

## **Build an app and they will come? Lessons learnt from trialling the *GetThereBus* app in rural communities.**

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**Abstract:** Real-time passenger information (RTPI) systems have been identified as having benefits in terms of passenger willingness to travel by public transport and their satisfaction levels with services provided. The lack of this amenity in rural areas, however, may hamper public transport use, thus reinforcing patterns of over-reliance on personal vehicles. To explore the potential impacts of providing RTPI in rural areas, a smartphone application (*GetThereBus*) was developed to allow rural bus passengers to share real-time public transport data, and access real-time and timetable information. Through user testing of *GetThereBus*, this work aimed to address questions related to: the impact of limited availability of rural digital infrastructure on provision of RTPI; the potential for crowdsourced information to supplement published timetable information given digital limitations; and the potential impacts of such a system on the traveller experience.

This paper describes the *GetThereBus* development and evaluation phases. We found it was possible to design and develop a system that overcame many of the technological limitations experienced in rural areas, and users reported a positive response to the system. However, despite a campaign of user engagement, it proved difficult to recruit and motivate sufficient users to provide the data needed to achieve area-wide coverage.

## 1. Introduction

Real-time passenger information (RTPI) systems have been developing rapidly over the last 20 years. Such solutions have most often been developed and trialled in relatively densely populated urban communities, thus leaving unanswered questions regarding their usability in more sparsely populated rural environments. In this paper, we discuss the experience of designing and evaluating an RTPI system as an intervention study with rural communities in the Scottish Borders. This area was selected as it featured several routes operated by First South East and Central Scotland and is one of the more sparsely populated areas of the UK, with a 2014 density of 24 persons per km<sup>2</sup> compared to the overall UK average of 266 [1]. The research was predicated on the hypothesis that the lack of passenger information systems in rural areas may reduce public transport use and contribute to increased car ownership [2]. To explore this hypothesis, *GetThereBus* a smartphone application (commonly abbreviated to “app”) was developed which crowdsources real-time public transport data from passengers, and provides access to real-time updates and timetable information. Crowdsourcing involves outsourcing tasks to a (typically large) group of people (the *crowd*). In *GetThereBus*, the crowd consists of passengers on relevant bus services who are given the task of tracking (and sharing) the location of a bus via the application; this information is subsequently used as part of an RTPI system

Significant challenges exist surrounding provision of effective RTPI in rural areas due to limitations in infrastructure and services. Rural communities in the UK are less likely to have access to super-fast broadband; average broadband speeds in rural areas are typically lower than in urban areas [3]; and broadband coverage has been identified as a key issue for rural communities [4]. Alongside these technical challenges, further challenges associated with generating awareness and uptake of a new RTPI system formed the basis of the research questions for this study: first, to what extent would the lack of digital infrastructure in rural

areas hinder provision of RTPI? Once this has been determined, could an RTPI system based on information crowdsourced from bus passengers be developed that overcomes identified limitations? Next, to what extent would passengers contribute information to such a system, and, finally, could such a system be a sufficient substitute for an operator-supplied RTPI solution?

To address these questions, Section 2 considers existing evidence on the effectiveness of RTPI, including smartphone applications and systems that use crowdsourcing, and methods for encouraging user engagement. Section 3 briefly explains the RTPI system devised for this study and its technical requirements; Section 4 describes the *GetThereBus* development process and addresses the rural intervention study in the Scottish Borders; Section 5 concludes by evaluating the success of the study in relation to the research questions.

## **2. Literature Review**

### *2.1. Introduction to RTPI*

Providing RTPI is predicated upon access to both the software and hardware necessary to gather and disseminate accurate real-time data. Early real-time information systems largely relied on automatic vehicle location (AVL) systems deployed for operational efficiencies rather than provision of passenger information [5]. In simple AVL systems, an on-board GPS device communicates with the GPS satellite network and the resulting location and identifier data are transmitted to the operating agency for further processing and use [6]. As these systems improved in accuracy and decreased in cost, public transport agencies began to see the value in also using them to provide RTPI, generally via dynamic message boards at key public transport stops (e.g. from the mid-1980s in London) and from the late 1990s via the Internet [7]. The success of such systems, deployed in urban locations around

the world [8], demonstrated that the public had an appetite for timely, reliable information, a conclusion supported by numerous studies [9, 10].

