WALK SCOTLAND: TECHNOLOGY ON THE TRAIL – DEVELOPING A COMPREHENSIVE MOBILE TRAVEL MANAGEMENT APPLICATION FOR SCOTLAND'S HIKING TRAILS

JORDAN SWOPE

This dissertation was submitted in part fulfilment of requirements for the degree of MSc Software Development.

DEPT. OF COMPUTER AND INFORMATION SCIENCES

UNIVERSITY OF STRATHCLYDE

August 2019

DECLARATION

This dissertation was submitted in part fulfilment of the requirements for the degree of MSc Software Development of the University of Strathclyde.

I declare that I have sought, and received, ethics approval via the Departmental Ethics Committee as appropriate to my research.

I give permission to the University of Strathclyde, Department of Computer and Information Sciences, to provide copies of the dissertation, at cost, to those who may in the future request a copy of the dissertation for private study or research.

I give permission to the University of Strathclyde, Department of Computer and Information Sciences, to place a copy of the dissertation in a publicly available archive.

Yes [X] No [ ]

I declare that the word count for this dissertation (excluding title page, declaration, abstract, acknowledgements, table of contents, list of illustrations, references and appendices is 21,091 words.

I confirm that I wish this to be assessed as a Type 1 2 [3] 4 5 Dissertation.

Signature: 

Date: 18|08|2019

ABSTRACT

In a digital world, technology is finding new ways to keep users connected – even while they are trying to disconnect. More and more hikers are turning to digital resources to plan their experience on the trail, from mobile navigation applications to digital trail guides. The aim of this work is to develop a comprehensive companion mobile application for hikers, while exploring how technology can provide solutions for relevant development challenges while providing functionality that supports and enhances the benefits of hiking.

A review of previous research and existing literature was conducted to identify the key motivations of hiking, as well as the challenges to developing an 'off-the-grid' system. A comparative market analysis was also conducted to review similar resources and tools on the market, as well as identify functionality that resonates with users and where systems are currently failing. Having identified initial requirements from this analysis, a mobile application was developed using Android Studio to provide users a comprehensive resource for planning, executing, and documenting a hiking trip on one of Scotland's Rob Roy Way. The system was designed with the ability to scale to include all of Scotland's long-distance trails in mind. Initial user research was conducted, and user feedback, usability testing, and heuristic evaluation as carried out on the final prototype.

Results of user research and testing identified additional requirements and solutions for usability issues. Functionality was mapped to hikers' primary motivators and the technology utilized for development evaluated in consideration of how well they provided solutions to development challenges such as battery drain and off-line service. Future development looks to current trends and evolving technologies for consideration, and encourages continued research on the key motivations of hikers and how technology can adapt to support them.

ACKNOWLEDGEMENTS

I thank Dr Kieran Egan of the University of Strathclyde for supervising this work.

TABLE OF CONTENTS

TABLE OF FIGURES

1 Introduction

Go take a hike. More than an old adage to many, these words offer those with restless feet a solution for enhancing their health and reconnecting with nature. Behavioural psychology indicates that among numerous benefits, hiking can enhance subjective well-being and overall quality of life. Though there has long been a disparity between technology and nature – after all, hikers often head to the woods to disconnect – today's digital society is seeing the convergence of territories to meet user demand. Walkers are lightening their backpacks by removing guidebooks and maps and turning to digital resources instead. And while there are plenty of existing technologies on the marketplace, there are few that offer a comprehensive bundle of resources that supports all a user's needs. This begs the question – how can a system be developed that meets the needs of hikers while enhancing the benefits of why they hike in the first place?

Walk Scotland is a comprehensive mobile application that aims to provide everything hiking enthusiasts may need to plan, manage, and execute a trip on one of Scotland's many walking trails, efficiently easing the process and making the trail more accessible for hikers both amateur and experienced alike. Developed through a process of co-design, it combines navigation tools, itinerary planners, educational resources, and more to create an all-in-one resource that fits in the palm of the hand for those going off-the-grid.

This project looked at prototyping and evaluating a trail technology that provides functionality that aims to support and enhance walkers' key motivations for hiking. Based on motivations identified by existing research, hikers' interests and incentives can be categorized into six primary objectives - a desire to reconnect with nature, health and wellness, sightseeing and curiosity, intrapersonal reflection, a sense of community, and a sense of accomplishment. System design and analysis will map the requirements of this 'all-in-one' comprehensive technology to the benefits they offer users, asking how functionality can be designed and implemented to engage hikers' key motivations and encourage recreational activity.

The application design will evaluate how existing technologies are able to provide solutions for the key challenges that face 'off-the-grid' systems such as supporting off-line service while on remote or rural trails, dealing with battery drain, and providing personalization and

accessibility. Once indicating feasibility, the prototype was evaluated on its usability (indicated by the system's learnability) and acceptability by users. User experience was evaluated through research, feedback, and testing to indicate the product's value, usability, adoptability, and desirability.

Finally, next steps for development are identified as a result of usability testing, heuristic evaluation, and user feedback analysis. Looking to the dynamic evolution of technology, up-and-coming tools are considered for the potential impact or role they may play in future iterations of development.

2 Literature Review

2.1 Go Take a Hike: The Psychology of Hiking

It was the Greek physician Hippocrates who once said that walking is a man's best medicine (Bergland, 2015). Hiking is, by definition, the act of walking in nature for both short and long distances – an economical form of recreational activity and natural exercise promoting fitness and ecological enjoyment among related benefits (Encyclopaedia Britannica, 2019).

What is it that drives people to their feet and out on the trail? When it comes to recreational travel, a person is influenced by both a desire to leave their environment behind as well as the desire to pursue or gain certain rewards – a contradictory process that finds people seeking an optimized experience fuelled by novelty and familiarity (Iso-Ahola, 1983). Emotional, ecological, and novelty value influence engagement in hiking tourism (Lee, et al., 2018). Diverse motivational themes include curiosity, escapism, spiritual pilgrimage, and more. Walkers may be searching for adventure, tracing their heritage, seeking to experience new cultures, or advance their health, among other motivations (Davies, 2018). As compared to other forms of tourism, the journey isn't a means to an end but rather the objective itself (Gómez-Martín, 2019).

Existing literature has sought to identify the key motivations of recreational tourism, in particular nature-based and more recently hiking-based. In their report for Natural England, Hynds and Allibone (2009) research what motivates people to participate in organized walking activities. They summarize their findings into three primary categories – social contact, improving health, and enjoying the natural environment. In a study conducted by

Lee et al. (2015), an exploratory factor analysis was carried out to identify four primary motivations of hiking tourists – enjoying the natural environment and escaping daily life, pursuing a new type of travel, pursuing a healthy lifestyle, and pursuing intimacy. The results indicated that these motivations influenced tourists' subjective well-being positively. While researching hikers in Norway, Svarstad (2010) categorized motivations into three categories – hiking to establish a sense of belonging and continuity, hiking as a way to live out a critique of society, and hiking as recreation of societal performance abilities.

For the purpose of this project's development, six key motivations have been identified from existing research. The first is an inherent desire to reconnect with nature. The 'biophilia hypothesis' contends that humans have an innate relationship with nature (Kellert & Wilson, 1993). "Because humans began living in cities, separated from the natural world, relatively late in our evolutionary history, it is unlikely we have erased all the learning about nature's value embedded in our biology," and this is why outdoor activities such as hiking remain popular (Nisben, et al., 2010).

Figure 2.1 – Key Motivations of Hiking

The second objective is the physical and mental health and wellness benefits associated with hiking, leading to an overall enhanced quality of life. Studies show that regular exercise

improves health and fitness, and with walking being one of the lowest impact sports, hiking has cardiovascular benefits that combat the likes of heart disease, hypertension, diabetes, obesity, anxiety, osteoporosis and arthritis, and more (American Hiking Society, 2013). Trails are used to promote healthy lifestyle, sense of community, and more, with hikers seeking motivational attributes (such as scenic views), consequences (such as physical activity), and values (such as self-esteem) (Hill, et al., 2014).

The third motivation is cultural curiosity and exploration. Tourism has long been intertwined with the notion of sightseeing, placing an emphasis on the visual nature of exploration (Adler, 1989). Fourth, hiking can contribute to intrapersonal reflection. Time spent on the trail produces "an emotional centre of gravity," which reveals much about ourselves (Balkien, et al., 2016). "Walkers tend to cultivate dispositions and techniques that promote inner-reflection in search of self-actualization and self-restoration," (Collins-Kreiner & Kliot, 2017). And finally, hiking can also provide trailblazers with a sense of community.

2.2 Tourism, Technology and the Trail

In a sense, hiking and technology have intertwined histories that date much farther back than smart mobile devices or Internet guide books. Urbanism and the subsequent dawn of industrialism in the nineteenth century saw a widespread evolution of transportation, which in turn saw walking become less a necessity and more an activity of leisure (Chamberlin, 2014).

Of course, there has long been a disparity between hiking and technology. Human survival has always affected our relationship with our environment, but technological advances have, in ways, served to separate people from nature. "Without technology, humans would be directly exposed to nature. Historically, they would have hunted, lived, travelled, and socialized in nature. Slowly across history, humans developed technology to protect ourselves from the elements of nature," (Schultz, 2002).

Still, recent advancements have seen technologies developed to support fitness, health, and wellness, tourism, and more. The digital society is seeing the convergence of two otherwise diverged territories. By the end of 2018, 5.1 billion people (67% of the world's population) globally subscribed to mobile services – a number expected to reach 6 billion by 2025 (GSMA, 2019). There are nearly 2.46 million applications on the Android mobile

marketplace, and 1.96 million available for Apple's iOS (Clement, 2019). Technology pervades our daily activities, even those that aim to 'disconnect' us. With *Walk Scotland*'s specification in mind, this poses the question – how can a system be developed to support recreational and ecological activity? And how can the system's design meet user demands and exceed the standard of similar products on the marketplace?

2.2.1 Comparative Market Analysis

For the purposes of this review, this analysis has categorized mobile applications on the marketplace based on their focus – hiking and trail guides, regional (Scotland) trail guides, maps and navigation, itinerary planning, and other relevant technologies.

2.2.1.1 Hiking and Trail Guide Applications

In her review *Go Take a Hike,* Schweikhard (2019) offers a comprehensive roundup of online hiking resources. She identifies *AllTrails* and *Hiking Project* as stand-out applications for trail maps and resources. With more than 75,000 international trails, "*AllTrails* is one of the largest online crowdsourced trail databases." Functionality of the application includes the ability to filter trails by difficulty, length, route type, elevation, traffic, and more. Users can record their routes and access the database by creating a free account. The application additionally supports offline access to maps and navigation. A free application, *AllTrails* has a 4.5-star rating with 29,687 reviews on the Google Play store, and a 5-star rating with 225.2k reviews on the Apple store (AllTrails, Inc., 2019).

Guthook Guides provides detailed maps, including Scotland's West Highland Way, with offline capability that include elevation profiles, route creators, and waypoint data (AtlasGuides, 2019). *Hiking Project* offers a similar portfolio of international trails, offering topological trail maps synced with an itinerary (Recreational Equipment, Inc., 2019).

2.2.1.2 Regional Trail Applications: Scotland

There are minimal resources on today's marketplace when it comes to applications and guides specific to Scotland's hiking trails. *Scotland Great Trails* is available solely on the iOS marketplace for £1.99 and has a 2.3-star average rating the three reviews. The application's functionality features trail routes divided into stages, as well as maps where users can mark *Foursquare* accommodation, restaurants, shops and more. User reviews note a rigid structure of route itineraries (Appwizard, 2018). The National Trust for Scotland (2018)

offers the free *Trust Trails* application on the Android and Apple markets, which allows users to search and explore trails, but solely those on National Trust properties.

Trail-specific applications seem to be limited to the well-known West Highland Way. *The West Highland Way* features a 3.7-star average rating with six reviews on the Apple store, and a 4-star average rating with nine reviews on the Google Play store. Features on this free application include information on the route and potential itineraries, accommodations filtered by type, local restaurant recommendations, links to purchase recommended equipment, a digital visitor book, FAQs, a sign-up page to connect and chat with others, a way for businesses to list themselves on the application, links to packages and guided tours, links to useful information such as baggage transfer providers, transportation, laundry services, and more, weather information, and emergency numbers. Reviews commend the comprehensive nature of the application, with some users noting the information as invaluable while others note a poor infrastructure that is difficult to navigate (BFN Productions Ltd., 2019).

TrekRight: West Highland Way is available on both Android and iOS marketplaces for £8.99, with a 4.8-star rating with five reviews on the App Store and a 3-star rating with three reviews on Google Play. *TrekRight* "includes detailed offline maps, handy reference information, comprehensive walking directions, and powerful location-aware functionality that enables you to simply enjoy your walk" (The Trekopedia Team, 2019). The application offers real-time location-aware information such as distance, nearby points of interest such as food and accommodation, elevation charts, directions, and the ability to flag and add notes to favourites or things the user finds interesting. An encyclopaedia offers comprehensive reference information. Additional features include a digital compass, route and itinerary planning, and maps that are supported offline. *West Highland Way Offline Map* boasts offline functionality, elevation charts, and more to the Android market (Shutt, 2018). *West Highland Way* is another application available solely on the Android marketplace, with an average 3.5 star rating out of 13 reviews. Though not updated since 2013, the application offers overlaid routes on Google Maps, locations of essential facilities such as accommodation, food, and historic sites of interest and the ability to save favourite places, customizable itineraries, and a digital diary. Users noted functionality issues such as maps failing to load or display distance correctly (Hill, 2013).

The *Scotland Explore* application, available on the iOS App Store, provides Visit Scotland's regional area guides for users to download for free (APS Group, 2019). With *ScotlandVR*, Visit Scotland looks to the future of technical tourism by creating a way for users to "explore Scotland's attractions through spectacular 3D models and real 360 tours," (Visit Scotland, 2017).

2.2.1.3 Maps and Navigation Applications

Map and navigation applications are prominent hiking resources. Widely used are both *Google Maps* and *Apple Maps*, which come natively with Android and iPhone devices but are also available on their respective marketplaces. *Google Maps* has been installed more than 5 billion times, and offers features such as StreetView and recently AR, real-time updates, offline navigation capabilities, and more in more than 220 countries and territories (Google LLC, 2019). Apple Maps offer similar navigation capabilities, including proactive suggestions and transportation information (Apple, 2019).

Outside of the native Google and Apple navigation offerings, hikers recommend *OS Maps* by Ordnance Survey (Ordnance Survey Ltd., 2019). Available on both marketplaces, this comprehensive application offers detailed maps of Great Britain online, allowing users to plot and follow routes and supporting offline capability and AR features. Ordnance Survey (2018) offers *Locate*, a cross-platform application that "converts GPS location readings from your mobile phone to Ordnance Survey National Grid references, enabling you to determine precisely where you are on an Ordnance Survey map," even without signal. *Map My Hike* is an application by UnderArmour that allows users to track their routes and get performance statistics (MapMyFitness Inc., 2019).

2.2.1.4 Itinerary Planning Applications

With over 55K on the Google Play Store and 12K reviews on the App Store, *TripIt* is one of the most downloaded itinerary planning applications on the marketplace. Users can simply forward any relevant booking emails to their account and their information will be collected into a comprehensive itinerary, though this raises concerns regarding security and data collection (TripIt, Inc., 2019). *Google Trips* offers similar functionality with trip details imported from Gmail, as well as recommended attractions and things to do, all while supporting offline access (Google LLC, 2019).

2.2.1.5 Other Relevant Applications

One of the best known names in the tourism industry is *TripAdvisor*, an application that allows tourists to source reviews and recommendations for accommodations, activities, and more (TripAdvisor, 2019). *Trover* curates a digital social atmosphere where travellers can share their experiences through photography (Trover Inc, 2019). *Foursquare* city guides allow users to track where they have been while sourcing recommendations for accommodation, food and drink, and more (Foursquare, 2019). And of course, weather applications such as the *Met Office Weather Forecast* can provide valuable and location-specific information pertinent to outdoor recreational activities like hiking (Met Office, 2019).

2.3 Walk Scotland: Why Develop for the Scottish Market

Tourism has been growing exponentially over the past decade, with recreation and nature-based tourism on a steady incline. According to the World Tourism Organization, "tourism has experienced continued growth and deepening diversification to become one of the fastest growing economic sectors in the world (UNWTO, 2019). In 2017, international tourist arrivals grew by 7% to 1.3 million, with international tourism generating $1.6 trillion USD in export earnings. By 2030, UNWTO forecasts international arrivals reaching 1.8 billion.

Scottish tourism, like the rest of the world, has been on the rise in recent years. According to Visit Scotland's 2018 Tourism Performance Summary Report (2018), there were 11.8 million trips by Great Britain residents and 2.5 million international inbound trips to Scotland, totalling 153.14 million trips – a 3.13% change from 2017 to 2018 and a 7.57% increase from 2016 to 2018. The overall spend totalled £104441.80 million, with holidays being the most popular reasons for trips for both domestic and international markets. Accommodation occupancy rated at 71% for hotels, 50% for guest houses and B&Bs, 55% for self-catering units, 55% for hostels, and 34% for touring caravan and camping sites.

With tourism being one of the fastest growing economic sectors in the world, the industry holds considerable influence on both Scotland's economy and job market. According to a report by the Scottish Government on behalf of the Tourism Leadership Group (2018), the tourism industry accounts for nearly one in twelve jobs in Scotland, employing nearly 207,000 people. It contributes around £6 billion of GDP to the Scottish economy, or 5% of the total. Tourism employment has grown 12% since 2011. There are 14,000 tourism

businesses in Scotland, again representing nearly one in every twelve. A report by Scottish Natural Heritage on the economic impacts of nature-based tourism in Scotland notes that nature-based tourism accounts for £1.4 billion income and 39,000 associated FTE jobs (Bryden, et al., 2010).

Scotland's People and Nature Survey 2017/18 (SPANS) reports that approximately 82% of Scotland's adult population has visited the outdoors for recreation, with 57% visiting weekly and 23% visiting on a daily basis (Wilson & Seddon, 2018). These figures estimate 546.5 million visits to the outdoors by Scotland's adults, the highest annual figure recorded with an increase from 395.8 million recorded in 2013/14. Health and exercise were among the most frequently cited reasons for visiting the outdoors, and walking remains the most popular outdoor activity with 84% of visits (or 457.4 million) including walking.

Scotland's terrain features 26 long-distance hiking trails that stretch 1,700 miles. In 2015, nearly 2.1 million long walks or hikes (defined as a minimum of 2 miles or 1 hour) were taken over 9.4 million nights with an average of 5 nights per trip. These trips equated to £776 million expenditure with an average of £83 spend per night and £375 spend per trip. A consumer profile of long-distance hikers in Scotland in 2015 revealed that 46% were male and 54% female. The largest percentage of hikers were aged 55-64 (23%), followed by those aged 45-54 (21%), 35-44 (18%), 25-34 (17%), 65 and over (12%), and 16-24 (9%). In 2016, Visit Scotland's website received 124,941 page views on their walking page and 68,120 page views on their walking routes and trails page, making walking the second most popular activity page on the site (Visit Scotland, 2017).

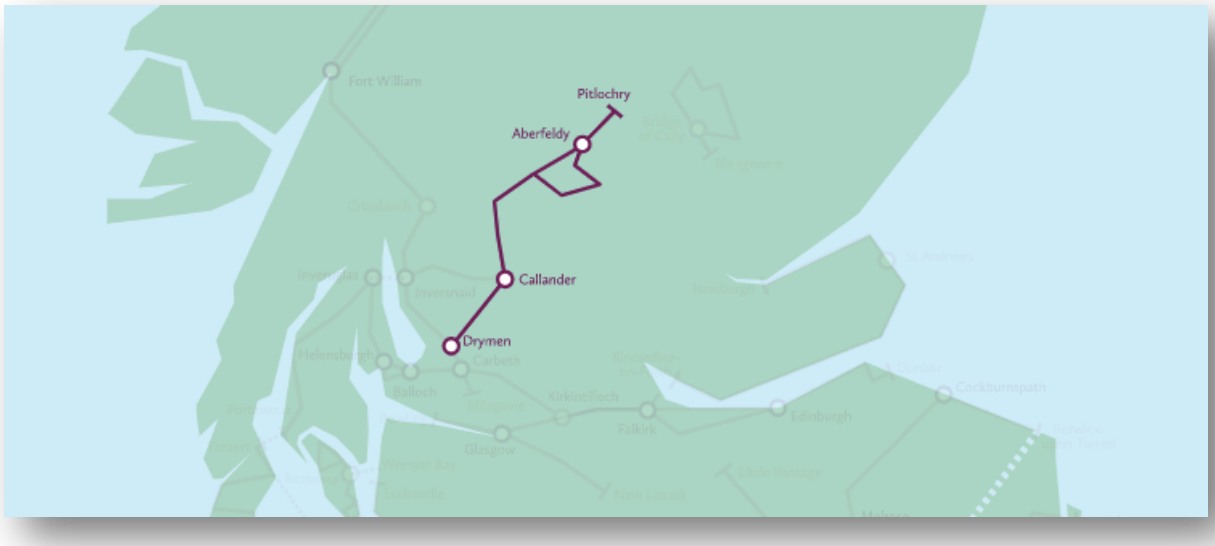


Figure 2.2 – Map of the Rob Roy Way (Scotland's Great Trails, 2019)

Walk Scotland is built with the capability to scale to include all of Scotland's Great Trails, something not seen on the marketplace today that targets all tourists both international and domestic. With that in mind, this project aims to develop and evaluate a functional prototype application based on one single trail. For this focus, the Rob Roy Way was chosen as it met a core set of criteria that marked it as both marketable and relatively unrepresented on the app store today. Officially one of Scotland's Great Trails, the Rob Roy Way follows the paths of notorious Scottish Outlaw Rob Roy MacGregor (Scotland's Great Trails, 2019). The trail weaves its way 77 miles (124 km) "through glens, along rivers and burns and past mountains and lochs" from Drymen to Pitlochry – or 94 miles (151 km) for those opting for a detour on an alternative route (RobRoyWay.com, 2010).

