The Broadford Bay Trail: A Digital Trail Guide for a Remote Rural Area

Wojciech Dziejma
MSc Advanced Internet Applications
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Supervised by Prof. Rob Pooley
Plagiarism declaration

I, Wojciech Dziejma, confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (e.g., ideas, equations, figures, text, tables, programs) are properly acknowledged at any point of their use. A list of the references employed is included. The acknowledgements section below lists the individuals that contributed to the non-technical aspects of the project i.e. content writing and aesthetic design. Any code that is not my own but is used within my code files under a suitably permissive licence is clearly indicated in the comments directly preceding it.

Signed:

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1. Abstract
The application of ICT to tourism has seen an increase of activity with the proliferation of mobile devices in recent years. Research themes such as context-aware recommenders, tourism application and website usability, and the social and economic impact of tourism ICT feature strongly in specialist literature. A plethora of applications aimed at fulfilling the needs of tourists has been developed, often using the advanced hardware capabilities of smartphones and tablets. A decreasing barrier to entry has led to many communities and areas wishing to promote themselves to prospective visitors through the digital medium. The project looks at how standard web technologies (Javascript, HTML, CSS) can be employed to build a digital trail guide (DTG) package for a remote rural area, namely the Broadford Bay Trail, centred around the communities Broadford and Strath on the Isle of Skye, Scotland. In terms of components, this DTG package contains a web-based administrative interface, a website front end, and a set of mobile device front ends, all sharing a common data source. The functionality is tailored to the rural context and maintenance by a community group. The project uses a user-centred iterative model of design and development involving prototyping and user research. A usability field study of the mobile front version forms a summative assessment of the success of the project’s outcomes and supplies information about needed improvements.
2. Introduction

2.1. Problem statement
Sparsely populated often rural areas lack modern digital, interactive resources for the tourist to aid in getting dynamic and useful information in a portable and usable format. The challenges for developing such resources are different that for digital tourist guides in urban areas. Landmarks can be scattered more widely, there is usually fewer streets and more open areas, unlike in cities where obstacles about, navigation is complex and routing functionality is necessary. In rural areas, quite often there is significant community engagement but insufficient economic motivation to undertake digital tourism projects. This is in contrast to cities where numerous commercial points of interest are present, offering a potential source of revenue and creating the need for recommenders and adaptive learning algorithms to stay up-to-date with frequently changing urban environments. Rural environments are usually more static. Finally, the network and cellular infrastructure can be limited meaning that it cannot be assumed that a user will have a data connection. Digital tourism resources for rural areas have specific content, functionality and reliability requirements.

2.2. Aim
The main aim of the project was to build a multi-platform digital trail guide, designed in mind with rural areas. This was done by developing a set of interoperable web and mobile modules to allow quick and cost-effective building of a customised and localised package. The focus was placed on suitability for the rural environment and providing high usability for the two primary user groups: the local community and visitors. The current guide was built the Broadford and Strath area on the Isle of Skye but the intention is to use it as a portfolio item for marketing such trail guides on a commercial basis. As such, the Broadford Bay Trail can be seen as a pilot project and the first step in breaking into the trail guide app market.

2.3. Objectives

2.3.1. Practical objectives i.e. outcomes
The main practical outcome was a working system and public-facing system that provides the content and functionality in detailed in the Requirements section across relevant
platforms: the web and handheld devices. This meant implementing the following components using suitable technologies:

- data back end
- web front end
- cross-platform mobile front end for Android and iOS (deployable to tablet and phone formats)

A further objective was to perform a field study to evaluate and compare the components’ usability upon completion of the Broadford Bay Trail app, to allow improvements for subsequent guides and to compare it to established standards.

2.3.2. Learning objectives

Working within a commercial context, it is often difficult to experiment with one’s own ideas they are usually linked to a client requesting a specific product. This project was an attempt to break from heavily budget-driven commercial work to the exploratory opportunities an education setting affords. Accordingly, it was planned to allow research and skills development in the following areas relevant to my professional interests:

- multiplatform mobile app development (requirements gathering, through specification to implementation, leveraging of current third-party libraries and frameworks)
- working with digital mapping (using leading mapping APIs) and GPS in mobile devices
- web back-end to mobile app content distribution and offline functionality
- distributed application deployment on a cloud platform
- evaluating tourist guide app usability in an outdoor setting

2.3.3. External objectives

There are other objectives that needed to be achieved for the produced guide to be a successful product, but they were not seen to be part of the MSc project requirements as they were be fulfilled with the help of third parties. In particular, this meant supplying an attractive visual and engaging content with an accurate translation.
2.4. **Context**

This section briefly describes the area that the pilot guide will be developed for and the non-technical aspects of the project.

2.4.1. **The area**

This section is based on (McNeil 2006) and offers the basic context for the project. Broadford and Strath encompass over 80km of coastline as well as some of the island’s highest peaks, with Blaven a height reaching 928m. There is a wide variety of landscape types and rich geology. There are nine Sites of Special Scientific Interest, three Special Areas of Conservation, one Special Protection Area and one National Scenic Area.

Broadford and Strath is home to a population of about 1400. An estimated 326,000 tourists visit the area annually.

![Figure 1. Location and boundaries of Broadford and Strath area (McNeil 2006)](image)

2.4.2. **The clients**

The main client is the Broadford and Strath Community Company (BSCC), an umbrella organisation for all community groups in the area. The BSCC have been looking to develop a local
heritage guide app, but they have been so far been unable to obtain funding from public sources to allow the project to proceed. The main point of contact was Shirley Grant, a Director of the BSCC and their Project Officer.

The secondary client is Cànan Ltd, a digital agency based on the Isle of Skye where I work full-time. Cànan was seeking to create a digital product for the tourism market and agreed to

Unfortunately, shortly after the start of the project, Shirley Grant had to move away abroad from the island due to personal reasons. This made it impossible to remotely meet and organize the community volunteers, an eventuality accounted for in the risk management plan. Accordingly, the execution of the content side of the project passed on to me, with support from Cànan. This added to workload but it was possible to accommodate this within the allocated project time without significantly reducing the technical scope.

2.4.3. Content

The project started with an audit of both published and unpublished content. There was an existing landscape study (McNeil 2006) and a Broadford Trail leaflet (Duffield 2012) that serve as a point of departure for creating mobile- and web-friendly copy. Once the inventory of stations on the trail was completed, custom images were provided by a local photographer. Initially, the text was planned to be written mainly by community volunteers but when the contact with the BSCC became more and moved away shortly after the start of the project, a commercial writer was hired to select places for the trail and provide content. The Gaelic translation was contributed by Cànan’s in-house translator.
3. Literature review for Digital Tourist Guides

This chapter looks at the main themes in recent research at the intersection of information technologies and tourism, presents a critical summary of the topic and outlines recommendation for further background research. The literature review tends to focus on articles published after 2007. This is because modern devices because smartphones became more widespread after that date, with iOS and Android released to the public in 2007 and 2008 respectively, and with improvements to web standards like HTML5 and CSS3 also showing increased adoption.

Almost every academic paper at the intersection of ICT and tourism begins by stressing the considerable impact that new digital technologies have brought to the tourism sector. Tourism sites have been present since the start of the Internet and even mobile tourist guides date back to the mid and late 90s (Abowd et al. 1997; Cheverst et al. 2000), with a steady progress in sophistication and functionality offered.

![Figure 1. Progress of functionality trends in mobile guides (Emmanouilidis et al. 2013)](image)

Based on the relevant literature discovered in a non-systematic review on Google Scholar and Heriot-Watt Discovery, the following themes were established: context-aware recommender systems for tourists, semantic web technologies in tourism applications, use of modern mobile device capabilities in tourism, social and economic aspect of tourism in ICT, usability evaluation of tourism applications and features and functionalities of digital resources for tourists. This grouping into themes was validated by consulting a recent systematic review of which brings together relevant research output from the USA and China (Li et al. 2013). The review analyses 262 articles from 107 journals and 57 conferences and ranks the most commonly occurring themes of research tourism-related issues in ICT,
and on use of ICT in tourism disciplines. Among the most prominent topics in the first one are, in order, application systems (groups, artificial intelligence, geographic information systems (GIS), mobile applications, recommender systems, semantic web and ontology, and web services (information integration and exchange). In the latter group there are: the effect of IT on tourism, relevant mode research (e-commerce, online marketing, and social media), evaluation (primarily web but also mobile), tourism and the information society, and applications of ICT in tourism. The relative frequency of these topics has been taken as a strong indication of their prominence in the research domain. Ultimately, the themes deemed most relevant to the MSc project chosen for the literature review were refined and narrowed down to: advanced mobile technology usage for digital trail guides (mainly GIS and AR), evaluation in tourism ICT, the development process for tourism applications, and typical features and functionalities.

3.1. **Advanced mobile technology usage for digital trail guides**

Any modern digital tourism resource should consider use of the mobile device medium. The combination of technologies it offers, combined with their natural suitability for use in tourist mobility contexts means that smartphones in particular have huge potential to provide the next generation of tourism services (Wang et al. 2011).

3.1.1. **Geographical Information Systems (GIS) and GPS positioning**

With most current mobile devices including GPS functionality, GIS applications are a natural choice for digital tourist guides. Chu et al. (2012) describe an mobile guide application similar in features to the planned project, mainly containing a combination of a map and AR for locating POIs, intended to be use in an outdoor setting of a geopark in north Taiwan. The “Yehliu Geopark mGuide” used importance-performance analysis (IPA) to determine expectations and satisfaction. A survey feature that stands out it inclusion of a comparison with traditional guiding services in the requirements analysis. It comes as no surprise that high usability is singled out as the most important user expectation, especially since users rated their preference for provision of guiding services by “commentators” (i.e. human guides) ahead of their provision by mobile hand-held devices. The guide takes the form of an Android app which allows users to select “packages” (different trails) to lead them through a specific set of attractions in the geopark. The mGuide has an attractive user interface – it uses a proprietary mapping SDK to place users on a custom map of the area,
with a unique graphical presentation matching the character of the park. The Yehliu Geopark previously had an application designed for Windows Mobile 6 PDAs, but the Android redesign extends the functionality from a simple map, to a location-aware GIS map with AR features. With increased use of GPS there are the problems of delays in the initial position fix as well as significant power drain but the paper mentions that these are increasingly ameliorated by modern implementations of GPS in mobile devices.

Parks and scenic areas are likely environments for deploying digital trail guides to augment traditional interpretative media which have different strengths and weaknesses. A comparison between modern interpretative devices (multimedia apps with GPS and an MP3-based audio guides) with traditional materials (text-and image-rich pamphlets and signage) has been performed by Wolf et al. (2013). The results indicate that a digital trail apps with GPS support is especially likely to increase engagement with the location, although not as much as traditional signage. They are best at encouraging detours from the main trail, and visiting minor attractions, and excel at keeping the attention of visitors due to the multimedia content. Additionally, they promote short-term factual learning, especially when they offer audio material. Map-based mobile applications with GPS support are an effective complement to traditional signage, and in most cases, can a substitute of analogue interpretative materials such as pamphlets. A crucial factor for supplying high quality resources using geospatial information is possessing the location data in the first place. Efforts to automate the process geotagging data in the tourist domain have been undertaken (Dickinger et al. 2008) although tagging manually should also be feasible within the scope of a restricted rural area or a specific trail to follow.

3.1.2. Augmented reality (AR)

A feature that tends to accompany GIS in digital tourist guides is augmented reality. Kouvanis et al. (2012) claim to offer a view of the state of the art in tourism usage of AR, however, features only a limited set of examples of from several cities. It includes an inventory of available frameworks and SDKs that could be used for implementing location-based AR in mobile apps. Augmented Reality can offer the tourist an experience unmatched by other media. Yovcheva et al. (2013) propose a framework for assessing AR experiences and offer suggestions for further research. They also claim to “provide tangible help for developers and designers to engineer augmented tourism experiences”.