## *2.2. Recent Evolution of RTPI*

Over time, and with the evolution of personal mobile devices such as smartphones, RTPI has become more targeted to individuals and available at more stages of the journey. Unlike traditional message boards, which were useful primarily for estimating wait times and/or determining which vehicle to board at the physical stop, real-time information provided via smartphone applications or websites may be checked in advance of or during a journey, thus allowing users to amend their travel plans as required [11, 12]. While of clear benefit to travellers, such systems increase complexity for the service provider, as they require both a comprehensive, system-wide network for gathering vehicle location data, and a mechanism for communicating that information to passengers in a way that is accurate, timely, and personal (for example, allowing the user to search for specific routes, times, origins, and destinations). As many RTPI systems also provide static information on planned services, service providers must also ensure that schedule data are kept up-to-date. Despite this complexity, smartphone applications providing RTPI have been steadily entering the market, particularly for urban areas, with options such as OneBusAway (<http://onebusaway.org>), Citymapper (<https://citymapper.com>), Transit App (<http://transitapp.com>), NextThere (<http://nextthere.com>), and Moovit (<http://moovitapp.com>) providing RTPI platforms for multiple cities. Further, some service providers, such as the Chicago CTA (<http://www.ctabustracker.com>), provide bespoke apps that are reflective of traveller needs in their particular cities.

As RTPI systems are developed, the way in which the data generated may impact upon service provision and capacity of operators should also be addressed. While it is

possible that data crowdsourced from passengers may be utilised for improvements in information provision [13], thus demonstrating benefits in passenger/operator communication, the use of crowdsourced data to support or enhance operator *capacity* improvements is less well understood. Exploration of such impacts arising from operator installed RTPI systems [14] indicate operators can benefit from: improved situational awareness for dispatchers allowing individual operators to handle more of the fleet; schedule adherence feedback to operators; enhanced scheduling, service design, and operations from analysis of historic data; providing passengers with next stop announcements and next arrival predictions at stops; improved understanding of passenger journeys through collection of boarding and alighting data; and covert alarm monitoring to inform dispatch operators of on-board emergencies. Here, while we do not preclude the potential for crowdsourced RTPI systems to be incorporated into the operator data ecosystem, we aim to focus, primarily, on establishing the capabilities of our proposed system given the research questions identified above.

### *2.3. Design Considerations for Provision of RTPI*

While many RTPI systems depend solely on information drawn directly from transport service agencies [15], a growing number of smartphone applications rely on crowdsourcing data from users to provide others with timely updates on traffic and travel. This type of service can be participatory, where the user actively provides information, or opportunistic, in which applications run in the background of a smartphone and collect sensor information from on-going activities [16]. For example, in Waze (<https://www.waze.com>) drivers can actively share pertinent information such as delays, road hazards, and fuel prices with other users; on the other hand, traffic congestion data available on Google Maps (<http://maps.google.com>) is derived from data collected while users run the Google Maps application with location sharing enabled on a smartphone or connected mobile device [17].

More recently, the public transit application Moovit (<https://moovitapp.com/>) crowdsources data both on infrastructure (such as entrance and exits to stations) as well as disruptions and other general information. In all cases, having more users likely results in higher numbers of data contributors, which may result in more data about the transport network being available. However, such approaches can suffer from the “free rider” problem, where persons avail themselves of the information provided, without providing data themselves; this is a common issue in crowdsourcing or wiki-style projects [18]. Another RTPI model currently experiencing growth is the use of social media outlets, such as Twitter (<http://www.twitter.com>), to allow for real-time sharing of information between public transport operators and their passengers. Here, information is shared in both *formal* and *informal* ways; examples of the former include updates sent directly from operators/other agencies to their followers, while informal routes include passenger reports of delays or disruptions [19].

User engagement is a critical factor in encouraging adoption and active participation in crowdsourcing activities. It has been suggested that three critical elements precede a user’s determination to participate: personal interest in the topic, goal clarity, and motivation to contribute [20]. The aims, objectives, and potential benefits of crowdsourcing activities are key factors in attracting participants. Once attracted, however, the motivation to sustain participation may be reliant upon factors such as simplicity and system design [21], user feedback [22], and provision of incentives. Both research and system design are crucial components if adequate crowdsourced data is to be collected to provide useful, accurate information to travellers, particularly in rural areas where the *crowd* may be small [2].

