A PASSENGER CENTRIC INFORMATION ECO-SYSTEM FOR INTEGRATED FLESIBLE TRANSPORT SYSTEMS IN RURAL AREAS

Nagendra R Velaga, Research Fellow, dot.rural Digital Economy Research Hub, King's College, University of Aberdeen, Aberdeen, UK, AB24 5UA. E-mail: n.r.velaga@abdn.ac.uk

John D Nelson, Professor and Director, Centre for Transport Research, College of Physical Sciences, University of Aberdeen, Aberdeen, UK, AB24 3UF. E-mail: j.d.nelson@abdn.ac.uk

Konstantinos Papangelis, Ph.D Student, dot.rural Digital Economy Research Hub, King's College, University of Aberdeen, Aberdeen, UK, E-mail: k.papangelis@abdn.ac.uk

David Corsar, Research Fellow, dot.rural Digital Economy Research Hub, King's College, University of Aberdeen, Aberdeen. mail: dcorsar@abdn.ac.uk

Peter Edwards, Professor, Computing Science Department, University of Aberdeen, Aberdeen, UK. mail: p.edwards@abdn.ac.uk

ABSTRACT

In recent decades, use of demand-responsive flexible transport services (e.g., dial-a-ride services, shared taxicabs, car-club) in rural areas has been promoted as a promising solution to connect rural dwellers to appropriate transport nodes (such as train stations/bus stops). It is accepted that such demand responsive transport services, that aim to provide desired level of flexibility, have the potential to improve accessibility and connectivity in remote and rural areas. Notwithstanding the application of Intelligent Transport Systems (ITS) solutions the deployment of such Flexible Transport Services (FTS) continues to face some critical problems, particularly with respect to achieving widespread coverage of real-time passenger information and communication systems.

Building on an on-going programme of Digital Economy research, the main aim of this paper is to present a passenger centric information eco-system for rural flexible transport systems. To achieve the above aim, the following objectives are formulated: (1) to understand the various operational and technology-related deployment issues with FTS in rural areas; (2) to describe the development of a passenger centric information system; and (3) to evaluate the impact of the developed information eco-system for various FTS services.

Keywords: Flexible Transport Services; Real time passenger information; crowd-sourcing; linked open data.

INTRODUCTION AND BACKGROUND

Around the world, many rural communities face a range of challenges associated with accessibility and connectivity to basic amenities such as health care, education, work and other services (e.g., shopping centres) (Audit Scotland, 2011; Velaga et al., 2012a). The lack of transport accessibility has a strong impact on people living and working in rural areas and particularly on certain mobility impaired groups such as the elderly and disabled (Kenyon et al., 2002; Takeuchi et al., 2003; Social Exclusion Unit, 2003; Mulley and Daniels, 2012). In order to enhance the accessibility and connectivity, a flexible and integrated transport system (FITS) - which can provide flexibility in one or more dimensions such as choosing route, time, mode of transport, service provider, payment system, and also target integration with other modes of transport - is identified as one of the promising solutions (Mageean and Nelson, 2003; Palmer et al., 2004; Nelson et al., 2010; Velaga et al., 2012b).

Flexible transport services (FTS) operate in various forms such as: shared taxicabs, shuttle vans, dial-a-ride services and car-clubs (Li and Quadrifoglio 2010). Moreover, a well designed FITS aims to integrate different transport services and modes (e.g., a FTS service connecting remote areas with nearer public transport nodes) and tries to achieve optimal and cost effective transport options to end users (Scott, 2010). Typically, for most of FTS services, each trip associates with a certain deviation in the route and a time window on pick-up and drop-off of individual passengers (Bent and Van Hentenryck, 2006). Real-Time Passenger Information (RTPI) provision is a basic requirement for such FTS services. However, most of FTS services are small scale, supported by subsidies, operated by local authorities, stand-alone services which often cater for a specific group of the population or fill a specific need; such services use very little or no intelligent transport systems and advanced information and communication technology support. Normally, mini vehicles that are used for FTS often suffer with a lack of infrastructure (for example, vehicle tracking system) ICT (e.g., wireless communications services). As a result the users of such FTS are often without RTPI; this in turn may lead to ineffective flexible transport systems.