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There is an issue of whether users will prefer an AR view to a familiar and established digital map if they need to find a destination. Langlotz et al. (2013) offer an informed journalistic opinion about this, and the answer seems to be negative, although research on the matter is not in abundance (Yovcheva et al. 2013). Another pitfall that be kept in mind is that AR in a rural guide should not to be strictly reliant on network connectivity, which might be simply unavailable.

3.1.3. Data connectivity

Constant connectivity is seen as the future of digital tourist services (Buhalis & Pistidda 2009) but although high speed mobile internet access has progressed beyond large area Wi-Fi and Wi-MAX to widespread deployment of GPRS and recently LTE networks, any innovations are likely to remain confined to major urban areas for the foreseeable future. As such, DTG implementations deployed in scenic rural areas much be prepared to deal with the reality of unreliable and intermittent access to the Internet. Early implementations of location-based mobile guides (Curran & Smith 2006) used GPS with good effect, but were always limited by the restricted Wi-Fi infrastructure. Unexpected loss of connection can discourage and confuse users, and this is apparent even in pilot studies (Evjemo et al. 2007). An effective digital tourist guide for rural areas must be resilient to loss of connectivity.

3.1.4. Proximity technologies

In recent years, smartphones have started being equipped with technologies that allow contact-oriented interactions, notably near-field communication (NFC) and variants of Bluetooth. The applications and perspectives for NFC in tourism have been surveyed in depth (Pesonen & Horster 2012) but it is difficult to find published research on the latest technologies such as Bluetooth LE (low energy) and Apple’s implementation of it as the iBeacons standard, which have only entered the consumer marker towards the end of 2013. In all likelihood, ICT in tourism should see an increased use of ambient computing technologies, however have not been researched in more detail as their applications to outdoor guides is deemed secondary. The main fields of application are in museums and indoor exhibitions with content-heavy points of interest within a limited space, just like GPS is better suited to the outdoors.
3.2. Evaluation of tourism applications

Not & Venturini (2013) have suggested a method for discovering functionality requirements and usability problems in digital tourist guides that is more cost-effective than traditional moderated usability evaluation, and has less complexity than remote usability testing. They advocate a hybrid approach, combining analysis of logs\(^1\) from in-context use and remote asynchronous testing in a commercial project released to the public. The paper describes how the former component was applied, and states the intention of triangulating it with the latter in a future evaluation. The current study collected visit durations, URL trails, search history, as well as ecological data such as position, distance to other POIs, time of day/night and user characteristics. A statistical analysis of the data revealed clear relations between geographical and temporal context and system use, and offered recommendations for increasing the adaptivity of the interface. Interestingly, no confirmation of the necessity of including a map in a tourist app was found. Overall, Not & Venturini (2013) represent a useful case study of system similar to the MSc project, and offer ideas for an analytics-based evaluation. The exact approach used applies only to web applications but the possibility of transferring it to native mobile app testing exists through mobile analytics packages embedded within an app.

For application systems composed of a website working in tandem with a mobile application, evaluation should be considered both in a desk situation and in the field. For the former, (Law et al. 2010) have compiled a systematic review of website evaluation methods in the tourism industry. For the latter, multiple field evaluations of tourist applications in natural and rural environments are available to guide study design. Such studies range from simple and informal to comprehensive and systematic.

An example of an informal field study is (Evjemo et al. 2007) which evaluates and compares two apps for outdoor and indoor use (RegionGUIDE and MuseumGUIDE). The data gathered was mainly self-reported metrics on user satisfaction and usefulness, with added general observations of usability problems by the evaluators. On the other side of the spectrum, Wolf et al. (2013) is a complex study of interpretative media with an extensive statistical analysis run by a large team in a national park. It consisted in approaching real visitors and

\(^1\) The open-source web analytics package PIWIK (http://www.piwik.org) was used in this case.
provided them with the same content (script, images and audio material) in various media, digital and analogue, to test. The aim was to compare the effectiveness of the media. Interestingly, this study featured a division into first-time, occasional and regular visitors, as well as a control group, who were just asked to explore on their own, without any additional materials. Both these studies involved approaching real tourists as they were about to begin exploring an area, and describe some of the pitfalls of in-the-field testing.

Additionally, an issue that should be kept in mind with any evaluation is the variation between users and general accessibility requirements. When designing and evaluating digital resources for the tourism industry it is important to consider the needs of internet users aged 50+ who are often active tourists with considerable spending power (Zangerl et al. 2011). This study specifically mentions a correlation between the volume of information displayed on a destination site and the level of anxiety, and advocates including older users within participants for usability testing. An important aspect of usability is ubiquitous access: the multilingual, multimodal and independent of devices (Grün et al. 2008).

3.3. The development process for tourism ICT

Various strategies for involving users in tourism ICT design can be employed. Scenario-based design is one technique that can be used to engage multiple stakeholders in a tourism setting (McCabe et al. 2012).

For trail guides containing a heritage interpretation element, it seems that community engagement during the development process is a salient issue. An example of this is described in Gretzel and Lee (2009) where a digital heritage application was developed in a participatory model based on the principles of Community Informatics (Gurstein 2000). The “Hearne Storybook” dealt with the goals of heritage preservation first and foremost, but it was also developed to be used by former residents and to promote heritage tourism to visitors. The paper sets out a development process for external specialists working with a local population and outlines the following steps: prepare a “heritage preservation inventory database” which gathers textual and multimedia content, annotate the content with GIS data, apply for funding using these resources, develop digital project in collaboration with community. The content of the “Hearne Storybook” was structured around a number of heritage themes from the area’s past. The content included interviews
with community members about those themes. Gretzel and Lee (2009) stress the importance of reaching out to community members in setting goals for digital heritage and sustainable tourism digital resource, rather than just presenting them with a product developed away the context and possible local challenges, most notably restricted access to GIS resources and limited network infrastructure. Participation at all stages of the process, in fact it was the community themselves who selected the name of the project. The project also stresses the necessary high usability for such projects and frames in the broader perspective of not only “user friendliness” but also “community friendliness”. A guide that is “community friendly” should be low cost and low maintenance, be accessible to content curators regardless of their technical skills, and recruit a community champion oversee its continued development.

3.4. Features and functionalities of tourism applications

The inventory of features and functionalities is particularly vast in mobile guides, and a classification framework of mobile guide IT services has been proposed, focusing mainly on urban applications (Grün et al. 2008). This survey covers a broad range of services, most of which are not germane to the MSc project, for example Accommodation, Gastronomy, News, and Shopping, but it does set out a broader framework for evaluation of mobile guides, by which the MSc project can be classified on three axes of delivery, initiation and customisation with regard to services it provides.

The latest developments in mobile guides are analysed and classified in Emmanouilidis et al. (2013), where a comprehensive taxonomy for this type of application is proposed, but again mainly concentrating on urban environments.

It seems that despite a large array, the tourism sector in 2013 is not making full use of the available range of features for tourism, with mobile technologies especially crucial according to a worldwide survey of 50 academics, students and tourism professionals (Buhalis & Wagner 2013). Social media, mobile and interactivity were indicated as key features for the future but especially websites do not seem to be taking full advantage of the options. This conclusion was the result of a benchmark study of 20 popular national destinations worldwide with regard to use of Web 2.0 features, returned an average score of 2.21 out of a maximum of 5. On the adjectival scale this was barely above “limited”, with the highest
score being 2.61 and the UK placing 9th with 2.34. Generally, the presence of Web 2.0 technologies at the high point of the Web 2.0 trend has historically been low in tourist websites (Schegg 2011) and the transitions between Web 1.0, 2.0 and 3.0 were and are slow in the industry (Eftekhari et al. 2011).

A typical set of functionality for a digital guide is exemplified by Chu et al. (2012) who offer 4 main ways to facilitate the interaction with the park environment: guiding tours (allowing choice of duration), location (an AR interface for locating POIs), map (allows browsing of POIs on a map) and guiding (provides multi-media content about specific attractions regardless of location).

Two of the basic conventions for interacting with a digital tourist guide are a “planner” and “explorer”. These two modes have been described and evaluated with regards to their acceptance in the field by Riebeck et al. (2008). The “explorer mode” shows POIs nearby and lets users request more information as they decide their itinerary themselves, and the “planner mode” guides them along one of several itineraries and offers navigation instructions as well. The former mode ultimately achieved higher acceptance, mainly because of being rated higher on its spatial orientation functionality. The study was done in an urban environment with a relatively high density of POIs, so the acceptance results might not fully apply in the sparse network of POIs in a rural location, but the idea of dividing the functionality of a free-form exploratory mode and a fixed planner/trail mode is highly applicable. A prominent early implementation of the “Explorer” convention is the “Walled City to Wireless City” Digital Tourist Guide for Derry (Derry City Council 2006, pp.10–12) which featured 13 special PDA devices available for hire from the local tourist office. The hardware landscape has changed considerably since then, with 67% of the UK population being classed as “Next Generation Users” who own mobile devices and actively engage with them (Dutton et al. 2013, p.12).

In the outdoor realm, an integrated web and mobile app system has been employed in a ski touring mobile guide (Haid et al. 2008). In this model, the ski tour analysis and planning was done one a PC, and the ready itinerary was downloaded to a GPS-enabled mobile device for quick reference in the field. Accordingly, the evaluation consisted of two parts: think-aloud task-based tests performed at the desk, and a real-use task-based field study which
consisted of following a planned trip. Relevant minor usability points raised were: users were generally unfamiliar with the system term POI\textsuperscript{2}, and that they preferred an aerial photo view of the map due to better recognition of terrain features. Importantly, the study indicated that users valued the usability of such a split web/mobile package.

High usability and relevant content seem to stand out as the two most important characteristics of mobile websites for tourists (Stienmetz et al. 2012).

3.5. Other prominent research themes
Certain themes, while not directly relevant to the MSc project, are prominent in current research, and have been described as the future of tourism ICT (Li et al. 2013; Buhalis & Law 2008): advanced use of artificial intelligence, recommender systems using semantic web and ontologies, and pervasive computing.

3.6. Critical summary
The large range of tourism ICT applications seems to be a testament to the current and future potential of the field. As mobile technology becomes ever more advanced and users’ tourism habits move more towards the digital, the range of solutions is likely to become even more diverse. Progress has been seen especially in mobile guides, and websites seem to have taken on the role of a secondary tool for visitors as the technological progress allows more in-the-context use of tourism ICT, rather than simply gathering information before setting off. E-commerce functionality seems to be more developed in websites than in the more interpretation-and guiding-oriented mobile platform.

The field of tourism ICT is a broad one and even the concept of Digital Tourist Guides involves a complex interplay of disciplines. For the purposes of the MSc project, it is necessary first to make a distinction between several terms occurring in the literature, namely Digital Tourist Guide, Mobile Tourist Guides, and Digital Trail Guides.

A Digital Tourist Guide is the widest term and can offer any functionality useful to a traveller with interpretation, food, commerce, navigation, recommendations, social interaction being just a few options. Mobile Tourists Guides are a version of the same idea that is designed specifically for mobile delivery, for example by including AR functionality. Digital Trail

\textsuperscript{2} Although since the participants were in all likelihood native speakers of German, this could have been a factor
Guides, which are the topic of the MSc project, are a special type of Digital Tourist Guide, by definition having a mobile, in-the-context side to them. They do not need to be confined to the mobile platform, but they usually offer a structured itinerary and focus mainly on navigation and interpretative material. When the abbreviation DTG is used in the present report, it will be taken to mean a Digital Trail Guide specifically, and is synonymous with “DTG package” including all the integrated components, mobile and web.

On the basis of the classification framework proposed in Figure 3, the plan for the mobile part of the MSc project can be described as an information-oriented system for a general audience, providing basic customisation with pull functionality. Push functionality could be included in the form of GPS-triggered proximity activation of POIs. The services it will provide focus on tourist attractions, navigation & orientation.

The research also reveals a wide inventory of usability pitfalls, although it is impossible to compile an exhaustive list. For example audio materials should be short and segmented, rather than long and detailed (Wolf et al. 2013). Generally, there is a problem with using audio in the outdoors where device speakerphones might be too quiet because of environmental conditions. Headphones can help solve this but at the same time hurt social interaction. A possible solution would be to include a parallel format of the audio/video information e.g. closed captions. This would have the benefit of increasing accessibility as well. There should be a strong link between the virtual POIs and the physical location encountered (Evjemo et al. 2007), which is where location-based AR markers could be used.

