REPLICATE	**Project no. 691735** **REPLICATE PROJECT** **Renaissance of Places with Innovative Citizenship And Technology**	This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

REPLICATE PROJECT

REnaissance of PLaces with Innovative Citizenship And Technology

Project no. 691735

H2020-SCC-2015 Smart Cities and Communities

Innovation Action (IA)

D5.8 Travelwest Journey Planner

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Revision [1]

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Revision history

Version	Date issue	Author	Organization	Description
V1	10th November 2017	MC	BCC	First draft
V2	17th November 2017	MC	BCC	Second Draft following internal BCC comment. Issued to deliverable partners for Internal Review.
V3	23rd November 2017	GC	Route Monkey, TREL, BCC	Final Draft - Internal Review Comments included. Issued to Tecnalia for Quality Review.
V4	29th November 2017	MC	Route Monkey, TREL, BCC	Quality Review comments integrated. Submission version.

Contents

1 REPLICATE

1.1 Background to project

The REPLICATE project will generate smart city business models, and tailor-made solutions in the areas of energy, transport and ICT starting from the districts: Urumea Riveside (San Sebastián), Novoli (Florence) and Ashley, Easton and Lawrence Hill Neighbourhood (Bristol). In summary there will be pilot actions in energy efficiency, efficient and sustainable transport and integrated infrastructures, the latter being the key elements for the integration and development of cross-sectorial solutions. Three follower cities participate in the project: Essen (Germany), Nilufer (Turkey) and Lausanne (Switzerland).

Being a demonstration project, the main concept that is on the top of the project is REPLICABILITY: it will be necessary that the project results could be applicable throughout the lighthouse cities and in other cities which want to evolve towards the 'smart city' concept, and could grow in scale too. To ensure the large scale deployment of innovative technologies are successfully demonstrated in the lighthouse districts, specific studies will be necessary for each of the demonstrated solutions to ensure that they are scalable and can be replicated.

Prior to REPLICATE project San Sebastian, Florence and Bristol have already collaborated in a STEEP project (Systems Thinking for Comprehensive City Efficient Energy Planning) which has allowed the cities to generate Smart City Plans. STEEP project has defined a collaborative and participatory methodology to reach the objective of defining an Action Plan for particular districts of each city.

The main objective of REPLICATE project is the development and validation in three lighthouse cities (San Sebastián - Spain, Florence – Italy and Bristol – UK) of sustainable City Business Models to enhance the transition process to a smart city in the areas of energy efficiency, sustainable mobility and ICT/Infrastructure, in order to accelerate the deployment of innovative technologies, organisational and economic solutions to significantly increase resource and energy efficiency, improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

2 INTRODUCTION

2.1 Relationship to other project documents

The definition of the work plan of the REPLICATE project is essential for achieving an effective innovation management system. This deliverable complements the Project Management Plan and the District Management Plan in order to achieve impact and market objectives.

This deliverable has been put together with close attention to the original project documentation including those set out in Section 2.2.

2.2 Reference documents

This document is based in the following project level documents:

Ref.	Title	Description
REPLICATE Grant Agreement signed 240713.pdf	Grant Agreement	Grant Agreement no. 691735
DoA REPLICATE (691735)	REPLICATE Annex 1 - DoA to the GA	Description of the Action
REPLICATE Consortium agreement signed December 2015 (7th December version)	Consortium Agreement	REPLICATE project - Consortium Agreement
REPLICATE Project Management Plan	D1.1 Project Management Plan (v.1) (29/04/2016)	REPLICATE Project Management Plan
REPLICATE District Management Plans	D1.6 District Management Plan Bristol	REPLICATE District Management Plans
REPLICATE Communication Plan	D11.1 Communication Plan	REPLICATE Communication Plan

These will also be stored on the shared online platform.

Where there are contradictions, the documents listed above supersede this document. The Grant Agreement is the contract with the European Commission so takes precedence over all other documents.

2.3 Abbreviations list

API	Application Programming Interface
CA	Consortium Agreement
GA	Grant Agreement
DoA	Annex I-Description of the Action
EC	European Commission
EV	Electric Vehicle
GIS	Geographic Information System
GPS	Global Positioning System
H2020	Horizon 2020
HTTP	Hypertext Transfer Protocol
Hz	Hertz
ICT	Information and Communication Technology
MaaS	Mobility As A Service
P&R	Park & Ride
PC	Project Coordinator
PL	Pilot Leader
PMP	Project Management Plan
SWPTI	South West Passenger Transport Information
TC	Technical Coordinator
UWE	University of the West of England
UN	United Nations
UX	User Experience
WP	Work Package
WPL	Work Package Leader

3 DELIVERABLE CONTEXT

3.1 Deliverable Description

This deliverable describes the reasoning behind and process of developing the upgraded Travelwest Journey Planner. It describes the stages that partners have gone through to develop, test and deliver the upgraded planner.

Section 4 describes how the upgraded Travelwest Journey Planner fits with the concept of advanced mobility services for citizens.

Section 5 outlines how the Travelwest Journey Planner was developed to optimise personal mobility options.

Section 6 outlines the development of a real time parking app that optimises personal mobility options by reducing time spent finding a parking space.

The conclusions in Section 7 link the development of these advanced mobility services back to the aims of REPLICATE and identify how their impacts can be maximised, developed further and replicated in other cities.

3.2 Link to wider objectives

The primary objective of the deliverable is to align with the purpose of REPLICATE:

- to identify, develop and deploy replicable, balanced and integrated solutions in the energy, transport, and ICT actions through partnerships between municipalities and industries.

It will also provide benefits to the Wards of Ashley, Easton and Lawrence Hill which is the location chosen for the Bristol Pilot. This location is to the northeast of Bristol City Centre.

The specific aims of the Bristol pilot, as set out in the District Management Plan, are:

- to tackle inequalities and increase community engagement and resilience in east Bristol by demonstrating new, intelligently managed services with citizens and communities.

The specific objectives of the Bristol pilot that are identified as relevant to the deliverable are:

- OB3 Enable greater sustainable mobility to increase health and wellbeing as well as enable better access to training and employment
- OB4 Engage citizens in their energy use and travel patterns to change behaviour
- OB5 Contribute to an objective to significantly reduce CO2 emissions.

This deliverable should also support achievement of Travelwest's policy goals to:

- deliver an improved journey planning service to both citizens and tourists, with a focus on multimodal journeys and personalised service
- reduce road congestion in Bristol City Centre
- encourage behavioural change towards use of alternatives to car transport, particularly for regular journeys and major events.

4 ADVANCED MOBILITY SERVICES FOR CITIZENS

4.1 "Mobility as a Service"

Mobility As A Service (MaaS) describes a shift away from personally owned modes of transportation and towards mobility solutions that are consumed as a service. This is enabled by combining transportation services from public and private transportation providers through a unified gateway that creates and manages the trip, which users can pay for with a single account. Users can pay per trip or a monthly fee for a limited distance. The key concept behind MaaS is to offer both the travellers and goods mobility solutions based on the travel needs.

Travel planning typically begins with a journey planner. For example, a trip planner can show that the user can get from one destination to another by using a train/bus combination. The user can then choose their preferred trip based on cost, time, and convenience. At that point, any necessary bookings would be performed as a unit. It is expected that this service should allow roaming, that is, the same end-user app should work in different cities, without the user needing to become familiar with a new app or to sign up to new services.

It is with the MaaS concept in mind that the Travelwest Journey Planner has been developed. By integrating new data via new Application Programming Interfaces (APIs) the Travelwest Journey Planner provides new optimised personal mobility opportunities. It goes beyond what is currently available through commercial providers and opens up opportunities in terms of new ways of understanding urban travel.

4.2 Travelwest Journey Planner overview

Travelwest is the one-stop website for travel information in the West of England, however you like to travel. Figure 4.1 shows the existing Travelwest home page.