Pertinent considerations when determining methods to aggregate and disseminate RTPI include constraints faced by the public transport operator, consumer needs, and quality of information provided, processed, and shared. While some proposed RTPI systems involve

the installation of on-board equipment (such as smartphones [23], Bluetooth, or Near Field Communication [24]), or other direct action by the transport operator, such systems may be limited by the willingness or ability of operators to make necessary investments, or by concerns regarding data reliability and accuracy [25]. When endeavouring to overcome these issues by allocating the data collection task to passengers via a smartphone application-based crowdsourcing tool, considerations emerge regarding the impact on consumer phones, such as battery life, which can be drained quickly through crowdsourcing applications that rely on continuous location sensing [26]. This, combined with the inconsistent quality of smartphone-based mode detection algorithms [27, 28], may introduce the need to ask users to actively provide data about their public transport journeys rather than continually and passively collecting data. This approach may limit the completeness of data collected (as customers may neglect to indicate every public transport journey made), thus impacting on data reliability; however, being parsimonious in terms of device battery life may be of greater importance. Finally, using a smartphone-based application may itself introduce concerns regarding inclusivity, as not all passengers have access to smartphones and necessary cellular data contracts. While research has been carried out into how this could be addressed by the use of SMS messages [29], without access to the functions available to smartphone applications (such as GPS), the overall scope of a SMS-based system is likely to be limited to the dissemination of RTPI.

### **3. The *GetThereBus* Development Process**

After consideration of the issues reviewed above, the decision was made to develop a smartphone application that asked passengers to actively provide information while on-board public transport vehicles. Development of the resulting *GetThereBus* application followed a co-design methodology, progressing through several iterative development cycles,

summarised below, each of which extended the system to incorporate identified user requirements and considerations.

### **3.1. Technical Trial**

An initial version of *GetThereBus* was trialled in Aberdeen in December 2011 to evaluate the feasibility of a crowdsourcing approach to RTPI. This area was selected as its proximity to the research team enabled shorter, less costly development cycles than conducting testing activities in the Scottish Borders would have incurred. The trial system (shown in Figure 1) included the following functions: user registration and login, route selection, a Google Maps based visualization, and the ability to share location information. The map displayed the user's location as a blue dot, the vehicle locations inferred from the timetable using purple pins, and real-time vehicle locations using green pins. When location sharing was active, a new location was transmitted every second and the map showed only the user's location. Users could also set up alerts to be notified of the expected bus arrival time at a selected point on the route, a specified number of minutes before the bus was due. This functionality was removed prior to the finalisation of the application to simplify the application's design and implementation.

This trial focused on the First Aberdeen route number 17, a cross-city route running from Dyce to Faulds Gate. Eight participants were instructed to board buses on this route at various stops and times throughout the day, and to share their location while travelling. These journeys were arranged to ensure that, other than for the first participant to travel, each participant received RTPI. Following the trial, participants attended a structured focus group exploring their experience of using the system. The focus group was recorded and transcribed.





Figure 1 Screenshots of the initial version of GetThereBus; screens shown are: log in (left); route selection (centre); map based RTPI visualisation (right).

The main discussion points that emerged during the focus group related to: concerns regarding potential for incorrect/unintended use of the “I’m on bus” button and failing to deactivate at journey end; desire for display of additional travel information, such as bus stops and vehicle routes; preference for map- rather than text-based description of estimated time until arrival; concerns regarding data coverage in rural areas and downloading of map tiles (images); and desire for alternative methods of accessing information, such as SMS. The discussion also noted that *GetThereBus* would be useful in rural areas that have low frequency bus services and otherwise no available RTPI, and that the application would allow users to adapt travel plans when a bus is running early or late.

### 3.2. Understanding the Rural Bus Passenger Experience

Following the Aberdeen technical trial, a series of activities were undertaken to adapt and test the system for the Scottish Borders. Our activities focused around the route of the First X95/95/95A service operating between Edinburgh Bus Station and Carlisle Railway Station. Other than the urban areas of Edinburgh, Galashiels, Hawick, and Carlisle, this route largely operates in either Accessible Rural or Remote Rural areas (as defined by [30]). The

X95 route (the longest variant) is approximately 94 miles, taking between 3 hours 36 minutes and 3 hours 55 minutes, operating at 30 minute intervals from early morning (starting at 0615) until late evening (the last bus terminates at 0019). The 95 and 95A variants operate between Edinburgh and Hawick.