In terms of evaluation, especially field studies can prove difficult to organise. There is the possibility to recruit tourists in the field, but this needs prearranged promotional material

Figure 3. Classification framework of mobile tourist guides from (Grün et al. 2008)
and can deliver unpredictable results. Alternatively, participants could be prearranged taken to the evaluation area in a more planned manner.

Based on the required functionality, it is necessary to make the distinction between urban guides and outdoor/rural guides, with the majority of implemented systems falling into the former group (Grün et al. 2008, pp.4–5). A typical pattern for an outdoor guide (Chu et al. 2012; Riebeck et al. 2008) can be characterised by an interplay of 4 basic parts: a structured itinerary UI for in-the-field use, a navigation UI for locating/identifying POIs in the physical world, a map UI with an associated POI taxonomy, and a content inventory that allows browsing interpretation material out of location context. In any case, there is usually an opposition between fixed-navigation mode where the user is led along a certain path and free-navigation mode where they roam without any externally-influenced pattern.

To summarise, it is likely that user expectations will keep on growing, especially regarding content quality and usability, and embracing mobile technologies will be a necessary element to successfully compete with other destinations.
4. Requirements

Although at the start of the project, the client was the Broadford and Strath Community Company, the person I was liaising within the organization, the Development Officer, left her post and moved abroad unexpectedly when the planning of the trail guide began. Unfortunately, there was no one else from the side of the Community Company who would take on this role and gather the community volunteers. This was a low-impact high-risk eventuality in the risk assessment, with the contingency plan to go ahead without input from the client. Due to this, Cànan’s requirements and the departing Development Officer’s ideas became the primary source of this specification. Later on, Cànan’s was able to win part-funding for the project from the Gaelic Language Innovation Fund, for developing a trail guide involving Gaelic. The following requirements specification comes for a combination of information gained from the literature review, from the initial vision for the Broadford and Strath Trail Guide and from Cànan business development needs, that is launching a tourism app in the area. This mix of ideas was applied to the problem statement to collate the list in the subsequent sections of this chapter.

4.1. Trail map

This is the primary functionality of the system. The software must indicate the user’s location relative to the points of interest (POIs) and be adequately detailed, both visually and content-wise, to allow usable navigation and finding trail stations. The map should also indicate where the user is located and dynamically update this information. No routing is available in the system, as this is technically complex and routing options available from the mapping API are likely to be inaccurate considering the rural area and mixed modes of transport, with local paths travelled on foot being important. Each POI has a unique id URI identifying it in the front ends and a content structure established at the IA planning stage.

4.2. Dynamic content

A key requirement was that content throughout the system needed to be editable at a common data source to allow propagation of updates to the front ends. This allows the community volunteers or other clients work on the content and maintain it. In practice this can be realised as a CMS administrative panel that links to the data back-end.
4.3. **Compatibility with multiple platforms**

To reach the highest possible number of visitors, availability on the major software and hardware platforms is a priority. To achieve this, the system will offer a web front end and two hybrid (i.e. WebView-based) mobile front ends.

4.3.1. **Web front end**

This will be a website allowing access to the information from the back-end. It should contain the same basic functionality as the apps and work well on mobile devices. Its aim is to allow users to access the information even if they do not have a mobile device at hand, and also to promote the mobile apps.

4.3.2. **Mobile front end (apps)**

The core of the project will be a set of hybrid mobile apps presenting the data added and curated through the web back-end in a location-aware format. Compatibility with the two main platforms (Android and iOS) and tablet and phone form factors is required. A cross-platform implementation is one of the key challenges of this project.

4.4. **Reliability without a network connection**

The system should be suitable for use with limited or no network connectivity, as is common in rural areas. To achieve this is needs to have to have the ability to work without a data connection available by using a synchronisation mechanism when previously online. For the mobile apps, this should allow on-demand checking updates from the back-end and the capability to cache the information internally. An extra benefit of such an approach is that content changes will not have to be distributed as updates to the apps in app marketplaces but available directly through the app.

4.5. **High usability through evaluation**

The system should offer a high level of usability for the target audience and be fit for use in the outdoor environment for which it is intended. More specific information and evaluation criteria are described in the Methodology section. It is envisioned that the product will achieve good usability at the evaluation stage, and that the field study will provide input allowing further improvements after it is released publically in time for the MSc deadline.
4.6. **High technical quality**
Because the final product is intended to eventually be marketed commercially and customized for other clients, it is an obligatory requirement that the code quality is high enough to allow easy maintenance and future extensions without having to go back and refactor the basic code. Additionally, other developers might be taking the project forward so it is necessary that the project follows an accepted code style. Good software engineering practice and the appropriate tools will be used to achieve this requirement.

4.7. **Multilingual interface and content**
The content and interface should be bilingual to reflect Skye’s Gaelic heritage. This is also a requirement for Cànan from the perspective of a bilingual company. The possibility of localisation and translation should be kept in mind when building the system, for example by planning parallel content fields for each language and for interface text elements to be stored in easily translatable files.
5. Design

The project started with two streams in parallel: prototyping options for the front end, and at the same time, conceptualising the trail, structuring the content and preparing a back end to serve it. Two medium-fidelity prototypes were built even before the trail was planned.

5.1. IA and back-end

This phase started with content design and with conceptualising the trail itself. Once the number and location of stations was established, a content template was produced in the form of a table to allow uniform information for the POI content type.

<table>
<thead>
<tr>
<th>ID</th>
<th>Field Label</th>
<th>Short Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Name (en)</td>
<td>{poi_name_en}</td>
</tr>
<tr>
<td>1</td>
<td>Name (gd)</td>
<td>{poi_name_gd}</td>
</tr>
<tr>
<td>2</td>
<td>Lat</td>
<td>{poi_lat}</td>
</tr>
<tr>
<td>3</td>
<td>Lon</td>
<td>{poi_lon}</td>
</tr>
<tr>
<td>15</td>
<td>Order</td>
<td>{poi_order}</td>
</tr>
<tr>
<td>4</td>
<td>Description (en)</td>
<td>{poi_desc_en}</td>
</tr>
<tr>
<td>5</td>
<td>Description (gd)</td>
<td>{poi_desc_gd}</td>
</tr>
<tr>
<td>6</td>
<td>Interesting Fact (en)</td>
<td>{poi_fact_en}</td>
</tr>
<tr>
<td>7</td>
<td>Interesting Fact (gd)</td>
<td>{poi_fact_gd}</td>
</tr>
<tr>
<td>8</td>
<td>MP3 File</td>
<td>{poi_mp3_file_uri}</td>
</tr>
<tr>
<td>9</td>
<td>Image</td>
<td>{poi_image_uri}</td>
</tr>
</tbody>
</table>

Figure 4. Final POI content type data structure

Despite initial plans to build a complete back-end from the ground up in Python, it soon became apparent that even the user-facing components of the project will be a challenge to develop within the allocated time. As such, the decision to switch to a solution that would allow a quicker build was made. This solution is ExpressionEngine, a PHP (CodeIgniter-based) framework for building content management systems. This provided an admin panel to organise the content and provided common, repetitive functionality like database access, user management, and a WYSIWYG editor for content. ExpressionEngine does not come with any front end code, nor does it have a “theme” (template) ecosystem in the traditional sense. It also does not imply anything about how the information architecture and all
content types (Static Text and POI entries in this case) are to be defined by the developer. The front end templates were written completely independently to match the specification of the project and are dynamically populated with data using ExpressionEngine’s APIs, which function similarly to a templating language. In the end, adding the additional level of abstraction in the form of a framework meant that the specification could be fulfilled not only quicker but also more securely. It also meant that the back end organisation would be understandable to other developers familiar with ExpressionEngine.

5.2. Web

In parallel with the back-end and IA design, the web prototype was built as static HTML with some real content and some placeholders. The project has significant third-party framework leverage but with extensive customisation. The web prototype did not link to the back-end in any way other than pulling in JSON data for the map. The rest of the initial site was built as templates using a Ruby static site generator, Nanoc, because it shares a similar approach to template organisation as ExpressionEngine but is lighter-weight and quicker to develop for, with content in a flat file structure.

![Figure 5. Web prototype - static content page](image.png)
5.2.1. Mapping and offline capability

At the prototype stage, the mapping solution was changed from Google Maps to Mapbox, a competitor specialising solely in mapping solutions. This was done chiefly because Mapbox featured what seemed a richer API, with more options to manipulate the cartographic data, for example to customise its look and feel using a styling language called CartoCSS. For a trail application, having a distinct look and feel of the map is important to creating a unique experience. Mapbox also offered a desktop-based program, Mapbox Studio, that allowed editing the map tiles with regards to the objects shown, which was important for mapping a local area for pedestrian travel.
The offline map caching mechanism used in the prototype was exporting raster tiles from Mapbox TileMill (an earlier version of Mapbox Studio) as MBTiles (basically an SQLite database with the raster data) and later using a Python utility script called mbutil\(^3\) to generate a directory structure with png files of tiles at different zoom level. This allowed storing all of the mapping data in static files on the local filesystem which made working offline straightforward. Shortly after the prototype was completed at the start of 2015, however, Mapbox discontinued TileMill and moved all of their tile data to a vector format. This made the workflow described above obsolete.

Additionally, any distribution of Mapbox mapping data in prepackaged apps was disallowed\(^4\). The prototype available on the attached CD still implements a map as a series of pre-generated tiles from the filesystem but this had to be changed in the production version. It became obligatory for each device to download the maps through separate API calls in order for Mapbox to correctly track usage and bill accordingly. Work on functionality allowing offline mapping has been ongoing since late 2014\(^5\), but has not reached a production standard yet, and an alternative solution was required for the implementation stage.

\(^3\) https://github.com/mapbox/mbutil
\(^4\) https://www.mapbox.com/help/offline-map-cache/
\(^5\) https://github.com/mapbox/mapbox-gl-native/issues/584
5.3. Mobile

While the initial plan was to prototype using Axure RP, I had previously had the chance to work that with the package and found it easy to learn. I decided to take the opportunity to prototype and something completely different, namely the LiveCode platform, produced by an Edinburgh-based company (LiveCode Ltd 2015) and recommended at an industry event I had visited. The hope was that it would provide a more developer-oriented prototyping environment than Axure RP and transfer code from the design stage directly into production. In reality, LiveCode provided a proprietary, non-standard IDE with an idiosyncratic Lingo-inspired scripting language.

The basic POI screen flow was established (Figure 8), consisting of first locating oneself in the map and surroundings, then selecting a point to get identify it, and finally activating more information about it. Also prototyped were the static content screens (Figure 9) and a non-geographic way of accessing the place information in the form of a POI list (Figure 10).

![Figure 8. Mobile prototype - POI screen workflow](image-url)
While LiveCode was sufficient to build a basic interactive prototype, with experience it became clear that it was unsuitable for production use on the Trail Guide project due to a number of reasons. The LiveCode environment offers compatibility with a range of platforms but this is due the app code being executed in a bundled custom runtime and this makes it very far indeed from open web technologies. It was a sufficient tool for prototyping interactive screens but the pseudo-natural scripting language LiveCode, described by the company as a “very high level language” seems overly verbose. The platform has a large standard library and as long as the required functionality fits into the mould, then it if fast to implement but if custom coding is required then the scripting language seems cumbersome when compared to more abstract high-level languages. LiveCode seems to be a solution to a problem (cross-platform mobile development) that has already been solved by either WebView-oriented development or compilation to native languages. It seems the platform could have its place in education or hobby applications (user scripts etc.) but it was deemed too niche to develop a marketable product in. Ultimately, the app prototype could have been more efficiently coded in Ionic, the framework chosen for the final implementation, were it not much less prominent at the start of 2014 when the system was being designed and planned for implementation using Titanium SDK. The app prototype files are available on the MSc CD contain both the source and assets for the LiveCode project and an APK for Android to allow running the prototype.