As part of the Informed Rural Passenger (IRP) project, which is being under taken at the RCUK dot.rural Digital Economy Research Hub, University of Aberdeen, we are exploring how advanced mobile and ICT technologies might help in developing and enhancing RTPI in rural areas, where basic vehicle and transport infrastructures are not available. We have developed a passenger centric information eco-system - in which passengers act as both consumers and producers of the information. This is achieved by building on advances in mobile and communication technologies and crowd-sourcing. When acting as information producers, passengers are asked to provide information regarding vehicle location and other information (such as any incidents) during their journeys. This information is then integrated with other open data (such as weather reports and road works) and then made available to other users. We have examined the usability and effectiveness of such passenger generated information (using crowd-sourcing and linked open data principles) for FTS through detailed interviews with flexible transport service providers and operators. The following section provides the description of the passenger centric information eco-system, named *GetThere* which is being deployed on a trial basis in the Scottish Borders.

DESCRIPTION OF GET-THERE SYSTEM

The *GetThere* system is backed by an information eco-system designed as a service-oriented architecture using linked data and semantic web technologies. The eco-system consists of two types of components (data sets and web services) conceptually split across four layers. The base layer consists of several domain data sets, providing the information necessary to provide Real Time Passenger Information (RTPI) (e.g. timetable, routes, bus stop locations, real-time vehicle location, etc.). The middle two layers deal with annotating the domain data for some specific purpose, with the services generating the annotations, which are stored in the annotation data layer. The top layer consists of a set of application services, which uses the layers below to provide *GetThere* application services, for example, determining vehicle locations, stop arrival/departure times, or disruptions affecting selected services.

The domain data layer uses linked data to integrate relevant datasets. Linked data is a practise for exposing, sharing, and connecting pieces of data using internet technologies, primarily URIs (Berners-Lee, 2006). Using linked data, each thing (piece of data) is given a unique HTTP URI (for example, http://transport.data.gov.uk/id/stop-point/490011810W is used to represent a particular bus stop). This means when an agent (either human or machine) looks up that URI, they are provided with useful information using standards such as RDF[1]. An important feature of this approach is that it allows pieces of data to be linked through these URIs. For example, the information returned about stop point 490011810W links to http://transport.data.gov.uk/doc/administrative-area/082; the type of that link is defined as administrative area, meaning administrative area 082 is the area that stop-point 490011810W is located in.

Using linked data allows each data set to be stored separately, allowing the system to scale. It also allows new data sets to be incorporated easily. However, one of the main benefits is that it allows data to be provided and maintained by third parties (for example details of bus stop locations are provided by the UK Department for Transport), and we do not require to mirror it locally and ensure our copy is kept up-to-date.

The domain data sets include the National Public Transport Access Nodes (NaPTAN) and National Public Transport *Gazetteer* (NPTG) datasets, provided by the UK Department for Transport. NaPTAN provides details of every place of access to public transport in the UK. For bus stops, this includes their unique ID, location, name, and nearby points of reference. NPTG provides a topographic database of towns and settlements in the UK[2].

[1] W3C http://www.w3.org/RDF/

[2] www.dft.gov.uk/nptg/

The operators' data set provides details of all public transport operators in the UK. This dataset is based on Traveline's National Operators Code (NOC) Excel spreadsheet[3]. For each operator, it provides details including: their unique ID, name, license name, and Traveline area they operate in.

The timetable data sets link to both the NPTG and NaPTAN datasets, and provide timetable information for routes/services. Timetable information consists of a series of stop timing points for each trip, where each point defines the arrival and departure time along with linking to the relevant stop description in NaPTAN to provide, for example, the stop's location.