While there are not many applications targeting only Scotland's hiking trails on the marketplace, there are two mobile applications that focus on the West Highland Way already. With that in mind, the Rob Roy Way was selected based on the following criteria – it offered more than one route for hikers to follow, the route offered various styles of accommodation, it offered a degree of isolation (as compared to trails that more frequently stop through heavily populated towns), and it offered an intriguing history.

2.4 The Challenges of Taking Technology Off-The-Grid

When it comes to developing technology for recreational activity that takes place in often remote areas without strong network coverage or access to resources, there are several key

challenges to be considered. These can be identified as supporting off-line functionality when off-the-grid, coping with battery drain when away from resources for long periods of time, and providing personalization and accessibility for users.

2.4.1 Supporting Off-Line Service

While on remote hiking trails, it is logical to expect that users will be out of range of their mobile network. Additionally, international travellers may not have data turned on on their mobile device as they don't wish to incur roaming charges. Applications such as trail maps or mobile travel guides "should have an offline mode in which the user can still perform the most common tasks of the application without the need of a wireless connection," (Fling, 2009). Offline systems are best suited to native development as opposed to web-based applications.

2.4.2 Dealing with Battery Drain

One of the key challenges that developers of mobile applications – particularly those related to recreational activities such as hiking – face is power consumption. "Many aspects of an application affect its use of the device's power and thus the battery life of the device. Dedicated devices can be optimized for maximum battery life, but mobile applications may inadvertently make extensive use of battery-draining resources," (Wasserman, 2010). These resources can include the likes of device sensors, geolocation tracking tools, and more.

2.4.3 Providing Personalization and Accessibility

Technological advances, including that of smart mobile devices, have considerably improved life for those with disabilities – yet some applications are inaccessible to those with impairments as they do not provide personalization. Designing a system with accessibility in mind in turn aims to make hiking more accessible. A study by Park et al. (2014) proposed heuristic guidelines for designing accessible applications. These include – providing substitutive text on user interface (UI) components, the ability to focus on object, a logical focus flow, operating system accessibility support, press action support, substitutive action, and consistent UI.

3 Methodology

Walk Scotland was conceived, designed, and developed prototypically, focusing on pilot trail the Rob Roy Way. The system was designed to support the ability to scale to include all of

Scotland's long-distance trails. The application's conception stemmed from a comparison of existing hiking, navigation, and touristic applications, which provided the system's initial requirements. User research then assessed these functionalities and prototypes were constructed and ultimately tested. The final prototype was analysed by how well it supported the key motivations of hiking, how the technologies used addressed the key challenges to developing an 'off-the-grid' system, and how learnable and memorable the overall usability of the system's interface was.

Keeping in mind the five key components of the software lifecycle, this section will look at the design and development process, considering the project management methodologies and tools utilized, the requirements identified, the design and subsequent construction of the system, and the testing and analysis of the final prototype.

3.1 Agile Development

Project management aims at planning, executing, and managing the development of a system. With the ultimate goal of producing quality software, it's important that developers are armed with the best project management tools and methodologies to carefully configure the product. As technology and development practices have evolved, the industry has seen a variety of project management methodologies and tools utilized for team collaboration and efficient production. In 2001, seventeen developers met to deliberate over what would become the Agile manifesto – a set of principles that would spark a decade of project management innovation. The manifest affirmed four primary focal points for better development –

1. Individuals and interactions over processes and tools.
2. Working software over comprehensive documentation.
3. Customer collaboration over contract negotiation.
4. Responding to change over following a plan.

They went on to articulate twelve principles for Agile development. These stress prioritizing the customer through the continuous delivery of working software, which in turn means that evolving requirements are welcomed. Development should see motivated developers working alongside clients and stakeholders constantly as a self-organizing team, making the most of effective face-to-face conversation. The team should frequently reflect on its

effectiveness and consider opportunities for its growth. The pace of development should be sustainable, while emphasizing simplicity and attention to good design (Beck, et al., 2001).

Due to its adaptive nature, Agile project development is an iterative methodology. It is an efficient process with rapid turn-around, prioritizing the ability to create and execute to change. Iterative design follows a spiral model (as shown in Figure 3.1) with three distinct phases – assessment, design, and build. Assessment evaluates what users are currently doing and what their needs are so that the product design can offer solutions to those problems. Design involves creating ideas for the product delivery. Finally, the build takes those design concepts and builds them into prototypes. The idea is to fail quickly, efficiently, and as often as possible in order to minimize and learn from the mistakes made.

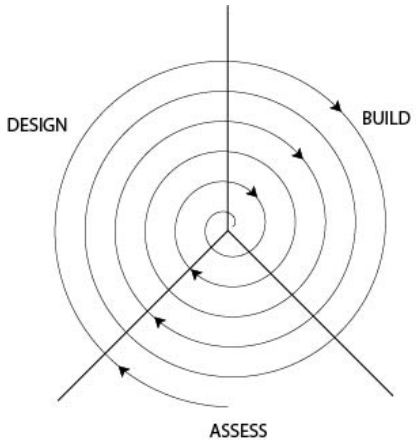


Figure 3.1 – Iterative Design Spiral Model

In the years since the manifesto was first published, there have been several types of Agile methodologies that have evolved upon the cornerstone principles, such as Kanban or eXtreme Programming. One of the most widely adopted Agile methodologies is Scrum, which was chosen for the development of *Walk Scotland.*

3.1.1 Working Iteratively with Scrum

Scrum is a software development framework that, in tune with Agile, prioritizes both adaptability and collaboration. “It is the opposite of a big collection of interwoven mandatory components. Scrum is not a *methodology.* Scrum implements the scientific *method* of empiricism. Scrum replaces a programmed algorithmic approach with a heuristic one, with respect for people and self-organization to deal with unpredictability and solving complex problems,” (Scrum.org, 2019).

Most traditional methods such as the Waterfall model – which sees a system developed through a more systematic flow of requirements, design, implementation, verification, and maintenance – were too inflexible for a system that seeks to implement several features and strives for adaptability and scalability. *Walk Scotland* was conceptualized with changing functionality in mind, knowing that both requirements and consequently the backend and user interface design would evolve in response to the results of user research and testing.

3.1.1.1 Scrum Events and Sprints

The Scrum framework articulates a series of events that aid the development process and administrate regularity. These include sprints, sprint plannings, daily scrums, and sprint reviews. Software is developed in iterative 'sprints', each aiming to produce a working prototype that fulfils the current prioritized functionality. What make this approach so effective? First, it allows the developer to monitor their progress. Second, it acknowledges that a software's needs are changing – requirements can evolve and new features can be added. The planning at the beginning of each sprint sees what functionality should be implemented during it. Daily scrum 'stand-ups' are hosted by the developers to review progress made, and reviews are also held following each sprint to demo the prototype, analyse requirements, and outline next steps.

This project's development took place over the course of five primary sprints, each lasting two to three weeks in length. As aforementioned, each sprint produces a prototype that is designed, constructed, and ultimately reviewed and tested. These continue until all 'must have' requirements are complete and the product is ready to be deployed. The first sprint involved identifying the initial requirements, developing user stories, implementing the product backlog, and developing a low-fidelity prototype by sketching concepts for the user interface design. The second sprint saw a medium-fidelity prototype developed in the form of wireframes developed using Adobe XD. This sprint also involved user surveys that analysed the initial requirements. The third sprint re-evaluated the initial requirements on the basis of the survey results, and saw the first high-fidelity prototype developed using the final technology (Android Studio). This front-end prototype implemented the infrastructure of the system. The fourth sprint built upon the previous prototype, implementing the functionality of the prioritized requirements. The fifth and final sprint revisited the prototype and continued to implement additional functionality. During this sprint, user

interviews and testing were also carried out. Sprint plannings and reviews included weekly demos and progress reports held with the project supervisor. User surveys, interviews, heuristic evaluations, and testing were additionally implemented as part of the planning and review process. Two of the five sprints involved collaboration with those outside of development – the second and fifth – through user research, testing, and industry expert evaluation.

3.1.1.2 Scrum Artefacts

As part of the framework, a series of scrum artefacts were produced throughout the development process. These "represent work or value to provide transparency and opportunities for inspection and adaption," (Scrum.org, 2019). Artefacts include product and sprint backlogs, increments, and more.

The product backlog is an ordered list of functional requirements needed in the final product. The product owner manages the backlog, adapting it as requirements evolve. The sprint backlog, therefore, is a list of the requirements noted in the product backlog chosen to be implemented during a specific development sprint, as stipulated per the sprint planning. This prioritized list of user stories is managed by the development team. For this project, the product backlog was managed utilizing YouTrack, as shown in Figure 3.2. YouTrack is an agile project management software that does issue tracking and is useful for managing progress via sprints. It allows for the configuration of agile boards for managing and developing projects. The initial use cases serve as the project backlog, which can be managed on YouTrack by updating their status or priority, moving them to sprints, etc. Epics can be defined, which are complex user stories that can be broken down into more comprehensive stories and tasks. YouTrack also offers predefined reports to track the progress of the project, as well as time management reports and tools like burndown and Gantt charts.

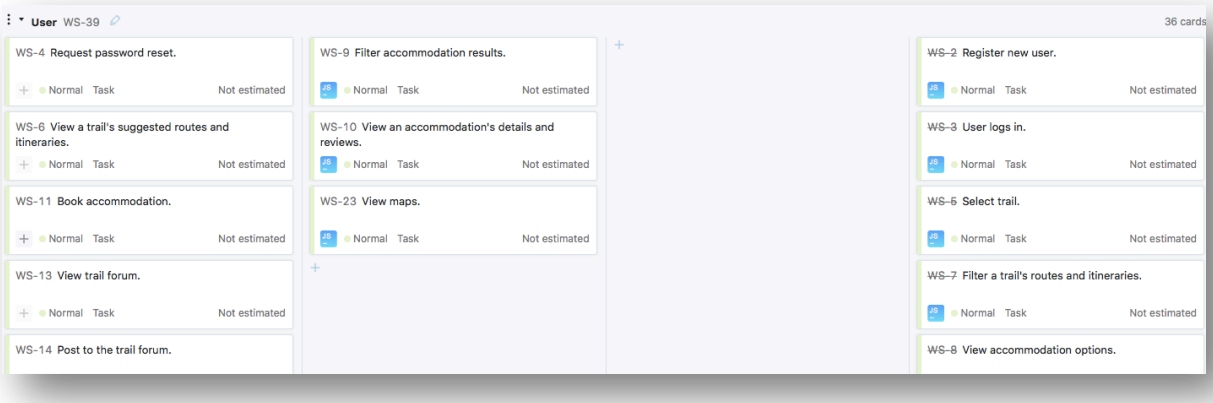
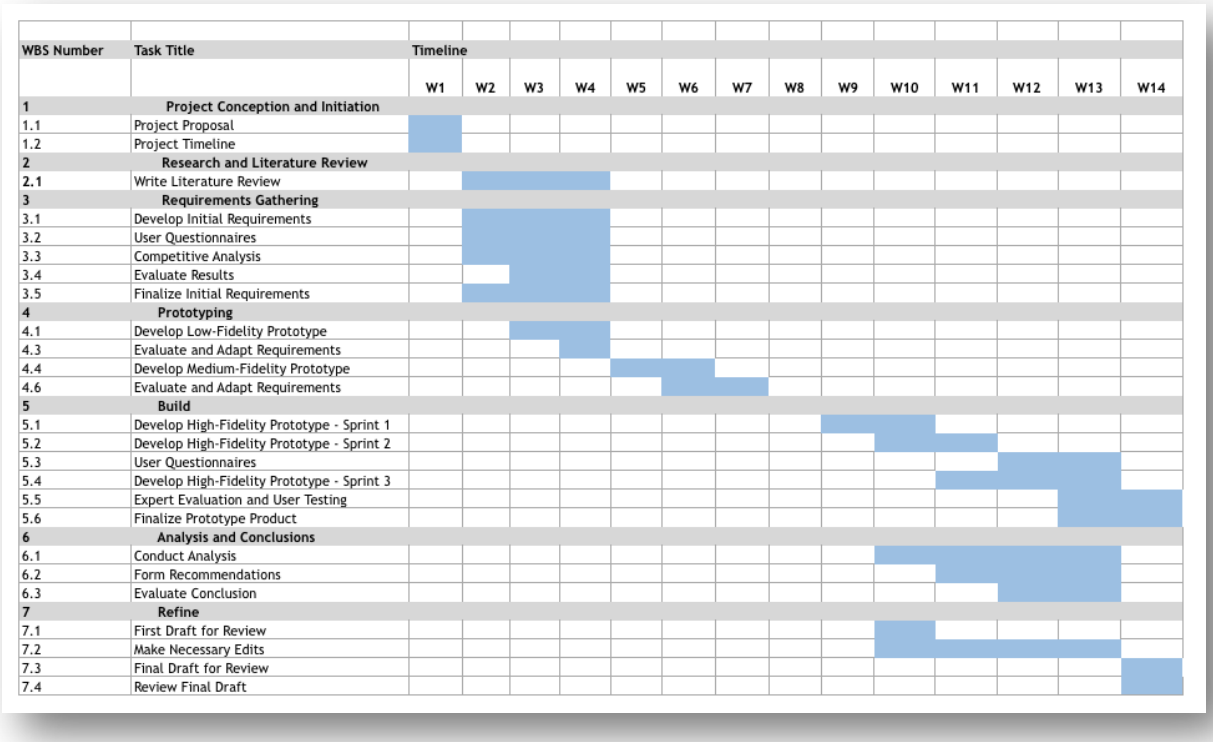


Figure 3.2 – Excerpt of product backlog of user stories on YouTrack.

A Gannt chart, as seen below in Figure 3.3, was developed at the beginning of the project to illustrate the planned sprints. Each sprint lasted two to three weeks at most, allowing time to develop a series of prototypes and test them for adaptations or additoins to be made in the next sprint.



WBS Number	Task Title	Timeline													
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	**Project Conception and Initiation**														
1.1	Project Proposal														
1.2	Project Timeline														
2	**Research and Literature Review**														
2.1	Write Literature Review														
3	**Requirements Gathering**														
3.1	Develop Initial Requirements														
3.2	User Questionnaires														
3.3	Competitive Analysis														
3.4	Evaluate Results														
3.5	Finalize Initial Requirements														
4	**Prototyping**														
4.1	Develop Low-Fidelity Prototype														
4.3	Evaluate and Adapt Requirements														
4.4	Develop Medium-Fidelity Prototype														
4.6	Evaluate and Adapt Requirements														
5	**Build**														
5.1	Develop High-Fidelity Prototype - Sprint 1														
5.2	Develop High-Fidelity Prototype - Sprint 2														
5.3	User Questionnaires														
5.4	Develop High-Fidelity Prototype - Sprint 3														
5.5	Expert Evaluation and User Testing														
5.6	Finalize Prototype Product														
6	**Analysis and Conclusions**														
6.1	Conduct Analysis														
6.2	Form Recommendations														
6.3	Evaluate Conclusion														
7	**Refine**														
7.1	First Draft for Review														
7.2	Make Necessary Edits														
7.3	Final Draft for Review														
7.4	Review Final Draft														

Figure 3.3– Excerpt of product backlog of user stories on YouTrack.

3.2 Requirements Gathering

At their core, requirements are a description of what the stakeholder needs from the software being developed, aiming to remove any ambiguity in regard to what is being built. They must be documented clearly, and this documentation serves as a contract between stakeholders and developers. Following Agile methodology, there are in nature constantly evolving. Requirements gathering is a continuous conversation – negotiation, even – between the clients and developers, and eventually the users.

Diverging from traditional Agile projects where initial requirements may be assigned by a client, the developer served as the primary stakeholder for *Walk Scotland.* In this case, initial requirements were developed based on the findings yielded by comparative market, finalized through the analysis of user survey findings, and eventually adapted following user research and testing on the final prototype. These functionalities serve as a foundation to build from, as iterative development endorses the adaption of requirements through user research and testing. These initial requirements are, in an Agile nature, apt to evolved throughout the length of the development process.

3.2.1 SWOT Analysis

To begin developing a thorough list of initial requirements, SWOT analysis was applied. SWOT is a business technique that provides a framework for conceptualizing a product or idea. It prompts reflection on four key criteria – strengths, weaknesses, opportunities, and threats.

When considering strengths, one should ask what the advantages of the concept are. What's the unique selling point of this mobile application? What does it do better than anyone else on the market? What resources could be utilized? What is the end goal?

When it comes to *Walk Scotland,* it was evident from inception that the unique selling point was the lack of anything quite like it on the market – Scotland's market, in particular. While mobile applications offering a range of tools from itinerary planners to trail navigation features exist, there are few that aim to combine every feature a hiker could desire on a trip into one comprehensive package. And while those few that do offer similar functionality target other markets such as the Camino de Santiago, there was no application designed with Scotland's Great Trails in mind. The end goal was efficiently articulated – a mobile

application that offered every resource a walker could need while planning, executing, and documenting a hike on a Scottish trail in one place, eliminating the need for various resources, both digital and physical alike.

When considering weaknesses, it is important to reflect on improvements that could be made or what features or ideas should be discarded. What would users see as a weakness? And what characteristics of the product would negatively affect its sales?

A primary concern when developing a product that aims to offer an 'all-in-one' resource experience is scale. How much is *too* much when it comes to features? Keeping in mind the thin barrier between functional efficiency and overload, when does the application become too confusing for a user navigate through? When does the size of the application work against developmental challenges like battery drain instead of providing a solution for it?

Recognizing opportunity is also important. What trends and technologies can be used in design and development? How can this product capitalize on its competitors' weaknesses? How can the idea scale, and what opportunities could that bring?

The recent months have seen progression in navigation technologies, looking to a future where 5G networks power an extensive Internet of Things. How can this application fit into this connected infrastructure, working alongside other technology such as fitness wearables? Maps have evolved into augmented reality. By building an application that looks to this future and could scale to adapt to these technological advancements, *Walk Scotland* could gain a leg up on competitors. Identifying potential key stakeholders is beneficial as well, such as local hiking organizations or tourism companies such as hotels or packaged tours.

Finally, it is also important to recognize threats to the concept. What are the difficulties in this development, and how do competitors overcome their difficulties? How do quality standards affect this idea? Will the product be able to adapt as technology evolves?

Developing an application for those interested in hiking is inherently incongruous – nature and technology are not concepts that go hand-in-hand. Recognizing the difficulties that accompany merging the two is impertinent before the application's functionalities can be conceptualized. Lack of network signal while off-the-grid, for example, is a primary threat.

How can the application offer efficient navigation services while off-line? Or how can it effectively manage battery drain when hikers don't have reliable access to power sources?

3.2.2 Initial Requirements

From this analysis, a set of initial functional and non-functional requirements were developed. Initial functional requirements included –

1. The system allows users to create, plan, view, and manage the details of a hiking trip.
2. Users should have to be registered in the system and logged-in to access personal trip data.
3. For each trail, users can…
    - View and filter suggested routes and itineraries.
    - Search accommodation options and link to booking options.
    - View and filter trail maps.
    - Utilize a digital compass tool.
    - View official trail news updates.
    - View, search, and post to a trail forum.
    - View and filter useful links regarding transportation and services.
    - View up-to-date weather information.
4. Users can create a new trip, as well as view past trip itineraries and data.
5. For each trip, users can…
    - View and edit the trip itinerary.
    - Log and edit journal entries, and share via social platforms.
    - View and edit a packing checklist.
    - View their hiking statistics each day and track their journey via GPS.
6. The system has two user roles (user and administrator).
7. Administrators can post and manage official trail news updates.
8. Additional features if time allows include…
    - Augmented reality added to the map functionality.
    - Hiking tips and knowledge made accessible to users.
    - Trail history and location trivia made accessible to users.

Initial non-functional requirements include –

1. The user should be able to use the application without internet connection (applicable to users physically out on the trail).
2. The application should encourage the minimization of battery usage while running.
3. The application should be built natively.

3.2.3 User Stories

To analyse the initial requirements, user stories were developed. This process helps to envision the architecture of the application and what the user interface will look like. Developing these aids in the visualization of how the requirements come together in the system, and provokes reflection on ways to narrow the scope of potentially vague requirements or elaborate simple concepts into the most efficient and effective system. The use case diagram in Figure 3.4 illustrates how the functionality relates to the actors. These user stories will become the Scrum product backlog, tracked utilizing the project management tool YouTrack as show below in Figure 3.5

Figure 3.4– Use Case Diagram

Based on the initial requirements, the following user stories can be derived. As a system user, I want to…

…register myself as a new user on the system.

…log in to access the system and to see my current and previous trip data.

…request password resent via email verification.

…select the trail I wish to see information for and details of.

…view the possible routes and itineraries for a trail.

…filter those routes and itineraries by length of trip and distance.

…view and search the possible accommodation options along the trail.

…filter accommodation results by town and type.

…view a specific accommodation's details and reviews.

…book an accommodation through the system for a trip, and import that data to the trip itinerary.

…view maps and navigation options such as maps and a compass.

…view and utilize pre-downloaded trail maps.

…filter maps to show different criteria (such as nearby shops and restaurants, nearby bathroom locations, nearby water sources, elevation data, etc.). Maps should also be filtered by day and stage.

…view and utilize a digital compass.

…view the official trail news and updates board.

…view trail forum.

…create a post and log it to the trail forum.

…search the trail forum by keywords.

…filter the trail forum by criteria such as location and date.

…view up-to-date weather data based on GPS location or town.

…view all of my trips, past and current.

…create a new trip.

…view the itinerary details, hiking data, and journal entries of past trips.

…view the details of my current trip.

…view the details of my trip itinerary, including accommodation bookings, trail itinerary and distances, and notes.

…edit the details of my trip itinerary and add notes to it.

…view my digital trip journal.

…create and log new journal entries.

…update images to a journal entry.

…share my journal entries across various social platforms.

…edit previously published journal entries.

…create a view digital packing l sit.

…add items to packing list.

…check off items on packing list.

…view details of my hike by day via GPS and statistics.

As a system administrator, I want to…

…log in to the system as an administrator.

…post official trail updates to the news board.