6 https://livecode.com/products/livecode-platform/livecode-for-developers/
5.4. Prototype testing

Testing the prototypes was quick and informal usability testing, with two users. Based on the feedback, several changes were made to the app. Most importantly, the font size adjustment was removed for the settings page, and the settings and geolocation activation were taken out into separate UI components to highlight their status as separate from the content. The web prototype was accepted without major changes in the structure, however, it has to be stressed that it was demonstrated on a computer and a large screen, not on a mobile device, which is what the summative evaluation was run on.
6. Implementation

The final prototypes marked an end to iteration on the applications functionality, navigation and interface structure, with the visual style, including fonts and colours, to still be decided. Finalising the design allowed choosing the range of technologies and third-party components to be used in the implementation of the public version, which is described in the following sections.

6.1. Naming the versions

In the interest of brevity the “web front end” will from now on be referred to as the “web guide” or “web version”, and the “mobile front end” as “app” or “app version”. It is important to clarify this naming decision because both front ends use standard web technologies and both are effectively run in the web browser. The names do not strictly imply that the web version works online only or simply as a website, however the app is packaged only to run on a mobile device i.e. it is distributed in a native app wrapper. More detailed discussion of the similarities and differences will follow in later sections.

6.2. Third-party leverage

In web industry nowadays, it is rare not to use resources written by other programmers, usually published an open licence. This can mean using third-party APIs, or plugins/modules integrated into the project, to avoid redeveloping basic features. In order to deliver a complete working system that will be distributed to users through public channels within the allocated time, the project had to make extensive use of third-party web technology code. There were several major technical challenges to be solved linked to the core requirements (caching, http request utilities, map tile handling, map UI and calculations etc.) and established libraries were used to handle them, rather than even considering approaching them in my own way. When solutions from others are used, they are indicated in the text with citations, and within the code with comments. Additionally, a full list of third-party packages used in the project can be found in the appendix.

6.3. Infrastructure and back end

Initially, the web prototype was hosted on a Linux shared hosting platform as static HTML files. The first version of the CMS back end was also hosted there, however, when it became apparent that it would be necessary to serve the data and web front end through https to
achieve sufficient offline reliability, it was decided that a more robust hosting solution was needed. At the moment of completing this MSc the software is running on a LAMP stack in a dedicated virtual machine instance on the Google Compute cloud infrastructure. A low-cost SSL certificate was procured from Comodo CA and the Apache server running on the VM was configured to use it. Setting up this infrastructure was an interesting experience as I had only worked with shared hosting previously.

6.4. Public availability
The prototypes are available only on the attached CD but both production versions are available publically. The website is available at https://broadfordbaytrail.org.uk.

The Android app is in the Google Play store at https://play.google.com/store/apps/details?id=uk.co.canan.broadfordbaytrail

The iOS build is working at the time of writing and has been deployed to iPad and iPhone development platforms successfully. Making it publically available through the Apple App Store is a slightly longer process due to extra requirements and will be finalised at a later date.

6.5. Core requirement implementation
This section describes the technical solutions to the core system requirements from chapter 4. The descriptions are brief and only indicate the key points about the implementation. Because both front ends use the same set of open web technologies and the features implemented were intended to be equivalent, they share parts of the code. However, the application structure and UI for mobile and web are built completely separately and using different conventions, and are far from running the same code twice in different wrappers.

Each requirement section below starts with describing the web implementation first, and then contrasts the app implementation. In the interest of readability, most screenshots illustrating the features discussed were included in the Screenshots appendix.

6.5.1. Compatibility with multiple platforms
In the context of this project, “multiple platforms” means “all screens on smart phones, tablets and computers” for the web version, and “the 2 major mobile operating systems” for the app.
**Web**

The website is fully responsive and works within a range of screen width media queries of 300px to 1920px due to flexible grid. It features two separate menu systems: one for desktop and a custom coded touch-optimised one for smart phones. Comparison screenshots from various screen sizes are included in the appendix.

An interesting aspect of the implementation worth describing is that the website also fulfils the requirements of a “progressive application” (Russell 2015) as implemented in the Chrome web browser. These are: being served through a secure connection, having a registered service worker to enable offline functionality necessary for an app, and finally a correct web application manifest file (Caceres et al. 2015). A progressive application, as described by Russell, is a fully offline capable website that is “installable” on a device in the chromeless browser wrapper, and essentially looking and functioning like a native application to the user. If a website fulfils a user agent’s requirements for considering it a valid progressive application, it will receive special treatment on a mobile platform, for example an unobtrusive banner to prompt the user if they would like to add it to the home screen (Fig. 11).

Although the format of a progressive application is used in the evaluation of this project, it is considered a progressive enhancement, not a feature that needs to be supported across all browsers. This is because the app is considered the primary version for use on mobile devices.

**App**

The original plan laid out in the research report was to use the Titanium SDK to build the final product. However, I had the opportunity to try the Titanium platform for developing a
simple, commercial application before starting the MSc and found it difficult to work with. It required a custom IDE and a chain of build tools that notoriously did not work well together and kept breaking with mobile platform updates. The process was also inherently slow because the app package (i.e. the APK for Android) needed to be fully built to preview any change. The build could take around one minute, and debugging interpreted JavaScript within a compiled package was difficult to manage meaning quick iteration was impossible. Titanium was clearly not the solution I had been looking for.

Since both the Titanium SDK and LiveCode were trialled and deemed unsuitable, and since native mobile application were not being considered on account of the time constraints, there was a need to make a final decision on the technology to be used for taking the prototype to a full product. Because of hybrid mobile applications\(^7\) maturing rapidly even since the start of planning the MSc project, and the appearance of new frameworks for hybrid development, the decision was made to use standard web technologies in a web view framework wrapper to build the mobile front end.

The choice was made to use Ionic\(^8\), a Cordova- and AngularJS-based HTML5 hybrid mobile application framework because it provided an extensive set of front-end components targeted specifically at multiplatform development. It also came with command line tools for packaging, testing and deployment to devices. Cordova provides the platform for running web applications inside a native wrapper and enhanced web view. AngularJS is an industry-standard front end MVC framework by Google, which aim is to make HTML documents or suited for handling dynamic model-driven views.

The application has one global view which uses the Ionic tabs directive to provide the main tabbed interface with four child views: map, about-the-trail, about-the-area, place-list. It also has a sibling view settings which is outside of the tabbed navigation. View routing and state handling is done by an Angular component, ui-router, and is specified declaratively

In Angular, controllers can be attached to particular parts of the view i.e. to particular HTML structures. The application has five controllers:

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\(^7\) i.e. ones based on an HTML5 web view in a native wrapper exposing certain device APIs

\(^8\) http://ionicframework.com/
**MainCtrl** - provides functionality shared throughout the application i.e. localisation capability, deals with place events bubbling into the application scope

**MapCtrl** - initializes and controls map (inc. tile manipulations), handles all map and marker events, provides geolocation, relies on TrailDataService

**ContentCtrl** - handles any functionality needed by the static content tabs

**PlacesCtrl** - loads data and handles events on the places list tab, relies on TrailDataService

**SettingsCtrl** - handles language switching model on the settings page

It also has two services (singeltons providing data to multiple controllers):

- **TrailDataService** - responsible for providing all GeoJSON and map content, including deciding whether to serve live online data or the fallback offline local copy
- **ContentTranslationService** - loads and updates translations, concatenates dynamic translations with static UI element translations

Having never developed a mobile application before, there was a learning curve to getting started with the Cordova/Angular/Ionic stack as they could only be effectively used with knowledge of all three.

### 6.5.2. Trail Map

**Web**

This version uses the Mapbox.js library and its associated tile server to load the map. It features dynamically generated pop-ups for POIs and a detail view in a map overlay. Location functionality is provided using the HTML5 geolocation API (specifically `watchPosition()`) in a thin map event wrapper to handle `locationfound` and `locationerror` firing.

**App**

The app uses the angular-leaflet directive\(^9\) as a way of integrating the LeafletJS mapping library into an Angular application. This is a different, more declarative approach, to working with the map and means that the syntax and structure of the code is different from the web.

version, which uses the mapping library directly. This is done in order to access the map Angular’s $scope and expose its data to the view.

6.5.3. Dynamic content
There needed to be a central data store that could communicate with both the website and the app. It was considered that the data that could be hosted in a no-backend-type solution, for example Firebase or another JSON-oriented platform, but because building out a full administrative interface with editing capability suitable for non-technical users was required, a self-hosted CMS was a more effective option. ExpressionEngine (EE) was chosen on account of the strong separation between the content structure and management, and the front-end code which could be completely custom-coded, starting from a blank file.

Web
The website is essentially built from HTML partials which get assembled and parsed by the CMS. The EE tags within them serve as a database abstraction layer and get populated with the latest data from the CMS. The system is also configured to output some of its content format through URLs under the https://broadfordbaytrail.org.uk/en/get path:

- /resources-list – a JS file containing an nested object specifying which resources should be regarded essential for offline functioning of various parts of the guide
- /geojson – a GeoJSON\(^\text{10}\) file containing all the content and location data for the trail, as well as geographical parameters for the trail centre point, the bounds for the map, maximum and minimum zoom levels etc. This data is used by the mapping library but also by the map tile pre-caching solutions which need to calculate which tiles are required.
- /app-content – a JSON file with the latest text content for the static pages within the mobile app

App
The information architecture and navigation of the app is more fixed than the website. The views are preconfigured and most of the UI components are distributed with the application package. When online, however, the app fetches fresh JSON data for the map and the

\(^{10}\) http://geojson.org/geojson-spec.html
content, as well as the place images through Angular $http service calls. Offline behaviour is described in the next section.

6.5.4. Reliability without a network connection

This is probably the most technically challenging part of the project as it not only brought together information exchange between the server and the front ends, but also required a different approach for the web and the app.

**Web**

Offline reliability is not considered a core requirement for the website as there is a mobile app available which is by default more offline oriented. However, because the evaluation was supposed to compare equivalent features of both front ends, the website needed to be reliable offline at least in specific hardware and software context. To achieve this it uses an emerging technology called Service Workers (Gaunt 2014), currently described by a specification with the status of W3C Working Draft (Russell et al. 2015). A service worker is a programmable JavaScript proxy runs on the client-side in the browser. Once registered for a given URL origin, it can monitor and intercept any network requests made by that origin, and work that with them using the Fetch API and the Cache API. Service worker also runs in a separate thread, which means it can work with network requests without delaying the webpage. In fact, the service worker is completely isolated from the DOM, with which it can communicate only using events.

The service worker implementation in the trail guide is used specifically to make sure that any downloaded resources stay cached and are accessible if the user visits the website later without a network connection, as is likely in a remote outdoor context. It also calculates which map tiles will be needed and pre-fetches them when it is installed. The service worker lifecycle is mainly focused on the ‘install’ event.

The website does not rely on the service worker to deliver the core functionality, it is treated as progressive enhancement (Gustafson 2008). Importantly, it functions on a completely separate layer to the website. There is a feature check (for navigator.serviceworker) before attempting to register the service worker, and for browsers
that do not support it\textsuperscript{11} there is no further action. The service worker deployed for the trail guide uses a boilerplate library called sw-toolbox\textsuperscript{12} to handle common scenarios like pre-caching (map tiles and webpage resources), fetching network-first (content) and fetching cache-first (place images), according to recommendations for service worker best practice by Archibald (2014). The service worker requests from the CMS server a dynamically generated list of resources\textsuperscript{13} it needs to add to the cache after installation. It then calculates what tiles are needed to pre-populate the map tile layer on the basis of the map parameters, appends them to the list of resources and pulls all these items into the cache after it is registered for the origin. The algorithm for converting geographical coordinates and zoom levels into tile xyz identifiers is taken from Allensworth (2015) under the MIT licence.