Initial passenger interviews discussed in [31] and [32] revealed that individuals desire accurate and timely real-time information about the transport network, delivered via a mobile device (an application or SMS); that this information should be personalized to their journey; and that such information is particularly desired during periods of disruption to the transport network. These activities also identified that individuals use formal sources (e.g. vehicle driver, service operator, and local media) and informal sources (friends, relatives, other travellers) to gain transport information, including seeking alternative modes, routes, and journey completion arrangements during periods of network disruption. These findings suggested that there was potential for passengers in rural areas to use *GetThereBus* to both access information about their journeys and to complement their existing information sharing behaviours, and also contributed valuable information to the development of the final application.

### ***3.3. Preparation for Deployment of GetThereBus***

*GetThereBus* was subsequently updated to reflect the concerns raised during the technical trial focus group and the findings of interviews with rural bus users; this section describes the application's functionality, and activities undertaken to test the system in the Scottish Borders and raise awareness of *GetThereBus* among public transport users.

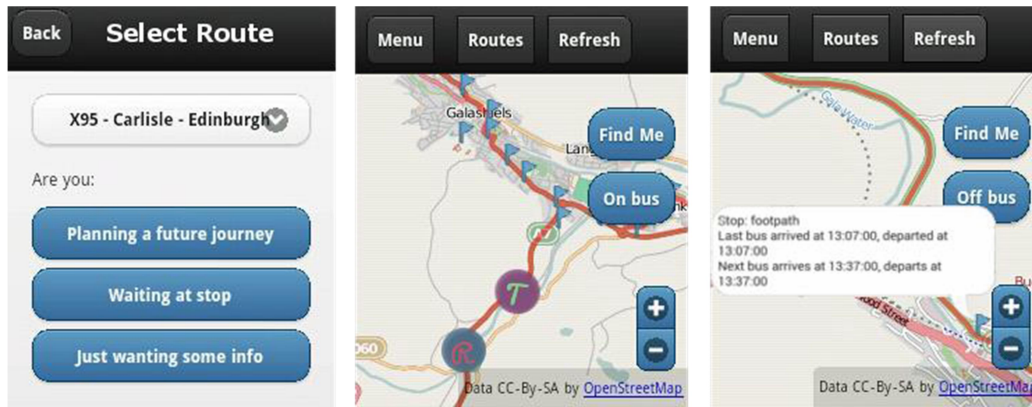


Figure 2 Screenshots of the final *GetThereBus* app: route selection (left); map based RTPI visualisation (centre); and accessing timetable information for a stop (right).

The registration page allows the user to sign up by providing a name, email address, and password. Following verification of the email address, the user can then log-in to the application. Once logged-in, the route selection page (Figure 2, left) prompts the user to select the service and direction of travel about which they wish to receive information. Once an option is selected, the user must indicate why they desire this information (planning a future journey, waiting at stop, or just wanting some information - a catch-all for other uses of the app) before viewing the map screen.

The map visualization uses OpenStreetMap (<http://www.openstreetmap.org>) and the map tiles from this open mapping platform are embedded within *GetThereBus*. This avoids downloading the tiles via the cellular data network every time the application is used (which is a requirement for use of Google Maps), an issue given the variable levels of network coverage in rural areas, and also reduces data transmission costs incurred by using the application.

The map is overlaid (Figure 2, centre) with: a red line indicating the bus route, blue flags indicating the physical bus stops, a "T" symbol indicating the location of buses on the selected route as inferred from the timetable, and, if available, an "R" symbol indicating the real-time location of buses as provided by users. The user can refresh the vehicle locations,