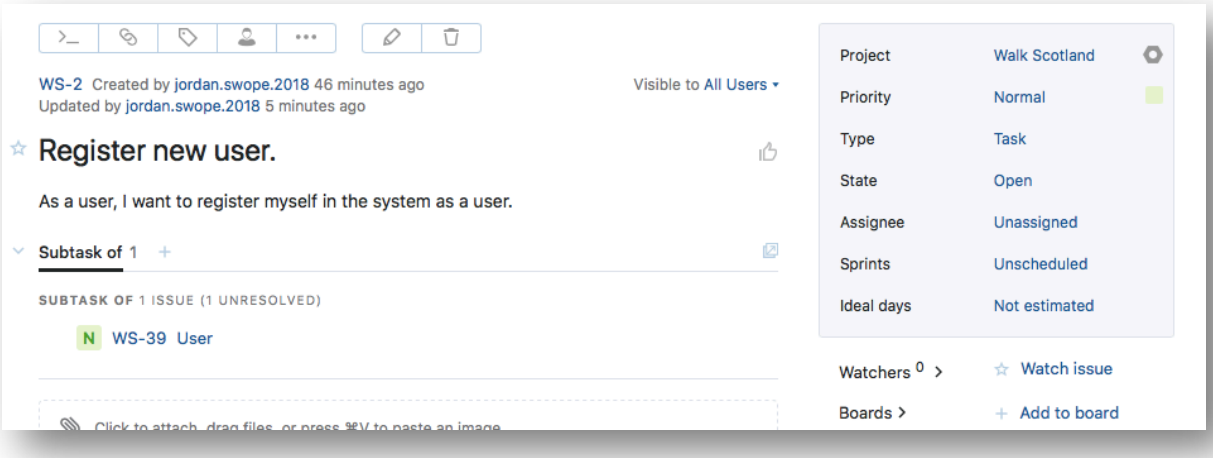


Figure 3.5 – Example of user story on YouTrack product backlog.

3.2.4 MoSCoW Prioritization

While these use cases were developed, the MoSCoW method was used to prioritize the requirements into must haves, should haves, could haves if time permits or what the system ultimately would not have. Prioritizing functionality encourages a discourse on the hierarchy of the project. For example, which user stories apply to which actor? This method is applied with each iteration as the product is developed. By indicating which requirements are must haves, the developer can measure progress and is able to tell when a sprint is complete as all the necessary requirements have been applied and the functionality is in place. Tools such as Git can be utilized for version control, and on YouTrack a backlog manages when sprints are complete, allowing for acceptance tests to say that the product is finished and

ready for deployment. Prioritized initial requirements for *Walk Scotland* can be viewed in Figure 3.6 below.

Functionality	MoSCoW Priority
M - Must Have, S - Should Have, C - Could Have, W - Won't Have	
Register	M
Log-In	M
Log-Out	M
View trail menu.	M
View trail options menu.	M
View and suggested routes and itineraries for a trail.	M
Search accommodation options and link to booking options.	M
View trail maps.	M
View current trip menu.	M
Filter routes and itineraries by length of trip (days and distance).	S
Filter trail maps to show different resources along the trail.	S

View bulletin board of official trail news updates.	S
View digital compass.	S
View location-based weather information with search functionality.	S
View, search, and post to trail forum.	S
View past trip itineraries.	S
Create a new trip.	S
View and edit current trip itinerary.	S
View trip journal and create, edit, and share journal entries.	C
Create and edit a trip packing list.	C
Track journey using GPS technology to view personal details of hike.	W
Emergency alert button.	W
Augmented reality maps and trail information.	W

Figure 3.6 – Initial Requirements Prioritized with MoSCoW

3.3 Design

This section looks at the system's design, or the plan and specification for its construction. It features both high-level and low-level components, from the architecture of the user interface to the code written to turn requirements into functionalities. Design is not only how it works functionally, but also what it looks and feels like. It is a continuous process of articulating and solving problems. A tool for building complex systems, abstraction looks at development through levels that begin with an idea and requirements that then have architecture (high-level design) and design (low-level design) and finally code. Abstraction is implemented through encapsulation, which involves grouping code and data into functions and classes.

3.3.1 System Architecture

High-level design shows an abstract overview of the application, breaking down the system where low-level design puts it back together. High-level design looks at the big picture. In object-oriented programming, this means identifying objects and classes.

3.3.1.1 MVC Architectural Pattern

Similar to methodologies that exist for project management, common architectural patterns can be utilized for high-level design. MVC - or Model, View, Controller - is an intuitive pattern that most graphical user interfaces (GUIs), particularly web and mobile applications, are built on. In this pattern, the model, the view, and the controller are interconnected. The central model is the application's data structure - this is where class functionality is built and lives. The view represents the system's interface - what the user ultimately interacts with. The controller is what speaks between the model and the view to bring the application to fruition. *Walk Scotland* followed this pattern, identifying key objects such as user, accommodation, news updates, and more in respective model classes. The user interface, or view, was designed through XML layout files that were in turn connected to the model through the controller code, which instantiated activities, interacted with the database, set data, and implemented functionality.

3.3.1.2 CRC Cards

Next, CRC (class - responsibility - collaborator) cards -useful strategy in the architectural design process of object-oriented projects - were developed. As illustrated in a *Walk Scotland* example in Figure 3.7, each card represented a class, with its name written at top. Then the card was divided into two sections - responsibilities and collaborators. The responsibilities represent the class's high-level functionality, while the collaborators indicate which other classes this class interacts with when executing these functionalities.

These CRC cards were developed from the Scrum product backlog that houses user stories. By identifying key nouns that may represent objects that are essential to the design infrastructure, classes were identified. The cards allowed for reflection on the system design and whether it possessed desirable qualities such as cohesion. They help to illuminate strengths and weaknesses in the system, promoting efficient and minimalist design that is not only functional but reduces redundancy.

Class: Accommodation	
Responsibilities: Knows accommodation name. Knows accommodation type. Knows accommodation location. Knows description of accommodation. Knows URL for accommodation website.	**Collaborators:** User

Figure 3.7 – CRC Card

The initial classes identified for *Walk Scotland* were – User, Administrator, Accommodation, NewsUpdate, UsefulLink, JournalEntry, and ForumPost.

3.3.1.3 Class Diagrams

At the low-level, a plan to develop the system and begin writing code is crafted. This is where the pieces begin to be put together. Class diagrams - as seen in Appendix A - were developed for the classes specified in the high-level design process. These diagrams illustrate the design of the back-end of the system, noting the attributes and the methods (or functionality) of each class. These diagrams, much like the requirements themselves, are apt to change as the project progresses, but they give a good understanding of the initial design of the backend.

3.3.2 User Interface Design

The aspect that is most closely associated with what we traditionally think of as design is the user interface (UI) design. The UI is the way in which the user interacts with the system. In the MVC architecture, it is the view.

When it came to design, several key methods were utilized. Personas and user stories were utilized to envision who is using the system and what functionality they need to be able to perform. Sketching and ideation began to generate potential solutions, while storyboarding and mapping begins to walk through the navigation of a system. Comparative research looks to best practices and the pros and cons of similar systems on the market. And finally, as

we've looked at before, prototyping creates a solidified design plan that can be used for testing or gathering feedback.

First, users' need to be able to discover what a system can do as well as how best to operate it. In his book *The Design of Everyday Things,* Don Norman lays out seven principles for good design. These include visibility, affordance, consistency, mapping, constraints, and feedback (Norman, 2013). A system's learnability is supported by the use of these to provide an effective conceptual model. *Walk Scotland*'s design aimed to implement each of these. Feedback was provided through appropriate error messages, while visual cues aimed to indicate what will happen as a result of an action. Once a system is learnable, it is then important to evaluate whether it is memorable. In order to support the system's memorability, the design aimed to leverage industry standards, maintain consistency throughout the user interface, and encourage recognition rather than recall. The user interface design also implemented Gestalt principles (visual perception principles) of design, such as proximity and common region, symmetry, continuation, common fate, and more.

The user experience design process consists of five stages that align with the spiral model of iterative design - understanding the problem (assess), generating potential solutions (design), analysing and selecting a solution (design), embodying solutions (build), and assessing the product and finding new problems (assess). These stages iterate through a workflow that involves studying users, sketching and storyboarding, applying UX criteria, building a prototype, and then applying UX research methods.

3.3.2.1 User Research

User-centric research and design methods are applied to better understand how people work and how the system can help them accomplish their goals.

The first stage of the design process is identifying and understanding the problem. We must understand the problem by looking at the users - what are the tasks, and what is the context? Being able to understand how, when, and why people are using the system is crucial to good design. For this, *Walk Scotland* studied users and best practices by implementing surveys and inspection methods. These approaches look to determine user needs and understand current practices, characteristics, and behaviours.

An initial user survey – as seen in Appendix B - was carried out on a group of ten participants who identify as hiking enthusiasts. This followed the development of the initial requirements and system sketching and initial wireframing, but came before the first high-fidelity prototype was developed during the third sprint. The questions aimed to identify their demographics, their subjective hiking experience, their key motivations for hiking, their use of and thoughts on technology while hiking or planning a trip, and their thoughts on the product concept and initial requirements. The survey was developed utilizing Qualtrics and distributed to a group participants recruited through local networks (such as mountaineering and hillwalking groups), from connections made with hikers on Scotland's trails, and through travel social media and blogging networks. Ethics approval was received from the university departmental ethics committee and user data was retained anonymously.

3.3.2.2 Low-Fidelity Prototype

Prototyping is a key component in the design process. It aids in reification, reflection, communication, assessment, and more. Prototyping takes an idea and makes it concrete - something that can be tested on and reflected upon, giving designers something to show stakeholders and users for feedback. These prototypes can take several forms and generally build throughout the design process in terms of their fidelity. A simple low-fidelity prototype, usually in the form of sketches, addresses basic functionality and organization. A medium-fidelity prototype, generally in the form of storyboards or wireframes, adds layout and navigation design to the equation. And a high-fidelity prototype, usually a front-end design, addresses the low and mid-level concerns as well as adding in graphics, interaction details, and realistic data. It is not the final product, however, as it ignores the backend programming.

Once the initial list of systematic requirements was identified, potential solutions were generated through ideation and visualization. First, a series of sketches of the system were designed to visualize potential navigation and functionality solutions. This served as the system's low-fidelity prototype conceptualized by the completion of the first sprint.

3.3.2.3 Mid-Fidelity Prototype

Next, the graphical user interface (GUI) was mapped out and elaborated upon by developing a series of wireframes developed using Adobe XD software, as shown below in Figure 3.8. This medium-fidelity prototype was the product of the project's second sprint.

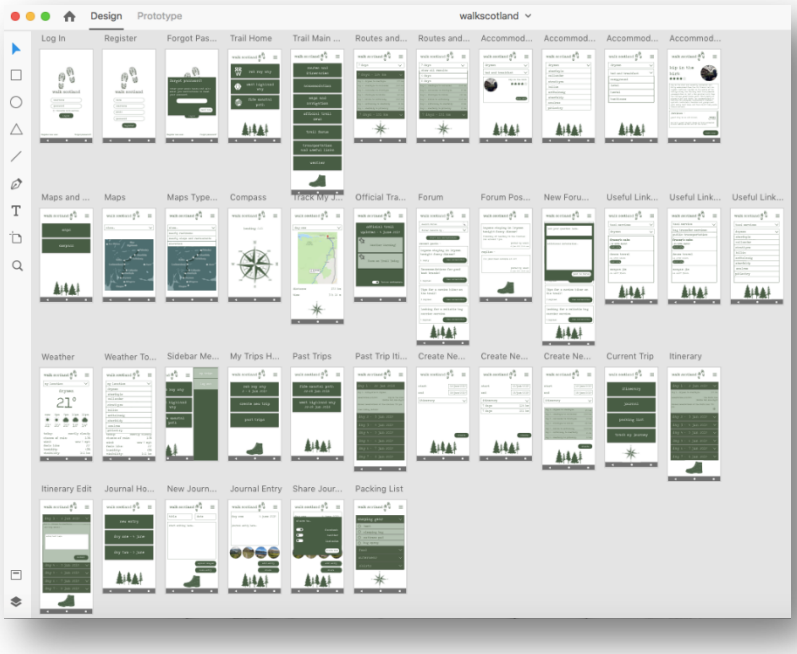


Figure 3.8 – Mid-Fidelity Prototype Wireframes

The design of the user interface aimed to provide a clean and minimalist aesthetic. A simple colour palette was designed, consisting of a thematic forest green (HEX code #4A674A), a pastel accent green (HEX code #B1C3B1), and white (HEX code #FFFFFF). A vintage typewriter font was utilized throughout the system, and logos and graphics were developed to give each activity a cohesive feel while establishing a marketable brand identity. The navigation mapped the system through two conceptualized menus - the trail menu, which offered users a variety of functionality specific to a particular trail, and the trip menu, which served as an itinerary planner and place to manage a user's trip details.

A landing page prompts users to log-in to the system by providing a username or password. A button in the bottom left corners displays the text 'register new user' and launches a registration activity when clicked. This activity prompts users to enter their name, username, email, and password before clicking 'register' and returning to the log-in activity. A button in the bottom right corner launches a pop-up for users who have forgotten their

password, prompting them to enter their email to receive reset instructions.

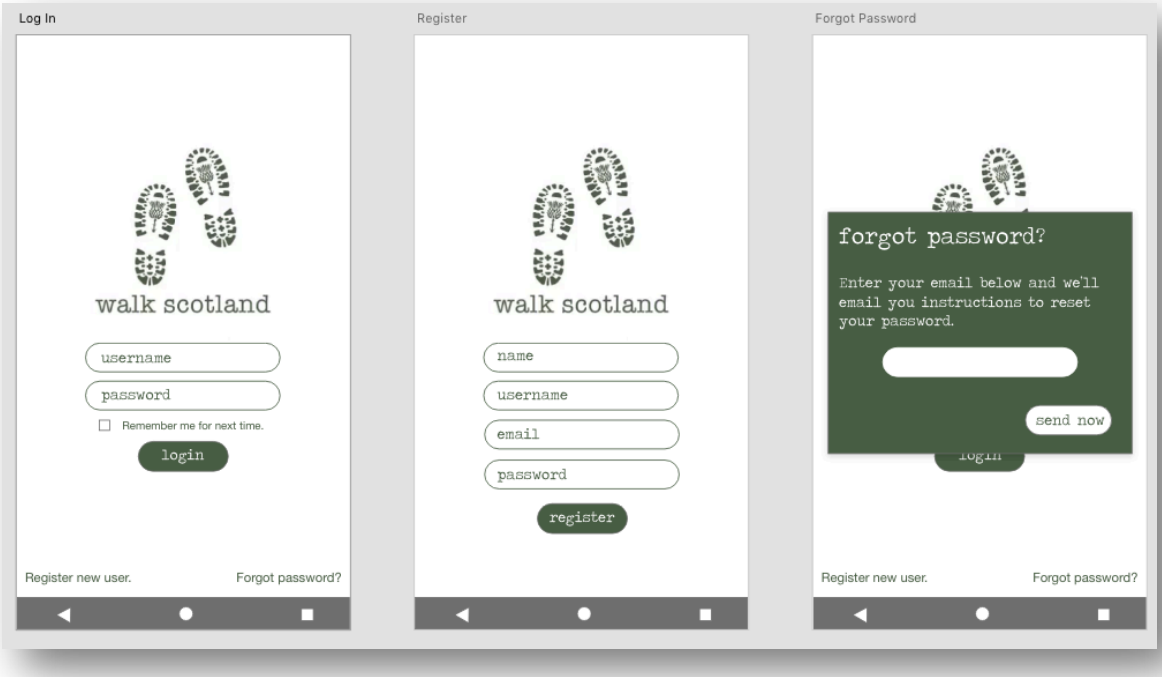


Figure 3.9 – Log-In, Registration, and Forgot Password (Wireframes)

Once the user logged into the system, they were brought to a landing menu that featured different trails - implemented for the purpose of showing how the system could scale to include not only the Rob Roy Way but all of Scotland's great trails. Upon selecting the Rob Roy Way button, a new activity is launched that brought users to a menu of trail-centric options. In the initial wireframes, these buttons included: routes and itineraries, accommodations, maps and navigation, official trail news, trail forum, transportation and useful links, and weather.

Figure 3.10 – Trail and Trail Options Menus (Wireframes)

Selecting the ‘routes and itineraries' button launches a screen that illustrates suggested routes (noted by length in days and distance) in a dropdown menu that expands to show the breakdown of each route by day. A dropdown spinner filters the routes by days.

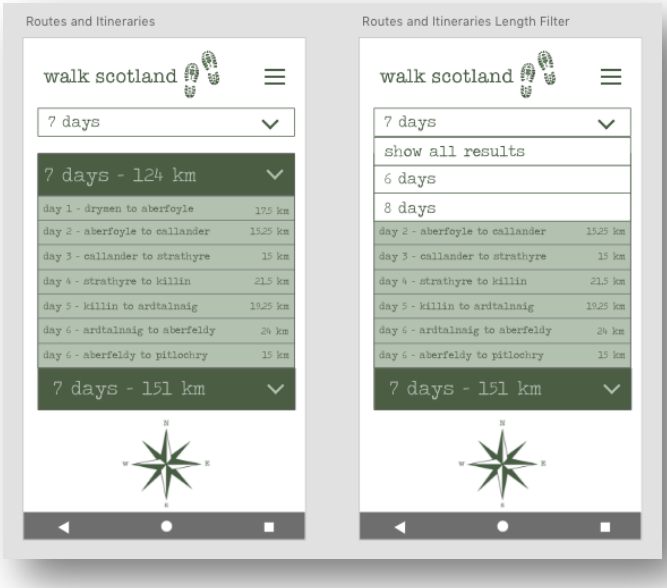


Figure 3.11 – Routes and Itineraries (Wireframes)

The ‘accommodation’ button brings users to a menu that illustrated details of suggested accommodations along the route, each with a button to view more information. The menu is filterable through the two dropdown spinner menus, representing towns and types (i.e., hotel, bed and breakfast, hostel, and more). Selecting the ‘more info’ button on a particular accommodation, a new activity is launched, portraying expanded details about the accommodation, user reviews, and a ‘book now’ button that links to the affiliate’s website.

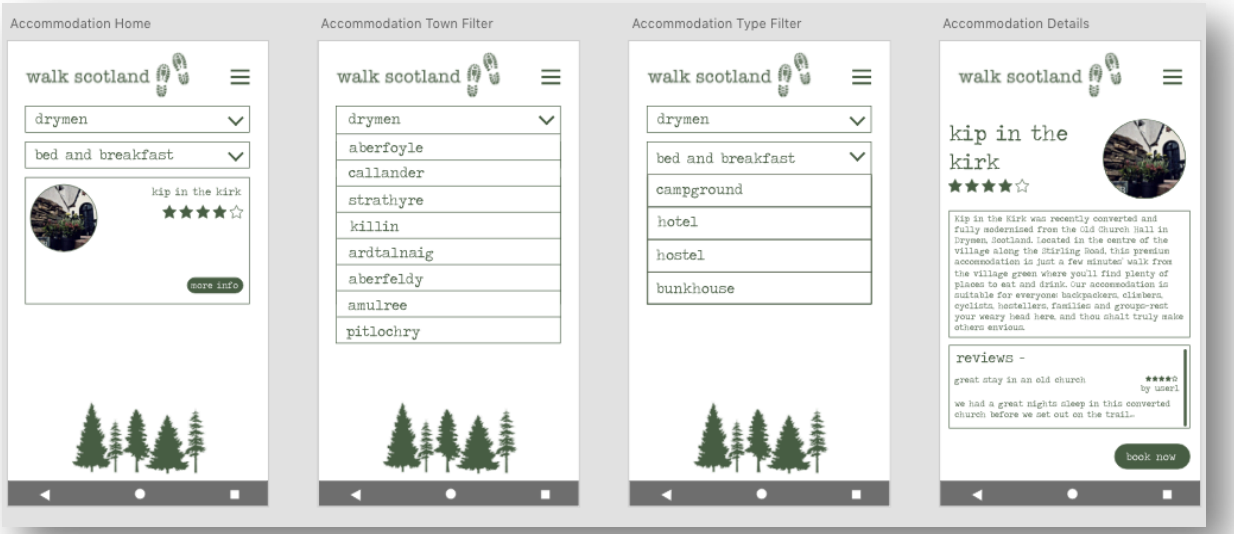


Figure 3.12 – Accommodation (Wireframes)

The ‘maps and navigation’ button launches a second menu in a similar style, with two buttons - one labelled ‘maps’ and the other ‘compass’. 'Maps’ launches a new activity displaying an interactive map of the trail, displaying the user’s location by linking to the device’s GPS. The user can filter the map to display different pinpoints (i.e., trail restrooms, nearby shops and restaurants, and more). The ‘compass’ button launches a digital compass, displaying the user’s heading.

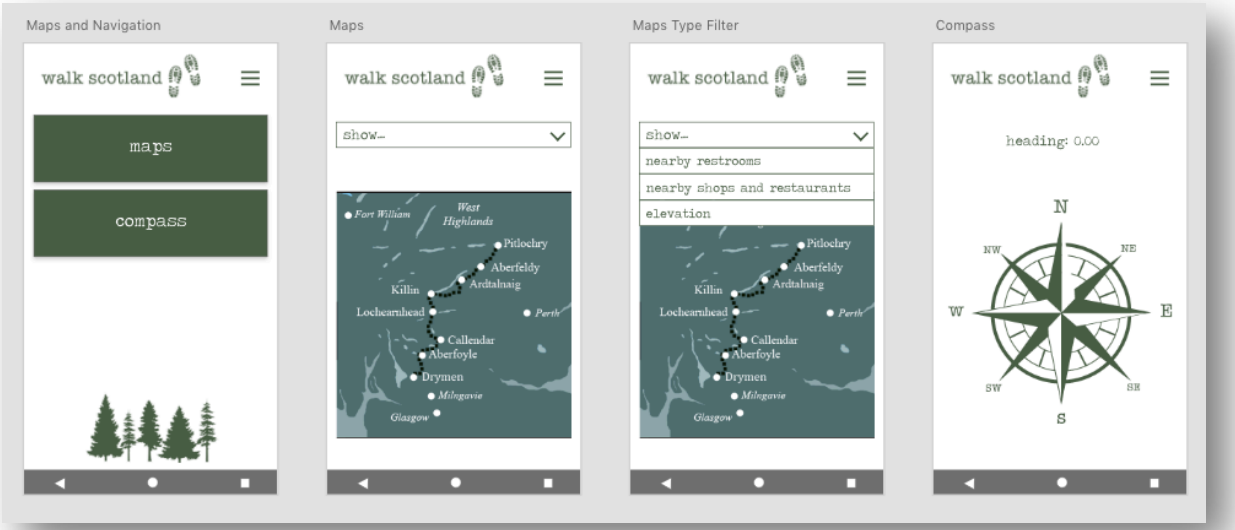


Figure 3.13 – Maps and Navigation Menu and Options (Wireframes)

The 'official trail news' button launches an activity that displays a bulletin board of updates and warnings prevalent to the trail, such as closings or events. A toggle button allows users to allow push notifications for new trail updates.