Because the map tiles represent the significant data payload, especially in mobile, the decision was made to limit the map area and zoom levels to a usable minimum. Ultimately, the map area is restricted to covering only the current extent of trail POIs at three zoom levels (14-16). This keeps the amount of map tile data to be pre-cached at approx. 16MB (320 tiles). Including even one additional zoom level to allow more detail on the map would quadruple the number of tiles resulting in a payload that would not be advisable on mobile phones. There would be room to further refine which tiles are cached, for example by allowing the user the option of which zoom level they want to use offline, or only allowing the detail zoom level if there is a network connection. Alternatively zones of different detail could be added with a maximum zoom level pre-cached only for certain areas with a larger concentration of POIs. The current zoom levels seem to be sufficient for the intended use of the app, and were not raises an issue by users during the evaluation. This has implications for future modifications to the trail in the CMS as there is a limit to the geographical extent of pre-caching the map. This means that if places that do not follow within the current map bounds are added by content editors, there will be a need to engage a developer to optimize the tile calculations.

\textsuperscript{11} Support is at roughly 40% of UK users as of November 2015 (http://caniuse.com/#feat=serviceworkers)
\textsuperscript{12} https://github.com/GoogleChrome/sw-toolbox
\textsuperscript{13} https://broadfordbaytrail.org.uk/en/get/resource-list
Having spent time on researching the service worker solution and implementing it, I was certain that it could be applied seamlessly to the app running in a web view. I knew that the service worker could be registered either through HTTPS or locally, and assumed a local device web you would fall into the latter category. Unfortunately this turned out to be wrong.

**App**
The definition of “locally” for service worker registration is strictly through http://localhost and this is the only non-HTTPS option. Since the web view on android device uses the file:// protocol and the local device path as its origin, it became apparent that the service worker solution would not work at all.

Due to this, only enough progress enough was made on the caching functionality of the app to allow fully evaluating it with users in an off-line scenario. What this means is that as submitted for the MSc deadline the mobile app will not automatically synchronize new content from the CMS. This section is a discussion of the partial solution implemented and the possibilities to complete it.

The map tiles are cached using our Cordova plug-in extension called TileLayer.Cordova by Allenworth (2015). It extends the LeafletJS TileLayer class to load map tiles from a local device file system and provides utilities for tile calculations and downloading.

In the app, dynamic caching has only been resolved for map tiles. If the map parameters (latitude and longitude bounds, and zoom levels) are changed on the server, it will recalculate and top up the cache with any extra tiles upon reading the new GeoJSON when online. At the moment, the application will only use the latest content and image files files from the server if it is online. If it is offline, it will fall back to the content and images distributed with the application package. The departure from requirements is that it does not currently cache CMS content updates. I have been unable to complete the implementation of this detail for the deadline. This would require writing code to download the images and save them to the Cordova filesystem14, as well as caching the content JSON and GeoJSON, most likely using the Local Storage API. Although this seems like a quick task, my experiences with the Cordova filesystem are that it takes time to test and resolve issues.

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14 Which is largely similar to the HTML5 File API http://www.w3.org/TR/FileAPI/
There would also have to be cache breaking functionality in the system, for example based on an update hash appended to the resource JSON files.

In any case the full solution should offer a better UI with a progress indicator for downloading the resources to be cached. At the moment this happens without notifying the user of how much data is cached and how long it will take, which is a potential usability problem. Also the web version would benefit from having the service worker notify the pages when it has finished pre-caching all the resources.

6.5.5. Multilingual interface and content

Both versions populate their interfaces, content areas and language switchers on the basis of a global language variable.

**Web**

The content in the CMS is structured with parallel language-specific database fields with the language prefix e.g. title_en, title_gd; place_name_en, place_name_gd. There is also a global server-side {lang} variable, linked to the first segment of the URL being /en/ or /gd/. These URL segments point the browser to the /en/ and /gd/ subdirectories on the server each with a PHP file that sets the {lang} variable before serving the rest the site. The website’s templates then use information to dynamically select the content on the server side.

**App**

The Broadford Bay Trail app is built using Angular hence all the language switching is done and the client-side, necessitating a different approach than a website which can have different pages for different language versions. Translations are displayed to the user on the basis of the main (global) controller for the application, which has a variable in the global scope (lang) as well as using a global $translate service. There are three main ways in which content is selected.

1. **String replacement.** There is a JSON source of content from the site which is pulled in and processed using Angular’s angular-translate module and distributed throughout the app content areas using directives and filters.
2. **Toggling visibility.** There are certain items in the UI which are shown or hidden based on the value of the $scope.lang variable.

3. **GeoJSON translations in map interface.** Because the content for the POIs enters the app in a GeoJSON format, it is handled by the MapCtrl directly.

### 6.5.6. High technical quality

A number of tools and practices were used to make the development process more structured and improve the quality of the final product.

Code quality tools like JSHint and JSCS were used, and the configuration files for these can be checked in the source code directories.

The project also used BugHerd\(^{15}\), a visual bugtracker, track layout and style problems across various screens. Close to 50 issues were identified and logged with this tool during the project’s development.

The automation tool GruntJS for the web version and GulpJS for the app have helped with streamlining the build and development process. The task configurations are available in a Gruntfile/Gulpfile in the root of each project on the CD.

The project uses git for version control and BitBucket\(^{16}\) as a code hosting platform. Deployments are automated in a Continuous Integration process using Codeship\(^{17}\), a cloud-based build tool that tracks the commits in the remote repository, build and test the project and are dynamically created VM and runs a configured deployment script to upload to the production server. Such a setup not only allows sharing of code and backups but also for instant incorporation of changes in the code to the production version. The project does not have a unit test harness set up at present but this is a possibility with Codeship, between the remote build and the deployment script itself. If recommendations were to be made about improving the tooling of the project, writing JavaScript unit tests would be the primary choice.

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\(^{15}\) [http://bugherd.com/](http://bugherd.com/)

\(^{16}\) [https://bitbucket.org/](https://bitbucket.org/)

\(^{17}\) [https://codeship.com/features](https://codeship.com/features)
Attention was paid to accessibility good practices when building the web version, equivalent to WCAG2 single-A level. The tota11y scanner from Khan Academy\(^{18}\) and the open source screen reader NVDA\(^{19}\) were employed for a basic accessibility check. Some shortcomings are still present, noticeably with NVDA access to JavaScript-generated map pop-ups, but these can be resolved given more time.

6.5.7. **High usability through evaluation**

An important core requirement of the project was achieving high usability through evaluation with users. In addition to a formative at the prototype stage, the next chapter describes the usability study that was undertaken at the end of the MSc stage of this Digital Trail Guide. Because Cànan hopes to develop and market the Digital Trail Guide product further, the study can be seen as a basis for iteration, rather than being summative and final.

\(^{18}\) [http://khan.github.io/tota11y/](http://khan.github.io/tota11y/)

\(^{19}\) [http://www.nvaccess.org/](http://www.nvaccess.org/)
7. Evaluation

This section describes the summative evaluation of the project. Due to the fact that this was a “Software Engineering Project” as defined in the MSc guidelines (MACS 2013, p.3), there is no central hypothesis that needed to be proved or disproved. Rather, the goal was to develop and evaluate the usability of the working software solution.

The evaluation was in the form of a usability field study comparing the website and the mobile app to assess the quality of the final product relative to user expectations, and an established usability questionnaire.

7.1. Aims of evaluation

1) Gain an overall indication of the usability of both front ends of the system
2) Compare the user-reported usability of using the website on a mobile phone versus the mobile app, under real outdoor conditions
3) Get qualitative feedback on the trail guide and the physical layout of the trail

7.2. Acknowledgment of limitations/biases

Due to the necessity of field testing the system in a fairly remote location as well as the time constraints of the project, it was not possible to conduct a high enough number of field trials to gain a small confidence interval for the findings. This is acknowledged as a shortcoming of the evaluation but for the purposes of initial usability testing, the number of users is deemed sufficient to give a general indication of trends.

The main premise of the evaluation was to make sure it is methodologically sound albeit based on an insufficient amount of data for in-depth insights. It has to be acknowledged that the users were a convenience sample; however every effort was made to make it representative of the intended audience. In any case, despite difficult logistics and weather conditions, the number of participants is in line with the recommendations of the MSc project evaluation section of the MSc guidelines (MACS 2013, p.6).

Due to the nature of the field study requiring it to be run personally, it is necessary to acknowledge the possible social desirability bias (Albert & Tullis 2008, p.126) which means that the scores are likely to be higher than if they were collected in a more impersonal fashion.
7.3. Professional, legal, ethical and social issues

As with any piece of research, especially involving users, there are a number of important issues to address in how it is planned and executed.

The use of human participants in experiments, in this case in a usability study, requires relevant University ethics approval forms to be completed. As participants were not staff or students of Heriot-Watt, a full ethical approval form (MACS Research Ethics Committee 2011) needed to be completed. A risk assessment form was also completed for the field study.

From the side of the participants, consent for using their data had to be obtained, along with informing on how it would be used. Since there is no need to personally identify the subject, the data was anonymised during collection and disposed of after the evaluation was completed. Also, there were be open questions in final part of the survey, and as such there was scope for users entering information that might be sensitive. This is a usual drawback of taking free-form feedback, and participants were instructed not to put in any personally identifiable or sensitive data in the open ended fields, and also that filling them was is not obligatory and that they could retract their consent for using their information at any time.

Further practical issues relating to external factors had to be considered. The field study involved activities in an area where study timing and the weather could cause issues. The evaluation took place outdoors in November and December, and at times during the inclement aura for which the Isle of Skye is famous. Although these conditions are not typical of the summer tourist season, it is assumed that if it is possible to use the app the results will be transferable to better weather. The evaluation had to account for the possibility of cancellation of user sessions if the conditions were particularly bad.

7.4. Study design

Because the difficulty of organizing user sessions outdoors, and considering a fairly remote location, the study had a within-subjects design to maximise the available data from a small group of participants.
The participants were asked to use the app to find and visit eight of the places on the trail, clustered close to the village centre. They were also asked to read content pertaining to each place found within the application and informed that they would fill in a short survey after the study. The figure below shows the topographical layout of the selected subset set of trail points.

The sequence of testing for each individual person was: start on the path north of the Liveras Cairn, visit 4 places using one version of the trail guide, reach the changeover point roughly in the middle, visit four other places using the other version and finish at the other terminal point to complete the questionnaires. To compensate for transfer of learning the app and the trail, participants were randomly assigned the version they started with. The version assigned as first was used to explore places 2, 4, 3, 6 on the map above, and the second for places 10, 9, 7, 8. The sessions were roughly 30 minutes long, plus an additional 15 minutes questionnaire and interview time, and were run unaccompanied to limit potential influence from the researcher. The only point of contact was the changeover point, which marked the boundary between using the two versions of the guide. After filling in all the parts of the questionnaire, there was an informal conversation with the participants about what they liked and did not like in the particular versions, sometimes with demonstrations of the problems. This was a valuable opportunity to add information to the open questions sections of the questionnaire.
7.4.1. Choosing the metrics

The study focuses on self-reported metrics on purpose, and ignores other quantitative measures of success. The core feature of the product is to help people locate a number of places and guide them between them. As such, it is natural that any task-based study should focus on the success rate of finding the places. This would make gathering task success data challenging. In an uncontrollable and random outdoor environment, it did not make sense to gather time-on-task metrics which could be influenced by walking speed, traffic, and weather among other things. There were options to measure task success with photography, for example asking the users to take a photograph of each site to match those already in the application.

Local users, however, would likely know most of the sites in the guide. Thus, considering the small sample size and the proportions of first-time and repeat visitors and locals such a success criterion was unlikely to deliver meaningful insights. Additionally, because the trail itself (the number of stations and how spread out they are) ended up being much more geographically concentrated than the initial design, there was not much scope for extensive task testing.

Ultimately, to include a task in the study, the participants were simply asked to use the guide to visit the 8 POIs in the test set. Participants were also informed beforehand that a short set of 3 comprehension questions relating to the content would be distributed post-task. These questions did not have the intent of testing how well the users did, but simply to motivate them to engage with the content, rather than simply the locations. The fact that the questions were not used to measure success was not revealed to the participants.

