.

G.6.2.7 Is there anything that you would remove from the design?

I am happy with every feature in the Cyclopath Edinburgh.

Nothing is needed to remove from the current version.

Appendix H

Final Design of Cyclopath Edinburgh

Figure H.1: Final Design of Cyclopath Edinburgh - Frame

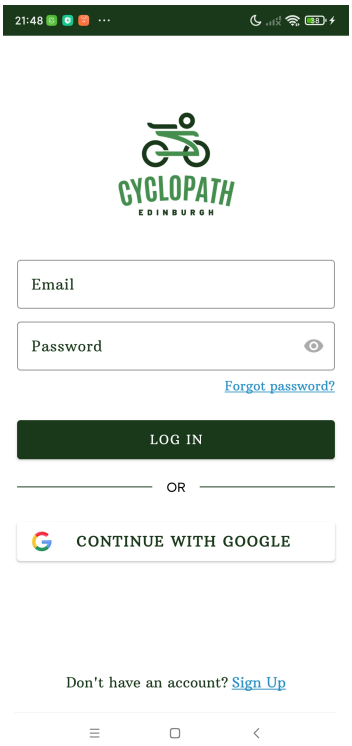


Figure H.2: Final Design of Cyclopath Edinburgh - Login

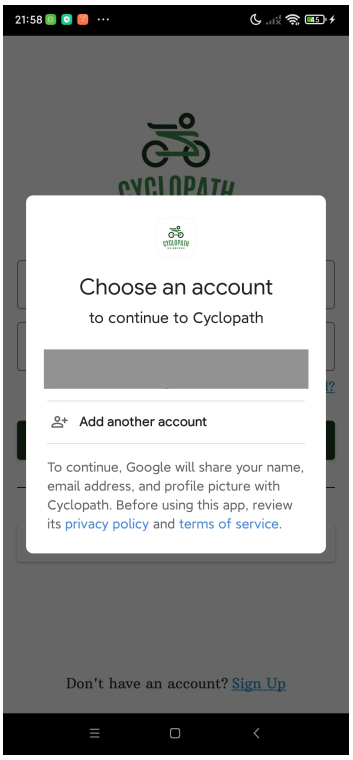


Figure H.3: Final Design of Cyclopath Edinburgh - Login with Google

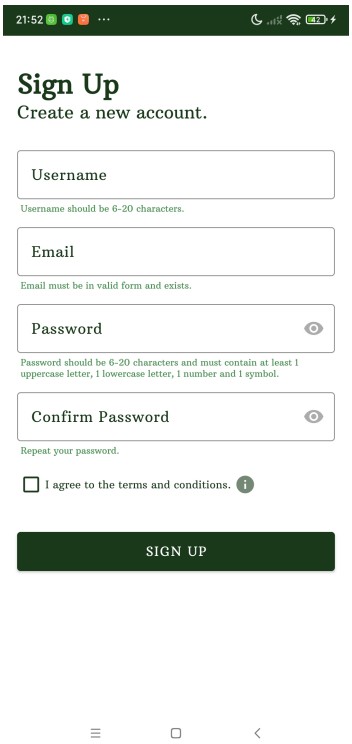


Figure H.4: Final Design of Cyclopath Edinburgh - Sign Up

Figure H.5: Final Design of Cyclopath Edinburgh - After Sign Up

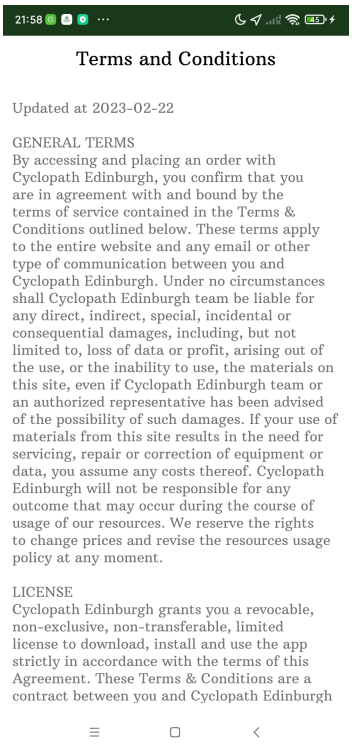


Figure H.6: Final Design of Cyclopath Edinburgh - Terms & Conditions

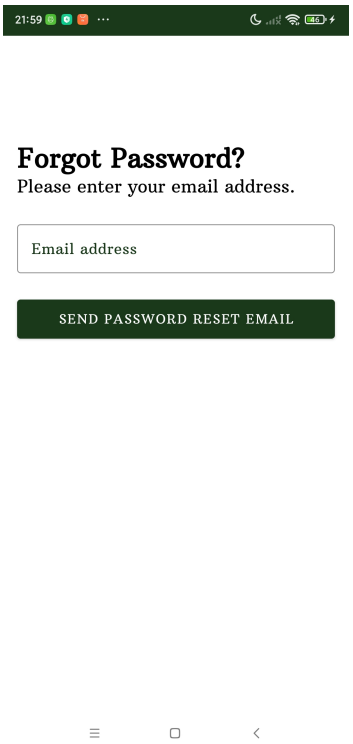


Figure H.7: Final Design of Cyclopath Edinburgh - Forgot Password