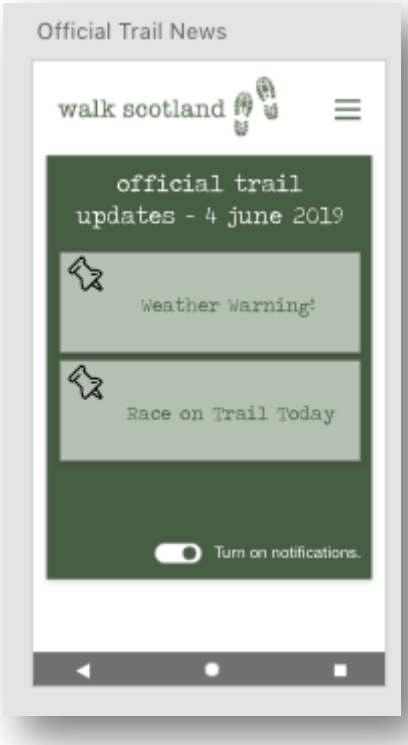


Figure 3.14 – Official Trail News Updates (Wireframes)

The ‘trail forum’ button brings users to an activity displaying a feed of recent trail-centric forum posts, ordered by date and time of posting. Users are able to view a particular post by selecting a ‘view conversation’ button, which expands the post in a new activity. Details of the post are displayed at the top, followed by comments. Users can search the main forum feed by keyword of filter their results by town. The start new conversation’ button allows users to create a new forum posting, prompting them to ask a question and then provide more information.

Figure 3.15 – Trail Forum (Wireframes)

The ‘transportation and useful links’ button launches an activity similar to the accommodation search page, instead providing information to useful businesses and services along the trail. Two dropdown spinner menus filter results by town or by service (such as taxi, bag transfer, or public transportation). Results are then displayed in a list providing phone numbers and a ‘visit site’ button that opens the business’s web page.

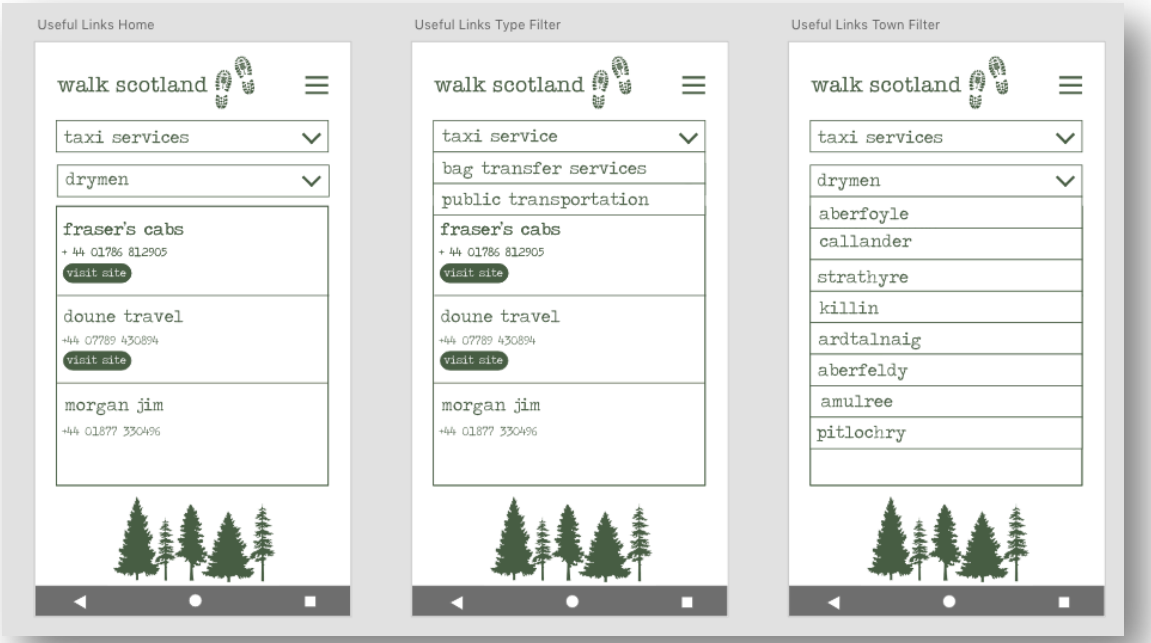


Figure 3.16 – Useful Links and Information (Wireframes)

Finally, the 'weather' button opens an activity that shows an up-to-date weather forecast based on the user's GPS location. Users are able to filter the information displayed by town.

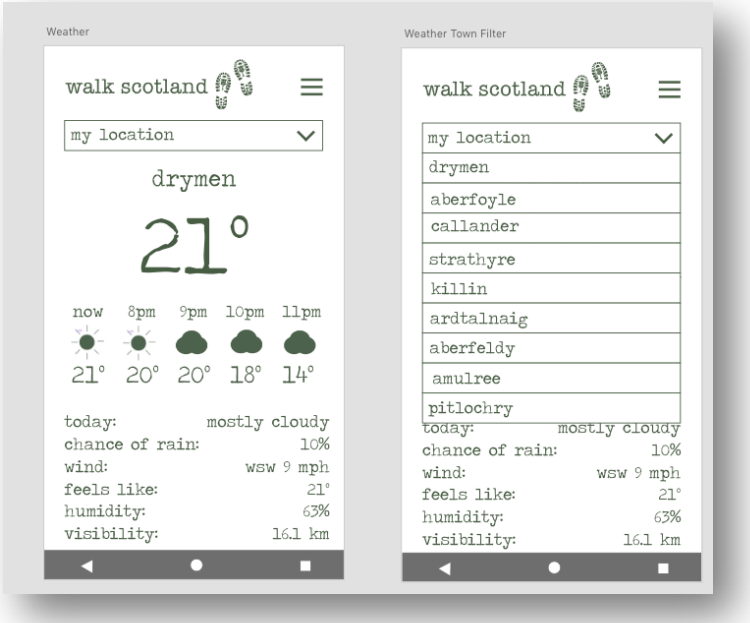


Figure 3.17 – Weather Forecast (Wireframes)

On the top of each screen is a logo that, when clicked, redirects users to the landing menu of trails. A hamburger menu on the top right corner of the screen expands when clicked to reveal a sidebar of options - the first being ‘my trips’ and the second ‘log out’.

Selecting ‘my trips’ launches a new menu, similar in design to the trail option menu. The first button(s) displayed represent current trips, and display the trail and dates of travel. The next button is labelled ‘create new trip’ and the final button displays ‘past trips’.

Figure 3.18 – Sidebar and My Trips Menus (Wireframes)

Selecting the ‘past trips’ button brings users to expandable itinerary list. Users can click on each day to see additional details such as destination, booking references, user notes, and hiking details.

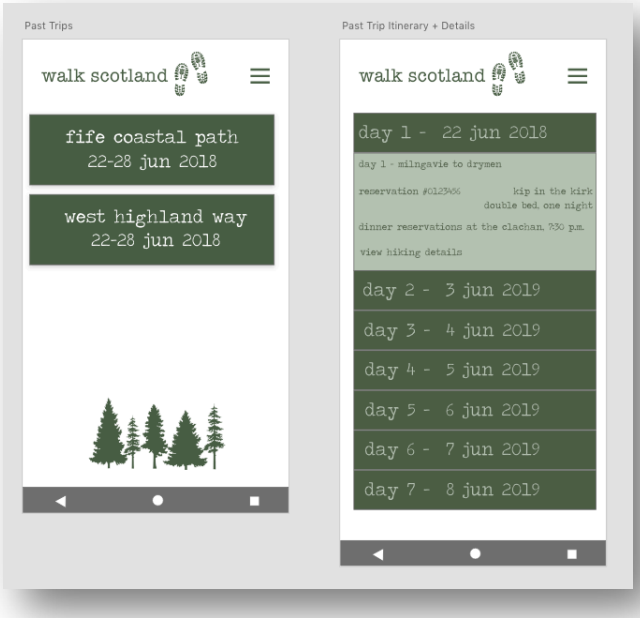


Figure 3.19 – Past Trip Menu and Itinerary (Wireframes)

Selecting the ‘create new trip’ button on the ‘my trips’ menu launches a new screen. Users are prompted to enter the start and end dates of their trip. A spinner menu expands to show a dropdown list of potential trail itineraries (data that mirrors that of the routes and itineraries page). Selecting a route option from the menu populates the view with details of the itinerary by day. The ‘create’ button, when clicked, creates a new trip and adds it as a current trip on the ‘my trips’ menu.

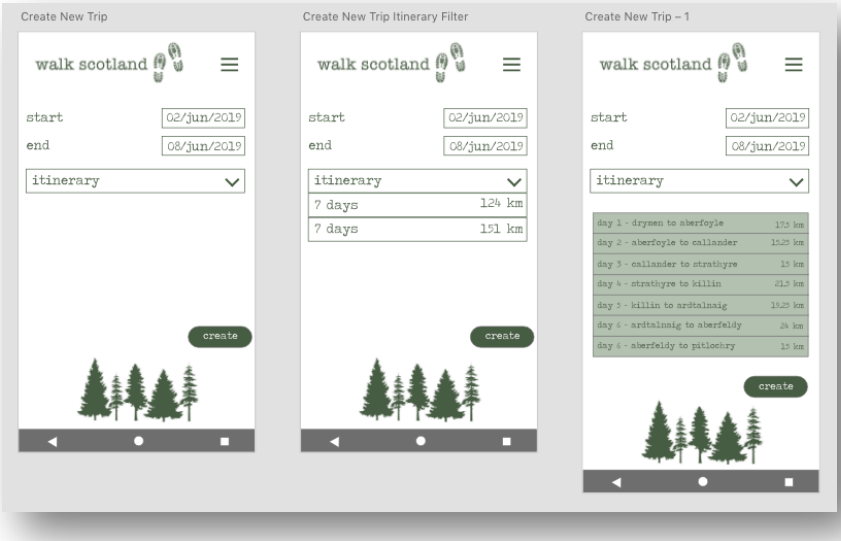


Figure 3.20 – Create New Trip (Wireframes)

Selecting a current trip from the ‘my trips’ menu launches another menu of consistent design. It lists four button options – ‘itinerary’, ‘journal’, ‘packing list’, and ‘track my journey’.

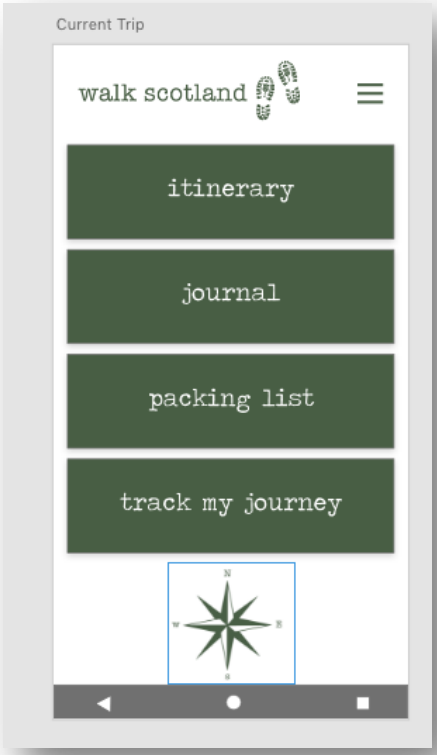


Figure 3.21 – Current Trip Menu (Wireframes)

The ‘itinerary’ option loads a screen similar to that showed on the ‘past trips’ itinerary. Users can select a + button that allows them to add trip details by entering text and selecting a ‘submit’ button when prompted by a pop-up window.

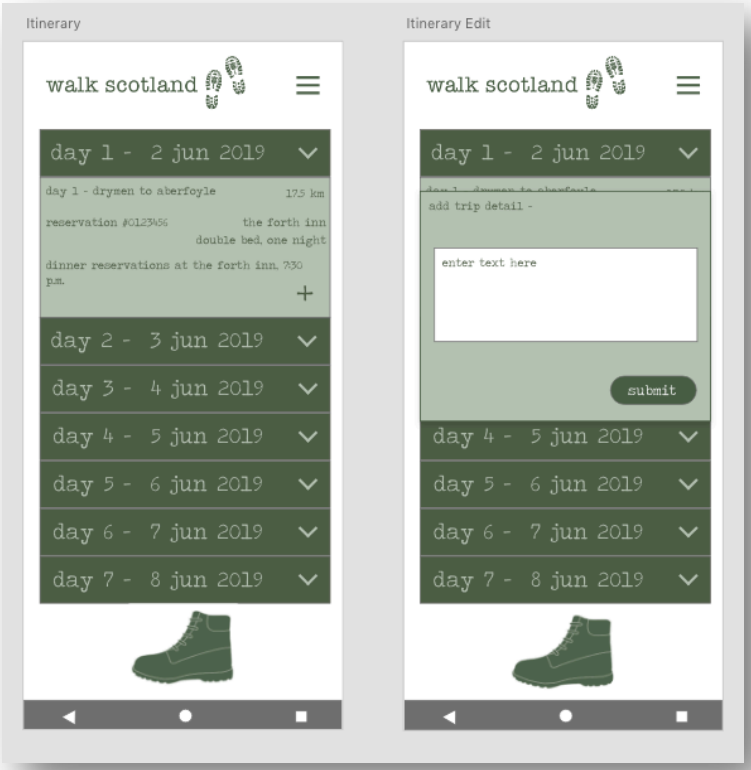


Figure 3.22 – Current Trip Itinerary (Wireframes)

The ‘journal’ button launches a new menu where a button at the top is labelled ‘new entry’ and those beneath represent published journal entries. Selecting ‘new entry’ launches a screen where users are prompted to enter title, date, and body text. A button labelled ‘upload images’ allows users to add a gallery of images from their phone gallery to the post. The ‘save entry’ button creates the journal post and adds it to the journal menu. By selecting a journal post button, users can see the details of their post, as well as the images. A button labelled ‘edit entry’ brings users to a populated view similar to the ‘create entry’ screen. A button labelled ‘share’ prompts users to share their entry via select social media platforms.

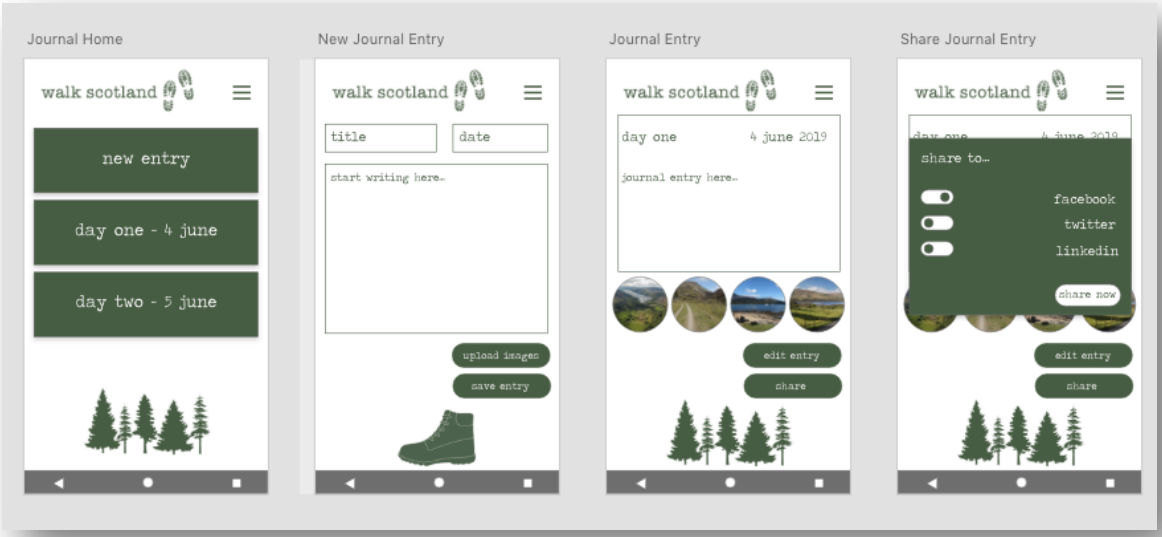


Figure 3.23 – Journal (Wireframes)

The ‘packing list’ button in the ‘current trip’ menu launches an expandable list. Users can select a category (such as camping gear or clothing) to see a list of children options, or in this case, items to pack. A click box on each items allows users to mark which items have been packed.

Finally, the ‘track my journey’ button in the ‘current trip’ menu launches an activity with a map view that illustrates the user’s journey. A spinner at the top of the page allows users to filter their data by day. Below the map view, users can see statistics such as their distance hiked and time.

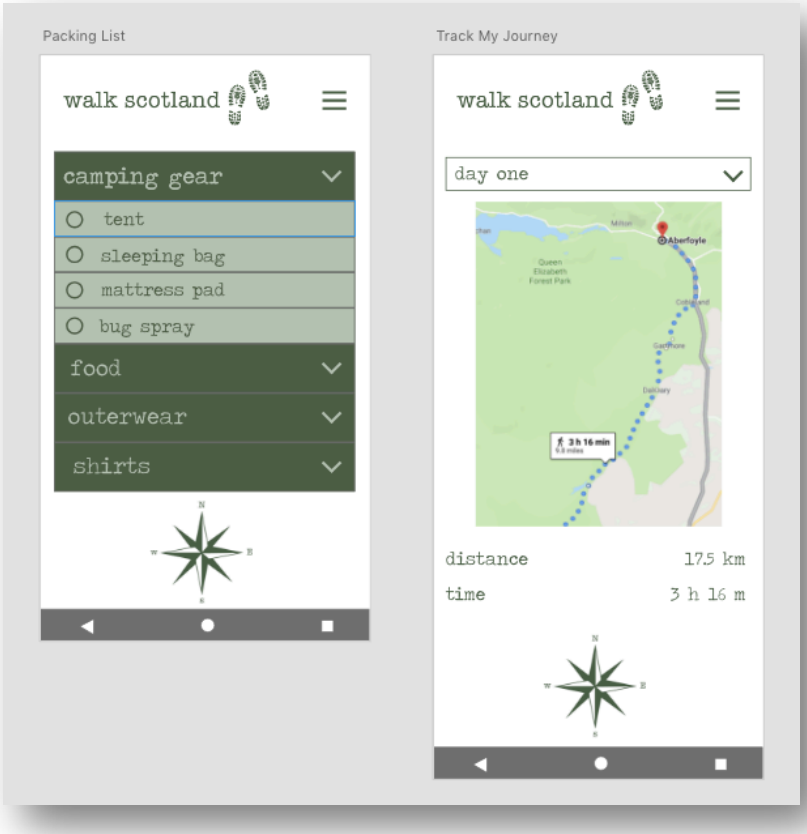


Figure 3.24 – Packing List and Track My Journey (Wireframes)

3.3.2.4 High-Fidelity Prototype

With the approach selected, the project continued onto its third sprint, which focused on embodying the proposed solutions in the form of a high-fidelity prototype. This was the first prototype built using the final technology (and language) - Android Studio (Java). The final two sprints also produced high-fidelity prototypes, each expanding on the previous iterations by implementing design changes that supported the system's learnability and memorability, as well as features that had initially been given lower prioritization. The following section on the system's construction will go into further detail about the technologies and UI components utilized to implement the system's requirements.

3.3.2.5 Product Assessment

As the final stage in a process of generation and convergence, the product was assessed through a series of interviews and user testing to evaluate how users interact with it to see what works and what doesn't. It was originally planned to conduct a second survey following the third sprint/first high-fidelity prototype in addition to the conclusive user

interviews. This strategy was adapted, however, as it was deemed that results between the first and second survey and the second survey and user interviews may be redundant in the scope of the project timeline. In consideration of retaining the participant pool throughout the conclusion of the project, the second survey was combined into the final user interviews.

These user interviews were carried out on a participant pool of five hikers concurrently with usability testing upon the final prototype. The interview script can be viewed in its entirety in Appendix C. Participants were recruited as a follow-up to the initial user survey. Ethics approval was received from the university's departmental ethics committee and user data was retained anonymously. Participants were advised that they were answering a series of questions pertaining to their demographics, hiking experience and motivations, use of technology on the trail, and their thoughts and reactions to the prototype's implemented design.

Usability testing, detailed further in the system testing section, was additionally carried out on this participant pool in order to measure both the learnability and memorability of the system's navigation and design.

3.3.3 Database Design

A minimalistic database was designed and implemented utilizing SQLite to support the user registration capability. SQLite is a relational database system that is embedded into the program, as compared to client-server engines. *Walk Scotland*'s implemented database consists of a table 'User' with four columns - _ID (an integer value as well as the primary key), name (a text value), email (a text value), and password (a text value). Values are added to the table when a new user registers in the system, and retrieved when a user logs in. Conceptually the database can be scaled to include additional tables representing objects in the system's design, such as a journal entry, to promote data persistence throughout the system.