7.4.2. Evaluation conditions

The hardware was provided and was the same for all users, a typical low-spec phone running a modern version of the Android OS, with the web version pinned to the home screen to look like an application alongside the full mobile app. Both pieces of software displayed icons of the same name: “The Broadford Bay Trail” and were not overtly qualified as either a website or app to the users. Post-study, upon enquiring for more information about the trail, some users were surprised that one version was the same as the website available at https://broadfordbaytrail.org.uk.
7.4.3. Questionnaire design
The questionnaire consists of the following parts: introduction and consent, usability of first guide variant, usability of second guide variant, basic demographics, opinions on the trail and technology preferences and a quick content check. The design was informed mainly by guidance from (Albert & Tullis 2008) and (Sauro & Lewis 2012), with the SUS section adapted from the companion website of the former (Tullis & Albert 2012). The questionnaire is included in full in the Appendices section.

Introduction
This part contains the privacy/ethical disclaimer, an overview of the study process, an outline of the risks, and instructions for the task.

Usability (the same set of questions for each front end)
The Standard Usability Scale (Brooke 1996) was chosen as a self-reported means of assessing usability on account of its wide adoption in research and industry, and clearly established benchmarks. The SUS part of the questionnaire was administered immediately following interaction with the given guide version i.e. once at the changeover point and once at the end.

Qualitative questions
Because SUS does not give specific qualitative information as to the major usability issues, follow-up questions were included in the study to gather opinions from users:

1. What are the most important improvements, if any, you would suggest for this version of the guide?
2. What improvements, if any, would you suggest to the trail layout and locations themselves?

Question 1 was asked after each version of the trail guide and question 2 at the very end of the session. It has been proven that a study involving as few as 5 users is likely to discover a significant proportion of usability problems, assuming a high probability of those problems occurring (Nielsen & Landauer 1993) so the anticipation was that this was a sensible way of identifying some of the most serious issues. Post-study, the information in the open
questions was supplemented by an informal conversation about particularly difficult or frustrating problems.

**Demographic data and technology preferences**
Basic demographic information (age, nationality, familiarity with the area) and questions included to control for participants’ preferences for using guides, websites and apps on smart phones. This part was administered post-study.

**Content check**
This is a quick set of 3 true/false questions relating to the information within the guide. They could potentially yield the measure of success rate in finding details within the guide but this seems to be too close to reading comprehension to form a valid metric of success. Hence, they are not used in the study but are included and introduced at the start of a session only to ensure participant engagement with the content.

7.4.4. **Hypotheses**
The study aimed at finding out if both front ends will achieve at least a SUS score of 70 in identical conditions, which is considered a standard for “good” usability (Bangor et al. 2009) and whether, despite having the same features implemented, the app would score higher than the website.

**Hypothesis 1A**

*The trail website will score at least 70 points on the SUS scale when used on a phone.*

**Hypothesis 1B**

*The trail app will score at least 70 points on the SUS scale.*

**Hypothesis 2**

*The website will less usable than the mobile app when used in the field, all other conditions equal.*

Hypothesis 2 is not a forgone conclusion as the website is specifically optimized for use on smart phones and has the exact same feature set as the app, but realized according to web
conventions, not native app conventions. As such, it could outperform the app in SUS scores.

7.5. Sample description
This section describes the characteristics of the target population and how participants were selected for the study.

7.5.1. Target Population
It is envisioned that the appeal of the digital trail guide will be broad, especially within the area is popular with tourists as the Isle of Skye. However, because the guide is designed to be easily editable by community volunteers, this appeal might extend beyond just infrequent visitors. Depending on whether the content will be expanded to include less known places, the guide could be of use for both people who already know the Broadford area, including local residents. This means that three broad groups could be distinguished within the target population: tourists unfamiliar with the area (first-time visitors), tourists familiar with the area (repeat visitors) and locals (residents of Skye and neighbouring areas).

7.5.2. Sampling method
Unfortunately, due to the time of year the evaluation took place (December, in the off-season) there was not much scope for random recruiting of tourists. This was further impacted by a particularly stormy evaluation week, with ferry cancellations, severe weather warnings and widespread flooding making the recruitment of the tourist/visitor target population group very difficult. Recruitment through facilities like the former tourist information office and a local hostel were unsuccessful. An advertisement was put in the Broadford and Strath community newsletter to recruit local participants. Acquaintances from elsewhere with a known interest in visiting Skye were also invited to travel to take part, and they represented visitors segment of the potential users reasonably well. Within the available resources, effort was made to make sure that this convenience sample reflected as much as possible the actual intended target audience. However, it is acknowledged that the sample is neither random nor matched to the proportions of the 3 user segments in the intended target audience, and this has to be considered when evaluating the applicability of the results.
7.5.3. Sample description

The total sample size is \( N = 10 \) and all illustrations and calculations are based on this size. The question about user population segment had 3 values on the questionnaire (local, first-time visitor, repeat visitor) but because of the small sample size these were converted to a binary opposition (local, visitor) when processing the data. Accordingly, the sample is 60% local and 40% visitor. The sample shows variation in nationality and usage of smartphones. Nationality is split almost evenly between home and abroad, 5 being UK and the remainder German (1), US (1) and Polish (3). Use of smartphones is at 40% Android (the testing platform), 40% iPhone and 20% non-smartphone users. Age (Tab. 1) is clustered around the mid 30s, with some outliers at minimum 24 and maximum 63. As to the preferred format for a digital trail guide to an unfamiliar area, all participants except one chose “App on phone”, highlighting the need for trail guides websites to be available in an app format.

7.6. Statistical Analysis

Due to the nature of the field study requiring it to be run personally, it is necessary to acknowledge the possible social desirability bias (Albert & Tullis 2008, p.126) which means that the scores are likely to be higher than if they were collected in a more impersonal fashion.

7.6.1. Descriptive statistics

The individual SUS scores for each version were calculated according to the standard method by Brooke (1996), keeping in mind that the component questions of SUS do not constitute reliable measures by themselves. Interestingly, the mean and median are the same for both SUS sets. The raw data was checked again for input errors but was entered correctly. The frequency information is be shown on the following histograms.

<table>
<thead>
<tr>
<th>Mean</th>
<th>35.70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>36.00</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>10.874</td>
</tr>
<tr>
<td>Range</td>
<td>39</td>
</tr>
<tr>
<td>Minimum</td>
<td>24</td>
</tr>
<tr>
<td>Maximum</td>
<td>63</td>
</tr>
</tbody>
</table>

Table 1. Age in years

<table>
<thead>
<tr>
<th>Mean</th>
<th>78.0000</th>
<th>78.0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>78.7500</td>
<td>78.7500</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>11.83216</td>
<td>12.06464</td>
</tr>
<tr>
<td>Range</td>
<td>35.00</td>
<td>32.50</td>
</tr>
<tr>
<td>Minimum</td>
<td>60.00</td>
<td>65.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>95.00</td>
<td>97.50</td>
</tr>
</tbody>
</table>

Table 2. Descriptives of SUS scores
The SUS data within the sample has been established to conform to an approximately normal distribution on the basis of the standard indicators recommended by Löfgren (2013). For SUSweb and SUSapp the skewness was very low (0.255 with SE 0.687 and -0.007 with SE 0.687 respectively) and although the data was somewhat kurtotic (-1.410 with SE 1.334 and -1.238 at SE 1.334 respectively) the skewness and kurtosis z-values\textsuperscript{20} fall within a +/- 1.96 z-value range, which, according to Löfgren, could be taken as an indication of normality.

A further reason to accept the plausibility of normal distribution were two normality tests prompting not to reject the null hypothesis of the data being normal since the p-value for both tests is greater than 0.05.

<table>
<thead>
<tr>
<th></th>
<th>Kolmogorov-Smirnov\textsuperscript{a}</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>df</td>
</tr>
<tr>
<td>SUSapp</td>
<td>.151</td>
<td>10</td>
</tr>
<tr>
<td>SUSweb</td>
<td>.208</td>
<td>10</td>
</tr>
</tbody>
</table>

\textsuperscript{*} This is a lower bound of the true significance.

\textsuperscript{a} Lilliefors Significance Correction

Table 4. Tests of normality

Finally, a visual confirmation of a distribution close to normal was seen on a normal Q-Q plot.

\textsuperscript{20} i.e. the skewness and kurtosis divided by their standard error (SE)
Because the data has not been proven to lack a normal distribution, it is assumed that it is approximately normal for the purposes of further inferential analysis with parametric tests.

7.6.2. Overall system usability (Hypotheses 1A and 1B)

Due to the assumed normal distribution and the SUS scores being interval type data, a t-test can be performed to check the significance of the score comparison. In this case, it is the standard 1-sample t-test that is used to test whether the each version’s SUS score mean is greater than 70 in a statistically significant way. The null hypothesis will be rejected at the significance level $p < 0.05$. The hypotheses for the web version achieving at least a “good” level of usability are as follows:

$H1A-0$: $meanSUSweb < 70$ (null hypothesis)

$H1A-1$: $meanSUSweb \rightarrow 70$

By analogy, the hypotheses for the app version can be phrased as:

$H1B-0$: $meanSUSweb < 70$ (null hypothesis)

$H1B-1$: $meanSUSweb \rightarrow 70$
A one sample t-test with a test value of 70 yields the following results:

<table>
<thead>
<tr>
<th></th>
<th>t</th>
<th>df</th>
<th>Sig. (1-tailed)</th>
<th>Mean Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUSapp</td>
<td>2.138</td>
<td>9</td>
<td>.031</td>
<td>8.0000</td>
<td>-.4642 - 16.4642</td>
</tr>
<tr>
<td>SUSweb</td>
<td>2.097</td>
<td>9</td>
<td>.035</td>
<td>8.0000</td>
<td>-.6305 - 16.6305</td>
</tr>
</tbody>
</table>

Table 6. One sample t-test results

On the basis of the 1-tailed significance values, the null hypotheses are rejected in both 1A and 1B, and the hypotheses H1A-1 and H1B-1 are accepted.

7.6.3. Comparative Usability of front ends (Hypothesis 2)

The final research question is which system users rate higher on a smartphone: a responsive website wrapped in a chromeless webview and optimised more towards mouse interaction and a larger screen, or an HTML5 mobile application in a native wrapper. The expectation would be that the app should be preferred; hence we can formulate the following hypotheses.

H2-0: meanSUSweb <= meanSUSapp (null hypothesis)

H2-1: meanSUSweb > meanSUSapp

Again, the null hypothesis will be rejected at the significance level p < 0.05. The normal distribution of the data allowed use of a paired samples t-test with the following outcomes.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (1-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUSapp - SUSweb</td>
<td>.0000</td>
<td>14.71</td>
<td>4.65</td>
<td>-10.529 - 10.529</td>
<td>.00</td>
<td>9</td>
<td>.500</td>
</tr>
</tbody>
</table>

Table 7. Paired samples t-test results

The null hypothesis that the app has a higher SUS score than the web version cannot be rejected on the basis of the 1-tailed significance value.
7.6.4. Analysis conclusion

For hypotheses 1A and 1B, it has been shown that the SUS score for each version have surpassed the benchmark level of what constitutes “good usability” (70 SUS points) and that the results for both versions are statistically significant. On the other hand, for hypothesis 2, there is no statistically significant difference between the mean SUSapp and SUSweb scores that can be proved on the basis of the data. This does not necessarily mean that there is no SUS score difference but that it is not possible to determine it with the given data. Because the SUS means and medians are equal, it is possible that the difference is very small, hence would only be detectable in a much larger sample size.

7.7. Qualitative questions

Although it can be demonstrated that both versions have reached a good standard of SUS usability, there doubtlessly remain multiple improvements needed to make the product better. To add an additional actionable body of information, the participants were asked after the study about what they entered in the open questions suggesting improvements. In particular, any annoyances or difficulties they encountered were clarified to plan improvements to the UI. This section describes the most commonly indicated areas of usability problems. Were a participant is quoted directly, their participant ID is quoted.

7.7.1. Touch/click interactions

Touch target (marker) sizes in the web version where too small for the majority of finger sizes. While they worked as click targets, in an outdoor environment for the distractions, they should be bigger to facilitate getting to the POI information.