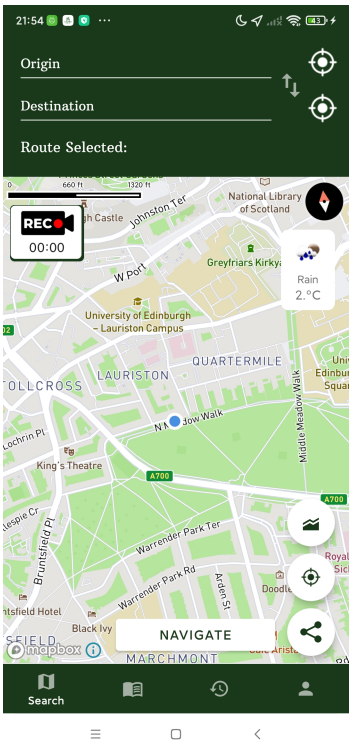


Figure H.8: Final Design of Cyclopath Edinburgh - Main Page

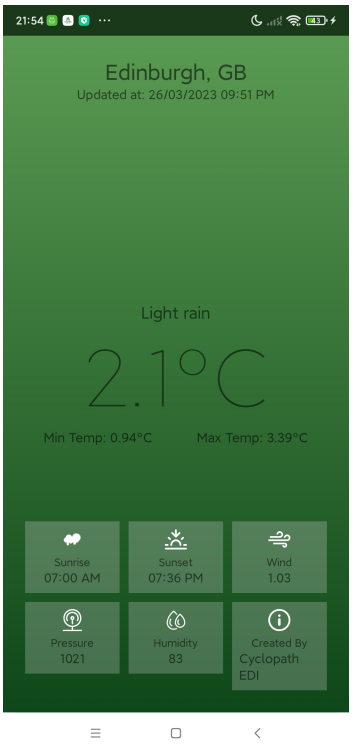


Figure H.9: Final Design of Cyclopath Edinburgh - Weather Forecast

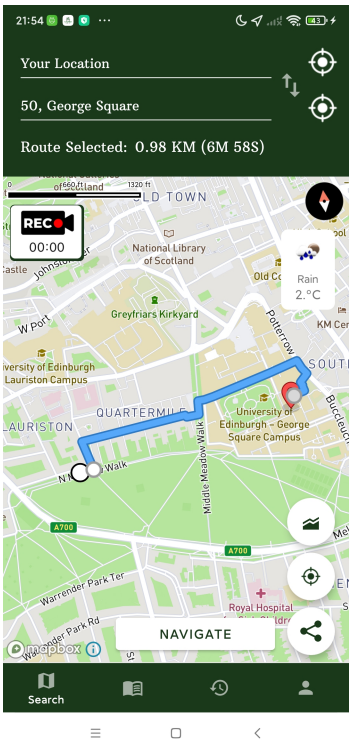


Figure H.10: Final Design of Cyclopath Edinburgh - Search Route

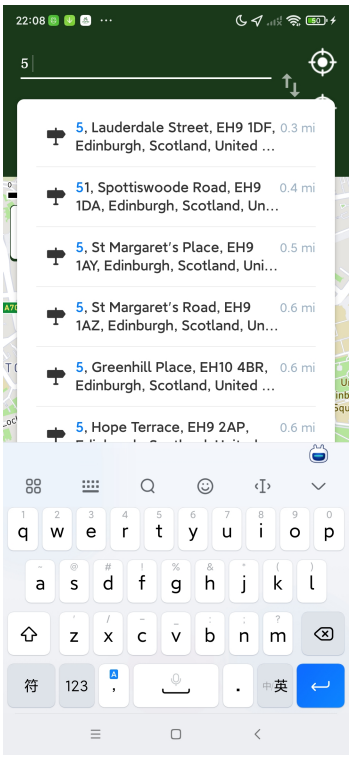


Figure H.11: Final Design of Cyclopath Edinburgh - Autofill Suggestion

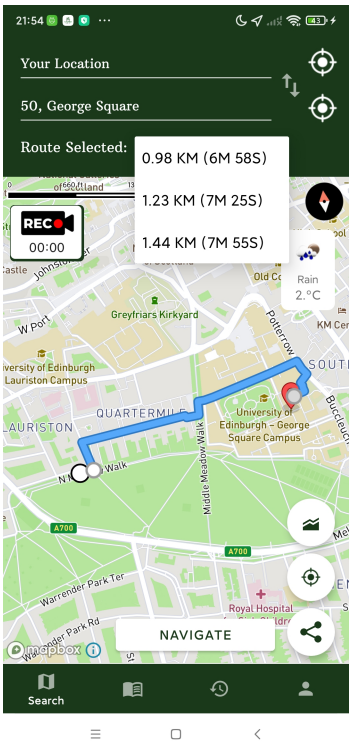


Figure H.12: Final Design of Cyclopath Edinburgh - Route Selection

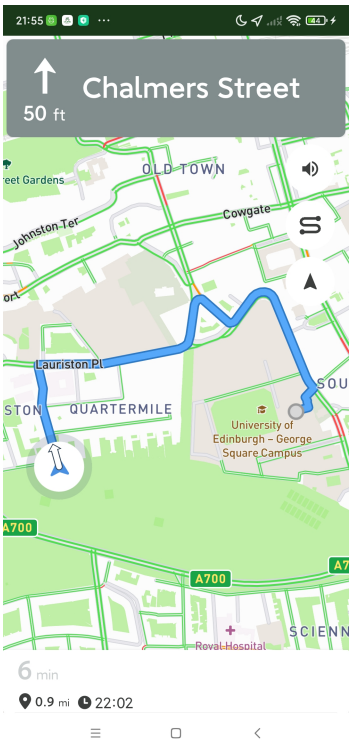


Figure H.13: Final Design of Cyclopath Edinburgh - Navigation Overview

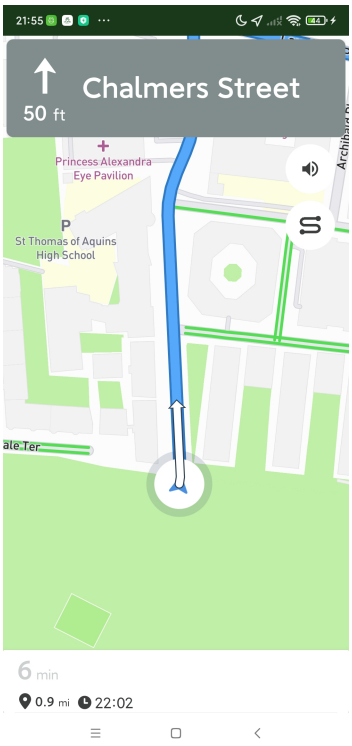


Figure H.14: Final Design of Cyclopath Edinburgh - Navigation Recenter

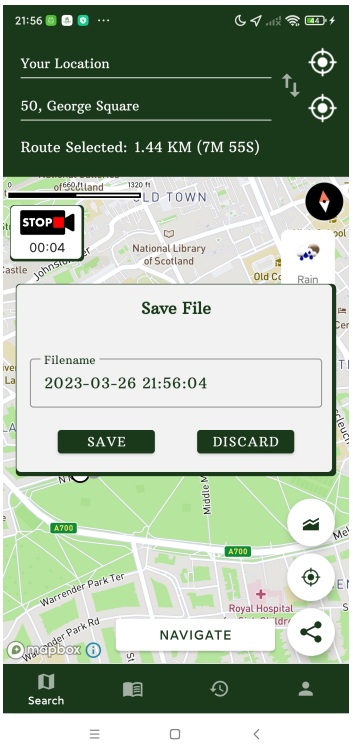


Figure H.15: Final Design of Cyclopath Edinburgh - Record Track Popup

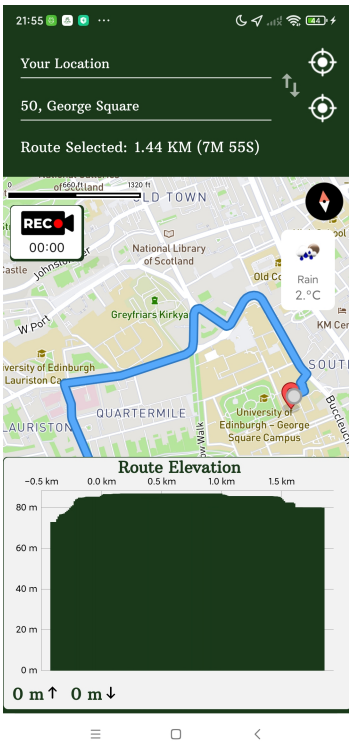