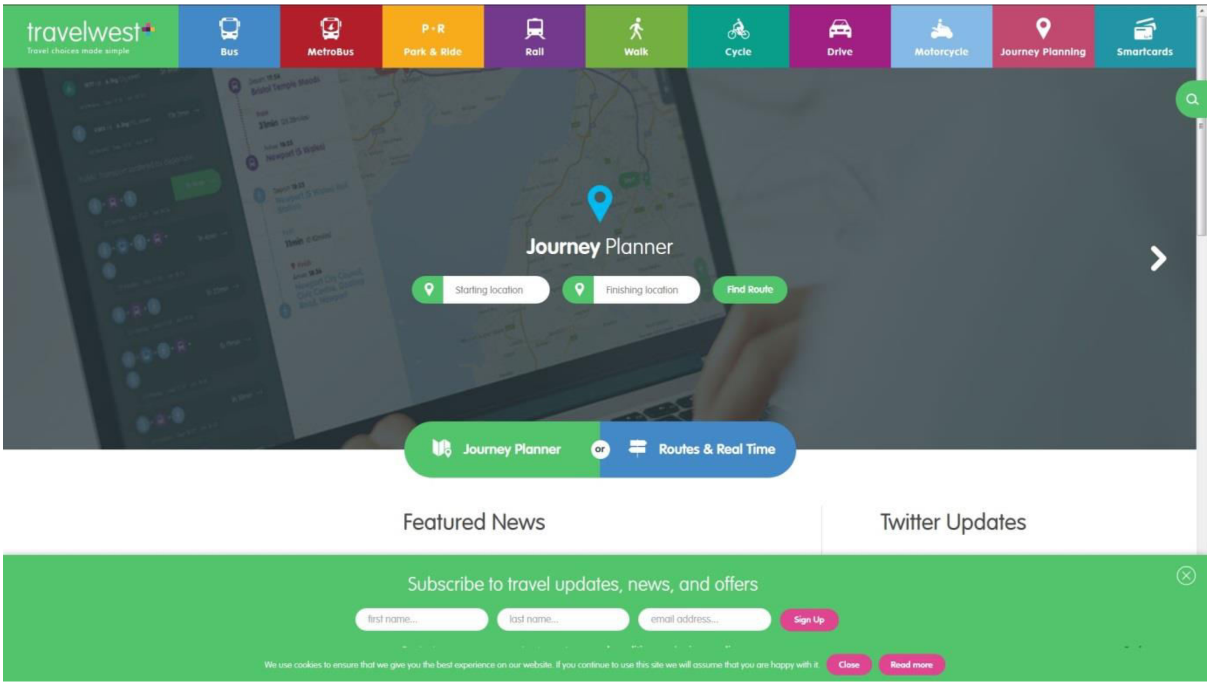


Figure 4.1 – Existing Travelwest website homepage

Its aim is to provide users with all the information they need in the simplest way – to help make their life easier, healthier and save them money by encouraging them to grab their bike or trainers, or to catch the bus. It also aims to keep users informed about initiatives implemented across the West of England to promote sustainable travel relating to public transport, walking, cycling, car sharing and electric vehicles while also providing useful resources for schools, businesses and developers.

Travelwest was funded via the Local Sustainable Transport Fund provided by the UK Department for Transport until 31st March 2016. Since 1st April 2016 it has been funded by the four Local Authorities comprising the West of England: Bristol, South Gloucestershire, Bath & North East Somerset and North Somerset.

The Travelwest Journey Planning web app allows users to find their journey options, real time information for buses and trains, and their nearest bus stop or train station, bus service routes, and much more. Prior to REPLICATE, however, it had limited multimodal functionality and so only catered for a subset of journeys as it did not offer journeys with certain combinations of travel modes.

Further details are elaborated in section 5.

4.3 Real time parking availability information system overview

By definition MaaS aims to encompass a wide range of modes. The key is to provide users with excellent information such that they can use the most appropriate mode of travel for their journey. For a range of reasons private car use is likely to remain the chosen mode for some journeys for the foreseeable future.

Therefore, personal vehicles are here to stay and whilst it may be impossible to totally eliminate their impact on the environment, the aim is to reduce this impact. The real time parking availability information system has been motivated by this objective.

Recent studies show that a key contributor to congestion and increased CO_2 emissions within cities are drivers searching (or cruising) to find a vacant on-street parking space. It has been shown that approximately (depending on the city) 20-30% of vehicles in congested urban areas were cruising to find a parking space with a parking search time varying in the order of several minutes.

In the city of Bristol alone, we have shown, using our collected trip and publicly available census data that over 790 metric tons of CO_2 is generated every year due to cruising, at a total cost of £368,000 (€415,000) in terms of fuel wasted. This waste could be avoided if useful parking availability information was made available to drivers. Whilst we may not be able to eliminate cars from the roads, even a small reduction in the parking search time can lead to significant reduction in the time, fuel, and money spent and reduce the impact on the environment by reducing emissions. Whilst the benefit may appear to be small for an individual user, the cumulative effect can be quite significant. Therefore, one of the aims of this activity is to reduce parking search times using data gathered from other road users.

Further details on the approach are elaborated in section 6.

5 OPTIMISED PERSONAL MOBILITY – JOURNEY PLANNING

5.1 Development and testing of Travelwest Journey Planner upgrade

With the principles of MaaS in mind the Bristol REPLICATE partners have been upgrading the Travelwest journey planner.

A number of strategic priorities were identified by Travelwest as follows:

- P&R and Car multimodal planner
- Cycle and Train multimodal planner including cycle/e-bike hire
- Ferry planner (commuters and tourists)
- Customised routing for travel disruptions
- Car parking average prices.

Partners undertook some preliminary analysis of these options, including feasibility and impact studies.

The practicality and benefits of upgrading the journey planner to allow for these strategic priorities was assessed with the following upgrades considered possible within the REPLICATE project (prioritised, based on available person months and data):

- P&R and Car multi-modal planner. This offers motorists an alternative to driving into the city centre and encourages use of multi-modal transport by suggesting that they park their car in one of the Park & Ride sites located on the outskirts of Bristol and continue their journey on one of the dedicated bus services.

- Cycle and Train multi-modal planner. This functionality allows users to identify cycle hire locations and plan a route around the city (and beyond) by incorporating train and bus services.

To achieve these priorities, a number of activities were needed:

1. Development of new multimodal APIs

2. Development of a new Travelwest Journey Planner front end

3. Integration of the APIs with the upgraded Travelwest Journey Planner

4. Testing and launch of upgraded Travelwest Journey Planner.

5.1.1 Development of new multimodal APIs

Route Monkey technical feasibility and approach

A series of face-to-face scoping meetings and calls were undertaken between Bristol City Council and Route Monkey between June and August 2016. During this period the strategic priorities for Travelwest were discussed and evaluated by Route Monkey and subsequently actual deliverables were agreed as above.

Solution development strategy

The project plan was based on a solution development strategy which starts at the simplest end of the solution complexity spectrum and progresses in stages towards the most complex end by adding functionality at each stage.

The additional functionality at a given stage will allow the resulting solution to accommodate changes in:

- Algorithms used (A)
- Waypoint types considered (W).

It may also involve updates to input and output data specifications, in line with the above updates.

The algorithms will be developed in a development environment for subsequent use within a production environment, as follows.

Development environment
The first step is to design and build a development environment providing the core systems that are required to support the development of additional functionality in line with the above strategy.

This stage will include set up development, integrating with external APIs and set up of the development database. Once the development environment is in place, the work will incorporate algorithm development with the learning aspect being added at the algorithm refinement stage.

Production environment
The work will then progress to building production systems to incorporate the solution created under the development environment, and integrating this with Travelwest systems.

This will involve setting up the cloud infrastructure, configuration, integration with Travelwest, testing and ongoing technical support, hosting and licensing.

5.1.2 Development of a new Travelwest Journey Planner front end

Development of the Framework - User Experience (UX) and Design

The wire-framing and prototyping phase is complete. This has been approved and signed off.

Screenshots of the designs are shown in Figures 5.1 and 5.2.

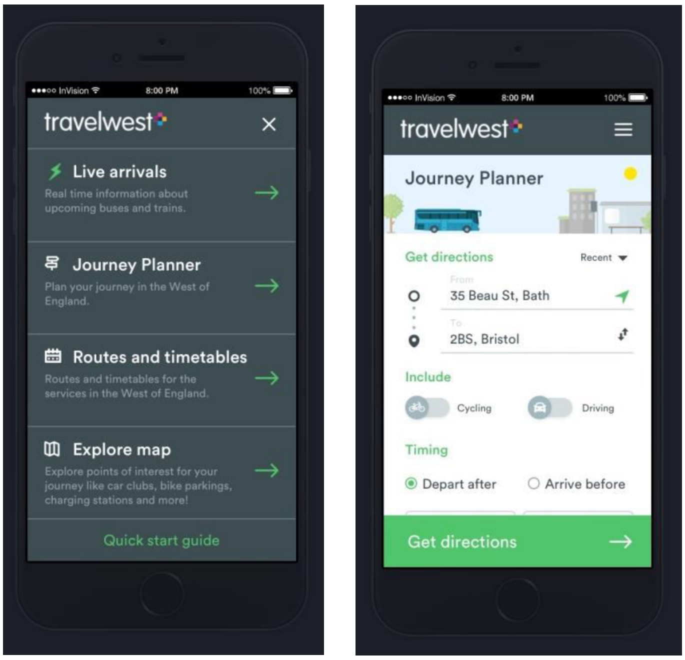


Figure 5.1 - Mobile version (refreshed home page and new "Include Cycling" and "Include Driving" options)