7.7.2. Activating selected and detail view

Several users suggested going directly to the POI detail view, without an intermediary step of a POI header with the name being shown and an extra click required to access the information. The rationale for the implemented version was that users would be interested in checking the name of the place and keeping it location on the screen before deciding to access more details, but it seems an action could have been saved if all the information is displayed immediately, even though it covers the whole screen (#2, #4). “One click should be enough” (#3). “Too many gestures to get information on each POI” (#5).
Bugs related to activating the selected state of the marker from different parts of the application were discovered, and remain to be fixed.

The bright colour of the location header in the app version which was intended to make it stand out was sometimes interpreted as a warning signal, especially complemented with the X icon. “The red strip at the top of the map looks like a warning thing. It wasn’t obvious that it is meant to be there and that you get more info there” (#2). “There could be an introduction explaining (i)21” However, for another user, the red POI header was “too distracting” (#4).

Back button interaction22 problems such as the detail view of a place not being included in the history stack of the application were also reported (#10). Eventing for the back button might prove to be problematic in the web version.

7.7.3. Geolocation issues
Overall, few issues with geolocation were reported but the combination of having the activating button and the person marker the same colour as in the web version was preferred over making the marker a more similar style to the locations ones. It was also not obvious for several users that there was an option of geolocation (#5, #6).

7.7.4. Web version issues on small screens
Because the web version, despite being presented as an app, was a responsive website also designed for larger screens, it was expected that it would have specific issues.

Having to scroll all the way to the top of any page to get to the menu was a pain point (#10) and could be avoided by adding a duplicate menu at the bottom of the page while in a small screen. Indeed very few users used the menu button at the top of the web version because they would start scrolling immediately trying to get to the content, and they would navigate to the map page through the link on the main map image in the middle of the starting page, rather than through the menu as it is more likely while viewing the web version on the larger screen.

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21 The “i” in a circle icon used to get more details about the POI selected on the map
22 An Android-specific issue
The positioning of the marker pop-ups (POI title and image) was also problematic. “Photos of various places should be better localised on the map no matter the zoom. Currently in the strong zoom many photos display in the same place when individual locations are chosen. This is a bit confusing” (#7). The zooming and scrolling separation between the Trail Map page and the map itself was also a source of confusion: “need to press within map to scroll but not on any open window”. This is a clear drawback of having the map not be full-screen but placed within the context of a page. There are no fundamental technical obstacles to resolving these issues and the website would simply need a lot more mobile specific optimisation.

7.7.5. Performance related issues
Several users were put off by performance issues related to interaction. Especially the web version it was noticeably slower, leading to user confusion with scrolling and touch events being delayed. “It could look a bit more attractive if transitions between screens could be smoother” (#3). Although users did not often suggest performance is a problem in their comments, the observations of them using the guide have definitely highlighted this problem. As the project uses numerous third-party libraries, much work remains to be done on optimising which parts of them are not being actively used and how the all work together. Definitely the CSS load could be much less and an audit of what JavaScript components are strictly necessary to include in the deployed version. Additionally, at the current stage of the project all console logging was left enabled and none of the source files were minified, to make examining the project easier. Image optimisations could also lighten the load, although delays due to bandwidth this is secondary since the guide can work fully off-line, and is designed to aggressively cache the resources when possible.

7.7.6. Additional features suggested
Some features were features were suggested that did not target usability issues as such but were ideas for extending the system. While there are numerous elements of functionality that could be added to any system, it is felt that the ones described in the section could have more validity because they were suggested by real users, after using the guide. For example, a stronger “planner mode” of the system (Riebeck et al. 2008), could help users progress from the initial app launch to fully engaging with the places quicker. One idea to do it was to organize it is the places into logical sequence and the system would suggest the
next one based on a proximity alert. “It would be good to have an obvious button for starting the walk” (#2). “A little bit difficult to get into it” (#6). Especially with more places on the map, adding a “visited” state for markers could be desirable (#10).

Several users remarked on missing multimedia content, especially audio recordings. This would take the trail guide more towards an audio guide but certainly could be considered if the appropriate recordings were available. Sounds were also suggested as an interface element, to alert the users about reaching an important location.

One user also suggested routing capability and estimating time/distance, but these were excluded on purpose while evaluating the technical requirements and the available GIS data for the area.

7.7.7. Accessibility

A special consultation session with a Skye and Lochalsh Access Forum representative was scheduled to get feedback on the accessibility of the system and the physical trail but had to be cancelled due to the inclement weather conditions, unsuitable for a wheelchair user.

7.7.8. Trail layout

As to the layout of the trail, suggestions were made about restoring the Lime Kiln area, and adding additional sites like the ammonite site at Irishman’s point, the Campbell Memorial or the Isle of Pabay out in the bay. These will be passed to the Broadford and Strath Community Company when they take ownership of the project early in the new year. It would also be desirable to modify the map, to include the smaller local paths which were not included in the Mapbox data.
8. Conclusions

8.1. Reflections on field testing of software designed for outdoor use
There is a difference in how users interacted with the prototypes, informally and indoors, and how they interacted with the system in the real context it was designed for. Although it had its logistical challenges, running the field study was a good experience of trying to run a study in an unpredictable environment.

8.2. Comparing web and mobile usability
The data delivered surprising insights into the minimal, if any, difference in perceived usability of the versions. Even though, most users would on their own comment that they preferred one version over another, the data did not seem to reflect this. It is entirely possible that this was due to a flaw in the study design or execution, however it would be interesting to find out more about the effect size in a larger sample.

8.3. Workload
Having gone through the experience of organizing and executing this project, I can say in hindsight that the project plan was too ambitious and I planned too many new technologies to learn. This caused the need for a rapid re-evaluation of how much I could do myself and required introducing numerous third-party components to achieve the project’s goals. This was just on the technical side, and not including the content visual design and crucially, the infrastructure set up time for deploying the application publically. This had not been accounted for at the planning stage. By necessity, this meant that the work I have done on this project has been fairly thinly spread out across a large number of areas, without innovative technical solutions and heavy third-party leverage throughout.

8.4. Further perspectives
The Broadford Bay Trail guide project will be handed over to the Broadford and Strath Community Company in early 2016. A training session for the content curator will be run and recommendation has been made to recruit a community champion to extend the trail.

Multiple improvements are needed at all levels of the package, most notably in the data synchronization, web front-end performance and user experience, but there is a hope that the project will proceed, and can be applied to other places.
9. References


Derry City Council, 2006. *Wireless City Project - Good Practice Transfer Document*.


Oxford Internet Survey 2013.,


Löfgren, K., 2013. Normality test using SPSS: How to check whether data are normally distributed. Available at: https://www.youtube.com/watch?v=liedOygLn0 [Accessed December 8, 2015].


McNeil, H., 2006. Broadford & Strath Landscape Legacies: Landscape Character Study,


10. Appendices

10.1. Commit list

In order to show how the code base evolved, this section lists the git commit titles over the course of the project. The web/app prototypes were not version controlled but their sources and final versions are attached on the codebase CD and described in the next section.

10.1.1. Website codebase (79 commits)

383c8c6 Split /get/resource-list into 'web', 'img' and 'app'
37f20b5 Adjust popup interactions
94bad69 Improve geolocation UI
09a1459 Limit map scrolling
47de46f Enable bounds check on location found to make sure the user falls within the cached tiles
370c85f Complete geolocation including animations and dynamic position update
05b244b Use mapbox (mustaches) template for popup markup
80b177f Modify geolocation to continually update marker position
d106abb Make overlay size correctly on small screens
23d8c9 Add constantly updating location and a togglable location UI
0ef2f99 Add selected icon and interaction
27f02c5 Improve geolocation UI
25666fc Adjust map bounds for mobile website restricted panning is obscuring part of the popup
a8869a Request all resources from service worker securely
4f4268c Adapt website worker for web/app resource list split
ab574df Shift /get/resource-list to a nested array
67f4d0e Split /get/resource-list to serve common and app resources separately
c435779 Improve map offline resilience switch back to http, adjust caching strategies, double cache tiles, change offline map background
5edd1ec Precache map tiles correctly substituting URLs in service worker to minimise data cached
4578dc8 Finalise and test web app manifest Now working on Chrome 46 Lollipop 5.1
d1f1d478 Fix manifest <link> element
6e77b9d Update web app manifest
fbcc139 Make map scrollable on narrow screens
d4ae63 Cache both resources and map tiles using the service worker
044ae4c Let ServiceWorker get resource-list from serves + calculate XYZ URLs for tiles in map script
7d04efb Enable service worker with hardcoded list of resources to precache
15d6a14 Emit app static content through JSON
4900ba2 Add web app manifest and associated resources
3fcb78f Expand GeoJSON with map config and adapt map script to match
2e0f2fe Add bounds as an object to geoJSON
e207039 Extract content page images into templates
aac88cb Add sw-toolbox and restrict map bounds
5f932f7 Fix mobile menu not working outside Trail Map page
1ecc6bf Add stubs for content/resource JSON files
0dde354 Add basic service worker
4d1600e Update SFTP deployment batch file
fbe2fb4 Recommit again to fix missing files
b60592 Recommit template files
5b23f7c Move repo one level up in dir structure
9cdc08b Add selected marker images
d638047 Suspend download app buttons until publishing in Google Play at least
0ea9692 Remove rmdir from deploy script
290a439 Improve responsive layout of POI overlay
af72fa8 Fix minor BH bugs
5234c99 Add app marketplace logos
b106b1e Try rmdir with sftp
57be6a Another try
851aa3e Another deploy try
0e5586f Experiment with relative paths for deployment
f94fe21 Add bounds to map panning and zoom
6ee33a2 Add deployment config for Codeship
9c2f8ed Change locate icon and animate it
4374e19 Add https for static map on homepage
d5b2a79 Delete bbt-backup dir
4365bbd Add favicon
fd73c0 Add geolocation with basic functionality
d09912d Restart development after summer break
97d69ac Update marker icons + refresh scripts
baab0d3 Handle language switch on homepage with no /en/ or /gd/ segment in URL
984a3ae Add Gaelic content to homepage and footer
0841680 Add Analytics
ec97542 integrate V's corrections, fix BH queue, delete unneeded files inc app
d51f223 upload to broadfordbaytrail.org.uk
e37e60a finish v1 of styled map screen
235f018 finish mqs for header menu, uploaded to live
73e92f2 style map page
8c0508a correct a few Gaelic strings
f887c77 read external json in
3188b8e finish basic content page template
caa5f53 style/layout for homepage
da500e style basic header and footer
ff4a638 add colours to css + general small progress
App codebase (68 commits)

d2956da Merge branch 'cacheExperiment'

93a6681 Fix refactoring typo in geojson access that broke the whole app! because
the app relies on Cordova FileSystem now, it will not run correctly in a browser on
a computer

aa8dfc Tidy up comments and minor refactorings, final pre-MSc commit

b2b22cd Update geolocation icon colours to green

5d7cd3 Make back button exit app from the map screen

7a6dbb0 Delay downloading/sync check of offline tiles until FS is ready to fix a
strange bug where the FileSystem is not ready despite being called after
DeviceReady? this one took 2 days to pinpoint

9d388d7 Add checking of network status in MainCtrl

d964a Add fallback to cached GeoJSON for map

c212ce9 Use ionic wrapper for deviceready

9eb1686 Try and catch deviceready at the right moment to access the file system

4d2b7c Tweak geolocation timeouts and UI messages

8db2409 Add content header images to static files (they are different than the site
and are not designed to be editable)

a6cca49 Fall back to resources from local filesystem

683c1cb Consider device state before tile caching

32ed8ae Add tile caching

d479d1e Substitute angular-leaflet layer for TileLayer.Cordova

e85e809 Add TileLayer.Cordova for caching on the local file system

3933ecc Keep service worker in project before branching to experiment with
filesystem tile caching