Figure H.16: Final Design of Cyclopath Edinburgh - Elevation

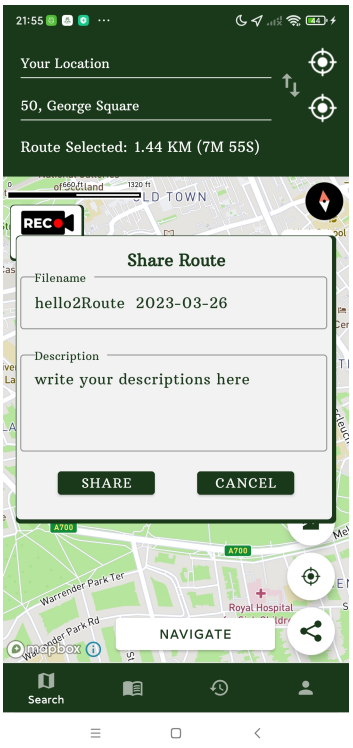


Figure H.17: Final Design of Cyclopath Edinburgh - Share Route Popup

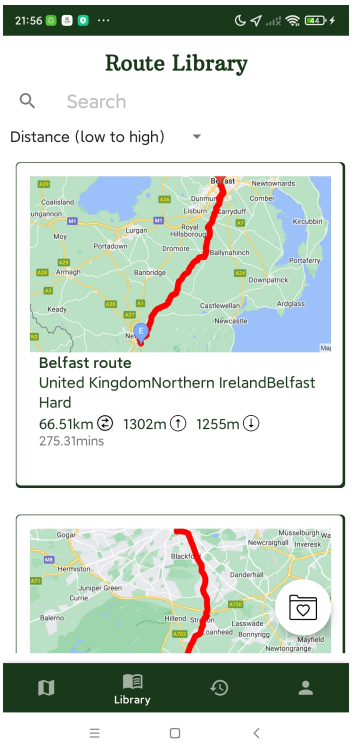


Figure H.18: Final Design of Cyclopath Edinburgh - Route Library

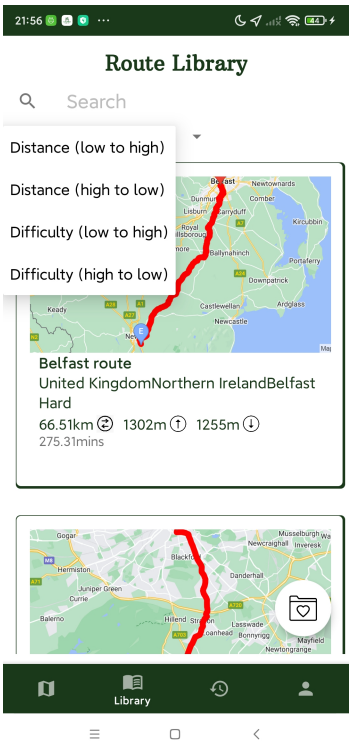


Figure H.19: Final Design of Cyclopath Edinburgh - Route Library Sort

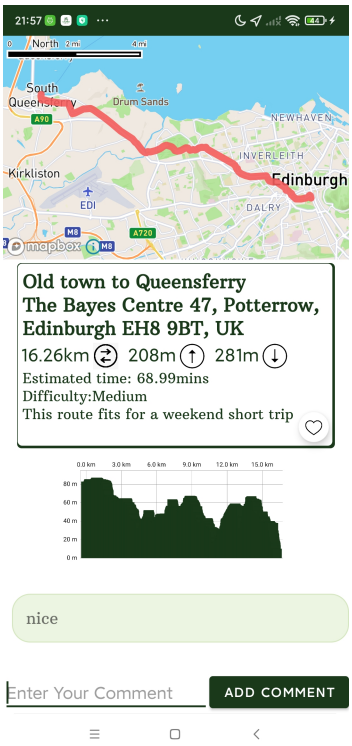


Figure H.20: Final Design of Cyclopath Edinburgh - Route Details

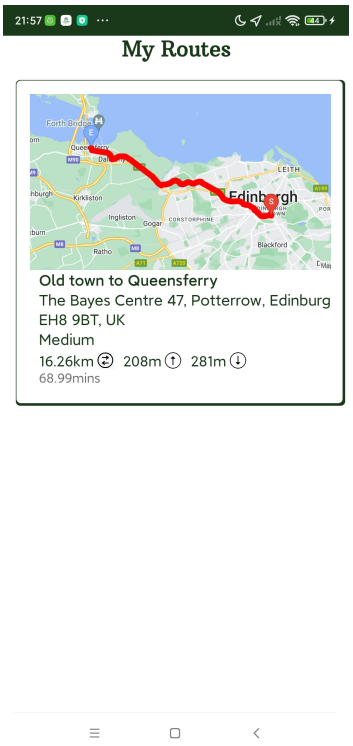


Figure H.21: Final Design of Cyclopath Edinburgh - Favourite Routes

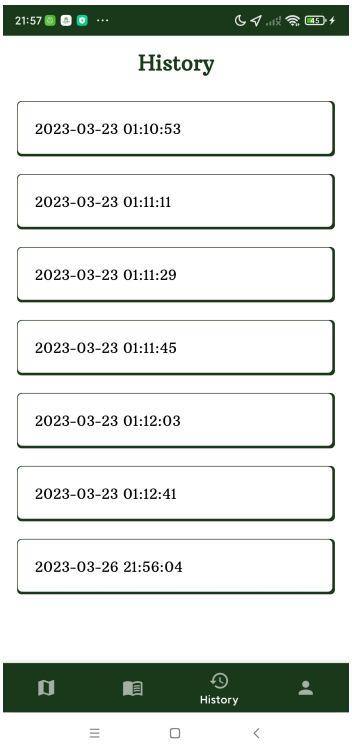


Figure H.22: Final Design of Cyclopath Edinburgh - History Tracks

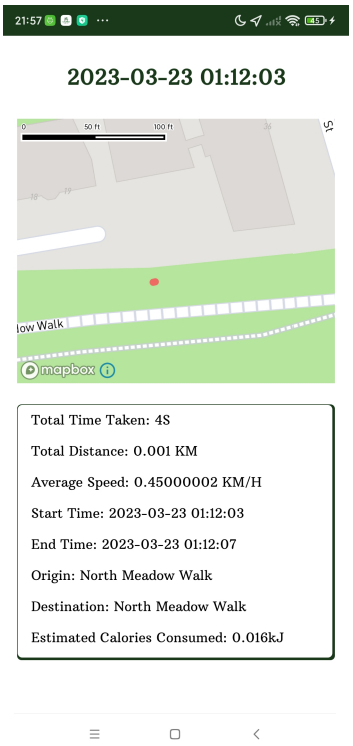


Figure H.23: Final Design of Cyclopath Edinburgh - History Track Details

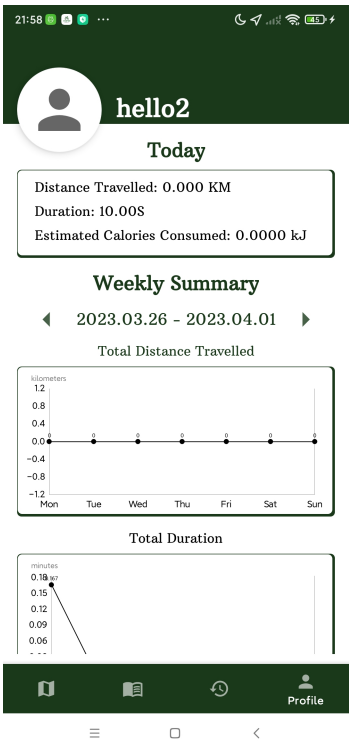