The transport infrastructure data set details the road network, based on map details extracted from openstreetmap.org. This is used to define the actual route a bus takes, in terms of the roads travelled along.

Finally, transport observations crowd-sourced from users are stored in the user observations data set. Here, we use semantic sensor network models[4] to represent the observation and the sensor that captured it (which can be either the user or a sensor on a smartphone). Such observations are linked to the service/route (in the timetable data set) that the user is travelling on.

Provenance provides a record of the entities, activities, and people involved in producing a piece of data, which can be used to perform assessments about its quality, reliability, or trustworthiness[5]. Given these potential uses, the eco-system features a provenance annotation service that provides functionalities for generating and accessing the provenance of data within the eco-system. This includes inferring provenance for user observations, and maintaining provenance records for data hosted by third parties, which can be used by services to support data assessment (Corsar et al., 2012).

As part of the RTPI eco-system, a mobile application (named, *GetThere*) was developed. The *GetThere* smartphone app is an Android app that interfaces with the eco-system to provide users with RTPI. The *GetThere* application enables users to provide or receive information related to their journeys. Figure 1 shows four different screens describing the function of the mobile application; and the main functions of the app are:

- Sign up/log in, which allows new users to register with *GetThere*, and then log in to start using the app.
- Selecting a route (including direction of travel) to view information about. This connects to the eco-system, obtains a list of all routes from the timetable data set, and displays them to the user. The user then selects one, and presses the "view locations" button.

[3] http://travelinedata.org.uk/noc.htm
[4] http://www.w3.org/2005/Incubator/ssn/ssnx
[5] http://www.w3.org/TR/prov-dm/

- Viewing transport information on a map. Here various pieces of information are displayed about the selected route. These include the location of all stops along the route. Tapping on a stop will then show the arrival and departure time of the previous and next bus/vehicle at that stop. This allows the user to determine when a bus should have been at that stop, to estimate if it is running late. A red line is used to display the physical route that the bus will travel along, to give users an idea of where the bus goes. Two types of vehicle location are also displayed: a purple circle with a '*T*' indicates an estimated vehicle location, based on the timetable/schedules; a green circle with a '*R*' indicates a real-time location, reported by other *GetThere* users. As *GetThere* is designed for rural areas, where mobile data coverage is typically quite poor/slow, all maps are included within the app. This means only maps close to the routes travelled are shown, with areas out-with being shown as a grey box.
- Providing transport information. Currently, this is limited to providing location information. When the user boards the vehicle, they tap the "on bus" button, which starts a background process that uploads their location (and so the vehicle's location) every minute to the *GetThere* system. Location is only obtained and uploaded every minute to reduce the impact on battery life.