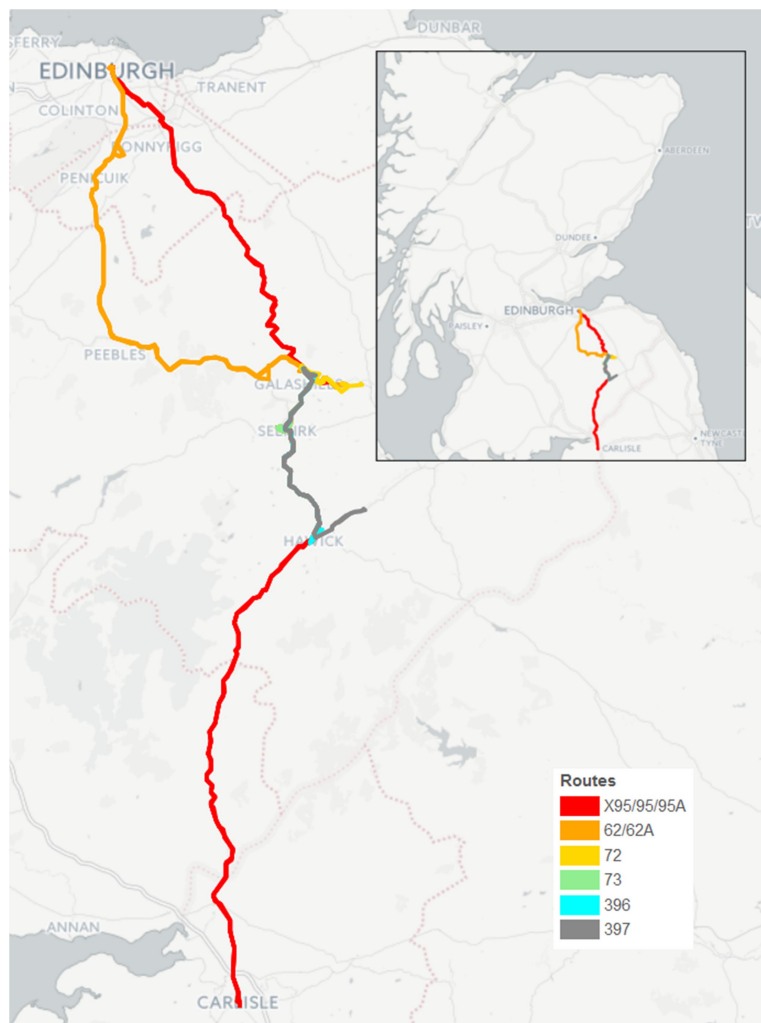
return to route selection, zoom, locate themselves, display the menu, and indicate that they are on a bus (via the “On bus” button). Tapping on a stop flag displays the previous and next timetabled arrival/departure times (with respect to the current time) for the selected route at that stop (Figure 2, right).

Additional screens (not shown in Figure 2) provide access to help, frequently asked questions about *GetThereBus*, and a form to submit feedback on the application.

Tapping the "On bus" button activates location tracking, transmitting the GPS location of the user's device every minute to the *GetThereBus* server, where it is aligned to the road network by a map matching process, before being used to provide others with the real-time bus location. If no cellular data signal is available when transmitting a location, the data is cached on the device until a signal becomes available or the next location is obtained, at which point the location is uploaded to the server. The user is reminded every hour when the location tracking is active via a notification message prompting them to stop the tracking if they are no longer travelling. The minute upload frequency was selected following tests which determined that it balanced the device battery usage with provision of sufficient information for waiting passengers to monitor a vehicle's location and estimate its arrival time.

The system was also updated with timetable, routes, and stop data for selected bus routes in the Scottish Borders. The routes, shown in Figure 3, were selected based on the following criteria: operated by First South East and Central Scotland; calling at Galashiels (the area's most populated town) or acting as a feeder service for those that do; and calling at the area's other highly populated settlements (Hawick, Peebles, Selkirk, Innerleithen, Melrose, Walkerburn, and Stow) as defined by [33].

Data presented by the application is managed by the *GetThere* server which runs several web services that support the application's functionality. Where possible, open data, i.e. data that “anyone can freely access, use, modify, and share for any purpose” [34] was used. Data sources included: OpenStreetMap, which provides the map tiles and data about the road network; NaPTAN (<https://data.gov.uk/dataset/naptan>) which provides details of bus stops; and bus timetable data provided by Traveline Scotland (<http://travelinescotland.com>). For further details on how this data is represented, integrated, and used see [35, 36, 37].



*Figure 3 Map of the Scottish Borders and routes supported by GetThereBus, based on OpenStreetMap. All routes follow the same general in- and out-bound paths.*

During this development period the application was tested several times between Edinburgh and Galashiels, with an extended test in January 2013 between Stow and Carlisle,

during which *GetThereBus* was used by a researcher to share his location during one outbound and one inbound journey. Using a car, two researchers simulated passengers at several points along the route between and within settlements using *GetThereBus* while waiting at the roadside approximately five minutes before the scheduled arrival time for the service at that location. The system operated as expected during this test, providing RTPI along the entire route. While areas of low/non-existent mobile data coverage existed, the available information was sufficient for the “passengers” to estimate the bus arrival time at each waiting point.