Figure H.24: Final Design of Cyclopath Edinburgh - Profile Fragment

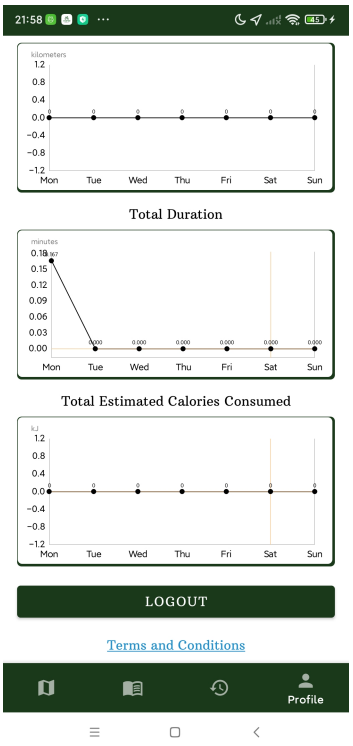


Figure H.25: Final Design of Cyclopath Edinburgh - Profile Fragment

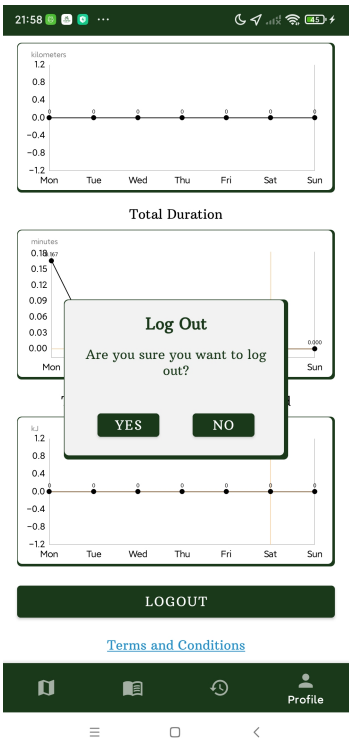


Figure H.26: Final Design of Cyclopath Edinburgh - Logout Popup

Appendix I

Test Cases for Final Design of Cyclopath Edinburgh

All of the test cases in Appendix F have been completed. Below are the additional test cases:

I.1 Navigation between Pages

Test Scenario	Preconditions	Expected Result	Status
Navigate from 'Sign Up' page to main page	Successfully login after press the 'Login' button.	Display the default fragment - 'Search' fragment.	Success
Show the 'Save Track' popup	Press the 'Stop Record' button in the 'Search' fragment	Display the 'Save Track' popup.	Success
Exit the 'Save Track' popup	Click any place outside the popup.	Display the previous state of the 'Search' fragment.	Success