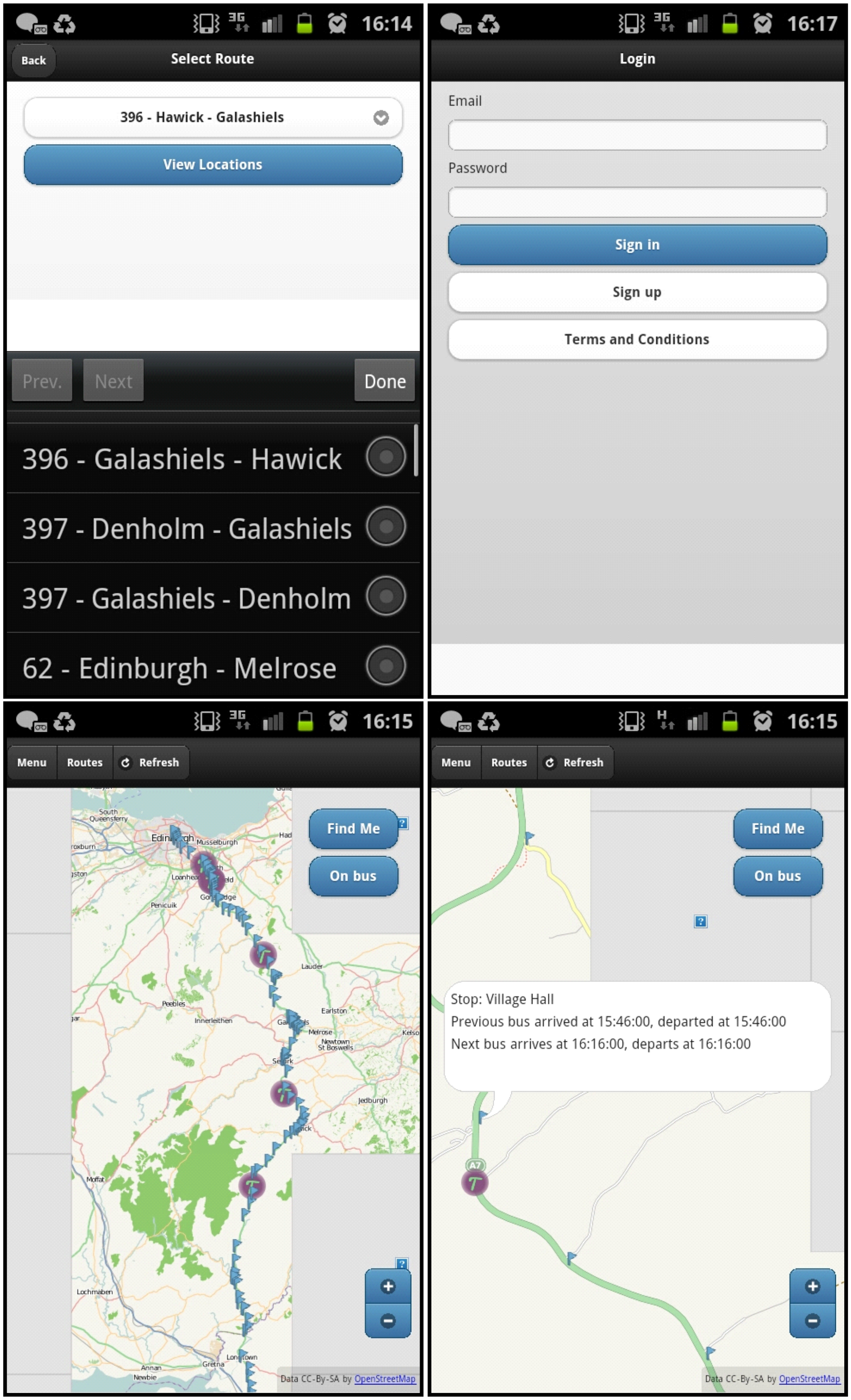

Figure 1 - *GetThere* application

EVALUATING THE DEVELOPED RTPI SYSTEM - INTERVIEWS WITH FTS OPERATORS

In order to evaluate the usability and potential impact of the developed information eco-system for FTS context, we have conducted interviews with three different types of rural flexible transport operators in Scotland that serve school-based trips, elderly and health-related trips, and general open access FTS that provide transport connectivity to basic amenities and other transport nodes in rural areas, where there is no public transport provision. The main aim and objectives of the interviews are illustrated in Table 1.

Table 1 – Interviews with FTS operators

<table>
<tr><th>Type of Operator</th><th>Date</th><th>Main aim/objectives</th></tr>
<tr><td>Local council operated FTS for school-based trips</td><td>Dec 2012</td><td rowspan="3">• to understand the operation of each FTS service that provides service for a certain group of people
• to identify requirements for Real-Time Passenger Information (RTPI)
• to understand the current technological issues for RTPI provision
• to demonstrate the passenger centric information eco-system (GetThere).
• to evaluate the usability, effectiveness and impact of the developed information eco-system for FTS services
• to explore the user generated information context and to investigate proof of design and concept.</td></tr>
<tr><td>An open access FTS, operates in rural areas where there is no public transport connectivity</td><td>Jan 2013</td></tr>
<tr><td>Integrated multi-mode transport for health-related trips</td><td>Jan 2013</td></tr>
</table>