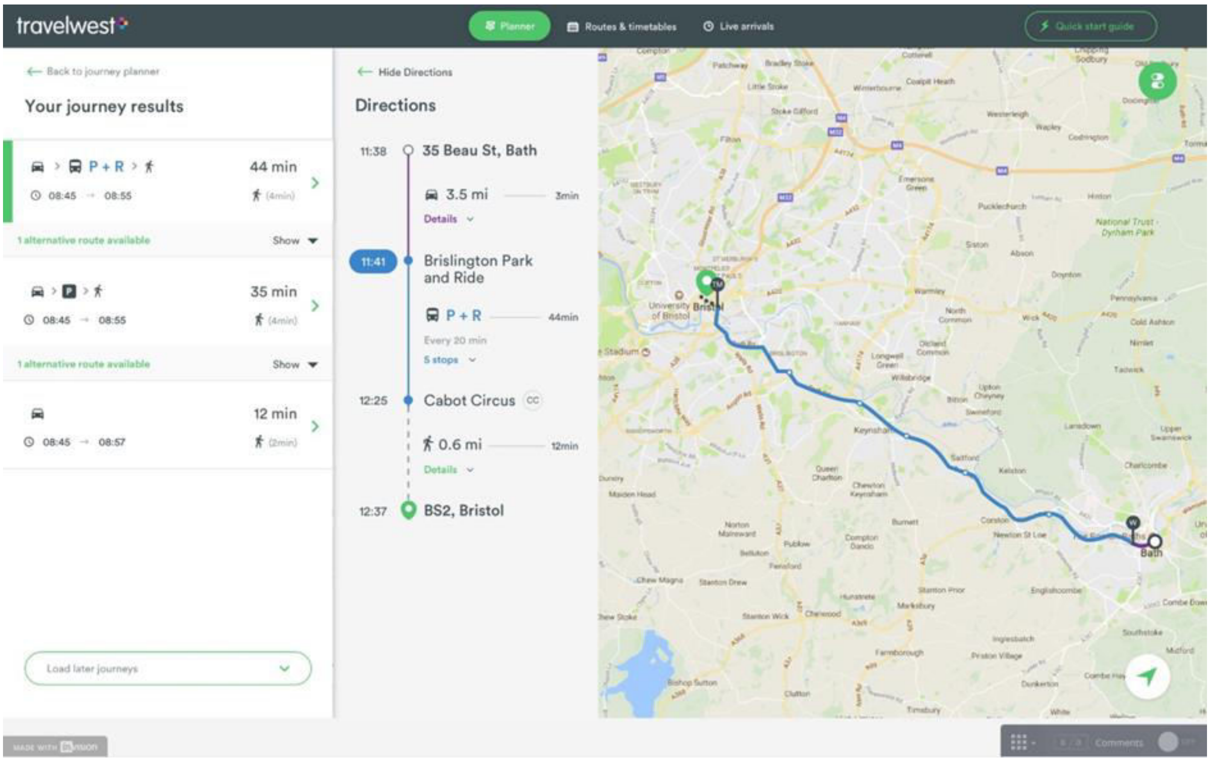


Figure 5.2 - Desktop version – showing new car and Park & Ride option

User Testing

User testing was carried out throughout the project on both Mobile and Desktop layout. This was done through 'on-the-fly' research around Bristol. It involved asking a specific question to a person and observing how they used the tool to find the information. The findings directly affected the design, User Interface, User Experience and how best to optimise the user journey.

Once it was apparent there were no major 'sticking points' during key user journeys, more in depth research was carried out which involved an interactive prototype of the app. The experience provided a realistic experience on how the app would look and function once complete. Users were asked a series of questions and talked through their actions and what they would expect to see when completing a set action.

Results from user testing show that 100% of the testers would use these journey planning tools, and that multimodal journey options are popular with potential users.

A detailed User Testing Report was produced and this is included at Appendix A. This shows the significant evolution of the product following user testing.

5.1.3 Integration of the APIs with the upgraded Travelwest Journey Planner

API integrations

The Journey Planner is functioning as expected and the APIs are integrated:

- South West Public Transport Information (SWPTI) – Successfully integrated. When developing the interface the data was checked to ensure it was in line with the designs.
- GIS – Successfully integrated. Waiting for Bristol City Council GIS to update the API feed so the data can be fetched.
- Google – Successfully integrated.
- Bristol Urban Things – Successfully integrated. Waiting for Bristol City Council GIS to update the API feed so the data can be fetched.
- Route Monkey – Successfully integrated. Confident in the functionality of the app, i.e. results are being plotted, including the new multimodal transport options and offering desired functionality outlined in designs. Route Monkey, Bristol City Council and the web developer (Green Chameleon) are reviewing the quality of results to confirm there aren't any discrepancies or irrelevant results returned.

- Map Layers – All layers have been successfully integrated. Waiting for Bristol City Council GIS to update the API feed so the data can be fetched.

App Development

The app is currently being tested at in an un-styled format to ensure that integration between the new Route Monkey API and the journey planner functionality works well. Quirks are being ironed out and decisions made on which "unreasonable" journey options not to offer the user.

Figures 5.3 and 5.4 show examples of the working, un-styled, multi-modal Travelwest Journey Planner.

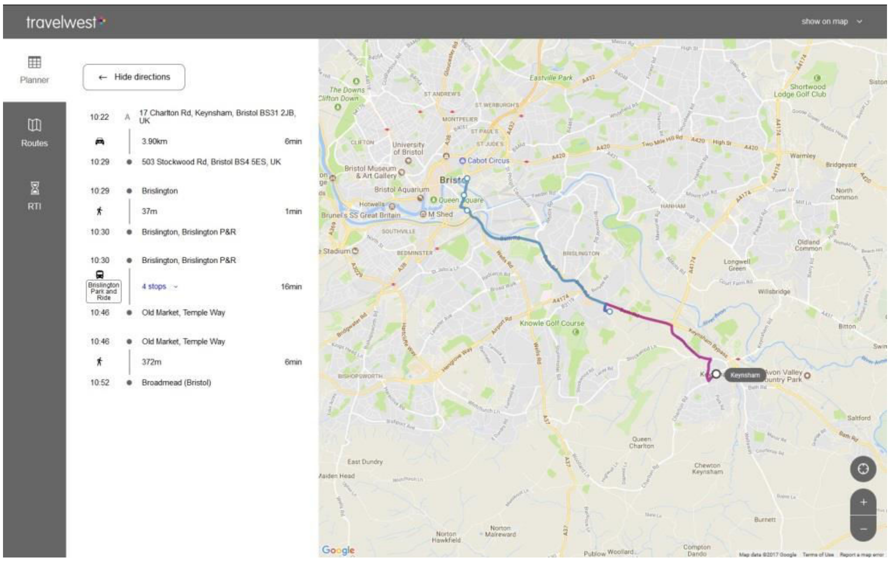


Figure 5.3 - Example showing real working example of the un-styled Journey Planner selecting a multimodal car + park & ride journey

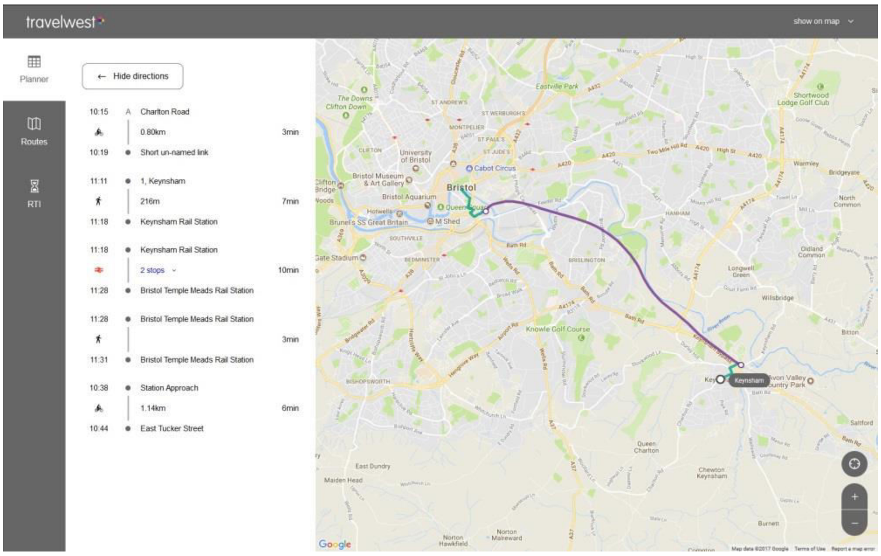


Figure 5.4 - Example showing real working example of the un-styled Journey Planner selecting a multimodal cycle –train-cycle journey

5.1.4 Testing and launch of upgraded Travelwest Journey Planner

The remaining work to be carried out in November and early December is:

- Finish testing the un-styled version and integrate the APIs
- Final changes to interface - layout & styling and interaction
- Bug fixes & testing
- BETA launch.

The un-styled version of the app is ready and being tested. The plan is to do a soft launch in mid-December 2017.

5.2 Lessons learnt, replicability and scale-up

The Travelwest Journey Planner upgrade has highlighted a range of activities which will be essential to the wider roll out of optimised personal mobility solutions.

Data from a variety of sources has been identified from a range of static and dynamic sources; these have been categorised, cleaned and made available through a number of platforms including GIS applications, an open data platform, Bristol's operations centre and "The Bristol API".

These have been brought together and repurposed using Route Monkey's algorithms to provide more customised journey solutions. Route Monkey has demonstrated the ability to provide customised responses to queries from the Travelwest Journey Planner via a new API that has been developed for this project.

The journey algorithm identifies alternative ways to break the journey and swap modes of transport, it is mode of transport agnostic and as such new transport modes can be added in the future to provide scale-up opportunities.

New API's are becoming available all the time; this additional data (e.g. services, timetables, road conditions etc.) can be added to the existing functionality to improve the quality of the service whilst at the same time allowing the planner to remain relevant to the city.

Bristol City Council has commissioned an upgrade to its existing journey planner to allow for a wider range of multimodal journeys. This goes further than products that are generally available on the market. Both the back end and the front end would have substantial potential to be repurposed for use in other cities.

Another area where REPLICATE has broken new ground is with the connection to live bike hire data. Through Route Monkey's connections to the live YoBikes API, the journey planner is able to include cycle hire options with cycles that have non-fixed parking places.

The principles developed through REPLICATE will also be adaptable as new live transport data streams become available.