A series of public engagement activities were undertaken to raise awareness of the system and attract users. The first was a stall at the Heriot-Watt University Scottish Borders Campus Student Union, in January 2013. A project member described and demonstrated the application to approximately 50 students and distributed information leaflets; 27 students expressed an interest in using the system and provided their contact details.

*GetThereBus* was published on the Google Play store (<http://play.google.com>) on 8th February 2013. With the support of Scottish Borders Council (<http://www.scotborders.gov.uk>), posters advertising the application were displayed alongside the timetables at stops along the relevant routes (Figure 4, left). Further public engagement activities took place in July and August 2013 when project members visited bus stops in Galashiels, Selkirk, Peebles, and Hawick, speaking with a total of 597 bus users (Figure 4, right). At each stop, a poster was displayed promoting the application, and researchers wore vests with *GetThereBus* branding and distributed postcards describing the application and linking to the website (<http://homepages.abdn.ac.uk/getthere/>) and Google Play page.



Figure 4 Awareness raising via posters at bus stops (left) and engagement activities at Hawick Mart Street bus stop (right). Photographs: authors' own.

#### 4. Rural Intervention Study

The data evaluated here was collected during a before-and-after intervention study conducted during September and October of 2013. While previous work [38] focused on examining the effects of the *GetThereBus* RTPI system on a sample population (as summarised briefly below, and available in more detail in [38]), here we examine the data contributed by participants of the intervention study with respect to the research questions identified above. The intervention study involved 15 participants; all were students at the Heriot-Watt Scottish Borders Campus, with an average age of 28. Nine females and six males participated, with nine participants making more than five journeys per week. The participants were selected based on their patterns of public transport usage, purpose of travel, and familiarity with the geographical area. Each participant was initially interviewed with the questions discussing their journeys, experience during disruption, and six possible effects of RTPI. These effects included: perceived waiting time, willingness to pay, adjusted travel behaviour, positive psychological effects, mode choice, and customer satisfaction. Following each interview, the participant was shown how to install and use *GetThereBus*. The subsequent intervention period lasted 18 days, during which participants were instructed to use the application to view and share information on their bus journeys. Each participant received a £50 gift voucher on condition of attending two interviews and using the “On bus”

function of the application while travelling during the intervention period. While findings in [38] focused primarily on the perceived effects of using the *GetThereBus* RTPI system by participants, they did not explicitly address the data generated by the system overall, nor the potential for such a structure to address current gaps in the provision of RTPI in rural areas. It is these questions to which we turn below by examining the data generated from the study.

Table 1 summarises the level of engagement by each participant during the study. The *anticipated number of journeys* column contains the participant's own assessment of the number of journeys they would make; *number of journeys* is the number of times the participant used the "On bus" function; and *total number of GPS data points* is the number of distinct GPS co-ordinates uploaded from the application. Figure 5 depicts the GPS data points provided by participants, which generally matched the expected route of travel for the specified bus route (primarily the X95, 95, or 95A). However, there was one exception where a participant appears to have shared their location by mistake. In this instance, GPS data was provided for three hours, supposedly for the 396 route; however, trips on this route last a maximum of around 35 minutes, and the data situated the participant travelling to and around the town of Berwick-upon-Tweed (far right of Figure 5), which is not on the 396 route. This example highlights the necessity to assess the quality of information obtained via crowdsourcing approaches before relaying it to other users; [35] discusses how such quality issues are handled in *GetThereBus*.

Analysis of how the five most active participants (participants 11-15 in Table 1) used *GetThereBus* indicates that they used the "On bus" functionality on average 42% of the time they used the application. In this regard, participant 13 was the most active, sharing their location during 53% of their uses of *GetThereBus*; participant 11 was the least active, sharing their location during 33% of their uses of *GetThereBus*. Here we consider use of the application to include seeking information (either bus locations (both real-time and locations



inferred from the timetable) or timetable information for a stop) or using the “On bus” functionality.

Table 1 Data generated by participants during the intervention study.