A detailed questionnaire was prepared covering various issues related to RTPI provision in flexible transport systems. As illustrated in Table 1, three major interviews are conducted; in each interview two or three people who were involved in service design, operation and maintenance in each FTS service type were brought together and asked a set of questions on issues related to RTPI provision. As part of the interview, the developed passenger centric information eco-system was demonstrated and a set of questions that cover usability, effectiveness and impact of the developed eco-system, proof of design and concept of user generated information context were discussed.

Findings from Interviews

The summary of findings from the interviews is illustrated below:

(1) Existing FTS services particularly in rural areas are low-tech systems and use very little or no ICT support.

(2) Currently, there is no provision of RTPI for passengers; however, the formal channel of communication is:

   a. When there is a considerable delay due to disruptions, vehicle driver may communicate to the travel dispatch centre through mobile or wireless communication.

   b. The authorities at the dispatch centre note the possible delays and intimate to passengers who phone to the dispatch centre and enquire about the vehicle delays.

   However, there are many difficulties with this type of communication and often the passengers are uninformed.

(3) It was identified that passengers eagerly look for timely, accurate and personalised information about the delays and disruptions. Particularly, in flexible routed demand responsive transport, due to route variations, there is a time window for pickup and drop-off; passengers require to know the exact variations in the time window.

(4) It was identified that RTPI requirements depends on type of FTS and level of flexibility in the route. FTS services that provide patient and school transport demand require more sophisticated RTPI; whereas elderly shopping and leisure trips may not be significantly affected by delays. Also, if it is a door-to-door pick-up and drop-off service, passengers are relatively fine with the delays as they do not have to wait at stops.

(5) FTS operators mentioned that a system like *GetThere* is very useful for rural FTS; however, a low tech system with SMS would be more helpful to passengers, who use a second generation phone; this is particularly required for specific FTS that support elderly shopping, recreational and health-related trips.

(6) Further enhancement of *GetThere* towards integration of different modes of transport (such as health-related transport, e.g., ambulance with other private taxies) is sought. That means the information provision is not just for one mode of transport; for example a passenger may need to use multiple modes (e.g., FTS, bus and then train) to accomplish a trip, the passenger needs RTPI during each interchange.

(7) It was pointed out that creation of crowd-sourced passenger information – which mostly depends on real-world passengers to generate RTPI – leads to other issues such as trust and reliability of information generated.

(8) Some co-design issues with *GetThere* system were identified:

   a) A pop-up message that exactly states when the vehicle will arrive at origin (or a particular location); if there are delays, exactly how much delay and what are the alternative options?

b) Some smartphone users (generally elderly) may not have experience in using apps. A detailed description/user guidelines/training will be more useful.

c) Further level of map zoom-in is required.

d) User friendly logins (e.g., save password / automatically login when a passenger is on bus along the route) are very helpful.

e) It was mentioned that normally, users will forget to press "off bus" when they alight. A mechanism that automatically detects when the passenger is off-bus is required.

f) A game-based approach could attract many young people.

SUMMARY AND CONCLUSIONS

In this research we have explored the RTPI issues in flexible transport systems that connect rural dwellers to basic amenities and other transport nodes such as bus stops and stations. It was identified that currently there is very little or no RTPI provision due to lack of transport infrastructure such as AVL; passengers eagerly look for timely, accurate and personalised passenger information. Moreover, the RTPI requirements are based on the type of trip, level of flexibility and targeted passenger group.

As far as authors are aware this is the first attempt to explore the user-generated passenger information context in demand responsive FTS. Our findings showed that such a user centric approach (i.e., where passengers are both information creators and consumers) are beneficial to some of the flexible transport services that use very low tech systems; because, in the user generated information scenario, the requirements for new infrastructure (e.g., Automatic Vehicle Location systems) is minimal, resulting in very low implementation cost . However, there are some issues such as trust and reliability of information generated need to be addressed.