The creation of a flexible journey planner will allow for additional modal functionality to be added such as the green mobility options demonstrated in this project (On demand EV minibus and Electric Vehicle Car Club).

Some tailoring of the algorithm would be required for each city (identifying travel hubs and available modes of transport).

Whilst the current Journey Planner does not yet include payment (beyond signposting to payment options) in future it is expected that these will be integrated in to these sorts of platforms to provide truly integrated MaaS experience.

It is expected that providing users with better information will encourage people to use new travel modes and ultimately help reduce carbon emissions and congestion.

This deliverable has successfully brought together a wide range of disparate data from a variety of providers and delivered it in an attractive, easy-to-use, personalised format.

6 OPTIMISED PERSONAL MOBILITY - REAL TIME PARKING

6.1 ParkUs Background

Since 1950 the proportion of people living in cities has been increasing. A 2014 UN urbanisation report estimates that 54% of the world's population live in urban areas. This proportion is expected to rise to 66% by 2050. As cities continue to grow in population and overall size, further demand is placed on transportation infrastructure such as road networks. Vehicular congestion is a major problem in most cities in the world and is likely to get worse in light of the aforementioned trend.

Providing users with real-time parking availability is a widely researched problem. However, most of this previous work presents solutions from one of two main categories. First, those that rely solely on parking availability information that is manually inputted by the user, such as Alphabet's now discontinued OpenSpot project, and ParkJam. Secondly, there are those that use physical infrastructure, such as sensors in parking spots and CCTV footage of parking spots. These require huge upfront investments for development, installation and ongoing costs for maintenance. For example, the SFPark project in San Francisco cost $23M to equip 6,000 (less than 25% of) on-street parking spaces with sensors connected to the Internet. As a consequence, recent research has focused on finding ways to monitor in real-time parking occupancy without incurring huge physical infrastructure set up and maintenance costs.

Our previous effort, ParkUs 1.0 (see Appendix B at the end of this report), attempted to achieve this by automatically detecting parking and un-parking events using a driver's smartphone accelerometer and magnetometer sensor data (no user input or separate infrastructure installation was required). Although more accurate and energy efficient than its competitors such as PhonePark, Park Here and Park Sense respectively, ParkUs 1.0 was not able to detect driver cruising behaviour.

Detecting cruising (driving while searching for an available parking spot) combined with parking activity has a major advantage when it comes to providing real-time parking availability information. By detecting solely parking and un-parking activities the system only collects one data-point, such as where and when the driver parked and un-parked, thus yielding little information about the parking availability on nearby streets. On the other hand, detecting and monitoring cruising behaviour allows us to infer the availability of parking spaces on multiple streets. As it is assumed that a driver would park as soon as they find a vacant spot near to their desired destination. Therefore we can infer with reasonable certainty that there were no vacant parking spaces along those roads or parking bays that the driver searched shortly before they parked. Consequently we can now advise other users

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

looking to park in the same area not to waste time by (re-)searching those streets or car park, as they are most likely full. Instead we can potentially suggest a better search strategy or use of public transport instead.

An important aspect of ascertaining parking availability is to reliably identify and eliminate areas where parking is not available. It is well-accepted that detecting a cruising event is a proxy for lack of parking. The ability to detect cruising and use this information to update parking availability information has been the focus of the work so far and has resulted in the development of the ParkUs 2.0 app (see Appendix C at the end of this report).

6.2 ParkUs System Design

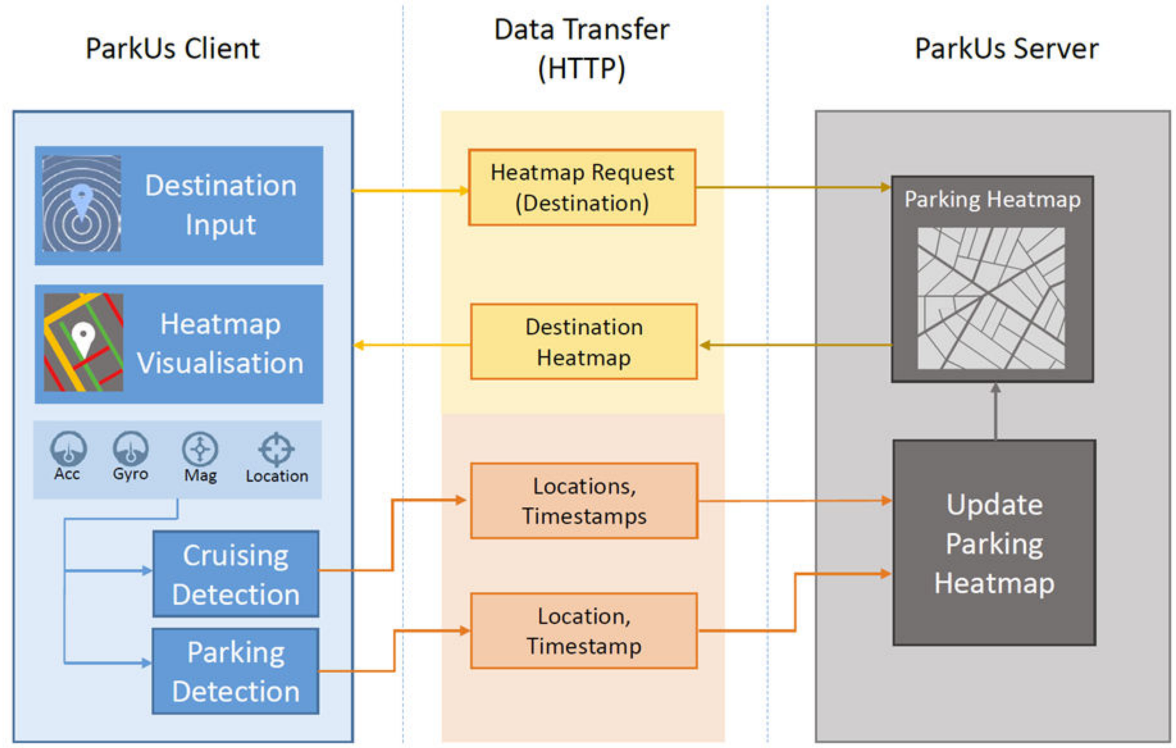


Figure 6.1: ParkUs system design

ParkUs is a crowd-sensing based solution which has been realised as an Android smartphone app augmented with an intelligent backend system (see Figure 6.1). The app collects location and sensor data from the driver's smartphone, uses a machine learning model to pick up patterns relating to 'vehicle cruising behaviour' and uses this in addition to input solicited from the vehicle driver (app user) once they have parked to update probabilistic parking availability information on the backend server.

The proposed cruise detection system relies on the principle of detecting a significant local minimum in the GPS trace with respect to distance from the destination. In addition to GPS data, other sensing data from the driver's smartphone such as accelerometer, gyroscope and magnetometer were also collected and it was found that features extracted from such sensor data can help in training models and effectively detecting when the vehicle does and does not cruise. Such information augmented with input from other users in the area (drivers flagging a parking event) can be used together to build a picture of parking availability in that area which can be made available to the end user.

When a user enters their desired destination address or postcode before beginning the journey, the app displays a heatmap of parking availability in the destination area within a radius specified by the user. The backend server keeps updating the road-by-road parking information as new data is received from other users in the destination area and sends an updated heatmap periodically to the smartphone app thereby resulting in a refresh of parking availability information.

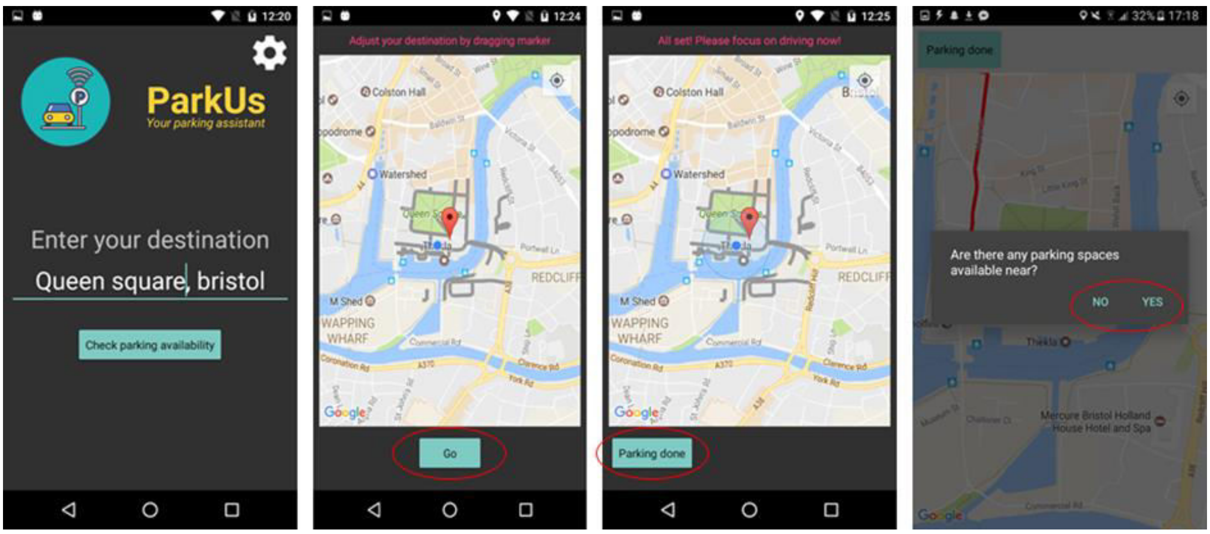


Figure 6.2: Screenshots of the ParkUs app showing the different steps involved when using the app

Figure 6.2 shows screenshots of the app depicting the steps involved in using the app. The user enters the destination street name / postcode and clicks on 'check parking availability'. This displays the current heatmap within a 200 metre radius of the destination. As seen from the figure, the streets coloured 'Grey' indicates that parking availability is unknown. This could be because no one has yet reported data from this destination area or that the information available for the destination area is stale. As more and more users use the app, the accuracy of the heatmap will improve.