<b>Participant ID</b>	<b>Anticipated No. of Journeys</b>	<b>No. of Journeys using <i>GetThereBus</i></b>	<b>Total No. of GPS Data Points Provided using <i>GetThereBus</i></b>
1	24	2	2
2	24	5	12
3	24	4	22
4	24	3	25
5	24	4	45
6	24	5	47
7	24	8	54
8	24	4	61
9	30	8	68
10	30	4	89
11	36	24	156
12	36	5	207
13	27	12	257
14	24	19	394
15	27	12	448

All five participants exhibited the behaviour of invoking the “On bus” functionality immediately after the map was displayed; this suggests that their intention was to share data rather than plan a journey (while the application requested users to provide a reason for their use of the application – either planning a future journey, waiting at stop, or just wanting some information – a catch-all for other uses of *GetThereBus* – it did not include a “share data” option).

When participants used the application without invoking the “On bus” function, they made between one and six requests for vehicle locations on one or two routes, and requests for timetable information at stops either to support journey planning or while they were at a stop.

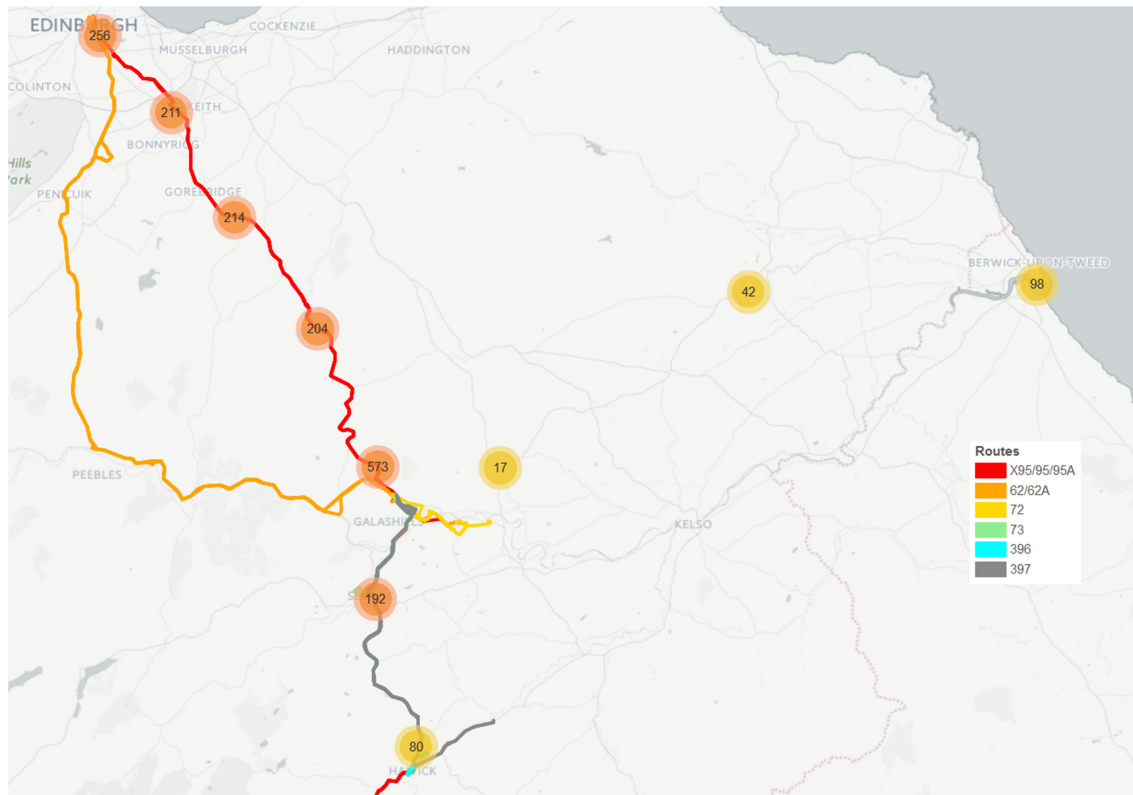


Figure 5 Map of GPS locations contributed by trial participants in the Scottish Borders along with routes supported by GetThereBus. Each circle represents a cluster of the specified number of contributed GPS locations. The area south of Hawick is not shown as no locations were provided for that area. The map is based on OpenStreetMap.