Table I.1: Test Scenario for the Navigation between Pages

I.2 Data Storage

Test Scenario	Preconditions	Expected Result	Status
Login with Google	Press the 'Login with Google' icon.	Enter a 'One-tap Sign In' page to continue with Google login.	Success
Total estimated calories consumed	Enter 'Profile' fragment.	Retrieve the estimated calories consumed from the storage.	Success
Weekly estimated calories consumed	Enter 'Profile' fragment.	Retrieve the estimated calories consumed from the storage.	Success

Table I.2: Test Scenario for the Data Storage

I.3 Functionalities

Test Scenario	Preconditions	Expected Result	Status
Invalid new user sign up	Password and Confirm Password do not match.	Show a toast message and prevent the user from successfully sign up.	Success
Valid user login	Enter the email and password correctly and press the 'Login' button.	Enables the user to enter to the main page.	Success
Invalid user login	Email given does not exist in the database.	Show a toast message and prevent the user from entering the main page.	Success
Set a location on the map as origin	Press a location on the map.	The location is set as origin and the name is shown in the field.	Success
Set a location on the map as destination	Press a location on the map.	The location is set as destination and the name is shown in the field.	Success
Provide sound navigation	Press the 'Unmute' button in the 'Navigation' page.	The sound navigation is provided.	Success
Overview a route	Press the 'Overview' button in the 'Navigation' page.	The overview of the route is shown.	Success
Recenter current location	Press the 'Recenter' button in the 'Navigation' page.	Center the map to the current location.	Success
Discard a track	Press the 'Discard' button in the popup	Stop and discard the recording.	Success
Continue a track	Click any place outside the popup.	Continue with the recording.	Success
Show today's estimated calories consumed	-	Display today's estimated calories consumed at the top of the 'Profile' fragment.	Success
Updates today's estimated calories consumed	Save a track.	The total estimated calories consumed is updated every time when the user reenters the 'Profile' fragment.	Success
Display the line chart of the weekly total estimated calories consumed	-	The line chart of the weekly total estimated calories consumed of specific period is displayed in the 'Profile' fragment.	Success

Table I.3: Test Scenario for the Functionalities

Appendix J

Summative Evaluation

J.1 Tasks - Think Aloud Protocol & Stakeholder Walkthrough

All the tasks in Appendix G.1 are done. Below are the additional tasks:

1. Click and view the weather icon.
2. Click and view the elevation icon.
3. Start navigation of your selected route (from your current location).
4. Search for a place and see the recommended routes.
5. Sort the routes by distance/difficulty.
6. Comment on the route.
7. Like a route and view it in the favourites.

J.2 Script - Stakeholder Walkthrough

The script is same as Appendix G.2.

J.3 Interview - Think Aloud Protocol & Questionnaire - Stakeholder Walkthrough

The script is the same as Appendix G.3. Below are the additional question:
What is the potential impact of the application for cyclists in Edinburgh, in terms of: a. Supporting their daily cycles? b. Discovering and exploring new routes? c. Improving their experience of their cycling trip? d. Encouraging them to cycle in Edinburgh?

J.4 SUS Evaluation - Think Aloud Protocol & Stakeholder Walkthrough

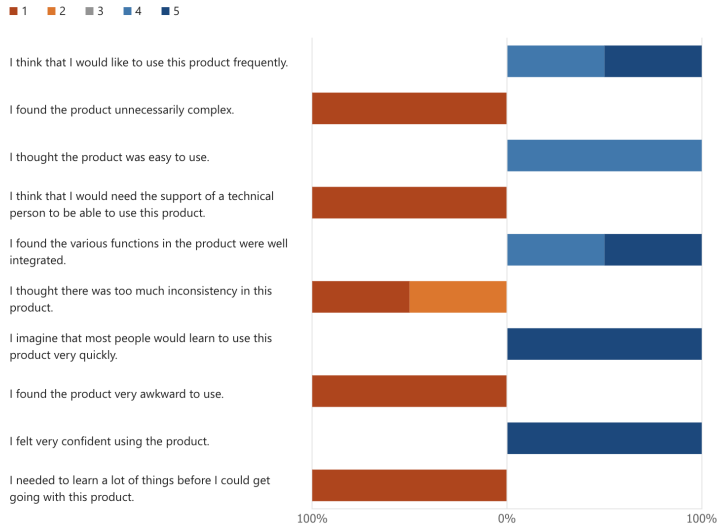
The script is the same as the Appendix G.4.

J.5 Quantitative Analysis

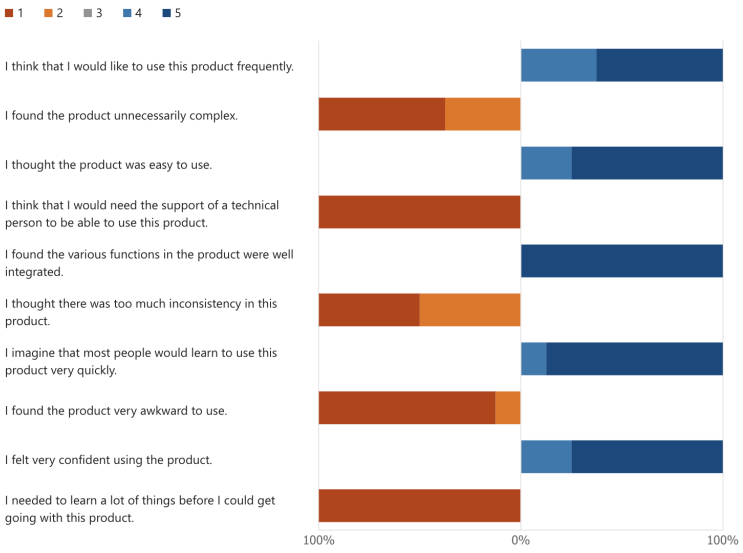
J.5.1 Results of SUS Evaluation by HCI Experts

2. **Rate on a range of 1 to 5.** (0 point)
   1 - Strongly Disagree
   2 - Disagree
   3 - Neutral
   4 - Agree
   5 - Strongly Agree