The user then clicks 'Go' and starts driving to their destination area. On arrival and after parking, the user clicks on 'parking done' to indicate they have parked. The app then asks them to indicate whether parking is available in the vicinity (based on a quick visual glance around) and followed by a simple 'yes/no' click. The backend then averages reports received from multiple users in a destination area to update the heatmap (e.g. Green indicating high likelihood of availability, orange indicating medium likelihood of availability, red indicating less likelihood of availability and so on) which would be useful for the next users querying for parking information in this area.

An important point to be noted is that the app has been designed to comply with typical motor regulations in most countries which prohibit the driver from using a phone whilst driving. The user only needs to interact with the app before setting off on a journey and after parking at the destination which makes it practical from a deployment perspective.

Whilst making vehicle parking information available on a smartphone is not new, the novel aspect of the ParkUs system is automatic cruise detection using sensor and location data and a parking availability inference system which requires minimal user interaction. This is the very first approach using machine learning to detect cruising behaviour. The benefit of detecting cruising in the destination area is that this could be considered a proxy for lack of availability of parking which can be useful to update the probabilistic parking availability on the roads where the driver is found to be cruising.

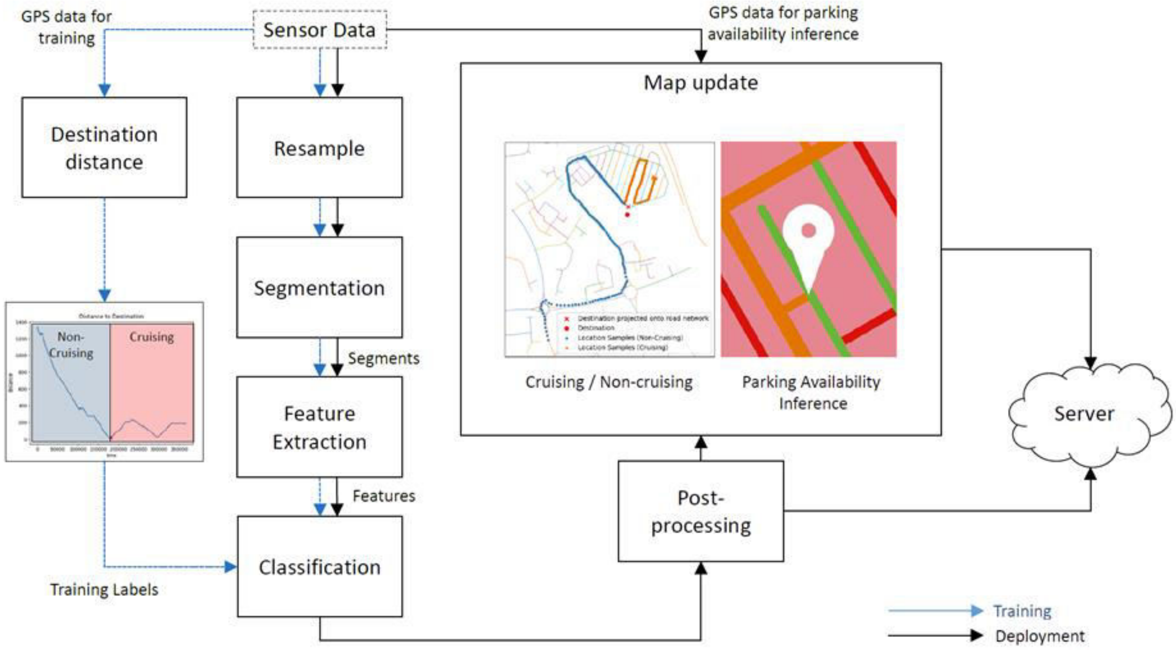


Figure 6.3: Data flow pipeline for training and deployment of the ParkUs system

Figure 6.3 shows the flow of data from the sensors on the smartphone to the set of labelled feature vectors to train a binary classifier. It also shows the flow of data once the classifier has been deployed, and the distance-based labelling is no longer needed. The advantage of the proposed method is that data can be automatically labelled. To start with sensing data is by default labelled as 'not cruising'. As soon as the significant minimum point is crossed, data is automatically labelled as 'cruising'. Such automatic annotation (or labelling) of data has tremendous advantages since it reduces the time required to annotate the data (compared to manual annotation) and the time spent training the model. Furthermore, the driver is not required to interact with the phone during driving, thus ensuring compliance with the law.

6.3 ParkUs Trials

Sensor data from a total of 41 journeys was collected from 5 volunteers over a period of several weeks between March and June 2017. Accelerometer and gyroscope data was sampled at a rate of 25Hz, while magnetometer data was sampled at a rate of 5Hz. Location data from Google's Fused Location Provider API was sampled at 1 Hz. For each journey, volunteers were asked to record their desired destination before setting off in their vehicle. The smartphone sensor data (such as accelerometer, gyroscope and magnetometer) were then collected along with GPS data for the entire journey until the user parked at their destination and pressed a 'parking done' button (as described earlier) in the application. Sensor and location data were then uploaded to a server where it was further processed. Furthermore, volunteers were not restricted in placement or orientation of their smartphones during the data collection phase. With the aim of maximising the generality of the cruising classifier, the data was collected at several locations across the city of Bristol, UK.

Manually identifying and labelling the starting time of cruising for each journey would be a time-consuming and error-prone task. To mitigate this problem, the method of determining this timestamp was automated taking into account the observation that in a typical journey in which cruising occurs, the distance to the destination will decrease until it hits a local minimum. At which point the distance increases again as the driver starts moving further away from their destination in the search for parking. This minimum might be caused by the driver passing by their destination and observing that no parking is available, or it might be caused by a circular route or S-shaped curve as might be observed in a car park. Overlapping time windows were used to extract features from real-time sensor data.

Three classifiers were trained using the data collected from the trial; decision trees, support vector machines and k-nearest neighbour. The output of the classifier was then post-processed using a finite state machine in order to reduce the effect of the classifier producing short 'gaps' of non-cruising during true cruising, or cruising during non-cruising. In order to alleviate the potential bias introduced by cross validation schemes such as in a standard k-fold cross validation scheme, a leave-one-user-out cross validation technique was applied during all steps of training and evaluation of the classifiers. It was found that SVMs outperformed the other techniques achieving an accuracy as high as 81% in being able to predict cruising events.

Further details on the trial outcomes can be found in Appendices B and C.

The evaluation of ParkUs is ongoing with a trial currently underway at the University of West of England (UWE) in Bristol, one of the partners in the REPLICATE project.

6.4 Lessons learnt, replicability and scale-up

Whilst this work is the first approach (only one of its kind to the best of our knowledge) to have shown that it is possible to devise a model to detect vehicle cruising which can be used for real time parking availability inference, realising a crowd-sensing based parking availability information system in general is complex. Without the app reaching a critical mass of adoption it will not be possible to provide accurate parking availability information. At the same time, without providing accurate parking availability information it is difficult to reach critical mass. It is essential for many users to be using the application on an ongoing basis such that up to date parking information can be recorded and displayed to the users. Whilst public outreach and engagement is vital to accomplishing this, enlisting a large number of users to start with would be quite challenging as our initial experience suggests.

Getting early adopters to regularly use the application is a challenge, as there may be little benefit for them initially. One way to work around this is to conduct trials in smaller areas of the city by employing a set of participants that live or work within these target areas. Once localised groups benefit from other users regularly using the app, the credibility of the application will be established and in turn will likely lead to more drivers using it. This is the approach that is being considered in the context of the Bristol pilot.

From a replicability perspective, the app has been designed such that it can work in any geography. As long as there are people using the app whose data is feeding into the backend, the app will continue to provide useful information. If an early adopter were to install this app in some other city/country and query for parking availability in a desired destination, the app will still show a heatmap but with the grey legend indicating that parking availability is unknown. As an example, Figure 6.4 shows the parking availability information returned by the app when querying for parking in an area in the city of San Sebastian, Spain.