Each participant was interviewed before and following their use of *GetThereBus*, using the same set of questions. Verbatim transcripts of both sets of interviews were analysed by four independent coders using the following methods: clustering the data by possible effects of RTPi; extracting the most salient statements of each participant for each effect; and interrogative hypothesis testing. Cohen’s Kappa and the Kappa coefficient were used across coder pairs which indicated a good strength of agreement between coders; the confidence interval indicated that the coding was not random and is reliable, and no indication of prevalence or bias was identified. The full findings of the intervention study are discussed in [36]; however, relevant to this analysis, participants reported that the RTPi affected their perceived control over their journey, reduced their waiting time, increased their willingness to pay for the *GetThereBus* application and the information it provides, made the bus service

easier to use, improved their perceptions towards the bus service, and affected their decision making.

## **5. Summary of Findings and Conclusions**

The research described here investigated four research questions, the answers to which will now be discussed:

*To what extent would the lack of digital infrastructure in rural areas hinder provision of RTPI?* As noted in [2], the lack of such infrastructure in rural areas presents several challenges for RTPI systems. However, this work found these did not prove to be a significant hindrance to the provision of an app-based RTPI system. The iterative co-development process meant such challenges were addressed through the application design, for example by minimising data transfer between the application and server by transmitting the user's location every minute, caching the map tiles on the device; the impact of variable levels of cellular data signals when the user is sharing their location were addressed by temporarily storing the user's location until a signal is present; and locations shared by users were subjected to a map matching process to align the location with the road network, reducing any impact of variable smartphone GPS accuracy.

*Could an RTPI system based on information crowdsourced from bus passengers be developed that overcomes these limitations?* Again, the study found that technical limitations could be overcome to provide such an RTPI system, when the crowdsourced information is appropriately processed (e.g. map matched to the road network) and integrated with relevant data sets (e.g. bus routes and timetables).

*To what extent would passengers contribute information to such a system?* Examining the information contributed during the intervention study, 66% of participants provided location data on less than 26% of their anticipated journeys, with only two (13%) providing

information on more than half of their anticipated journeys. These findings demonstrate that passengers did not, in general, behave as active data contributors and further strategies are needed to increase active participation. Based on the study reported here, it is likely that growing the number of total users (via additional marketing or incentives) would have the greatest impact, but other measures could include simplifying the method by which data are shared or providing periodic feedback to users on the impacts of their information sharing, thus encouraging altruistic behaviour. Passively collecting data at all times during which the application is enabled would provide a more robust data set, although concerns regarding the impact on battery life must be considered. Finally, the use of gamification elements within *GetThereBus* (for example, point scoring, or some form of competition between users) may have increased the participants incentive to contribute data during their journeys.

*Could such a system be a sufficient substitute for an operator-supplied RTPI system?*

Despite considerable effort centred around public engagement and participant recruitment, the limitations of the trial, in terms of its duration and the number of participants, mean that it was not possible to provide a robust answer to this question. Certainly the study participants found *GetThereBus* to be helpful and a source of added value when compared with traditional forms of travel information, which aligns with findings of previous studies of operator systems (e.g. Schweiger 2003 cited in [38], Borning 2010 cited in [38]). However, the contribution levels from users indicate that achieving comparative levels of area-wide coverage through crowdsourcing is a significant challenge. Given this, we recommend operators view crowdsourced data as supplementary to other data, recognising that crowdsourcing can provide some capacity related benefits, such as improved understanding of some passenger journeys, which complement and extend benefits arising from other data that are available, rather than relying solely on crowdsourcing for such benefits.

As the widespread availability of personal technology grows, it is critical to re-evaluate our expectations regarding the collection, provision, and access to accurate and timely public transport information, including in rural contexts. In this study, we have attempted to shift some of the responsibility for generation of this information on to the consumer, as a supplement to the timetabled information provided by the transport agency, in order to generate data that is more reflective of the real-time public transport environment. Considerations regarding the size of the crowd and the availability of the necessary underlying infrastructure, however, also reflect the concerns being faced in developing such a system in a rural or under-served environment. Overall, this work has demonstrated that there are significant challenges associated with crowdsourcing RTPI service provision in rural areas. While technical challenges can usually be ‘worked around’ to provide an acceptable level of RTPI system functionality, challenges associated with awareness and participation are particularly acute in rural areas and addressing these effectively will be essential to further work in this area.

## **6. Acknowledgements**

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