Table: User			
_ID (PRIMARY KEY)	name	email	password

Figure 3.25 – SQLite Database: User Table

3.4 Construction

3.4.1 Technology and Language

In order to develop a system that inherently works with tools provided by the mobile device it is installed on, it was clear from conception that *Walk Scotland* should be developed natively. Native mobile applications run on the device's operating system, as compared to a web-based application, which requires a web browser. Being able to operate with the device's native features (such as camera, geolocation, and sensors) was a primary consideration in choosing what kind of system to develop, as was the ability to operate the system offline (which is why a web-based application was not compliant with the system's non-functional requirements). With the majority of users owning Android devices, and taking into consideration the libraries and platform APIs available to developers, Android Studio was the chosen technology for development. This integrated development environment (IDE) is built upon IntelliJ software, and Java is the official language of Android development. *Walk Scotland* uses Android SDK (software development kit) 28.0.0, which provides required libraries and development tools for construction. The IDE offers built-in resources such as platform emulators, layout editors, code editors, debuggers, and more.

3.4.2 Build

3.4.2.1 Log-In Activity

Upon launching *Walk Scotland,* the user is first prompted to sign in to the system through an initial log-in activity (or screen). The view of the activity implements several graphical user interface (GUI) components. An ImageView displays the application's logo, while underneath two EditText boxes hint for users to enter their email and password respectively. Beneath, a button labelled 'log-in' launches the user to the main trails menu activity provided the correct information has been entered to each EditText. Appropriate error messages are raised if not. At bottom left corner of the screen is a TextView displaying 'register new user' - clicking on this text will launch the registration activity. At the bottom right corner is a similar TextView labelled 'Forgot password?' If a user is returning to the application and is already logged in, the onResume( ) sets the application to forgo the log-in activity and instead launch to the 'trails' activity as the landing page.

3.4.2.2 Registration Activity

Similar to the log-in activity, the registration activity displays an ImageView of the application's logo, followed by a series of EditText boxes prompting the user to input specific information. Three boxes hint for the user to enter their name, email, and

password. Relevant error messages are raised when the user attempts to select the ‘register’ button with any information missing. On selecting the ‘register’ button at the bottom of the screen, the user is redirected to the log-in activity. In the controller, selecting ‘register’ first checks that the email used for registration does not match any emails already in the database (raising an error message if it does) and inserts the information (name, email, and password) into the respective columns in the ‘User’ table in the SQLite database.

Figure 3.26 – Log-In and Registration Activities

3.4.2.3 Navigation Menu

To implement the sidebar menu visualized in the wireframes as containing the ‘My Trips’ and ‘Log Out’ buttons, the first high-fidelity prototype built upon Android’s options menu. This menu is a common user-interface component in the top right corner of the app bar that provides a space for actions with a global impact on the application, such as settings. Though the menu can hold up to six options, the original prototype held the aforementioned two. The menu API was used to present users with two actions - navigate to the ‘My Trips’ menu activity or log out of the system.

However, the aesthetic of the menu component did not feel as cohesive with the rest of the application's interface and was restructured during the fourth sprint. The Android Navigation Drawer was implemented in its place. A navigation architecture component of Android's NavigationUI class, this feature applies a panel menu on the left-side of the screen, expanded by clicking an indicator icon on the top left corner of the app bar or by sliding the screen from the left. A universal drawer applied to each activity allows for users to access key activities or functionalities such as log out from any screen, apart from the log-in and registration activities. Initially, the Navigation Drawer featured the same two options as the original Menu, but this design was later altered to include additional options as a result of user testing.

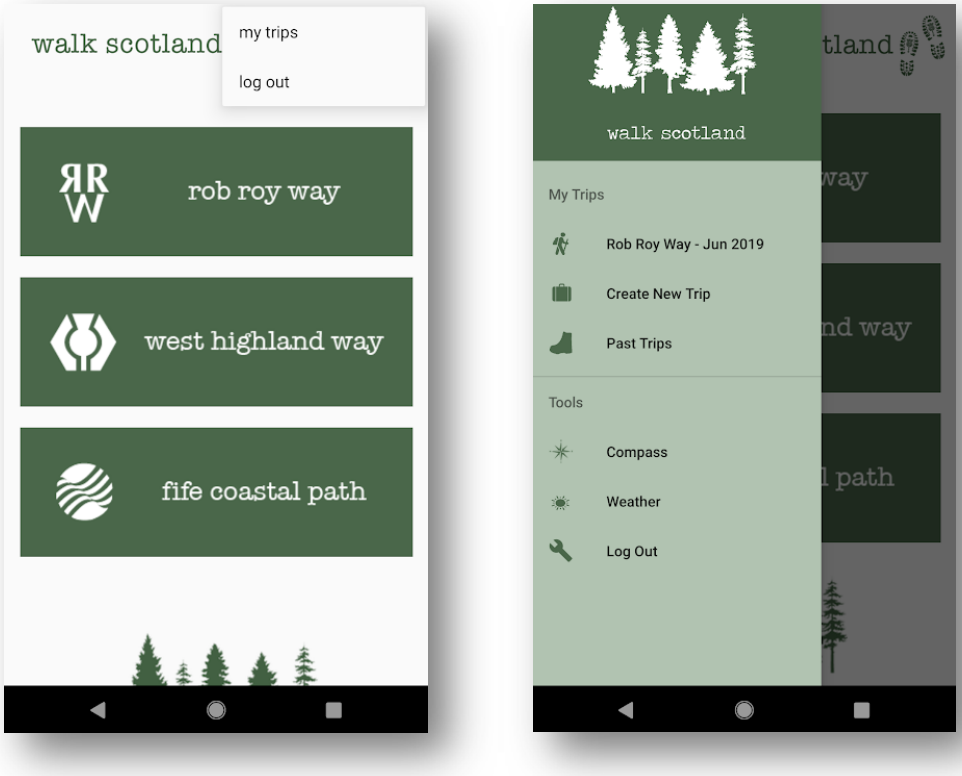


Figure 3.27 – Menu versus Navigation Drawer

3.4.2.4 Trails Activity

The 'trails' activity provides a simple scrolling menu GUI for the user. This activity serves as the application's home page once the user is logged into the system, and on resume the application is set to launch to this landing page if the user is already logged in. A LinearLayout inside a ScrollView is implemented, containing three buttons that each

represent one of Scotland's great trails. The top is labelled 'Rob Roy Way' and is the only button on the screen that is functional when clicked. The following two - representing the West Highland Way and the Fife Coastal Path - are implemented graphically to illustrate how the prototype could scale to include more trails in future iterations, but have purposefully been left dysfunctional for the time being.

3.4.2.5 Rob Roy Activity

On selection of the 'Rob Roy' button in the 'trail' menu activity, a new activity containing a similar menu of options is launched. A LinearLayout in a ScrollView contains seven buttons that in turn launch respective activities - routes and itineraries, accommodation, maps and navigation, trail updates, trail forum, transportation and useful links, and weather.

3.4.2.6 Routes and Itineraries Activity

To display the library of trail's suggested routes and itinerary data, an Expandable ListView was implemented. An Android subclass that extends the traditional ListView class, Expandable ListView is a view that displays items in a vertical list. These items are sectioned into two categories - parent views and child views, each constructed in respective XML layout files. Parent views feature an indicator icon that, when clicked, expand the list to display the child views. In this case, the parent views offered users a brief trail summary (length of trip in both days and distance), and the children broke down the itinerary by day, illustrating the start and end destinations as well as the daily distance.

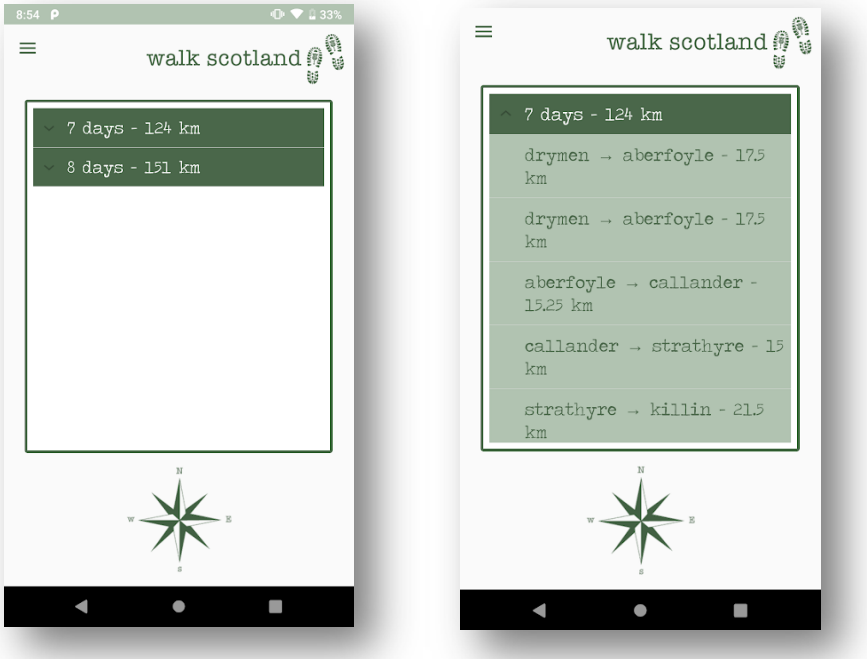


Figure 3.27 – Routes and Itineraries Expandable ListView

3.4.2.7 Accommodation Activity

Also located in the Rob Roy trail options menu, the 'accommodation' activity view is comprised of three Android UI components. Primarily, a ListView displays data of relevant accommodation businesses along the trail. A custom Accommodation Adapter class sets the ListView items' view to a layout designed in a respective 'accommodation item' XML file. Each accommodation item displays the name and description, as well as a rounded image of the business. A button labelled 'book now' connects to the accommodation's URL and, when clicked, opens the business's webpage in a separate browser window.

A model class defines Accommodation objects, with ID, name, town, type, description, photo, and URL as attributes. The controller code for the accommodation activity instantiates a test library of Accommodation objects and adds them to an ArrayList of type Accommodation. An AccommodationAdapter is instantiated and set as the ListView adapter, linking the Accommodation objects in the list to the final view.

The other two components to the activity's view are Spinners, a UI tool that provides users a way to select a value from a drop-down menu. Each spinner represents a category - in this case, town and type - and is filled with an Array of strings. This implementation allows users

to select a value from the spinner and filter the ListView of accommodation data to only show matching data - i.e., display bed and breakfasts in Drymen.

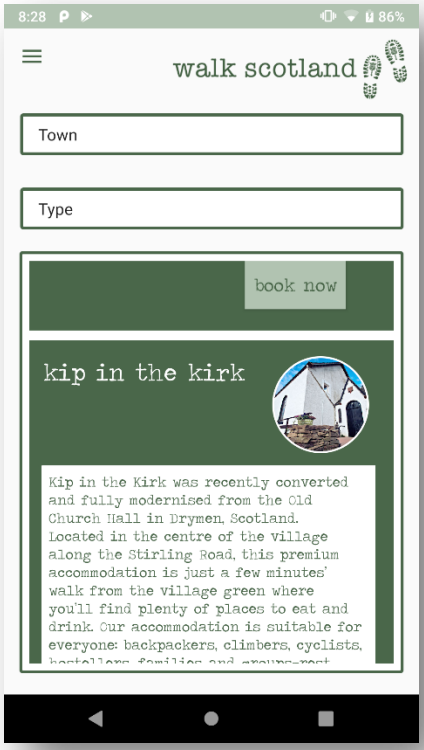


Figure 3.28 – Accommodation ListView

3.4.2.8 Maps and Navigation Activity

Selection of the 'maps and navigation' button in the trail options menu activity launches a new activity once again containing a similar menu. A LinearLayout in a ScrollView contains two buttons that in turn launch respective activities - maps and compass.

3.4.2.9 Map Activity

Upon selecting the 'map' button in the maps and navigation menu, the user is brought to an activity displaying a map view zoomed in on the region of the Rob Roy Way. This map view is built with OSMDroid - Open Street Map tools for Android developers.

```
implementation 'org.osmdroid:osmdroid-android:6.1.0'
```

Figure 3.29 – OSMDroid Gradle Implementation

OSMDroid provides a free replacement for Android's MapView feature, providing a modular tile system as well as support for online and offline tile sources. Overlays can be utilized for tracking a user's location, drawing shapes on the map view, and plotting icons on the tiles.

3.4.2.10 Compass Activity

This activity makes use of Android's built-in SensorManager, a hardware feature that allows the application to access the device's sensors. The code makes sure to disable sensors when the activity is paused - an important factor in reserving power as leaving the sensors running can drain the battery quickly.

```
@Override
protected void onPause() {
    super.onPause();
    manager.unregisterListener(this);
}
```

Figure 3.30 – SensorManager Exceprt: Saving Battery

The activity's GUI displays a compass ImageView, which moves using a RotateAnimation based on the SensorManager's detected movements. At the top of the screen is a TextView that displays the current header.

Figure 3.31 – Compass Activity

3.4.2.11 Trail Updates Activity

The trail updates activity aims to provide users with a GUI representing a bulletin board of official trail news. A ListView represents the board while a custom NewsAdapter converts NewsUpdate objects into postings displayed according to a news item XML layout.

Figure 3.32 – Trail Updates Bulletin Board

3.4.2.12 Trail Forum Activity

The first high-fidelity prototype implemented a simple forum based on populating a ListView in the 'trail forum' activity. A custom ForumAdapter converts ForumPost objects into a view set by a custom forum post XML layout. A forum post item displays the main post's text or question, and provides a button to 'view conversation'. Three GUI components above the ListView prompt users to create new forum posts by entering their main question in an EditText box (doing so is mandatory, clicking the 'post to forum' button without entering text here will raise an error message). A second EditText gives users an optional space to add more information, and a 'post to forum' button instantiates the text in the provided boxes as a new ForumPost object, mapping the mandatory EditText box's intake to the

‘question’ attribute and the second to the ‘additionalInfo’ attribute. Finally, the ListView’s adapter in notified that the data set has been changed, and a new forum post item is added to the list.

Figure 3.33 – Trail Forum ListView

3.4.2.13 Transportation and Useful Links Activity

Also featured in the Rob Roy trail options menu, the ‘transportation and useful links’ activity operates nearly identically to the ‘accommodation’ activity. It features the same UI components - two spinners and a ListView. The spinners are designed to allow the data in the ListView to be filtered by two categories - in this case, category (i.e., taxi service or baggage transfer service) and town. A custom UsefulLinkAdapter class extends ArrayAdapter of type UsefulLink, and sets items in the ListView to display according to a custom XML layout. The layout features the business’ name and phone number, and a button labelled ‘visit site’ opens the business’ webpage in a new browser window on click. A UsefulLink model class defines object attributes as business name, category, phone number, and URL.

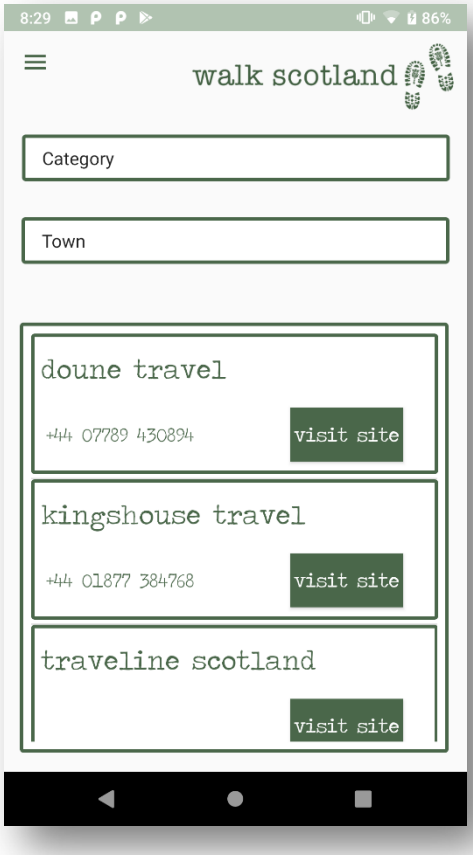


Figure 3.34 – Useful Link ListView

3.4.2.14 My Trips Activity

Again similar to the trail options menu, selecting 'My Trips' brings users to a scrolling menu of options. A LinearLayout in a ScrollView contains three buttons that in turn launch respective activities. The first button represents a user's 'current trip' and is labelled with the trail name and dates of the trip. To illustrate functionality, this primary button has been hardwired in order to launch and demonstrate the subsequent menu and activities. The second button is labelled 'create new trip' and the third 'past trips'. Conceptually, as new trip objects are created and instantiated by the user, a new button will be added to the menu, launching the respective 'current trip' menu when clicked.

3.4.2.15 Past Trips Activity

Keeping the GUI cohesive with other menus throughout, selecting 'past trips' from the 'My Trips' menu launches a scrolling menu. Buttons are currently hardwired to illustrate functionality but in future implementations would populate according to the user's data

(stored trip objects). Each button represents a user's past trip and on click launches a respective activity providing past trip details.

3.4.2.16 Current Trip Activity

Selecting a 'current trip' from the 'My Trips' menu launches a final scrolling menu activity where a LinearLayout in a ScrollView contains three buttons that in turn launch respective activities. Four buttons are represented this time – 'itinerary', 'journal', 'packing list', and 'track my journey'.

3.4.2.17 Packing List Activity

To display the user's packing list, a view structure nearly identical to that of the trail 'Routes and Itineraries' activity was implemented. An Expandable ListView provided the structure for the list, in which the parent views represented categories and children views represented individual packing list items. Each item's view was constructed in a respective XML layout file. In addition to text, the child views featured a checkbox that effectively allows users to 'check-off' which items have been packed.

Figure 3.35 – Packing List Expandable ListView

3.4.2.18 Additional Activities

There are additional activities currently represented in the system whose functionality has not been fully implemented. Rather, they are illustrated in the GUI to provide accurate navigation, but they were given low priority when requirements were being defined. Future iterations of the prototype will see these functions fully implemented. These activities, located off the 'My Trips' menu, currently include viewing and editing the trip itinerary, creating, editing, and sharing journal entries, tracking personal journey details based on GPS data, viewing past trip itineraries, and creating a new trip. A weather activity displays accurate forecast data based on the device's geolocation, and allows users to search a town's forecast as well.

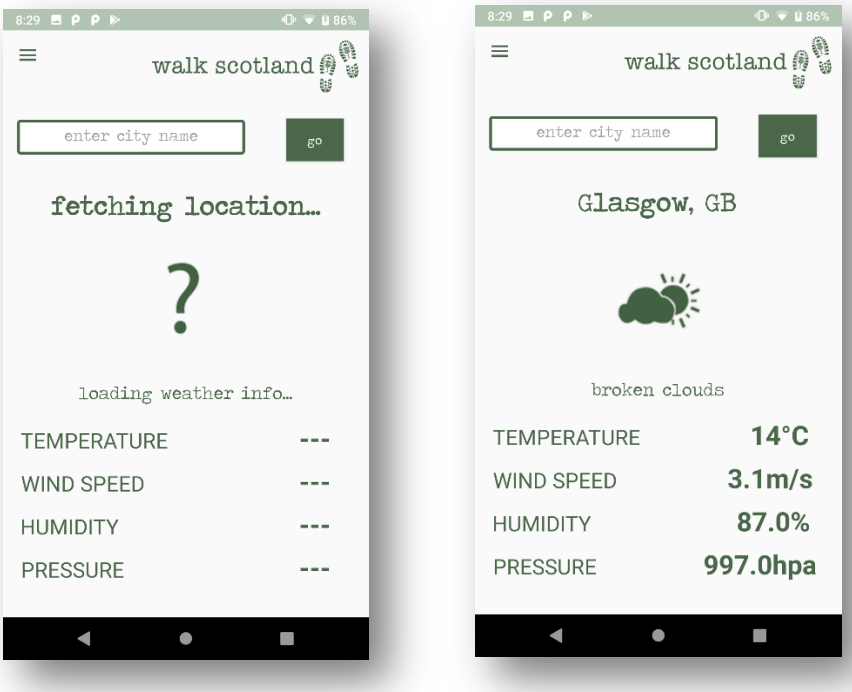


Figure 3.36 – Weather Activity

3.4.3 Version Control

Through development, Git - a project management tool - was utilized for version control. An indispensable tool for developers, Git is used in configuration management. It helps developers manage versions of their source code by controlling how changes to the code are made and saved. A Git repository on hosting service GitHub was created to contain *Walk Scotland'*s source code. Changes and additions to the code were then committed and

pushed to the repository throughout development. As necessary, the project was easily reverted to the previous commit. While Git can be useful for tracking changes among a team, it can also be useful to manage prototypes for a self-developed application. The ability to track changes as they are made, fix bugs, and make continuous updates adheres well to the agile nature of the project.

3.5 Testing

The final phase of the software lifecycle is testing, or the process of assessing and evaluating the application's functionality and usability. There are several forms of testing that look at both the system's back-end as well as the user interface and user experience design. Testing validates and verifies development. It unearths bugs and helps developers refactor, clean, and deliver a robust system. Ultimately, testing is key in delivering a quality finished product.

3.5.1 Usability Testing

As aforementioned, usability testing was also carried out following the development of final prototype in order to evaluate the user experience and practicality of the functionality and navigation - or the overall learnability of the system. This evaluation consisted of having candidates carry out a number of functions on the application. Their actions were monitored and measured for any points where they may encounter confusion or perform an error. Participants were asked to perform the following tasks.

1. Register and log in to the system.
2. Navigate to the Rob Roy Trail menu.
3. Create a new forum post.
4. Navigate to the My Trips menu and view your current trip.
5. Search for hotels in Drymen.
6. View the official trail news updates bulletin board.
7. Search for a taxi service in Pitlochry.
8. Get the weather forecast for Pitlochry.
9. Use the compass.
10. Create a new trip.
11. Create a new journal entry.

12. View your packing list.
13. Log out of the system.

3.5.2 Heuristic Evaluation

When it comes to testing a system's design, Jakob Nielson (2019)proposed ten heuristics for user interface that focus on how users perceive, remember, and use information. These include the following –

1. Visibility of system status.
    - "The system should always keep users informed about what is going on, through appropriate feedback within reasonable time."
2. Match between system and real world.
    - "The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order."
3. User control and freedom.
    - "Users often choose system functions by mistake and will need a clearly marked 'emergency exit' to leave the unwanted state without having to go through an extended dialogue. Support undo and redo."
4. Consistency and standards.
    - "Users should not have to wonder whether different words, situations, or actions mean the same thing."
5. Error prevention
    - "Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action."
6. Recognition rather than recall.
    - "Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate."