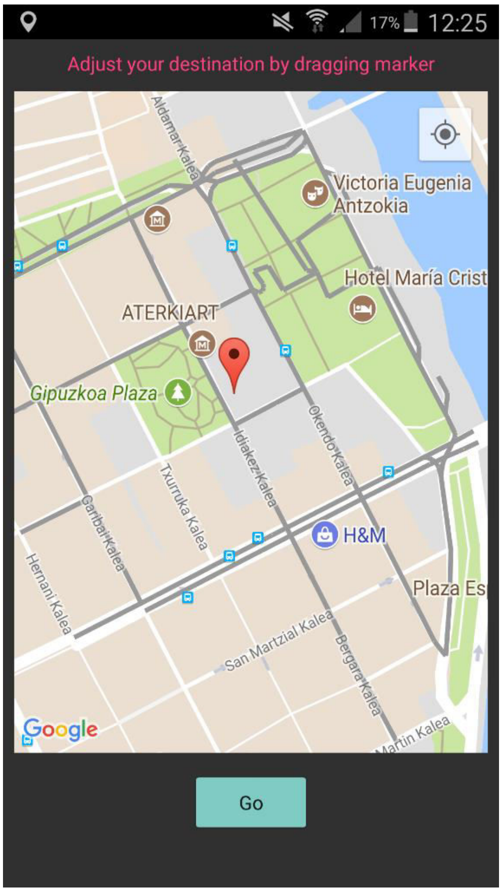


Figure 6.4: Screenshot depicting parking availability information returned by a query for an area in San Sebastian (in the absence of anyone using the app). The heatmap is shown in grey but parking availability status is unknown.

7 CONCLUSION

The development of the Travelwest Journey Planner has allowed Bristol to develop and trial new technologies that allow it to provide cutting edge optimised personal mobility services to its residents.

To achieve this REPLICATE partners have accessed new data sources, and repurposed them to allow for development of complex new algorithms that provide new multimodal journey options which were not previously available.

The trialling and refining of the ParkUs real time on-street vehicle parking information system is in progress. A trial is currently under way within the campus of the University of West of England in Bristol, one of the partners in the REPLICATE project. This opportunity will be used to further refine the app and validate the algorithms which form the backbone of ParkUs. Subsequently, the plan is to trial the app in the REPLICATE pilot area in the city of Bristol and report findings from this study to the different stakeholders.

Throughout the development of these new technologies our focus has been on the user experience as we consider that if these new tools are to be used to maximum effect, and the benefits to the city maximised, then they must be easy to use.

Through the development of the upgraded Travelwest Journey Planner and the real time parking app, the Bristol Pilot has (in line with REPLICATE objectives) identified, developed and deployed replicable, balanced and integrated solutions in the energy, transport, and ICT actions through partnerships between municipalities and industries.

At a Bristol Pilot level, the development of these apps is considered to have helped with the Bristol Pilot aims of enabling greater sustainable mobility to increase health and wellbeing as well as enabling better access to training and employment; engaging citizens in their energy use and travel patterns to change behaviour; and contributing to an objective to significantly reduce CO_2 emissions.

This deliverable also supports the achievement of Travelwest's policy goals of delivering an improved journey planning service to both citizens and tourists, with a focus on multimodal journeys and personalised service; reducing road congestion in Bristol City Centre; and encouraging behavioural change towards use of alternatives to car transport, particularly for regular journeys and major events.

We look forward to sharing further details of our methodology with REPLICATE partners, other cities and the European Commission in order to ensure that the lessons learnt and technologies developed can be used to maximum effect in other cities.

We also look forward to further developing these methodologies and technologies as the project develops to increase the integration between mobility, energy and ICT.

8 APPENDICES

Appendix A - TWJP User Testing report

Travelwest - Journey Planner

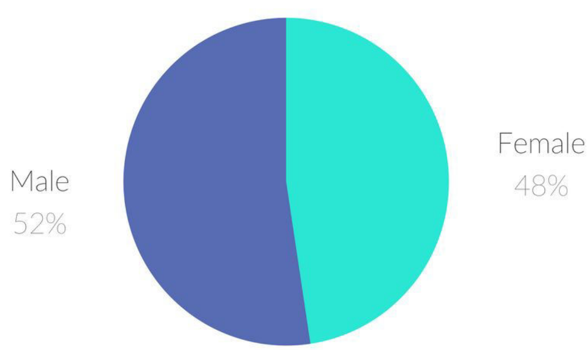
User testing report

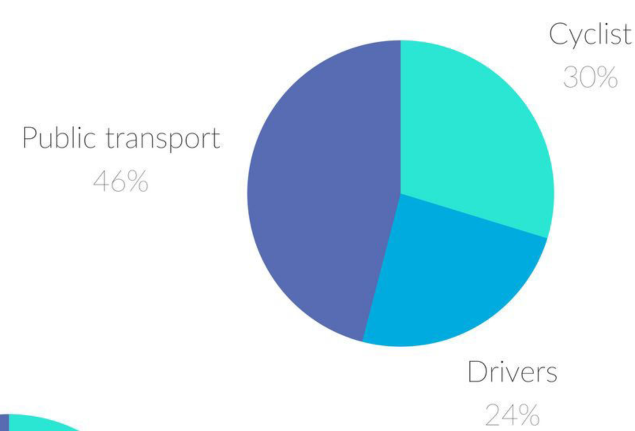
1. Overview

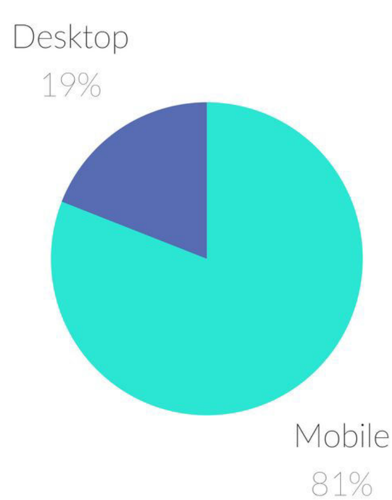
- User testing was carried out 24/07 - 8/08 2017
- We've tested the final UI/UX design
- We've interviewed 21 users
- Locations: Queen Square and Easton
- Method: field study

2. Users

- 10 females and 11 males
- Mobile version was tested by 16 users, desktop by 5
- Preferred mode of transportation (some users had more than one): 9 - driving, 11 - cycling, 17 - public transport/walking
- Most of them used Google Maps, First Bus or Bus Checker to plan their journeys







Travelwest - Journey Planner

User testing report

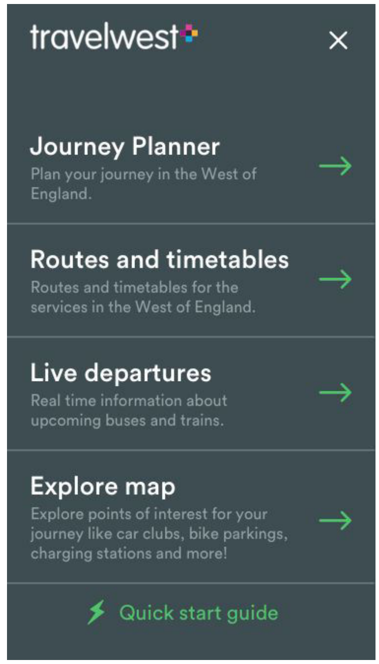
1. Interviews takeaways

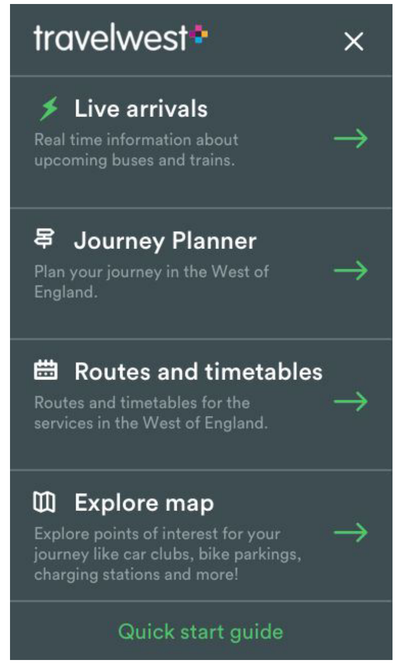
- Our testing mostly involved the mobile version; all the amends made on mobile design were then translated into a desktop version. By testing the desktop version we confirmed it's usability = it didn't require as many rounds of interviews and design refinements as the mobile version.
- The biggest challenge we've encountered during initial user testing was getting people to understand the real time information feature: both user flow and terminology seemed to be confusing users. We've given this feature a lot of attention while making amends before the next rounds of user testing.
- Journey planner feature was well received and understood correctly.
- Users were able to compare different journey results via different means of transport: travel time, walking time and modes of transportation involved.
- Multimodal journey results were not expected by users, but were appeared as a nice surprise to the users who included cycling or driving into the journey.
- Routes and timetables feature was generally well understood. Users didn't have trouble understanding the first parts of the user flow: select city and route. Users used both search fields and lists presented below to navigate through these screens. The difference between live arrivals and timetable were also clear. Users didn't have trouble finding 'PDF' with a full timetable to check bus departure hours later on during the day.
- Many users mentioned they use the "recent" feature on the other apps, and they feel like it would be nice to have it for quicker access to information. We've incorporated this feature into journey planner.
- Users generally enjoyed both look and feel of the journey planner. It felt familiar and intuitive.