ACKNOWLEDGEMENT

The research described here is supported by the award made by the RCUK Digital Economy programme to the dot.rural Digital Economy Research Hub; award reference: EP/G066051/1.

REFERENCES

Audit Scotland, (2011). *Transport for Health and Social Care*. Audit Scotland. Available at: http://www.audit-scotland.gov.uk/docs/health/2011/nr_110804_transport_health.pdf

Bent, R., and Van Hentenryck, P., (2006). A two-stage hybrid algorithm for pickup and delivery vehicle routing problems with time windows. *Computers & Operations Research,* 33 (4), 875–893.

Berners-Lee, T., (2006). *Linked Data - Design Issues*, available at: http://www.w3.org/DesignIssues /LinkedData.html (Accessed on 2nd Feb 2013).

Corsar, D., Edwards, P., Velaga, N. R., Nelson, J. D., and Pan J. Z. (2012). Exploring provenance in a linked data ecosystem. *In Proc. of the 4th International Provenance and Annotation Workshop*, IPAW.

Kenyon, S., Lyons, G., Rafferty, J., (2002). Transport and social exclusion: investigating the possibility of promoting inclusion through virtual mobility. *Journal of Transport Geography*, 10, (3), 207-219.

Li, X., and Quadrifoglio, L., (2010). Feeder transit services: Choosing between fixed and demand responsive policy. *Transportation research part C: emerging Technologies*, 18, pp. 770-780.

Palmer K., Dessouky M. M., and Abdelmaguid T., (2004). Impacts of management practices and advanced technologies on demand responsive transit systems. *Transport Res A-*Pol 38:495–509.

Papangelis, K., Velaga, N. R., Sripada, S., Beecroft, M., Nelson, J. D., Anable, J., (2013). Real-time passenger information in rural areas during disruptions: A conceptual model development and evaluation. *92nd Annual Meeting of the Transportation Research Board (TRB) of National Academies*, from 13 to 17 Jan-2013, Washington, D.C., USA.

Mageean, J. and Nelson, J., (2003). The evaluation of demand responsive transport services in Europe. *Journal of Transport Geography*. 11, 255–270.

Mulley, C. and Daniels, R., (2012). Quantifying the role of a flexible transport service in reducing the accessibility gap in low density areas: A case-study in north-west Sydney. *Research in Transportation Business and Management*. 3, 12-23

Nelson, J. D, Wright, S, Masson, B, Ambrosino, G., Naniopoulos, A., (2010). Recent developments in Flexible Transport Services. *Research in Transportation Economics*, 29, 243-248.

Scott, R. A., (2010). *Demand responsive passenger transport in low-demand situations*. NZ Transport Agency research report no.425.

Social Exclusion Unit, (2003). Making the Connections: Final Report on Transport and Social Exclusion. *Final report to Prime minister*, UK. Available at: http://www.ilo.org/wcmsp5 /groups/public/---ed_emp/---emp_policy/---invest/documents/publication/wcms_asist _8210. pdf (Accessed on 18/03/2011).

Takeuchi, R., F. Nakamura, I. Okura, and H. Hiraishi. (2003). Feasibility study on demand responsive transport systems. *Journal of the Eastern Asia Society for Transportation Studies* 5: 388-397

Velaga, N. R., Beecroft. M., Nelson, J. D., Corsar, D. and Edwards, P., (2012a). Transport poverty meets the digital divide: accessibility and connectivity in rural communities. *Journal of Transport Geography*, 21: 102-112.

Velaga, N. R., Nelson, J. D., Wright, S. D. and Farrington J. H., (2012b). The Potential Role of Flexible Transport Services in Filling Gaps in Rural Public Transport Provision. *Journal of Public Transportation.* 15 (1), 33-53.