7. Flexibility and efficiency of use.
    - “Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.”
8. Aesthetic and minimalist design.
    - “Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.”
9. Help users recognize, diagnose, and recover from errors.
    - “Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.”
10. Help and documentation.
    - “Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user’s task, list concrete steps to be carried out, and not be too large.”

Following the development of the final prototype, heuristic evaluations were carried out on experts knowledgeable in the field of software development. These experts carried out a systematic read of the user interface, examining the functionality based on the aforementioned heuristics. They were asked to use the prototype, test the functionality, and indicate design issues, making note of their severity and which of Neilson’s heuristics they violate.

3.5.3 Test-Driven Development and Unit Testing

Test-driven development (or TDD) relies on the repetition of a short-development cycle - in this case, sprints - in which requirements are turned into specific test cases. The software is then improved to pass these tests. Effectively, unit tests are written, and then back-end class methods are constructed in order to pass those tests. This occurs in place of writing code and then testing it. As this project worked with an iterative agile methodology in mind, TDD is an effective way to not only build the back-end functionality but to add changes and new functionality throughout sprints. Additionally, TDD keeps design simple and effective, as it encourages coding the bare minimum to pass the necessary tests. J-unit tests were

carried out on the class methods in order to track bugs and check that all requirements have been implemented effectively and that they run correctly. Each method written as part of the application's code was tested.

3.5.4 Regression Testing

Regression testing is useful for ensuring that any updates made to a system's code or infrastructure have not affected any other parts of the system's functionality. Because of the iterative nature of an Agile Scrum project, it is vital to ensure that by continually making updates and additions to the system, previously implemented features have not been broken. To ideally watch any bugs that may have been re-introduced to a system, previous tests that ensured their absence were rerun.

4 Analysis

4.1 Analysis of Technology Used

4.1.1 Developing for Android and Beyond

This study's comparative market analysis revealed that several of the applications pertaining to Scotland - and particularly Scotland's hiking trails - are deployed solely for Android or solely for iOS. These include applications published by stakeholders in the local tourism industry, like Visit Scotland. Deploying across multiple operating systems would widen the scope of potential user audience. While Android Studio provides the libraries and architectural support needed to build and deploy a native mobile application for Android, future iterations may look to alternative technologies to build and deploy on cross-platform devices. For example, React Native is a framework that allows for the development of a mobile application that can be deployed across all operating systems as a native application. The concept is as simple as 'learn once, write everywhere'. The ability to deploy for multiple platforms (i.e., Android and Apple iOS) is one of the many advantages of the technology - others include the ability to build quickly and cost effectively. While each respective device requires knowledge of a different programming language - iOS requires Swift and Android requires Java - React Native builds primarily with JavaScript, meaning that only one language is necessary to build an application that can be deployed to double the

4.1.2 Google Maps versus Open Street Maps

Incipiently, development sought to make use of Android's class MapView, which displays data obtained from *Google Maps*, to build the 'map' activities functionality. Though an efficient native tool provided through the IDE, MapView did not fit the criteria for providing the user with coverage when they are without network signal or data. Though users can download sections on the *Google Maps* application to use when offline, caching these tiles through another application is a violation of Google's Terms of Service. These terms stipulate that developers are granted a license to view and annotate maps, create KML files and map layers, and publicly display content with proper attribution online. However, prohibited conduct includes the mass download or creation of bulk feeds of Google Maps content, using Google Maps to create or augment a mapping-related dataset for use in a similar service, and more (Google LLC, 2019).

In order to then provide a solution to the challenge of prototyping an application that can operate off-line, OSMDroid was utilized in place of Google Maps. This Android library, available on GitHub, operates as a replacement for the MapView class. It provides a modular tile system that can support both online and offline map tile sources.

These offline tile caches can be supported in several different storage formats, such as OSMDroid's version of a SQLite database, Mapsforge, and more. Offline storage archives can be created using the OSM Map Tile Packager, which enables developers to download tiles and store them offline, or the Mobile Atlas Creator (MOBAC) - an open-source tool that supports array input map sources. This means that it could be used with Google Maps sources online, but other sources could be utilized instead to provide off-line access providing their terms stipulate its allowance.

4.2 User Experience Analysis

According to Frank Guo, there are four primary components of user experience - value, usability, adoptability, and desirability (2012). Is the product useful? Can users do what they need to? Is it easy and enjoyable to use? Basic methods of user experience aim at addressing these attributes. We first need to understand the users. Next, design and prototyping is carried out, followed by an evaluation of the system.

	Understanding Users	Evaluating Designs
Value	What do users need?	Does this design fulfil the need?
Usability	How do they do it now?	Can they get it done with this?
Desirability	What do they desire?	Is the design appealing?
Adoptability	Where do users look for things?	Can users find and access this?

Figure 4.1 - Components of User Experience

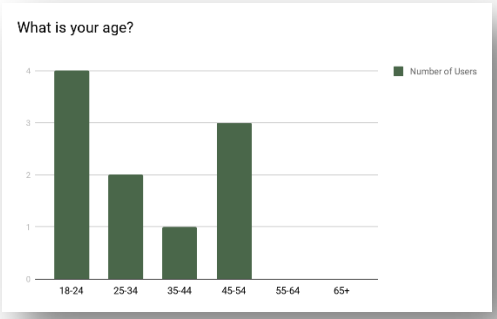
In order to first evaluate users' behaviours and needs, user surveys were distributed. To later evaluate the final prototype, user interviews were conducted.

4.2.1 User Survey

Overall, the results of this user survey (as detailed below) aided in adapting the system's initial list of requirements. By assessing users' opinions on the requirements and evaluating what they wanted to see the system offer the most, functionality was prioritized using the MoSCoW system as previously illustrated in Figure 3.6. Users supported the findings of previous studies by noting key motivations for hiking that fit into the model developed to categorize the system design. Finally, user interest in the conceptual design of the system was overall positive.

4.2.1.1 Participant Demographics

40% of survey participants were aged 18-24, 20% were 25-34, 10% were 35-44, and 30% were aged 45-54. 50% of participants identified as female and 50% as male. When it came to highest level of education, 70% of participants had received a bachelor's degree, while 10% had earned their Master's, 10% their Doctorate, and 10% a high school diploma or equivalent. 60% of users were employed full-time (40+ hours per week), 30% were currently students, and 10% were employed part-time. No participants identified with having any long-standing illness or disabilities.



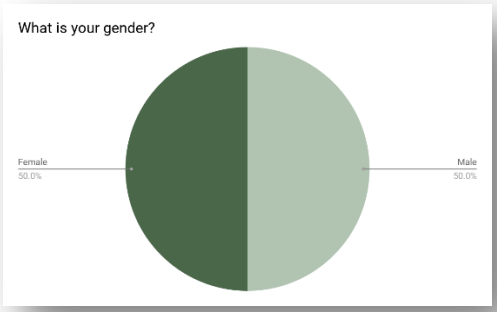


Figure 4.2 – Age and Gender Demographics

4.2.1.2 Participant Technology Practices

When it came to their personal mobile device, 50% of participants own an Android and 50% an iPhone. 80% said that they usually allow mobile applications to track their device, while 10% said they did not and 10% said that they were not sure. When asked what ways they combat battery drain, participants listed that they put their phone on airplane mode, low-power or battery-saver mode, they lower the screen brightness, they turn off blue-tooth and fingerprint functionalities, they limit or close mobile applications that may be running in the background, they restrict use, turn data off, or they shut off the device altogether.

4.2.1.3 Participant Hiking Experience

On a three-point scale of novice, intermediate, and expert, 80% of participants self-identified as intermediate hikers, while 20% identified as novice. 40% of participants had one to five years of hiking experience, 10% five to ten, 40% ten to fifteen years, while 10% identified as having 30 years of experience.

When asked to identify their key motivations for hiking, results mirrored those identified by previous studies and supported by behavioural psychology. Participants identified exercise and fitness, nature and scenery, travel and exploring new places, meeting people and a sense of community, recreation and adventure, sense of achievement, quiet time, fresh air, and time to recharge. Participants were then asked if they preferred to plan a trip or a hike on their own or if they resourced to tour companies or travel agents to plan it for them. 90% said they preferred to plan their own itineraries, while 10% preferred someone else to plan for them.

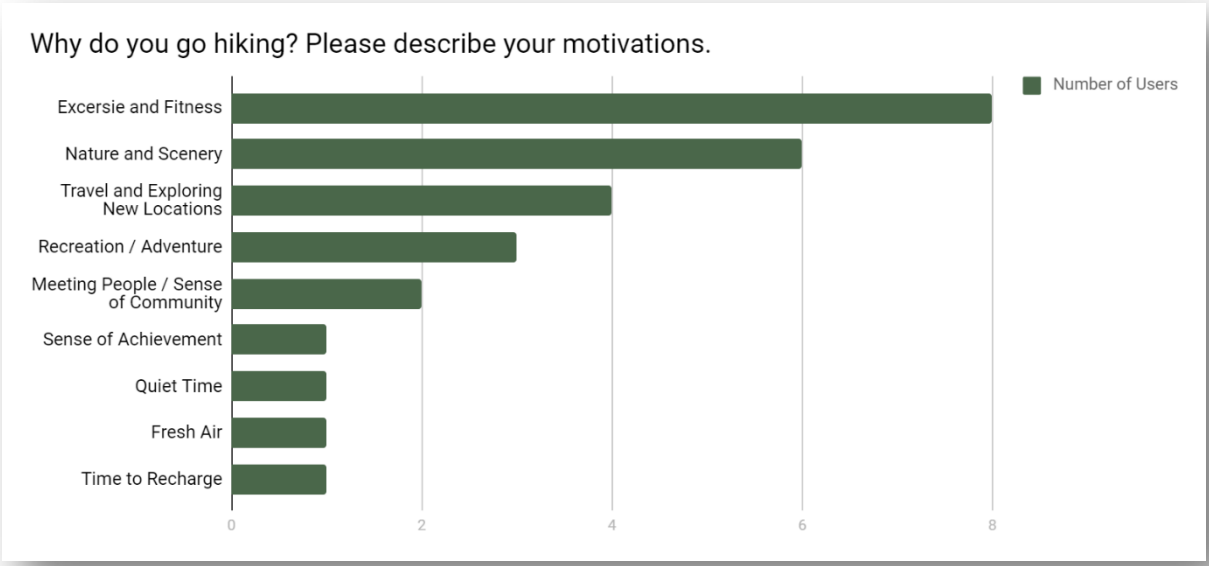


Figure 4.3 – Participants' Key Motivations for Hiking

4.2.1.4 Participant Use of Technology while Hiking and/or Planning a Trip

The next set of questions aimed to identify the resources that participants utilize when planning and executing a trip or hike. Users were asked to list any technologies or mobile applications used when planning and executing a hike or planning a trip of any nature. Listed technologies included *Google Maps*, *Apple Maps*, *AllTrails*, *Ordnance Survey Maps*, *Guthook Maps*, weather websites and applications, *Booking.com*, *Expedia*, *Yelp*, trail-specific websites or applications, *TripAdvisor*, *Airbnb*, *TripIt*, *Google*, *Skyscanner*, *Google Flights*, *Momondo*, *Hostelworld*, local tourism websites, tour companies, wearable fitness devices and relevant applications, cameras, music applications, and compass applications. A comprehensive list of relevant technologies, these results provide evidence that users employ multiple applications and resources when organizing a hiking trip. No user listed a single application, but rather all listed several. Each technology listed provides a single thematic capability (such as maps or booking accommodation) but few offer a bundle of functionality.

When asked how often they self-identify as using their mobile device while hiking, 90% noted some of the time while 10% noted not at all. When asked what features from a provided list they use their mobile device for while hiking, 80% of participants agreed they use maps and navigation, 90% said camera, 80% said weather information, 10% said news,

70% said trail information, 70% said booking accommodation, and 40% said itinerary planning. Other uses listed included posting to social media and making phone calls to restaurants, accommodations, and more. The popularity of these features among participants was used to prioritize the initial set of requirements. For example, with maps being the most utilized tool among participants, it was prioritized as a system must-have.

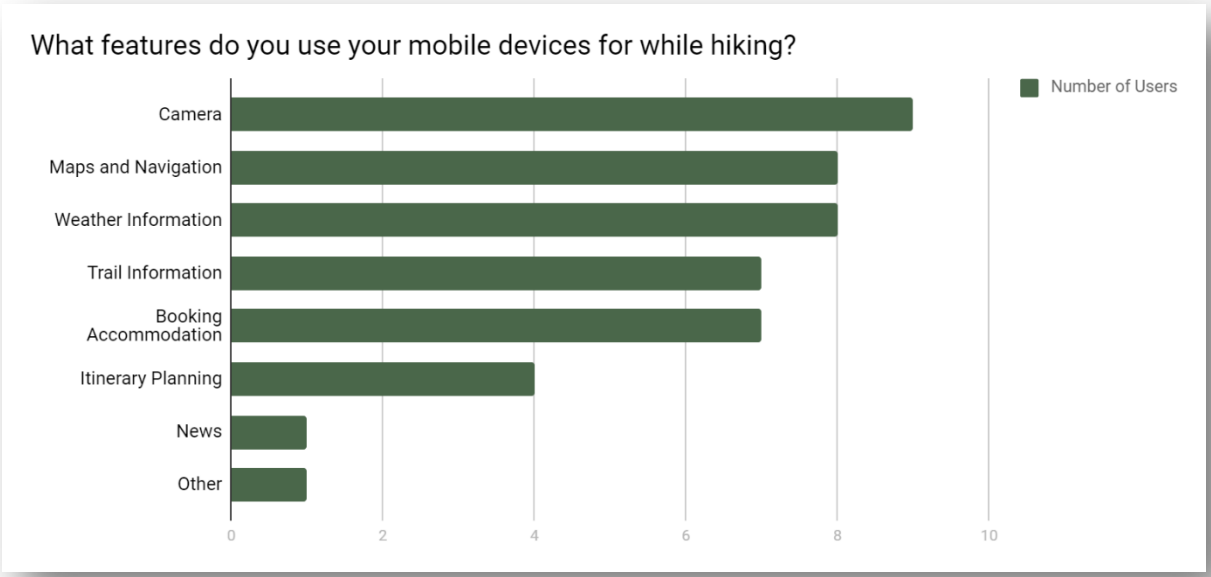


Figure 4.4 – Participant Technology Practices

Next, participants were asked to describe their thoughts on the use of technology while hiking, and if the prefer to disconnect completely while on the trail or if they prefer to stay connected. A majority users indicated a desire to connect but admitted that they keep technology at hand for situations where it may be needed.

Participant A: “I wouldn't mind using technology that was reliable, but you shouldn’t rely solely on it in case it goes wrong. It is important to be able to navigate without technology, but it can be very useful.”

Participant C: “I like being able to see where I am (especially if I go off the trail), change plans and find food on short notice, check ferry or train times, changes in weather warnings, take pictures... Overall I’d much rather keep connected.”

Some participants noted that they prefer the security and less weight that technology provides, while several noted they primarily use technology for taking pictures and listening

to music but little else, particularly as there is often no service. This indicates that many existing systems do not provide robust infrastructures that do not support off-line functionality.

Participants were next asked if they prefer to use technical or physical resources while hiking (such as mobile applications or physical maps and guidebooks). 60% preferred technical resources, while 40% noted they prefer traditional resources. Users identified AllTrails, Ordnance Survey Maps, and Google Maps as the key tech resources they prefer, and guide books, maps, and a compass as the preferred physical resources. Results indicated that a balance of resources is best, as technology may not always be reliable as a result of loss of service or power.

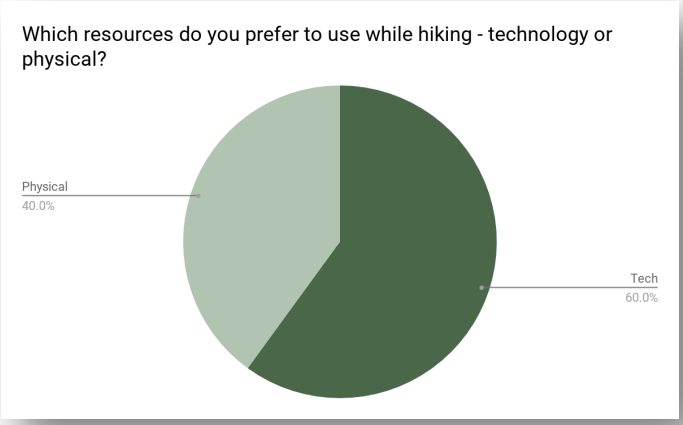


Figure 4.5 – Prioritizing Functionality

4.2.1.5 Participant Thoughts on Walk Scotland Initial Requirements

The final section of the survey aimed to elicit user opinions on the *Walk Scotland* application concept and design while gauging interest. In order to effectively analyse the initial set of requirements, participants were first asked to identify what they would like to see the application's maps and navigation features offer from a provided list. 80% of users agreed they would like to see water sources along the trail, as well as the ability to track and save personal hike data. 60% noted they would like to see history information and nearby attractions along the trail. 50% agreed they would like to see elevation maps and restroom locations along the trail. 10% were interested in augmented reality features.

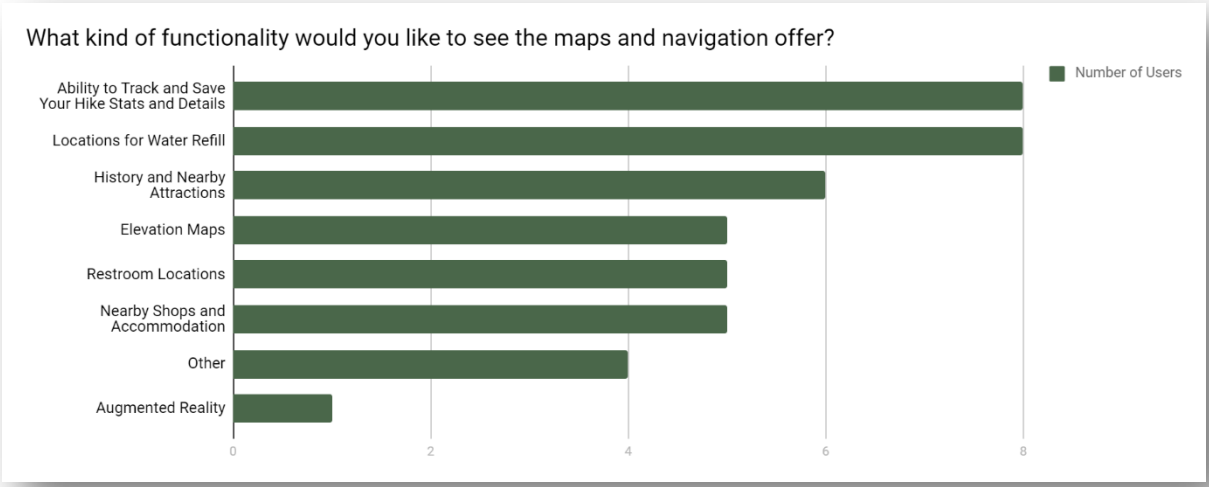


Figure 4.6 – Prioritizing Functionality

They were then provided with a list of functionalities based on the application's initial requirements. These included maps and navigation, trail route and itinerary options, a personal trip itinerary, safety alerts, a compass, weather information, accommodation information, official trail news updates, a trail forum, transportation and useful links, a journal, and a packing list. 50% of users noted maps and navigation as their highest priority feature. The second most-desired feature was trail route and itinerary options. The lowest-prioritized features included the packing list, journal, forum, and compass.

Participants were prompted to list any additional requirements users would be interested in seeing the system offer. These findings would be later utilized to revaluate the requirements and consider next steps for development. Participants noted they would also be interested in seeing emergency/escape routes, trail markers and mileage points, and trail closures. They also reiterated a desire for water and restroom locations along the trail, as well as an interest for the application to be offered in other languages for international travellers – a feature that would greatly enhance the system's accessibility in addition to widening the target audience.

When asked if they would be interested in a mobile application that allowed them to plan their hike from start to finish, 100% of participants said they would be. 60% said they would be willing to pay for an application like this, while 40% said they would not be. 50% of

participants said they would be extremely likely to recommend this product to other hikers, while 50% of participants noted they would be somewhat likely to recommend.

4.2.2 User Interviews

Key findings of the user interviews (detailed below) identified motivations for hiking that once again reiterate those identified by behavioural studies and existing research. This helps to categorize functionality and see how the system can both reflect and support these objectives. For instance, one participant identified the forum feature as an invaluable tool that not only provided information as well as encouraged trail safety, but ultimately provided that desired sense of community. Multiple participants also brought up a desire to see the application become more community-driven, with a way to mark suggestions for other users. Functions brought up by several participants included marking clean water sources, camping locations, scenic outlooks, and more on the trail. Again, this aids in providing users with a sense of community while on the trail.

4.2.2.1 Participant Demographics

Participants were first asked to introduce themselves briefly by stating their age and current occupation to better gain insight into user demographics. Two participants identified as being employed full-time, while three identified as students.

4.2.2.2 Participant Hiking Experience

The interview's next block of questions focused on the user's hiking experience, motivations, and practices. Participants were first asked how long they have been hiking and how often they go hiking. Participant A noted that they had been hiking recreationally for ten years and seriously for three, going for hikes three to four times a month. Participant B stated that while they had been hiking most of their life, they had been hiking seriously for the past few years and going for hikes a couple times per month. Participant C and D stated they have hiked sporadically throughout their life, hiking once or twice a month. Participant E noted they have primarily began hiking within the past year.

Participants were then asked to identify their key motivations for hiking, and the results once again supported those identified by previous studies. Those listed included exercise, quiet time and peace of mind, being outdoors and in scenic nature, travel and sightseeing, the challenge, and an overall sense of achievement. It was noted that hiking was not

something they needed to have a membership for, like a gym, but rather something that can be done at one's own pace.