2. Changes implemented

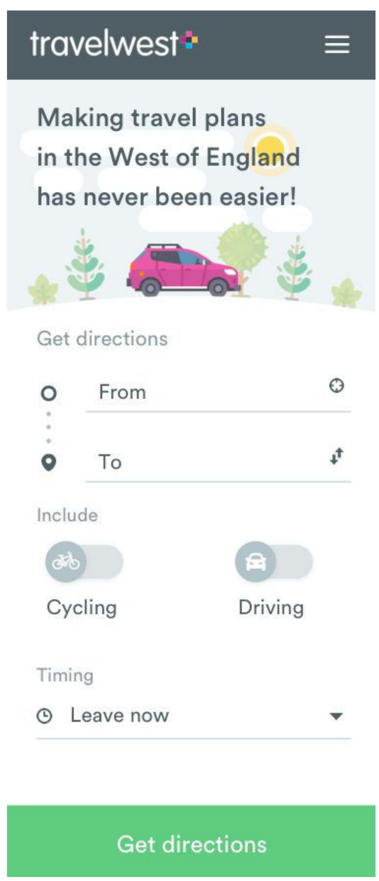
- **Refined mobile menu screen:**

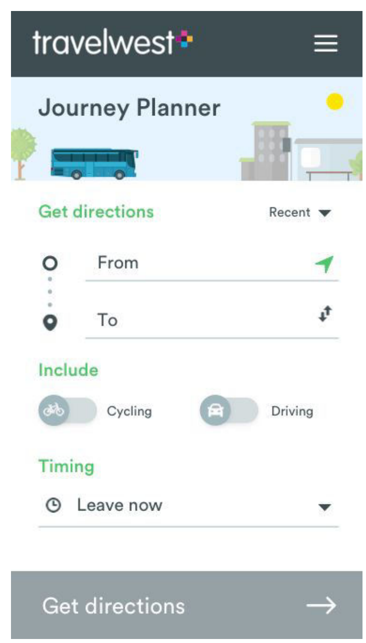
- We've changed the name from 'Live Departures' to 'Live Arrivals'.
- We've placed 'Live Arrivals' at the top of the list so it's easily accessible on the go.
- After these changes were made, this screen was easily understood. Options were easy to compare and find when needed.



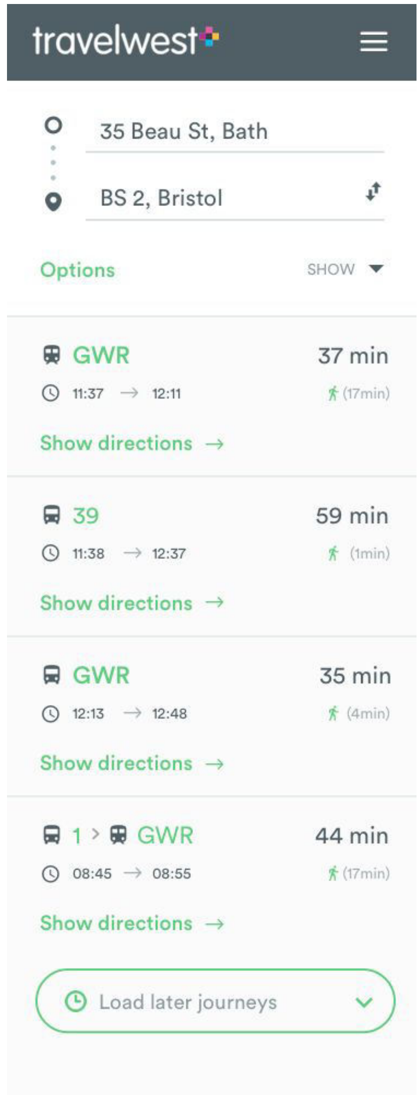


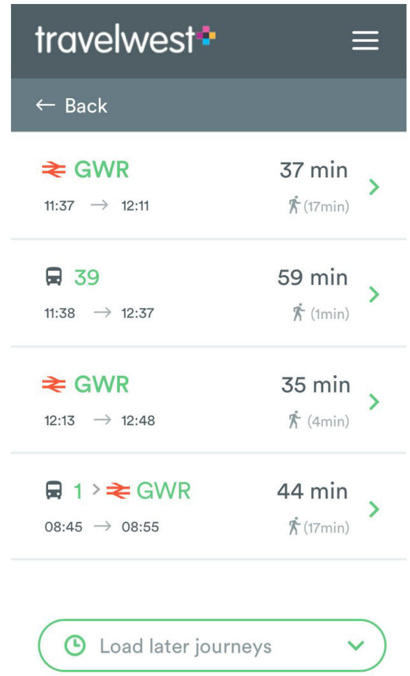
- **Refined mobile design:**
- General look and feel of the app was improved.
- Compared with the previous one, the new design accommodated more information and options on the smaller space and was just as usable.
- We introduced the 'inactive state' to the CTA buttons to guide users attention in a better way.
- The typography hierarchy was improved to attract attention.





- **Refined journey options results:**
  - We’ve replaced the locations inputs with a “Back” button. The lack of journey summary wasn’t confusing to the users.
  - We’ve replaced “Show directory” with a small arrow. The affordance was still obvious to the users..
  - We’ve changed the train icon for a national rail logo to make a clearer distinction between train and bus options.