More Details



J.5.2 Results of SUS Evaluation by Cyclists



J.6 Qualitative Analysis

J.6.1 Think Aloud Protocol and Stakeholder Walkthrough

Task	Navigation	Usability	User Interface
G.1.1	• The 'Sign Up' word is quite small, maybe hard to see by visually impaired people.	• The overall usability works well.	• Clean UI, very convenient to register. • Progress bar looks good. • Clear guidance and secure.
G.1.2	• Good to direct navigate after signing up since I no need to reenter the information.	• Google login is extremely good, convenient, and smooth.	• The overall user interface is nice.
G.1.3	• The recenter works smoothly with slow animation.	• The overall usability works well.	• Intuitive and clear icon.
G.1.4	• The overall navigation is good.	• Like the long-press feature which allows me to press on any location on the map to search for a route. • Clearly show the origin, destination and route. Route selection is good.	• Clear and precise.
K.1.3	• Works very smooth when pressing buttons.	• The 'Overview' and 'Sound' are useful for cyclists. It shows the information clearly. • The functionalities here are much better than other cycling app.	• I like the label comes with button as this makes the functionality of a button obvious.
G.1.9	• The overall navigation is good.	• Good as I can record my daily cycling trip easily.	• The overall user interface is nice.
G.1.10	• The overall navigation is good.	• The estimated calories consumed is good. Would be better if it is personalised by collecting user's weight and height. • Information shown is precise, clear, and useful.	• The overall user interface is nice.
G.1.11	• The overall navigation is good.	• Overall is good. Would be better to switch between weekly basis and monthly basis and setting some goals. • Encourage me to cycle more in order to consume more calories. • Acts as a fitness tracker which will fulfil my satisfaction.	• Very clear and useful.
G.1.12	• The overall navigation is good.	• The overall usability works well.	• The overall user interface is nice.

J.6.2 Interview and Questionnaire

J.6.2.1 What did you like most about the user interface?

Everything is clear, icons are intuitive and consistent.

Everything, I like the record track and the details it shows.

Consistent theme colour and simplicity.

Colour and font choice, give a calming effect. Especially the login pace seems to be clean and welcoming. The main page features a nice map.

J.6.2.2 What did you like least about the user interface?

Everything is fine.

J.6.2.3 What is your opinion of the colors and theme used across the whole application?

Great, simple and clean.

Excellent. Fits the theme of cycling well.

Like it very much, looks healthy and energetic.

J.6.2.4 What is your opinion of the fonts used across the whole application, including the font type and size?

The font type and size is nice.

J.6.2.5 What is your opinion of the icons used across the whole application?

All of the icons are intuitive.

No complaints. Everything is easy to understand.

J.6.2.6 Is there anything that you would add to the design?

Goal setting, profile, elevation in route selection, make record track more like a diary.

Weekly report in monthly basis.

Record voice comments when recording track.

Not that I can think of. I like the overall completeness of the app.

J.6.2.7 Is there anything that you would remove from the design?

I am happy with every feature in the Cyclopath Edinburgh.

Nothing is needed to remove from the current version.

I guess the current design works well. Great effort.

Appendix K

SUS Score Acceptability Rating Scale and Grading Scale

K.1 How to Calculate Your Usability Score using SUS? (Thomas, n.d.)

1. For each of the odd numbered questions, subtract 1 from the score.
2. For each of the even numbered questions, subtract their value from 5.
3. Take these new values which you have found, and add up the total score. Then multiply this by 2.5.

K.2 SUS Score Acceptability Rating Scale (Bangor et al., 2008)

Acceptability Ranges	Mean SUS Score
Not Acceptable	Below 50
Marginal	50-70
Acceptable	Above 70

K.3 SUS Grading Scale (Aaron Bangor and Miller, 2009)

Grade	Mean SUS Score
F	Below 60
D	60-69
C	70-79
B	80-89
A	90-100

Appendix L

Participants' Information Sheet

The PIS for Formative Evaluation and Summative Evaluation are the same for both think aloud protocol and stakeholder walkthrough except the RT number. Thus, I will only show the PIS for Summative Evaluation.

Participant Information Sheet - Requirement Gathering - Questionnaire

Project title:	Cyclopath
Principal investigator:	Philip Wadler
Researcher collecting data:	Chang Shian Goh, Chengyu Kang
Funder (if applicable):	No

This study was certified according to the Informatics Research Ethics Process, RT number 454672. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

The researchers of the study are Chang Shian Goh and Chengyu Kang, who are undergraduate students in the University of Edinburgh School of Informatics, and Philip Wadler who is their supervisor. This study is conducted as part of the undergraduate project of Chang Shian Goh and Chengyu Kang.

What is the purpose of the study?

We are currently implementing an Android application called Cyclopath which is mainly a cycling app for routing. The study is to conduct user analysis of cyclists in the UK at the beginning of the design phase. The purpose of this study is to find out the usability and the potential impact of the cycling app on cyclists. This will help us in our data gathering to further improve the implementation of our application. We hope that the application fulfilled your needs and user-friendly.

Why have I been asked to take part?

The reason why you are invited to participate in this study is because you are a cyclist in the UK, and thus used to plan the cycling routes. You might have some experience of using cycling app. We hope you can use your previous valuable experience to suggest improvements to our implementation of Cyclopath.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time without giving a reason. After this point, personal data will be deleted and anonymised data will be combined such that it is impossible to remove individual information from the analysis. Your rights will not be affected. If you wish to withdraw, contact the PI who is Philip Wadler (Philip.wadler@ed.ac.uk). We will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

If you decide to participate in the study, we will provide you a Microsoft Forms questionnaire. During this process, you will be asked some questions regarding your cycling habits, interests, difficulties, needs and your expectation of a cycling app. You will also be asked if you are interested to take part in our further research. If so, you will be invited to take part in a focus group held over Microsoft Teams with other cyclists. More detailed of focus group will be available in the Participants Information Sheet for focus group. This questionnaire should take around 10 minutes to complete.

Are there any risks associated with taking part?

There are no significant risks associated with participation. Your comments and answers will remain strictly confidential.