4.2.2.3 Participant Technology Practices

Participants were asked what mobile device they use. While three participants owned an iPhone, Android devices listed were then Google Pixel XL and the Samsung Galaxy S8.

In support of the initial user survey findings, the resources that participants list that they use when planning a hiking trip indicate that most users employ a variety of resources rather than a single application. Participants listed *Google*, *TripAdvisor*, *Yelp*, *Airbnb*, *Hostelworld*, and technologies for checking weather and routes.

Participant E: "It depends on the type of trip. Usually a kind of a map or a guide (online) to know what the terrain is like and then maybe a forum to see what people's thoughts are about that trail."

An interesting observation is the use of several review engines, which indicates the desire to see reviews reflected in the system's design. For example, future iterations of the accommodation search engine could prioritize displaying user reviews or allowing a user to review a business. Findings also indicated a distinct interest in trail-specific digital resources while also indicating a current lack of relevant or well-developed applications on the market.

Participant A: "If we can find and app that's featuring an area we're trying to hike, we'll use that if it's good. But those don't always exist."

Next, participants were asked if they tend to use technology while hiking or if they preferred to disconnect and why. Findings illustrate the key functionality that users turn to their mobile devices for while hiking. Those listed include taking pictures and interacting with social media (particularly to follow specific locations and trails and see if other hikers are reporting trail conditions or advice), researching food and stops along the trail and checking platforms for reviews, and utilizing maps in the case of getting lost or checking the trail.

Participant C refers to have technology, noting they will listen to audiobooks or podcasts when hiking alone, take photos, check maps regularly, keep an eye on weather, and stay in contact with people. They noted that a digital compass is helpful so long as it is accurate. "I

also have an interest in heritage and archaeology so if I spot something like an Iron Age fort or standing stones marked on the OS map, I'll occasionally take a detour to check it out."

Notes of interest include the community-fuelled aspect of resourcing recommendations from review platforms or social media, as well as a desire to see trail history and points of interest noted.

Participants were then asked to identify some of the challenges they have noticed with the technologies they use while hiking, or things they think the technologies could improve upon. Issues noted supported those identified as the key challenges posed to off-the-grid development. Participants listed battery drain and losing signal while on the trail. A hardware issue pointed out is the ability to use the device in adverse weather conditions like rain.

Participant E: ""The two biggest challenges would be battery life - we need apps that don't drain battery massively - and then also having signal. Sometimes when you're on a hike, that's when you're the furthest away from data. So being able to preload maps or download specifically helpful content to have available offline is useful."

Participant C: "Mainly the issues with loss of signal that disconnects a lot of online services. If they allow the option to download something to keep them usable offline that's fine, but if they stop working it can be an issue."

4.2.2.4 Participant Reactions to Walk Scotland Design and Implementation

In the interview's final section, participants were familiarized with *Walk Scotland's* description and specification. They were then able to interact with the application and get a feel for the design and user interface.

First, they were asked to describe their initial reaction to the concept, and if they thought it was something they would be interested in using when planning a trip on one of Scotland's long-distance trails.

Participant B: "Absolutely. There were a lot of resources when I was looking at hiking the Camino de Santiago - there were a lot of resources on different types and lengths of the hike, as well as resources on where to stay, forums… they were great to use and everything was easy to find. When we were planning the West Highland Way, we found that there

weren't that many resources out there and they were very limited. They seemed to be the same thing every time, and not very comprehensive. Like, they would have a couple places to stay, but not a full list of all your options in the town. It's nice to have all the information you need in one place so you don't have to keep searching."

Next, participants were asked how the concept could be improved upon, and if there were any features not currently offered that could be. These identified potential next steps for development and additional requirements evaluated. Participant A noted a desire to see accurate water sources listed, because while commonly-used platforms like Google Maps will likely have nearby shops and restaurant recommendations, they aren't likely to offer such trail-centric information. Participant B reiterated the importance of a forum for information sourcing as well as a sense of community.

Participant B, on their experience on the Camino: "Another option the forum had was to get updates on a weekly basis of the most up-to-date information. And as a single woman when I was hiking, that was important to know. I did have an area where I was approached by two women and I knew that they were part of a scam because I had read about it in the forum, and just knowing that people were watching out for each other and sharing that information… without the forum I would have had to search for it, so that was a really nice feature."

Participant A: "One of the scariest things about hikes in Scotland was not knowing when we were going to find water again, so knowing where along the trail clean sources of water are would be massively helpful."

Multiple users indicated a desire to see a community-driven navigation system. In this sense, hikers can contribute to a database of information, as well as report trail updates such as closures. Users could potentially pin water sources, camping sites, lookout points, bathrooms, or more to the maps. Indicating accommodation location on a map was suggested as well, in order to get a feel for its vicinity to the trail.

When asked to describe their initial reactions to the application's design, participants reported that it was "intuitive," "clean," "flows well," and has a consistent design throughout.

Participant D: “It’s nice to have an app that does everything in one - cuts down on having several.”

Once a user opinion of learnability was assessed, memorability was addressed. Though the scope of the project timeline did not allow for memorability testing, Participant A was asked if they were asked to return to the application in a month or so, if they would remember where everything was. “Once I saw what was in each menu, it’s easy to picture. It’s not like there’s a thirty-item list.”

Finally, in order to gauge interest as well as identify potential competitors or stakeholders, participants were asked if *Walk Scotland* brings to mind any other applications on the market that resemble it. While users noted seeing apps that offered some functionality here and there, or apps that were specific for other regions, there wasn’t anything that came to mind for Scotland’s trails in particular.

Participant B: “I’ve seen a few other hiking apps that are similar, but they’re either not up to date or they’re not very comprehensive. There are some really nice apps for the Camino. I just haven’t seen anything like that for the trails in Scotland.”

Participant A: “I liked having the ability to go start-to-finish with an ‘all-in-one’ app. I could research a trip, I could see the current conditions on it, I could see the recommended distances and points of interest. But then I could actually use that information to plan my trip, I could be involved in it while I’m on my trip, and then I could go back to it afterwards and see my past trips.”

4.3 Testing Results and Analysis

4.3.1 Usability Testing

Usability testing was additionally carried out on the final prototype. Participants were asked to perform a series of tasks on the application in order to measure the overall learnability of the application’s design and navigation. The optimal number of ‘clicks’ - or actions performed by the user on the screen to achieve a goal - was calculated based on the navigation. For example, to navigate from the trail home menu to the Accommodation activity would take two clicks, i.e. selecting the button labelled ‘Rob Roy’, followed by the button labelled ‘accommodation’.

It is important to note that apart from the first task (register and log-in), these clicks were measured from the trail home menu landing page. The number of clicks performed by users

to carry out each task were recorded and averaged to compare to the optimal navigation in order to identify areas of usability confusion.

Task	Optimal Clicks	Average User Clicks
1. Register and log-in to the system.	8	8.6
2. Navigate to the Rob Roy trail menu.	1	1
3. Create a new forum post.	5	6.2
4. Navigate to the My Trips menu and view your current trip.	3	3.4
5. Search for hotels in Drymen.	6	6.2
6. View the official trail news updates bulletin board.	2	2.8
7. Search for a taxi service in Pitlochry.	6	6.4
8. Get the weather forecast for Pitlochry.	4	4.8
9. Use the compass.	2	2.6
10. Create a new trip.	3	3.2
11. Create a journal entry.	5	6
12. View your packing list.	4	4.6
13. Log out of the system.	2	2

Figure 4.7 – Usability Testing Results

Results of the initial usability testing identified key areas of confusion in the system's navigation. Performance illustrated patterns of redundancy in the menus of the system, indicating that activities could be combined to make navigating the system more efficient (i.e., less 'clicks') and more intuitive. For example, the initial design only saw a button labelled 'My Trips' in the Navigation Drawer menu, which led to a menu of options that included current trips, 'create a new trip', and 'past trips'. Each button lead to their respective activity or menus. As a result of testing, these maps were combined. A 'My Trips' button was eliminated from the Navigation Drawer menu, and rather a category 'My Trips' was added to it with buttons leading to current trips, past trips, and the option to create a new trip.

Additionally, results indicated confusion on the location of the weather functionality. Deemed a location-based rather than trail-centric tool, this button was also moved to the Navigation Drawer menu in a new category ‘Tools’ along with the compass and log-out functions. These redesigns are visualized in Figure 4.8 below. These design changes were implemented on the final prototype following testing.

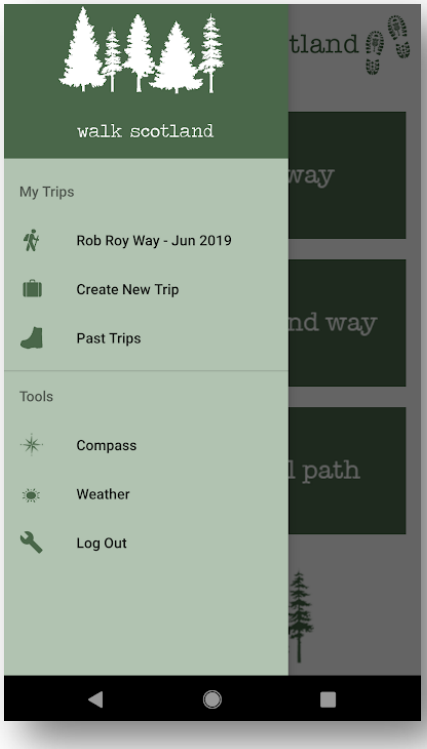


Figure 4.8 - Navigation Drawer after Design Changes Implemented

Other results indicated some confusion when it came to logging out, as some users noted their initial reaction was to look to the top-right corner. The possibility of the Navigation Drawer menu being implemented on the right side in future iterations of the system was noted, in order to keep in tune with conventional standards across similar systems. Additionally, redundancy was noted in the registration functionality, as new members were returned to the log-in page following registration and prompted to enter their information again to log in. A design change resulting from this testing would see the users brought to the trail menu landing page upon registering to make the process quicker and more efficient.

4.3.2 Heuristic Evaluation

Each issue is first evaluated for violating one of more of Nielsen's ten heuristics for user interface design –

H1. Visibility of system status

H2. Match between system and the real world

H3. User control and freedom

H4. Consistency and standards

H5. Error prevention

H6. Recognition rather than recall

H7. Flexibility and efficiency of use

H8. Aesthetic and minimalist design

Each issue is given a severity rating on a scale from 0 to 4 –

0 – Don't think this is a usability problem.

1 – Cosmetic problem that should be fixed only if extra time is available.

2 – Minor usability problem whose solution should be given a low priority rating.

3 – Major usability problem whose solution should be given a high priority rating.

4 – Usability catastrophe that needs to be fixed before the product is released.

4.3.2.1 Issue 1: Trail Menu

Issue reported: Only the 'Rob Roy Way' button on the main trail screen responds when the application is tested. It isn't clear if this is a platform compatibility issue or if the other two buttons ('West Highland Way' and 'Fife Coastal Path') are not implemented yet.

Heuristic(s) violated: H3, H6, H7

Severity rating: 3

Proposed solution: Check whether this is a platform-related issue and provide an appropriate fix. If this is due to requirements not implemented yet, then prioritize these accordingly.

Analysis: For current prototypes, these buttons were left dysfunctional on purpose. Their presence is not intended to confuse the user, although it is understandable that their lack of

functionality does. Rather, their presence in the main trails menu intends to illustrate how the system could scale in future iterations to include more of Scotland's Great Trails. These buttons would effectively be removed or adapted into the system before deployment.

4.3.2.2 Issue 2: Registration Password Confirmation

Issue reported: User asked to type password only once during registration.

Heuristic(s) violated: H4, H5, H9

Severity rating: 2

Proposed solution: Add an option for the user to confirm their password.

Analysis: A simple fix that remains consistent with design standards, a fourth EditText is added to the activity's view, prompting the user to re-enter their password they are able to register. An appropriate error message will be raised if the field is left empty or if the passwords do not match.

4.3.2.3 Issue 3: Password Visibility

Issue reported: Password is visible to the user during registration.

Heuristic(s) violated: H2, H4, H5

Severity rating: 4

Proposed solution: Hide the password, similar to the log-in screen.

Analysis: A high priority rating indicates this as a usability flaw that must be addressed immediately. This issue raises a design oversight that led to inconsistency between activities. The log-in activity password EditText is already set to only take texts of type 'textPassword' – this hides the password text by typing standard bullet points instead. The password EditText in the registration activity currently takes any type of text. An easily implemented fix on the Android Studio IDE, this issue has been resolved in the final prototype and the registration password now also takes test of type 'textPassword'.

4.3.2.4 Issue 4: Registration Escape Navigation

Issue reported: While trying to register with the same email, a message prompts the user to either log-in or select 'forgot password'. However, there is no button for that, hence the user relies on the back button of the device.

Heuristic(s) violated: H1, H3, H4, H6, H7

Severity rating: 2

Proposed solution: Add an option to the registration screen so that the user can return to the log-in at any point, without relying on the back button of the device.

Analysis: The proposed solution identifies the best design plan, which sees future iterations adding a button to the registration activity labelled 'return to log-in'. This provides users an emergency exit. All other activities should also be evaluated for ways to provide emergency exits without relying on the device's hardware.

4.3.2.5 Issue 5: Successful Registration Navigation

Issue reported: Successful registration leads back to the log-in screen. User must then re-type details in order to log-in.

Heuristic(s) violated: H1, H2, H4, H6, H7, H9

Severity rating: 2

Proposed solution: Successful registration lands users on the main page.

Analysis: To make the registration and log-in process more efficient, future sprints will prioritize re-organization of the registration navigation. Instead of being prompted to then log-in after registering, registration will also log the user in and

4.3.2.6 Issue 6: Navigation Drawer Indicator Deactivated

Issue reported: Menu button on the top left-hand side does not respond on click. However, sliding works (the menu does appear).

Heuristic(s) violated: H1, H3, H4, H6, H7

Severity rating: 3

Proposed solution: Check whether this is a platform-related issue (noticed when the application was tested on the tablet) and provide an appropriate fix.

Analysis: The hamburger navigation menu is an indicator that is consistent with industry standards, so its functionality is important as it may not be intuitive to attempt sliding the

screen from the left. Making sure the menu button opens the NavigationDrawer on click will be highly prioritized in the next sprint.

4.3.2.7 Issue 7: Weather Error Indicators

Issue reported: On clicking 'go' on an 'empty' or wrong city name, an error message pops-up (this is fine), but the application gives the user the impression that it's trying to fetch the location and load the weather info.

Heuristic(s) violated: H1, H3, H6, H9, H10

Severity rating: 3

Proposed solution: Consider to more clearly indicate what is happening. Maybe three dots cause the issue here. Is the application trying to fetch information?

Analysis: The current prototype attempts to provide feedback to the user by using a 'fetching information' graphic as the system is working with the device's geolocation to provide the local weather forecast. However, providing clearer feedback or even estimations could help clear up any confusion. Future sprints will more clearly indicate feedback, as well as check that the geolocation capability is working across different Android devices.

4.3.2.8 Issue 8: Does Not Support Cross-Device Functionality

Issue reported: The compass is not doing anything when the application is tested on a tablet.

Heuristic(s) violated: H1, H4, H9

Severity rating: 3

Proposed solution: Check for compatibility across platforms, i.e. device and Android version.

Analysis: This issue applies not only to the compass but across all activities. It is impertinent that the next development sprint makes sure that all functionality is supported across multiple devices, as well as tablets.

4.3.2.9 Issue 9: Lack of System Help and Documentation

Issue reported: Lack of help and documentation.

Heuristic(s) violated: H3, H9, H10

Severity rating: 2

Proposed solution: Could include an ‘FAQ’ and/or a ‘How To’ section.

Analysis: System help and documentation will be added as a new requirement to the system for future development consideration. An ‘FAQ’ activity will be added to the NavigationDrawer menu, highlighting the system’s capabilities.

4.3.2.10 Analysis and Development

Each of the issues indicated offer insight into providing a more robust system. By prioritizing these issues based on their severity, future sprints can focus on implementing solutions and in turn providing a better user experience. Each of Nielsen’s heuristics can be addressed through specific approaches. Violations to H1 can be fixed by providing feedback for the actions that users take. For example, if the system is stalled while loading, provide busy or loading symbols that appeal to standards. The use of metaphors and consistent language can address H2 violations, while H3 can be avoided by providing emergency exits and supporting undo and redo. Thinking across platforms, this could include providing a back button on the system in case a device does not support this feature inherently. Consistency across the design of the product as well as across similar products supports H4. Providing in-process feedback or preventing actions likely to fail validates H5, and H6 is addressed through recognition. The use of accelerators and offering personalization supports H7. Keeping design to a minimalist and de-cluttered standard addresses H8’s aesthetic for system design, and providing appropriate error messages addresses violations of H9. Finally, providing searchable system help and documentation addresses H10.

4.4 Mapping Motivation to Functionality

Walk Scotland’s initial requirements were not designed with these key motivations in mind, but rather these incentives provide a system for classifying system functionality. Of course, not all functionality is necessarily traced to a primary motivator, nor is every motivation yet represented in the requirements.

One of the six motivations identified was a sense of community. Features such as the trail forum aimed to provide users with this network both on the trail and online. The desire to

see this feature was supported by the user interviews, which noted that not only does the forum enhance the sense of community on the trail but adds a sense of security, knowing that the community is watching out for each other. As identified in the user interviews, the maps functionality has the potential to support this objective as well if it becomes a community-driven feature where users can mark suggestions.

Another motivation is that of intrapersonal reflection. By providing users an area to log and share their experiences and thoughts, the journal feature aims to provide users a space for this.

The third motivator was a sense of achievement. Though not yet implemented, the requirements feature a 'track my journey' functionality that supports this objective by providing users a way to view the distance they have hiked, among other statistics.

Sightseeing and curiosity were another key motive for hikers. The results of the user surveys and interviews indicated that users are interested in seeing information relevant to the trail displayed in the application. This could be the history of the trail or interesting landmarks to visit along the path. In alignment with the community-driven maps functionality users were curious to see, users could mark spots of interest, camping spots, or view points along the trail. The map tiled could be overlaid with markers that tell users where points of interest may be along the trail.

A primary motivator for hiking is health and wellness, a trait subtly reflected in features such as 'track my journey'. Looking to the future of technology, particular connectivity, this feature could expand to interact with fitness wearables to track health statistics as well, such as calories burned or average heart rate.

Finally, a user's desire to reconnect with nature is reflected in the conceptual nature of the application rather than any specific functionality yet. But features such as the forum, trail information, or trail updates could evolve to promote ecological wellness on the trail. Could the forum be used to organize trail clean-ups?

As requirements evolve, these key motivators are to be kept in consideration, because providing user functionality that can be categorized by these user objectives not only aims

to make the trail accessible and interactive but promotes ecological wellness and enhances subjective well-being.

4.5 Adapting and Prioritizing Additional Requirements

User research, usability testing, and heuristic evaluation have identified potential new functionalities and UI design solutions that provide a foundation for future development. In line with the Agile methodology that was utilized throughout this project, requirements continue to adapt and evolve. Figure 4.9 indicates new requirements identified throughout the course of system analysis, and prioritized them according to the MoSCoW method. These requirements are in addition to the continued development of the initial requirements.

Functionality	**MoSCoW Priority**
M - Must Have, S - Should Have, C - Could Have, W - Won't Have	
Check system deploys consistently across all Android devices.	M
Provide password confirmation in the registration activity.	M
Provide password security in the registration activity.	M
Provide system help and documentation.	M
Provide users consistent feedback on actions.	M
Make sure the NavigationDrawer indicator button expands the menu on click.	M
Filter maps by water sources, camping sites, lookout points, and bathrooms.	S
Restructure the registration navigation.	S

Move the NavigationDrawer menu and indicator button to the right side of the view so it expands from the right.	C
Implement new trails beyond the Rob Roy Way.	W

Figure 4.9 – Additional Requirements for Future Development Sprints.

5 Recommendations and Conclusion

Twenty-first century digital society faces a pandemic of inactivity due to the abundance of technology available to us. Ironically, this project sought to develop a technology that counters this trend. We are seeing more and more health and wellness technologies, as well as tourism technologies, emerging on the market, and this growth should continue to establish a market that does not discourage the use of technology but rather encourages users to get active and reconnect with nature through its use.

When were are considering an all-in-one companion technology with the key motivations of hiking in mind, how can we implement functionality to support and further these benefits for users? The prototype design saw features like the trail forum endorse the user's sense of community, for example. Looking to the future, what emerging trends and technologies can be adapted to continue this pattern? A primary motivation in hiking is a desire to reconnect with nature, which users in turn have noted sparks an ecological sense of responsibility. Perhaps future iterations of this application could provide information regarding taking care of the trail, or a way for trailblazers to organize clean-ups?

While there is a field of existing research examining the motivations of hiking and the impact recreational tourism has on the economy, ecology, and more, there is little scholarly work on the use of technology in relation to hiking or recreational tourism. Further research should be carried out examining the use of technology while hiking, particularly into users' motivations.

5.1 Next Steps for Development

5.1.1 Future Iterations

With additional functionality and solutions identified from the testing and analysis executed on the current prototype, sprints would continue to implement reprioritized list of requirements. The product backlog should be updated to reflect any additional requirements, and new sprint backlogs to break down what requirements are prioritized. Issues identified in the heuristic evaluation indicated issues with system security, another component to address in future iterations in order to finalize a robust system. Going forward, the process of usability testing and heuristic evaluation would be applied and analysed following each sprint. User feedback research would also be conducted on each sprint's prototype, exploring the options of focus groups that could interact with hiking enthusiasts or even key stakeholders, such as local organized hiking groups. Heuristic evaluation could also look beyond development experts to experts in the fields of tourism – particularly recreational tourism.

5.1.2 Usability Testing: Memorability

Next steps for usability testing, not carried out during the current scope of the project timeline, and would include revisiting the participant pool from the first round of testing and asking them to carry out the exact same tasks on the system. This testing, ideally carried out one to two months after the initial round, would aim to measure the *memorability* of the system. Now that users have used the system once, are they able to remember how it works? Do they remember where everything is, or do they have to re-familiarize themselves with the navigation? Metrics from this second round of testing would be compared to the first to see if they have improved to better match the optimal number of clicks for each task, as well as identify any areas of continued confusion. These results would then be analysed and implementation and design changes made.