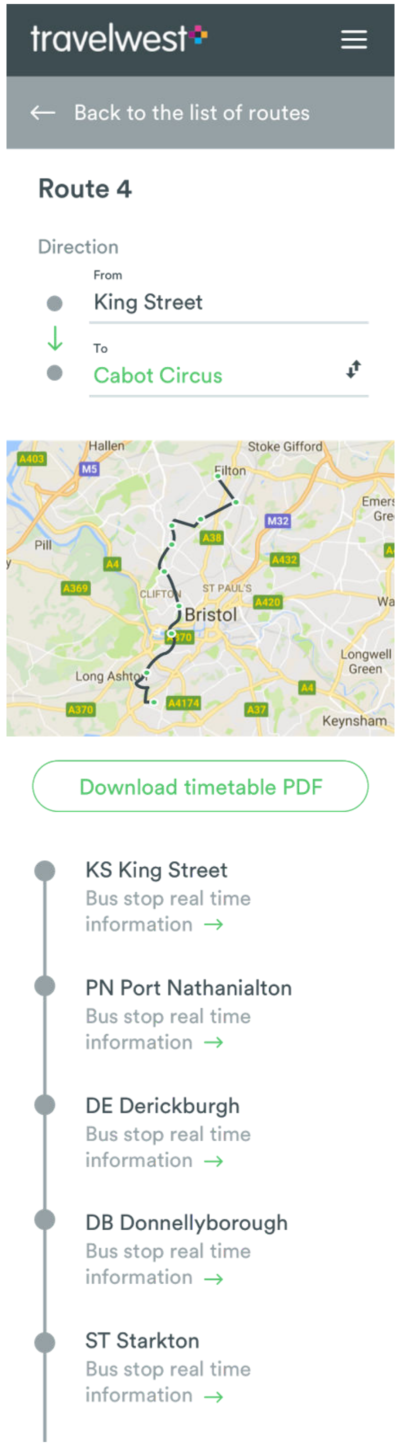


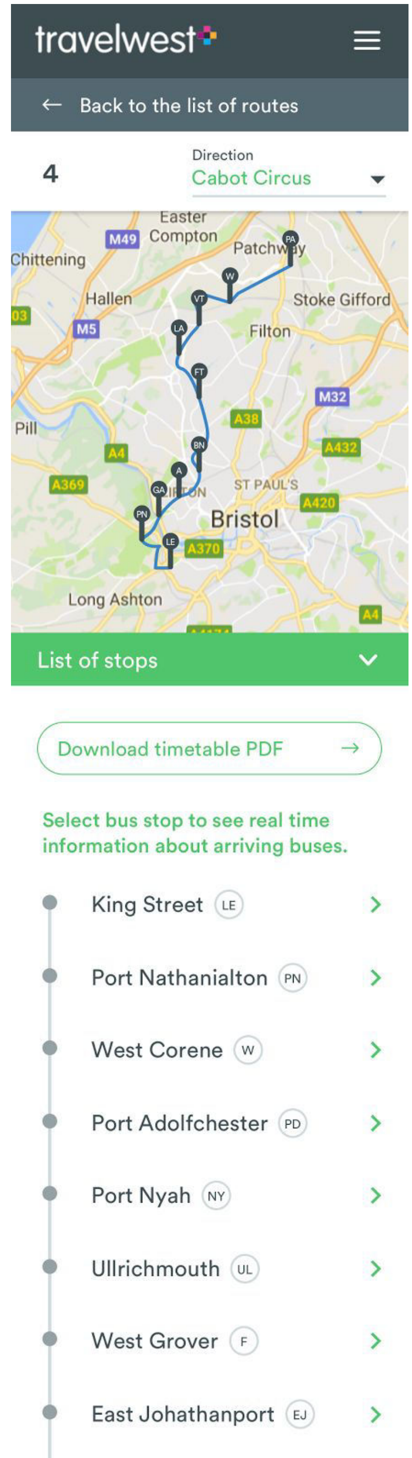


Travelwest - Journey Planner

User testing report

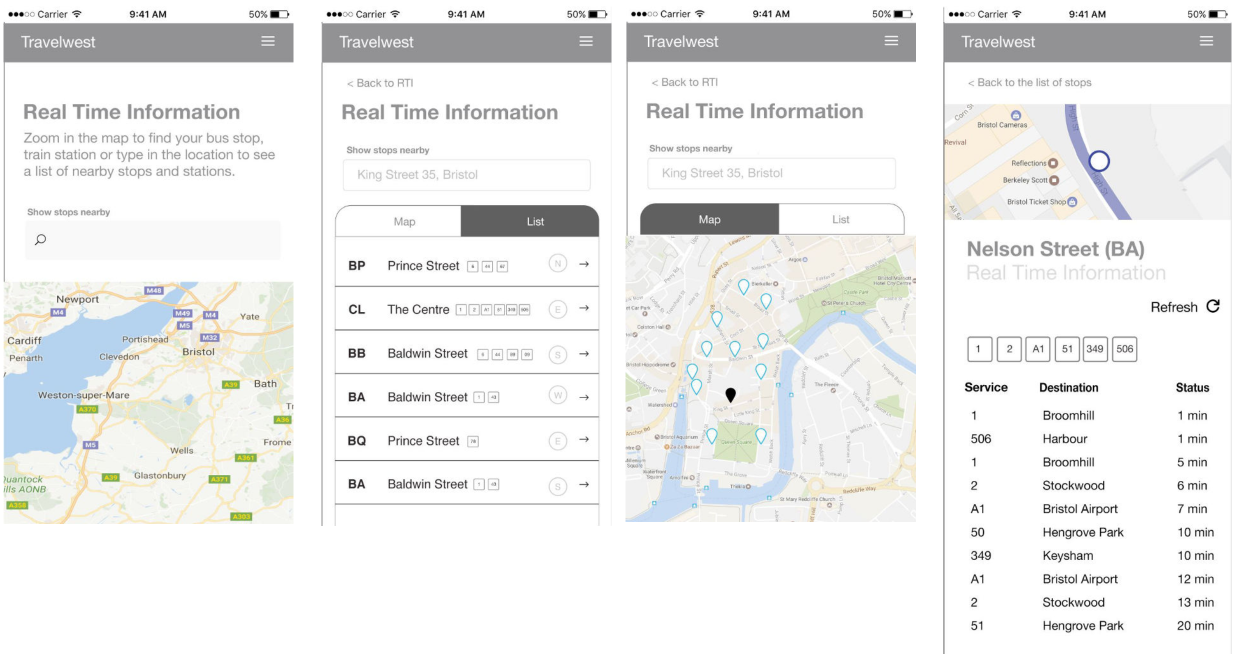
- **Refined route screen:**
  - We've increased the map size for a better experience.
  - We've replaced the bus stop icons and made them consistent throughout the application.
  - We've incorporated the CTA button on the bottom of the screen to indicate that there's more information accessible on this screen if needed. We've reused that pattern on the other screens as well.
  - We've introduced dropdown for route direction change and users didn't have any troubles understanding and using it.





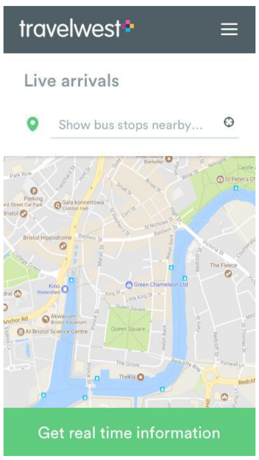
- **Refined real time information user flow:**

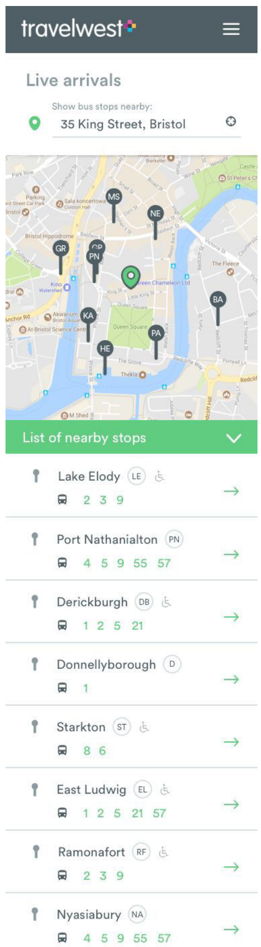
V1. What we've understood by testing this flow was that users grasped this logic when being presented with a map, pin with the location and bus stops around it. We've decided to move this step before presenting users the list of stops.

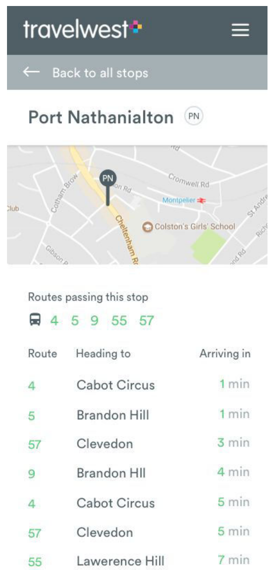


V2. We've reduced the number of screens by joining together map and list. Map helped users understand the feature, and we've increased it' s size.

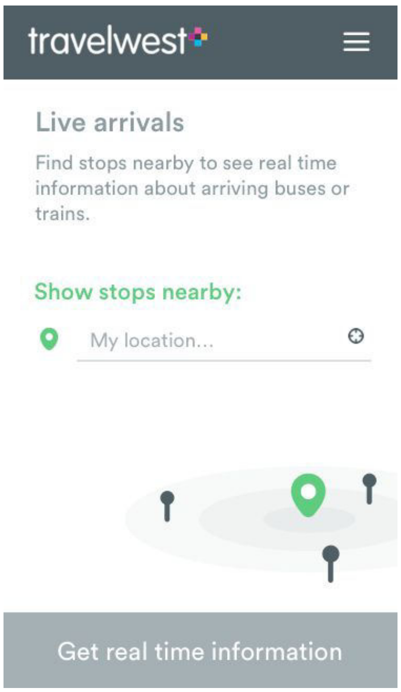
The first screen was still not received well: users used to Bus Checker or Google Maps tried to use it by zooming in the map - which is that was beyond our possibilities - so we had to rethink the beginning of the flow.





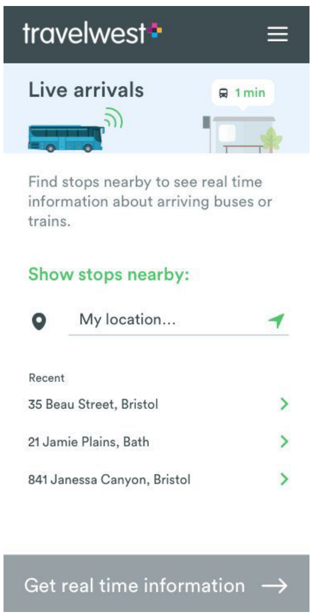


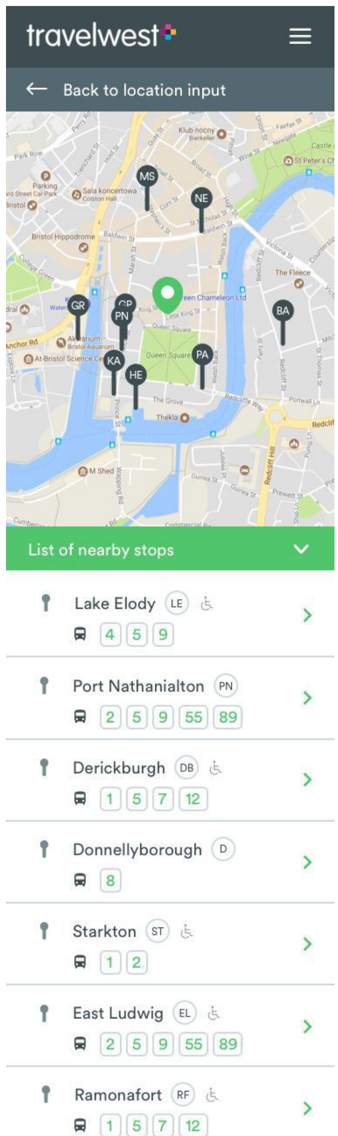
V3. First screen of the flow - We've tried to incorporate a more descriptive illustration instead of the map and added explanatory descriptions for CTA button, input field and it's title.

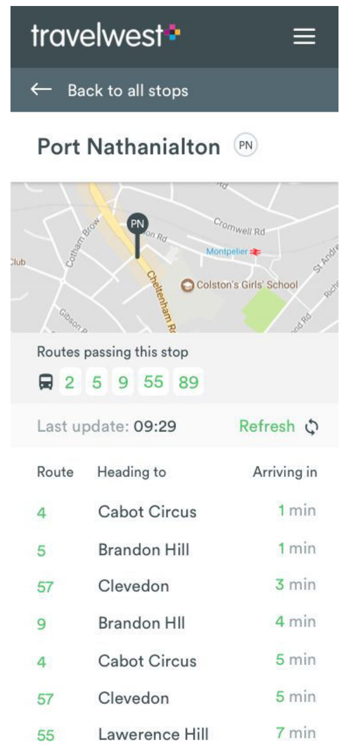


V4. We've made the look and feel of this screen consistent with other features of the app. We've kept location input only on the first screen and placed "back" buttons on following screens.

This version was well understood by users and required no further refinements.







Appendix B - ParkUs Paper 1

For full paper see:

[1] Pietro Carnelli, Joy Yeh, Mahesh Sooriyabandara, Aftab Khan, "ParkUs: A Novel Vehicle Parking Detection System",

Conference on Innovative Applications of Artificial Intelligence (IAAI), San Francisco, California, USA, Feb 2017.

Appendix C - ParkUs Paper 2

For full paper see:

[2] Michael Jones, Aftab Khan, Parag Kulkarni, Pietro Carnelli, Mahesh Sooriyabandara, "ParkUs 2.0: Automated Cruise Detection for Parking Availability Inference"

EAI International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services, Melbourne, Australia, Nov 2017.