Are there any benefits associated with taking part?

There are no physical benefits after this study. However, we do hope that the implementation of Cyclopath will help you in your cycling route planning in the future and improve your overall experience in cycling.

What will happen to the results of this study?

The results of this study will be summarised in the Chang Shian Goh and Chengyu Kang's BSc dissertation. Moreover, they may be summarised in publish articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a maximum of 2 years. All potentially identifiable data will be deleted within this timeframe if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researchers Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) and their supervisor Philip Wadler (Philip.Wadler@ed.ac.uk) .

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the researchers: Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) or the Principal Investigator: Philip Wadler (Philip.Wadler@ed.ac.uk).

If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be emailed to you by Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

General information.

For general information about how we use your data, go to: edin.ac/privacy-research

Participant Information Sheet - Requirement Gathering - Focus Group Study

Project title:	Cyclopath
Principal investigator:	Philip Wadler
Researcher collecting data:	Chang Shian Goh, Chengyu Kang
Funder (if applicable):	No

This study was certified according to the Informatics Research Ethics Process, RT number 454672. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

The researchers of the study are Chang Shian Goh and Chengyu Kang, who are undergraduate students in the University of Edinburgh School of Informatics, and Philip Wadler who is their supervisor. This study is conducted as part of the undergraduate project of Chang Shian Goh and Chengyu Kang.

What is the purpose of the study?

We are currently implementing an Android application called Cyclopath which is mainly a cycling app for routing. The study is to conduct user analysis for the cyclists in the UK at the beginning of the design phase. The purpose of this study is to find out the usability and the potential impact of the cycling app on cyclists. This will help us in our data gathering to further improve the implementation of our application. We hope that the application fulfilled your needs and user-friendly.

Why have I been asked to take part?

The reason why you are invited to participate in this study is because you are a cyclist in the UK, and thus used to plan the cycling routes. You might have some experience of using cycling app. We hope you can use your previous valuable experience to suggest improvements to our implementation of Cyclopath.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time without giving a reason. After this point, personal data will be deleted and anonymised data will be combined such that it is impossible to remove individual information from the analysis. Your rights will not be affected. If you wish to withdraw, contact the PI who is Philip Wadler (Philip.wadler@ed.ac.uk). We will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

If you decide to participate in the study, we will invite you to attend a focus group study over Microsoft Teams together with other cyclists. During this process, we will be discussed about your cycling habits, interests, difficulties, needs and your expectation of a cycling app in more detailed. You will be provided a whiteboard (virtually such as Padlet or in paper form) where you can enter your suggestions with regards to the functionality of the platform. The focus group will be recorded (we require your consent for this). The focus group should last around 1 hour.

Are there any risks associated with taking part?

There are no significant risks associated with participation. Your comments and answers will remain strictly confidential.

Are there any benefits associated with taking part?

There are no physical benefits after this study. However, we do hope that the implementation of Cyclopath will help you in your cycling route planning in the future and improve your overall experience in cycling.

What will happen to the results of this study?

The results of this study will be summarised in the Chang Shian Goh and Chengyu Kang's BSc dissertation. Moreover, they may be summarised in publish articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a maximum of 2 years. All potentially identifiable data will be deleted within this timeframe if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researchers Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) and their supervisor Philip Wadler (Philip.Wadler@ed.ac.uk) .

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

While the participation in the focus group is generally confidential, other focus group participants will be aware of who has participated in the focus group.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the researchers: Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) or the Principal Investigator: Philip Wadler (Philip.Wadler@ed.ac.uk).

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Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be emailed to you by Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

Alternative formats.

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General information.

For general information about how we use your data, go to: edin.ac/privacy-research

Participant Information Sheet - Summative Evaluation - Think Aloud Protocol, Interview and SUS for HCI Expert

Project title:	Cyclopath Edinburgh
Principal investigator:	Philip Wadler
Researcher collecting data:	Chang Shian Goh, Chengyu Kang
Funder (if applicable):	No

This study was certified according to the Informatics Research Ethics Process, RT number 737272. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

The researchers of the study are Chang Shian Goh and Chengyu Kang, who are undergraduate students in the University of Edinburgh School of Informatics, and Philip Wadler who is their supervisor. This study is conducted as part of the undergraduate project of Chang Shian Goh and Chengyu Kang.

What is the purpose of the study?

We are currently implementing an Android application called Cyclopath which is mainly a cycling app for routing. The study is to conduct user analysis for the cyclists in the UK after the first design and implementation phase. The purpose of this study is to find out the usability of the current implementation of application prototype and identify any usability issues in the design. This will help us to gather feedback to further improve the implementation of our application.

Why have I been asked to take part?

The reason why you are invited to participate in this study is because you are an expert in the field of Human Computer Interaction (HCI) at the University of Edinburgh. You may also be a cyclist in the UK, and thus used to plan the cycling routes and might have some experience of using cycling app. We hope that you can help us understand the usability of the application prototype, identify any problems in relation to the usability, and provide us with suggestions for its improvement.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time without giving a reason. After this point, personal data will be deleted and anonymised data will be combined such that it is impossible to remove individual information from the analysis. Your rights will not be affected. If you wish to withdraw, contact the PI who is Philip Wadler (Philip.Wadler@ed.ac.uk). We will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

If you decide to participate in the study, we will invite you to attend an online think aloud protocol over Microsoft Teams. During the process, we will ask you to verbalise your thoughts while performing a set of pre-determined task on the prototype. The think aloud session will be recorded (we require your consent for this). The think aloud session should last around 20 minutes.

Following the think aloud session, you will be asked to participate a short interview. During the interview, we will ask follow-up questions from the think aloud session and give you the opportunity to detail any usability issues that you have identified while interacting with the prototype. You will also be asked to comment on the overall usability of the platform, give your opinion on the application and its potential impact for cyclists. The interview should last around 10 minutes.

At last, you will be given a short questionnaire to answer. The questionnaire will include the System Usability Scale (SUS), which consisting of several questions for several options for each. The questionnaire will not take longer than 5 minutes to complete.

Are there any risks associated with taking part?