1450048 Add dynamically updated geolocation

a2d1516 Add single position geolocation (and associated refactor)

b1b99c1 Add scss structure for iPad map style overrides

fe5be53 Adjust iPad layout

7e2682c Implement geolocation functions not linked up to map yet

5e2106c Improve css coverage with autoprefixer

e056b9 Add service worker and adapt app for full offline use

db13142 Pull in translations for app content from CMS

63a0d3e Adjust sizing to work better on tablet

4fb381a Clean up code and add comments before pushing up to Bitbucket

39c2079 Link place selection on POI list to selecting the place on the map through
$rootScope, $emit (up) and $broadcast (down)
fa1e513 Add function to select a POI by poiId firing a native Leaflet event on the marker layer in question
00d256a Fix broken icon links on device
46bbaf4d Constrain to portrait orientation only
117c180 Align items on place detail overlay
5902423 Add select marker and map panning functionality
6403859 Finish refactoring TrailDataService - add error message - link to place list
27f7732 Implement the basic interactivity of markers (they display the header and content now with click events)
f662da2 Add language version to place detail
980b5a1 Read in data from service into map controller
b8048f7 Return simple promise from the TrailDataService
4c3020c Add POI details overlay
3ae1d0e Fix ui-angular events not firing by changing over to angular-leaflet
33e30f5 Align partner logos
ef456df Implement translations on everything except the map
f9689a5 Add logo images for sponsoring organisations
c644c7f Add working translation of content title using angular-translate
88ba50e Add language switching to settings controller
4d40f77 Make some progress with the TrailDataService GeojsonProvider
f53dde Non-working basic example of event
8e3e6ac Include new images and update about the area page
184b582 Add splash screen and map/zoom bounds
02be608 Remove leaflet zoom controls
6e5112d Add loading Mapbox BBT tiles and GeoJSON
690bf97 Add Mapbox GeoJSON (still not working on device though!)
78bc021 Add log message to mapCtrl
b2b7087 Restore webfonts deleted by local Ionic update
50a9252 Add static API map image to trail screen
770ae6e Display basic leaflet map
ababa01 Update all project packages through npm and add ui-leaflet
77d5fde Update Ionic library
f1c51aa Refactor controllers according to Pluralsight course
14d2e7d Complete content input of onto the tabs, except map and settings
celcada Refactor app structure from 'starter' to 'trailguide' by edits to tabs+js
3b5c6bf Generate default splash screens for Android
5bb4849 Style header and tabs footer on map page (no logo/title yet)
d8890e7 Remove Foundation media queries
0a2688c separate headers for each view
ab1a65 revert to ionic filenames for tabs, add JS code quality tool configs
ab11ef4 initial commit (Ionic tabs starter app with Ionic and bbt scss set up)
11. Third-party leverage

This section details which third-party products, modules and libraries were used to build the trail guide. The listing is mainly exported from the package managers used for controlling dependencies in the project, Bower and NPM.

11.1. Server-side

- ExpressionEngine https://ellislab.com/expressionengine
- Google Compute Engine https://cloud.google.com/compute/
- Bitnami LAMP stack https://bitnami.com/stack/lamp

11.2. Web (bower list)
11.3. App (bower list, cordova plugins list)

```
btt-app C:\Users\Mojtek\Dropbox\code\btt-app
   angular-leaflet-directive@0.10.0
       angular@1.3.6
       leaflet@0.7.3
       angular-translate@2.8.1
           angular@1.3.6
       ionic@1.0.0-beta.14
           angular@1.3.6
       angular-animate@1.3.6
           angular@1.3.6
       angular-sanitize@1.3.6
           angular@1.3.6
       angular-ui-router@0.2.13
           angular@1.3.6
       leaflet@0.7.3
       ngCordova@0.1.23-alpha
           angular@1.3.6
       platform.js@1.3.0
       sw-toolbox@3.0.0

com.ionic.keyboard 1.0.4 "Keyboard"
cordova-plugin-file 3.0.0 "File"
cordova-plugin-file-transfer 1.4.0 "File Transfer"
cordova-plugin-applocation 1.0.1 "Applocation"
cordova-plugin-network-information 1.1.0 "Network Information"
cordova-plugin-splashscreen 2.1.0 "Splashscreen"
cordova-plugin-whitelist 1.0.0 "Whitelist"
crg.apache.cordova.console 0.2.13 "Console"
crg.apache.cordova.device 0.3.0 "Device"
```

12. Codebase guide for attached CD

There are various technologies in various setups used for the code supplied on the CD so this section offers a brief summary of how the code is organized. Effort was made to include all the dependencies (bower_components, node_modules etc.) needed to build the projects, however, these are not needed if only browsing the source code.

12.1. web-prototype

The static-site-generator directory contains the source files for generating the web prototypes. The content, src and static directories contain the HTML/JS/CSS that is processed by Nanoc to output the full static site. The static-site-output directory contains the pure web technology assets. It should be viewed on a local HTTP server, not through file:// as it is built for server deployment.
12.2. **app-prototype**

This is a .livecode project with all the assets enclosed. The LiveCode environment would be necessary to open and inspect the contents. This is an unfortunate side effect of livecode being a proprietary technology. The fact that choosing livecode for any part of the project was a mistake has been discussed elsewhere elsewhere. A compiled Android APK of the prototype is provided in the build directory.

12.3. **web-production**

The source code for the web final version is limited to the front-end code that is output to the user. The pure production code is in `default_site` directory that contains `layouts.groups` (the HTML page templates), `get.group` (the JSON templates) and `dist.group` (the CSS/JS used by the site). The `src` directory contains the sources for `dist.group`: SCSS styles that get transpiled into CSS and JavaScript (mainly for the map) that gets concatenated with the deployed JS library code.

The `webapp-resources` directory contains the manifest and assets for installing the website as a progressive web app. There is no back end code included as this was provided with ExpressionEngine. Login information for the administrative interface and to the server to check configuration and content organisation could be provided but, because the system is deployed in production, cannot be included in here due to confidentiality.

12.4. **app-production**

The source code is an Ionic project. The `scss` and `www` directories contain the code written and assets created during the MSc, and the other directories are third-party components.
13. Screenshots

13.1. Web on large screen

Figure 13. Web on large screen - POI selected

Figure 14. Web on large screen - home page
13.2. Web on phone
Welcome to the Broadford Bay Trail

Broadford Bay is a stunning coastal area of both natural and cultural significance found in the south of the Isle of Skye.

We have created a trail between the New Pier in

Figure 18. Progressive app - home page

About the Area

The Isle of Skye is a key visitor destination which is internationally renowned for its spectacular scenery and historical and cultural richness. Broadford lies in the shadow of the Red Cuillin mountains and

Figure 20. Progressive app - static content page

Trail Map

The trail has 14 places located mostly along the shoreline of Broadford Bay, the map will show you the way!

Figure 19. Progressive app - initial map view
Figure 21. Progressive app - Old Pier Road area zoom

Figure 22. Progressive app - POI list

Figure 23. Progressive app - POI detail view
13.3. App on mobile

The Isle of Skye is a key visitor destination which is internationally renowned for its spectacular scenery and historical and cultural richness. Broadford lies in the shadow of the Red Cuillin mountains and along the southern side of Broadford Bay, where the other villages included in this trail, Waterloo, Breakish and Ashaig, are located. Views across the bay look to the Isle of Pabay and more distantly to Applecross on the mainland.

The wider area of Broadford and Strath is particularly special and includes many important facets of the Island’s heritage.
Figure 26. App - POI selected

Figure 27. App - POI detail view

Figure 29. App - POI list view

Figure 28. App - Old Pier Road area zoom
14. Study questionnaire
Broadford Bay Trail Usability Study - Introduction

Thank you for volunteering to take part in this study. Before you decide to participate, please read on to find out about the purpose of the study and what it will involve.

This study is part of an MSc project at Heriot-Watt University by Wojciech Dziejma and is being run to find out how easy it is to use the Broadford Bay Trail digital trail guide.

Your session will consist of a short walk through the main part of Broadford, using 2 different versions of a digital guide to find various points of interest.

The task is to visit all the places in the list in the order that makes for the shortest walk and read the information about each place. The walk will be unaccompanied and proceed in 2 parts: from here to Skye Gifts (next to the filling station on the waterfront, the old tourist information office) and from there to the end. **Please meet me at the small white Skye Gifts building in the car park before proceeding any further for the second part.**

As part of the study, you will be asked to fill in a survey of approximately 25 questions, mostly requiring just a tick. There will also be 3 true/false-type questions about the places at the end, based on the information in the guide.

*Because the session takes in an outdoor environment, there are certain risks involved. The weather is likely to be Skye winter weather. We are starting the session on agreeing that the conditions are suitable for a short walk within the village. Please make sure you are dressed warm, there is an additional warm and waterproof jacket for your use. The session can be interrupted if you are feeling cold, wet and uncomfortable, it is entirely your decision. Also, please be aware of the traffic, any obstacles and the surface conditions underfoot (especially on the footbridge and on the uneven Old Pier Road).*

The survey is completely anonymous and voluntary, you can quit the study or withdraw consent for using your data at any moment, without giving reasons. Please make sure you do not give any personally identifiable or sensitive information into your answers. The study should take about 30-40 minutes in total.

**Consent**

I agree to take part in a usability study of “The Broadford Bay Trail” digital trail guide. I have been given an explanation of the study, acknowledge that it is anonymous, and have informed that I can withdraw unconditionally at any moment. I am aware of and accept the risks as outlined above. Please tick.

[I agree and I want to participate] [I disagree and I do not want to participate]
**Instructions:** For each of the following statements, mark one box that best describes your reactions to the guide today.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th></th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think that I would like to use this guide frequently.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. I found this guide unnecessarily complex.</td>
<td></td>
<td></td>
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<tr>
<td>3. I thought this guide was easy to use.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I think that I would need assistance to be able to use this guide.</td>
<td></td>
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</tr>
<tr>
<td>5. I found the various functions in this guide were well integrated.</td>
<td></td>
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<tr>
<td>6. I thought there was too much inconsistency in this guide.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I would imagine that most people would learn to use this guide very quickly.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I found this guide very cumbersome/awkward to use.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. I felt very confident using this guide.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I needed to learn a lot of things before I could get going with this guide.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What are the most important improvements, if any, you would suggest for this version of the guide?

---

This questionnaire is based on the System Usability Scale (SUS), which was developed by John Brooke while working at Digital Equipment Corporation. © Digital Equipment Corporation, 1986.
**Instructions:** For each of the following statements, mark one box that best describes your reactions to the guide *today*.

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>I think that I would like to use this guide frequently.</td>
<td>[ ]</td>
<td>[ ]</td>
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<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2.</td>
<td>I found this guide unnecessarily complex.</td>
<td>[ ]</td>
<td>[ ]</td>
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</tr>
<tr>
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<td>I thought this guide was easy to use.</td>
<td>[ ]</td>
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<td>[ ]</td>
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<tr>
<td>4.</td>
<td>I think that I would need assistance to be able to use this guide.</td>
<td>[ ]</td>
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</tr>
<tr>
<td>5.</td>
<td>I found the various functions in this guide were well integrated.</td>
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<tr>
<td>6.</td>
<td>I thought there was too much inconsistency in this guide.</td>
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<td>[ ]</td>
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<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>10.</td>
<td>I needed to learn a lot of things before I could get going with this guide.</td>
<td>[ ]</td>
<td>[ ]</td>
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<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

What are the most important improvements, if any, you would suggest for this version of the guide?
About you

Age ______________________

Nationality __________________

How familiar are you with Broadford?

☐ I don’t know it at all, this is my first visit

☐ I know it somewhat, I have visited before

☐ I live here or visit it very frequently

Given the choice, what format of a digital trail guide would you choose for an unfamiliar area?

☐ App on phone

☐ Website on phone

☐ Website on computer

☐ Other _________

What type of phone do you normally use?

☐ Android

☐ iPhone

☐ Website on computer

☐ Other _________

☐ Not sure or don’t use a smartphone

Content Questions

Instructions: For each of the following statements, circle true or false.

The Old Pier was built in the 18th century. True False

There are over 100 names on the War Memorial. True False

James Ross created the recipe for Drambuie. True False

Opinions on Trail

Do you have any suggestions on improving the layout and/or locations of the trail? (use reverse if needed)