5.1.3 Preparing for Deployment

Once all must-have requirements have been implemented on the system and revaluated to indicate no severe usability issues, the prototype will be ready for deployment on the Google Play store, where users will be able to download it for free to run on their Android devices.

5.2 Looking to the Future of Trail Technology

Future iterations of development and user research should also current digital trends and evolving technologies. By implementing these practices into the system, *Walk Scotland* has the potential to provide unprecedented services that competitors do not.

5.2.1 Introducing 5G Networks

Recently introduced and steadily gaining popularity, 5G is the fifth-generation mobile network technology. It aims to provide connection speeds up to twenty times faster than current rates, making for more efficient data download and upload. It also aims to provide wider coverage and stable connections. In Scotland, 5G made its debut first in rural Orkney before it made its way to the big cities. 5G Rural First, a trial delivered by more than thirty partners such as the BBC, sought to demonstrate the potential of 5G technology for supporting rural business and communities (5G Rural First, 2019).

5.2.2 The Internet of Things

Society in the digital era is more connected than ever, and that notion extends beyond the Internet to the devices we use every day. The Internet of Things weaves a web of interconnected technology that work together - from smart refrigerators to medical devices and everything in between. Today people can control the temperature on their home thermostat by clicking a button on a connected mobile application. Perhaps most relevant to the recreational tourism and health sectors are the wearables available on the market today. Fitness trackers such as Fitbit, or even multifunctional devices like the Apple Watch, can track a user's recreational activity, heart rate, and more - all features that resonate with hikers' interests, particularly those motivated by health and fitness as well as a sense of accomplishment.

Though not yet implemented in the application's current prototype, initial requirements and user research indicated an interest in the ability to track one's hike and view details of their journey. Potential future iterations could consider the possibility of interacting with wearable devices to monitor a hiker's progress.

5.2.3 Virtual Living with VR/AR

Augmented reality superimposes computer-generated information onto an image of the real world, blending the user's view with digital elements. Google Maps recently launched

their augmented reality street view, which allows users to see their world through their screen while simultaneously being prompted with navigation instructions.

User research indicated an interest in relevant trail knowledge, nearby attractions, and more. Potential future iterations could consider the impact of integrating augmented reality into the system's maps and navigation. Not only could AR maps indicate directions in circumstances where the trail itself may not be clearly marked, but it could provide interested hikers in additional information. For example, features could include mountain identification, using a database of peaks along the trail to tell users the name and height when prompted by a camera. Or for hikers with an interest in history and sightseeing, notifications could indicate nearby attractions as users hike, as well as their distance from the trail and navigational directions to them. The possibilities are virtually endless.

References

5G Rural First, 2019. *5G Rural First.* [Online]
Available at: https://www.5gruralfirst.org/
[Accessed 8 August 2019].

Adler, J., 1989. Origins of Sightseeing. *Annals of Tourism Research,* 16(1), pp. 7-29.

AllTrails, Inc., 2019. *AllTrails.* [Online]
Available at: https://play.google.com/store/apps/details?id=com/alltrails.alltrails&hl=en_GB

American Hiking Society, 2013. *Health Benefits of Hiking.* [Online]
Available at: https://www.americanhiking.org/wp-content/uploads/2013/04/Health-Benefits-of-Hiking-fact-sheet.pdf
[Accessed 24 July 2019].

Apple, 2019. *Maps.* [Online]
Available at: https://www.apple.com/uk/ios/maps

Appwizard, 2018. *Scotland Great Trails.* [Online]
Available at: https://apps.apple.com/dk/app/scotland-great-trails/id545600392

APS Group, 2019. *Scotland Explore.* [Online]
Available at: https://apps.apple.com/us/app/scotland-explore/id1258076123

AtlasGuides, 2019. *Guthook Guides.* [Online]
Available at: https://play.google.com/store/apps/details?id=com.atlastguides.guthook&hl=en

Balkien, B., Ytterhus, B. & Bongaardt, R., 2016. When everyday life becomes a storm on the horizon: families' experiences of good mental health while hiking in nature. *Anthropology & Medicine,* 23(1), pp. 42-53.

Beck, K. et al., 2001. *Manifesto for Agile Software Development.* [Online]
Available at: https://agilemanifesto.org/
[Accessed 22 July 2019].

Bergland, C., 2015. *Psychology Today.* [Online]
Available at: https://www.psychologytoday.com/gb/blog/the-athletes-way/201506/hippocrates-was-right-walking-is-the-best-medicine
[Accessed 24 July 2019].

BFN Productions Ltd., 2019. *The West Highland Way.* [Online]
Available at: https://play.google.com/store/apps/detials?id=com.westhighlandway.walk&hl=en

Bryden, D. M. et al., 2010. *Assessing the economic impacts of nature based tourism in Scotland,* s.l.: Scotland Natural Heritage.

Chamberlin, S., 2014. *On the Trail: A History of American Hiking,* Bethlehem PA: Lehigh University.

Clement, J., 2019. *Number of apps available in leading app stores as of 2nd quarter 2019.* [Online]
Available at: https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/
[Accessed 10 August 2019].

Collins-Kreiner, N. & Kliot, N., 2017. Why Do People Hike? Hiking the Israel National Trail. *Journal of Economic and Social Geography,* 108(5), pp. 669-687.

Davies, N., 2018. Who walks, where and why? Practitioners' observations and perspectives on recreational walkers at UK tourist destinations. *Annals of Leisure Research,* 21(5), pp. 553-574.

Encyclopaedia Britannica, 2019. *Hiking: Encyclopaedia Britannica.* [Online]
Available at: https://www.britannica.com/sports/hiking
[Accessed 24 July 2019].

Fling, B., 2009. Mobile Web Apps Versus Native Applications. In: S. Weiss, ed. *Mobile Design and Development.* Sebastopol, CA: O'Reilly Media, p. 149.

Foursquare, 2019. *Foursquare.* [Online]
Available at:
https://play.google.com/store/apps/detaisl?id=com.joelapenna.foursquared&hl=en_GB

Gómez-Martín, M. B., 2019. Hiking Tourism in Spain: Origins, Issues and Transformations. *Sustainability,* 11(13), p. 3619.

Google LLC, 2019. *Google Maps/Google Earth Additional Terms of Service.* [Online]
Available at: https://maps.google.com/help/terms_maps/
[Accessed 17 August 2019].

Google LLC, 2019. *Google Trips.* [Online]
Available at:
https://play.google.com/store/apps/detaisl?id=com.google.android.apps.travel.onthego&hl=en_GB

Google LLC, 2019. *Maps.* [Online]
Available at:
https://play.google.com/store/apps/detials?id=com.google.android.apps.travel.onthego&hl=en_GB

GSMA, 2019. *The Mobile Economy ,* s.l.: GSM Association.

Guo, F., 2012. *Not Just Usability - The Four Elements of User Design,* s.l.: UX Strategized.

Hill, C., 2013. *West Highland Way.* [Online]
Available at: https://play.google.com/store/apps/detials?id=caltonhill.android.whw

Hill, E. et al., 2014. Appalachian and Pacific Crest Trail Hikers: A Comparison of Benefits and Motivations. *Journal of Unconventional Parks, Tourism, & Recreation Research,* 5(1), pp. 9-16.

Hynds, H. & Allibone, C., 2009. *What motivates people to participate in organised walking activity?,* Sheffield: Natural England.

Iso-Ahola, S. E., 1983. Towards a social psychology of recreational travel. *Leisure Studies,* 2(1), pp. 45-56.

Kellert, S. & Wilson, E., 1993. *The Biophilia Hypothesis.* Washington D.C.: Island Press.

Lee, H. et al., 2015. Nature-Based Tourism: Motivation and Subjective Well-Being. *Journal of Travel & Tourism Marketing,* 32(1), pp. 576-596.

Lee, S. A., Manthiou, A., Chiang, L. & Tang, R. T., 2018. An assessment of value dimensions in hiking tourism: Pathways toward quality of life. *International Journal of Tourism Research,* 20(2), pp. 236-246.

MapMyFitness Inc., 2019. *Map My Hike.* [Online]
Available at: https://play.google.com/store/apps/detials?id=com.mapmyhike.android2&hl=en_GB

Met Office, 2019. *Met Office Weather Forecast.* [Online]
Available at:
https://play.google.com/store/apps/detaisl?id=uk.gov.metoffice.weather.android&hl=en_GB

Nielsen, J., 2019. *10 Heuristics for User Interface Design.* [Online]
Available at: https://www.nngroup./com/articles/ten-usability-heuristics/
[Accessed 10 April 2019].

Nisben, E., Zelenski, J. & Murphy, S., 2010. Happiness is in our Nature: Exploring Nature Relatedness as a Contributor to Subjective Well-Being. *Journal of Happiness Studies,* 12(2), pp. 303-322.

Norman, D., 2013. *The Design of Everyday Things.* New York: Basic Books.

Ordnance Survey Ltd., 2018. *Locate.* [Online]
Available at:
https://play.google.com/store/apps/detials?id=uk.co.ordnancesurvey.oslocate.android&h=en_GB

Ordnance Survey Ltd., 2019. *OS Maps.* [Online]
Available at:
https://play.google.com/store/apps/detials?id=uk.co.ordnancesurvey.osmpas&hl=en_GB

Park, K., Goh, T. & So, H.-J., 2014. Toward accessible mobile application design: developing mobile application accessibility guidelines for people with visual impairment. *HCIK '15 Proceedings of HCI Korea,* pp. 31-38.

Recreational Equipment, Inc., 2019. *Hiking Project.* [Online]
Available at: https://play.google.com/storre/apps/details?id=com.hikingproject.android&hl=en_GB

RobRoyWay.com, 2010. *The Rob Roy Way.* [Online]
Available at: http://www.robroyway.com/
[Accessed 19 July 2019].

Schultz, W. P., 2002. Inclusion with Nature: The Psychology of Human-Nature Relations. In: P. Schmuck & W. P. Schultz, eds. *Psychology of Sustainable Development.* Boston, MA: Springer, pp. 61-78.

Schweikhard, A., 2019. Go Take a Hike: Online Hiking Resources. *College & Research Libraries News,* 80(2), p. 112.

Scotland's Great Trails, 2019. *The Rob Roy Way.* [Online]
Available at: https://www.scotlandsgreattrails.com/
[Accessed 19 July 2019].

Scottish Government, 2018. *Tourism in Scotland: The Economic Contribution of the Sector,* s.l.: s.n.

Scrum.org, 2019. *What is Scrum?.* [Online]
Available at: https://www.scrum.org/resources/what-is-scrum
[Accessed 22 July 2019].

Shutt, J., 2018. *West Highland Way Offline Map.* [Online]
Available at: https://play.google.com/store/apps/detials?id=jonshutt.westhighlandway

Svarstad, H., 2010. Why hiking? Rationality and reflexivility within three categories of meaning construction. *Journal of Leisure Research,* 42(1), pp. 91-110.

The National Trust for Scotland, 2018. *Trust Trails.* [Online]
Available at: https://play.google.com/store/apps/detials?id=uk.org.nts.app.android.trusttrails

The Trekopedia Team, 2019. *TrekRight: West Highland Way.* [Online]
Available at: https://play.google.com/store/apps/detials?id=com.trekopedia.WHW&hl=en

TripAdvisor, 2019. *TripAdvisor.* [Online]
Available at: https://play.google.com/store/apps/detaisl?id=com.tripadvisor.tripadvisor&hl=en_GB

TripIt, Inc., 2019. *TripIt.* [Online]
Available at: https://play.google.com/store/apps/detaisl?id=com.tripit&hl=en_GB

Trover Inc, 2019. *Trover.* [Online]
Available at: https://play.google.com/store/apps/detaisl?id=com.trover&hl=en_GB

UNWTO, 2019. *Why Tourism?.* [Online]
Available at: https://www2.unwto.org/content/why-tourism
[Accessed 19 July 2019].

Visit Scotland, 2017. *Insight Department: Walking,* s.l.: Visit Scotland.

Visit Scotland, 2017. *ScotlandVR - A Virtual Tour.* [Online]
Available at: https://play.google.com/store/apps/detials?id=com.visitscotland.vr

Visit Scotland, 2018. *Insight Department: Scotland's Tourism Performance Summary Report,* s.l.: Visit Scotland.

Wasserman, A., 2010. Software Engineering Issues for Mobile Application Development. *FoSER '10 Proceedings of the FSE/SDP workshop on Future of software engineering research,* pp. 397-400 .

Wilson, V. & Seddon, B., 2018. *Scotland's People and Nature Survey 2017/18,* s.l.: Scottish Natural Heritage.

Appendix A – Class Diagrams

Class - User
Attributes - _id: int name : String email : String password : String username : String
Methods - setName(String name) : void getName( ) : String setEmail(String email) : void getEmail( ) : String setPassword(String password) : void getPassword( ) : String setUsername(String username) : void getUsername( ) : String isLoggedIn() : boolean

Class - Administrator
Attributes - _id: int name : String email : String password : String
Methods - setName(String name) : void getName( ) : String setEmail(String email) : void getEmail( ) : String setPassword(String password) : void getPassword( ) : String setID(int id) : void getID( ) : int postNewsUpdate(NewsUpdate post) : void isLoggedIn() : boolean

Class Name - ForumPost
Attributes - header : String body : String author : User timestamp : Date published : boolean
Methods - setHeader(String header) : void getHeader( ) : String setBody(String body) : void getBody( ) : String setTimestamp(Date timestamp) : void getTimestamp( ) : Date setPublished(boolean published) : void getPublished( ) : boolean setAuthor(User user) : void getAuthor( ) : user

Class Name - Accommodation
Attributes – id : int name : String type : String description : String town : String url : String image : Drawable
Methods - setID(int id) : void getID ( ) : int setName(String name) : void getName ( ) : String setType(String type) : void getType ( ) : String setDescription(String description) : void getDescription ( ) : String setTown(String town) : void getTown ( ) : String setURL(String url) : void getURL ( ) : String setPhoto(Drawable image) : void getPhoto ( ) : Drawable

Class Name - ForumComment
Attributes - text : String timestamp : Date author : User
Methods - setText(String text) : void getText( ) : String setTimestamp(Date timestamp) : void getTimestamp( ) : Date setAuthor(User user) : void getAuthor( ) : user

Appendix B – User Survey

What is your age?

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and Over

What is your gender?

- Male
- Female
- Other (Please Specify) _____
- Prefer Not To Say

What is the highest degree or level of education you have completed?

- Less than a High School Degree
- High School Degree or Equivalent
- Bachelor's Degree
- Master's Degree
- Doctorate
- Other (Please Specify) _____

What is your current employment status?

- Employed Full-Time (40+ Hours Per Week)
- Employed Part-Time
- Unemployed
- Student
- Retired

- Self-Employed
- Unable to Work

Do you have any long-standing illness or disability?

- Yes
- No

Which of the following mobile devices do you own?

- iPhone
- Android
- Other (Please Specify) _____

Do you normally allow mobile applications to track your location during use?

- Yes
- No
- I'm Not Sure

Please list ways that you minimize battery drain while using your mobile device (i.e. low power mode, airplane mode, etc.)?

How many years of hiking experience do you have?

How would you describe your level of hiking expertise?

- Novice
- Intermediate
- Expert

Why do you go hiking? Please describe your motivations for hiking.

When planning a trip or a hike, do you prefer to plan on your own or do you resource to tour companies or agents to plan it for you?

- I plan and book my own itinerary.

- I prefer to have someone else plan for me.

Please list any technologies or mobile applications you use when you are planning a hike.

Please list any technologies or mobile applications you use when you are planning a trip of any kind.

Please list any technologies or mobile applications you use when you are physically out hiking.

How often do you use your mobile phone while hiking?

- Not At All
- Some of the Time
- Most of the Time

What are your thoughts on the use of technology while hiking? Do you prefer to disconnect completely while out on the trail, or do you like to stay connected?

Which resources do you prefer to use while hiking - technology of physical (i.e. guide books, paper maps, etc.)?

- Tech (Please Specify Which Kinds) _____
- Physical (Please Specify Which Kinds) _____

What features do you use your mobile device for while hiking? Please check all that apply.

- Maps and Navigation
- Camera
- Weather Information
- News
- Trail Information
- Booking Accommodation
- Safety and Alerts

- Itinerary Planning
- Other (Please Specify)

What kind of functionality would you like to see the maps and navigation offer? Please select all that apply.

- Elevation Maps
- Ability to Track and Save Your Hike Details
- Nearby Shops and Accommodation
- Trail Bathroom Locations
- History and Nearby Attractions
- Locations for Water Refill
- Augmented Reality

If there was a mobile application that allowed you to plan your hike from start to finish, would you be interested in using it?

- Yes
- No

Below are some of the features that the application would feature. Please rate them in order of importance, with 1 being what you would like to see the most.

- Maps
- Compass
- Trail Route Info and Itinerary Options
- Accommodation and Booking
- Trail Forum
- Official Trail News Updates
- Weather
- Local Transportation and Useful Links
- Journal
- Packing List
- Personal Trip Itinerary
- Safety Alerts

Would you be willing to pay for an application like this?

- Yes
- No

What changes would you make to improve this application, if any? Are there additional features you would like to see this application offer?

- _____

How likely would you be to recommend this product to other hikers?

- Extremely Likely
- Somewhat Likely
- Neither Likely nor Unlikely
- Somewhat Unlikely
- Extremely Unlikely

Appendix C – User Interview Script

1. To get started, can you tell me briefly about yourself? What is your age? What is your current occupation?
2. What kind of mobile device do you use?
3. How long have you been hiking? How often do you go hiking?
4. Why do you enjoy hiking? What would you say some of your key motivations are?
5. What kind of resources do you like to use when you are planning a hiking trip?
6. Do you tend to use technology while you're hiking, or do you prefer to disconnect? Why?
7. What kinds of technologies do you use when you hike?
8. What are some challenges that you have noticed when using these technologies while hiking? Are the things that you think they could improve upon?
9. *Walk Scotland* is a mobile application that aims to provide everything hiking enthusiasts may need to plan, manage, and execute a trip on one of Scotland's many walking trails, efficiently easing the process and making the trail more accessible for hikers both amateur and experienced alike. It combines navigation tools, itinerary planners, educational resources, and more to create an all-in-one resource that fits in the palm of the hand, while exploring the possibilities of providing off-line service for those going off-the-grid.
10. What is your initial reaction to this concept? Do you think this is something you would be interested in using if planning a trip on one of Scotland's long-distance trails?
11. How do you think the concept could be improved upon? Are there features not currently offered that could be?
12. What are your initial reactions to the application's design? Is it innate, or is it difficult to follow? At what points is there confusion?
13. Please describe your experience with this application. In your own words, please describe this application and what it offers users.

14. What do you like about this application? What do you dislike about it?
15. Does this application bring to mind any other applications on the market that resemble it?

Appendix D – User Testing Form

For this next section, you are asked to perform a series of tasks on the application. This is just to measure the overall learnability and usability of the application's design.

1. Register and log in to the system.
2. Navigate to the Rob Roy Trail menu.
3. Create a new forum post.
4. Navigate to the My Trips menu and view your current trip.
5. Search for hotels in Drymen.
6. View the official trail news updates bulletin board.
7. Search for a taxi service in Pitlochry.
8. Get the weather forecast for Pitlochry.
9. Use the compass.
10. Create a new trip.
11. Create a new journal entry.
12. View your packing list.
13. Log out of the system.

Appendix E – User Testing Results

Task	Optimal Clicks	Average User Clicks	User 1	User 2	User 3	User 4	User 5
1. Register and log-in to the system.	8	8.6	8	8	8	10	9
2. Navigate to the Rob Roy trail menu.	1	1	1	1	1	1	1
3. Create a new forum post.	5	6.2	5	8	7	5	6
4. Navigate to the My Trips menu and view your current trip.	3	3.4	3	3	4	3	4
5. Search for hotels in Drymen.	6	6.2	6	6	6	7	6
6. View the official trail news updates bulletin board.	2	2.8	2	4	2	2	4
7. Search for a taxi service in Pitlochry.	6	6.4	8	6	6	6	6
8. Get the weather forecast for Pitlochry.	4	4.8	4	6	4	6	4
9. Use the compass.	2	2.6	2	2	4	3	2
10. Create a new trip.	3	3.2	4	3	3	3	3
11. Create a journal entry.	5	6	6	6	7	5	6
12. View your packing list.	4	4.6	4	6	5	4	4
13. Log out of the system.	2	2	2	2	2	2	2

Appendix F – Heuristic Evaluation Form

Using the templates provided on the following page, please evaluate the prototype according to Jakob Nielson's *Ten Heuristics for User Interface*[1], as listed below. Please indicate five issues and note what heuristic they violate and the severity of the issue on a scale of 1-4.

---

1. Visibility of system status.
    - "The system should always keep users informed about what is going on, through appropriate feedback within reasonable time."
2. Match between system and real world.
    - "The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order."
3. User control and freedom.
    - "Users often choose system functions by mistake and will need a clearly marked 'emergency exit' to leave the unwanted state without having to go through an extended dialogue. Support undo and redo."
4. Consistency and standards.
    - "Users should not have to wonder whether different words, situations, or actions mean the same thing."
5. Error prevention
    - "Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone

[1] Nielsen Norman Group. (2019). *10 Heuristics of User Interface Design: Article by Jakob Nielsen.* [online] Available at: https://www.nngroup.com/articles/ten-usability-heuristics/ [Accessed 10 Apr 2019]

conditions or check for them and present users with a confirmation option before they commit to the action."

6. Recognition rather than recall.
    - "Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate."
7. Flexibility and efficiency of use.
    - "Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions."
8. Aesthetic and minimalist design.
    - "Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility."
9. Help users recognize, diagnose, and recover from errors.
    - "Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution."
10. Help and documentation.
    - "Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large."

Issue ID:	Issue Description:
Detailed description:	
Heuristic(s) violated:	
Severity rating:	
Proposed solution(s):	