There are no significant risks associated with participation. Your comments and answers will remain strictly confidential.

Are there any benefits associated with taking part?

There are no physical benefits after this study. However, we do hope that the implementation of Cyclopath will help you in your cycling route planning in the future and improve your overall experience in cycling.

What will happen to the results of this study?

The results of this study may be summarised in the Chang Shian Goh and Chengyu Kang's BSc dissertations. Moreover, they may be summarised in publish articles, reports and presentations. The recordings will only be transcribed and used for analysis. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a maximum of 2 years. All potentially identifiable data will be deleted within this timeframe if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researchers Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) and their supervisor Philip Wadler (Philip.Wadler@ed.ac.uk).

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses to minimise risk.

What are my data protection rights?

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Who can I contact?

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If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title, and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be emailed to you by Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

General information.

For general information about how we use your data, go to: edin.ac/privacy-research.

Participant Information Sheet - Summative Evaluation - Stakeholder Walkthrough, Questionnaire and SUS for Cyclists

Project title:	Cyclopath Edinburgh
Principal investigator:	Philip Wadler
Researcher collecting data:	Chang Shian Goh, Chengyu Kang
Funder (if applicable):	No

This study was certified according to the Informatics Research Ethics Process, RT number 737272. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

The researchers of the study are Chang Shian Goh and Chengyu Kang, who are undergraduate students in the University of Edinburgh School of Informatics, and Philip Wadler who is their supervisor. This study is conducted as part of the undergraduate project of Chang Shian Goh and Chengyu Kang.

What is the purpose of the study?

We are currently implementing an Android application called Cyclopath which is mainly a cycling app for routing. The study is to conduct user analysis for the cyclists in the UK after the first design and implementation phase. The purpose of this study is to find out the usability of the current implementation of application prototype and identify any usability issues in the design. This will help us to gather feedback to further improve the implementation of our application. We hope that the application fulfilled your needs and user-friendly.

Why have I been asked to take part?

The reason why you are invited to participate in this study is because you are a cyclist in the UK, and thus used to plan the cycling routes. You might have some experience of using cycling app and/or have some experience in UX (User Experience) design. We hope you can use your previous valuable experience to suggest improvements to our implementation of Cyclopath. You can also use your

interest to suggest ideas that may formulate the design of the implementation of our application.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time without giving a reason. After this point, personal data will be deleted and anonymised data will be combined such that it is impossible to remove individual information from the analysis. Your rights will not be affected. If you wish to withdraw, contact the PI who is Philip Wadler (Philip.Wadler@ed.ac.uk). We will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

If you decide to participate in the study, we will invite you to attend an online stakeholder walkthrough over Microsoft Teams together with other cyclists. During this process, we will be discussed about your user experience when interacting with the application to perform several tasks. We are particularly interested in identifying situations where the platform encourages you to make errors and misleads you about its intended purpose when completing the tasks supplied. The problems identified will allow changes to be made to the platform to improve the platform's usability. The stakeholder walkthrough will be recorded (we require your consent for this). The stakeholder walkthrough should last around 30 minutes.

Following the stakeholder walkthrough, you will be given a short questionnaire to answer. This questionnaire will allow you to comment on the overall usability of the platform, the problems you encountered while performing the tasks supplied, and to give your opinion on the application and its potential impact for cyclists. The questionnaire will also include the System Usability Scale (SUS), which consisting of several questions for several options for each. The questionnaire will not take longer than 5 minutes to complete.

Are there any risks associated with taking part?

There are no significant risks associated with participation. Your comments and answers will remain strictly confidential.

Are there any benefits associated with taking part?

There are no physical benefits after this study. However, we do hope that the implementation of Cyclopath will help you in your cycling route planning in the future and improve your overall experience in cycling.

What will happen to the results of this study?

The results of this study may be summarised in the Chang Shian Goh and Chengyu Kang's BSc dissertations. Moreover, they may be summarised in publish articles, reports, and presentations. The recordings will only be transcribed and used for analysis. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a maximum of 2 years. All potentially identifiable data will be deleted within this timeframe if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researchers Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) and their supervisor Philip Wadler (Philip.Wadler@ed.ac.uk).

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses to minimise risk.

While the participation in the stakeholder walkthrough is generally confidential, other focus group participants will be aware of who has participated in the stakeholder walkthrough.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including

rights of correction, erasure, and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments, and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the researchers, Chang Shian Goh (s1925709@ed.ac.uk) and Chengyu Kang (s1998909@ed.ac.uk) or the Principal Investigator, Philip Wadler (Philip.Wadler@ed.ac.uk).

If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title, and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be emailed to you by Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Chang Shian Goh (s1925709@ed.ac.uk) or Chengyu Kang (s1998908@ed.ac.uk).

General information.

For general information about how we use your data, go to: edin.ac/privacy-research.

Appendix M

Participants' Consent Form

The Participants' Consent Form for every data collection method in every data gathering stage is the same. Thus, I will only show one PCF.

Participant number:_____

Participant Consent Form

Project title:	Cyclopath
Principal investigator (PI):	Philip Wadler
Researcher:	Chang Shian Goh, Chengyu Kang
PI contact details:	Philip.Wadler@ed.ac.uk

By participating in the study you agree that:

- I have read and understood the Participant Information Sheet for the above study, that I have had the opportunity to ask questions, and that any questions I had were answered to my satisfaction.
- My participation is voluntary, and that I can withdraw at any time without giving a reason. Withdrawing will not affect any of my rights.
- I consent to my anonymised data being used in academic publications and presentations.
- I understand that my anonymised data will be stored for the duration outlined in the Participant Information Sheet.

Please tick yes or no for each of these statements.

1.	I agree to being audio recorded.	☐ **Yes**	☐ **No**
2.	I agree to being video recorded.	☐ **Yes**	☐ **No**
3.	I allow my data to be used in future ethically approved research.	☐ **Yes**	☐ **No**
4.	I agree to take part in this study.	☐ **Yes**	☐ **No**

Name of person giving consent	Date dd/mm/yy	Signature

Name of person taking consent	Date dd/mm/yy	Signature

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