Journal of Transport Geography 21 (2012) 102–112

Contents lists available at SciVerse ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Transport poverty meets the digital divide: accessibility and connectivity in rural communities

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ARTICLE INFO

Keywords:
Transport technologies
Rural communities
Accessibility and connectivity

ABSTRACT

Rural communities face a range of challenges associated with accessibility and connectivity which apply in both the physical and virtual sphere. Constraints in rural transport infrastructure and services are often compounded by limitations in the development and resilience of technological infrastructures. In this context there is significant disparity between urban and rural communities.

This paper will examine the context for accessibility and connectivity in rural communities highlighting key transport and technology challenges. It also explores barriers and opportunities to bringing together transport and technology solutions to enhance rural accessibility and connectivity. This is an area where current understanding is weak as most research has been focussed on urban environments. The paper focuses specifically on two issues of current research; firstly, the role of information and associated technologies in supporting rural passengers on public transport, secondly, the use of technologies to support flexible and demand responsive transport services in rural areas.

1. Introduction

Access to health care, education, work and other services (e.g., shopping centres) for people living and working in rural areas is a key issue around the world. The term accessibility has several definitions; for example in terms of economic and social opportunity, accessibility can be defined as proximity or facility for spatial interaction (Gutierrez, 2009). This also includes virtual access which refers to use of the Information and Communication Technologies (ICTs) as an alternative to physical mobility (e.g., e-work, e-services, e-business and e-commerce) (Kenyon et al., 2002, 2003). In the transport context, accessibility can be defined as facility or opportunities with which basic services can be reached from a given location by using a certain transport system (Gutierrez, 2009).

In this paper, the focus is upon transport accessibility and connectivity, particularly in rural areas. Many rural areas have limited or no connection to public transport; and traditionally rural transport has been based predominantly on road vehicles (Dingen, 2000; Gray et al., 2001). The lack of transport accessibility and connectivity in rural areas has a strong impact on those with limited access to private motorised transport such as children, older people, people with disabilities and the mobility impaired (Kenyon et al., 2002; Social Exclusion Unit, 2003; Audit Scotland, 2011).

The use of transport telematics that encompass a range of advanced computer, ICT, navigation and positioning systems and digital technologies in the field of transport can improve the efficiency and service quality of transport systems (Giannopoulos, 2004; Sussman, 2005; Deeter, 2009). Examples include real-time bus arrival information at bus stops (such as Countdown in London), intelligent public transport systems (such as electronic fare collection and automated vehicle scheduling), and shared flexible transport management (such as dial-a-ride share taxi services) (Chowdhury and Sadek, 2003; Robinson, 2008; Nelson et al., 2010; Politis et al., 2010).

Though such transport technologies have been widely deployed in urban and suburban areas in the developed world, their application in rural and remote rural areas has been very limited (Nalevanko and Henry, 2001). Potential exists for these technologies to contribute to the alleviation of accessibility and inclusion problems in such areas.

This paper examines key transport and technology challenges relating to accessibility and connectivity in rural communities identified and explored within the context of the dot.rural Research Hub at the University of Aberdeen (Research Council UK, 2010). Opportunities to enhance rural accessibility and connectivity through advanced transport and technology solutions are explored in the context of rural Scotland. These solutions relate to two specific applications areas; firstly, the role of information and associated technologies in supporting rural passengers on public transport with real-time passenger information systems; and secondly, the

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doi:10.1016/j.jtrangeo.2011.12.005

use of technologies to support flexible and demand responsive transport services in rural areas.

2. Accessibility and connectivity issues in rural Scotland

In Scotland, approximately 19% of the population live in rural areas (National Statistics, 2010). Definition and classification of urban, suburban and rural areas varies across the world and even within the UK. The Scottish Government uses a six-stage urban–rural classification (National Statistics, 2010):

(1) *Large urban areas* – settlements with population of 125,000 or more.
(2) *Other urban areas* – settlements of 10,000 to 125,000 people.
(3) *Accessible small towns* – settlements of 3000 to 9999 people within 30 min drive of a settlement of 10,000 + people.
(4) *Remote small towns* – settlements of 3000 to 9999 people not within 30 min drive of a settlement of 10,000 + people.
(5) *Accessible rural areas* – settlements of less than 3000 people within 30 min drive of a settlement of 10,000 + people.
(6) *Remote rural areas* – settlements of less than 3000 people not within 30 min drive of a settlement of 10,000 + people.

Fig. 1 presents a map of Scotland providing areal distribution of population according to the above classification. It can be seen that most of Scotland is remote rural and there are only four large urban areas (Aberdeen, Dundee, Edinburgh and Glasgow).

Fig. 2 presents accessibility and connectivity conditions in Scotland in the form of road travel time to different amenities (such as hospitals and shopping centres) for each postcode sector. It can be seen that in many rural areas in Scotland, patients need to travel more than one hour to reach a maternity hospital and accident & emergency centre. The number of older people in Scotland is projected to rise by 12% between 2010 and 2015 (to around 991,000 in 2015), with an 18% increase in the number of people aged 85 and over (Audit Scotland, 2011). The need for transport services for socially disadvantaged groups (e.g., elderly, young and disabled) in rural and remotely located areas is undeniable (Currie, 2010).

A 1998 study of car dependence in rural Scotland (Farrington et al., 1998) revealed that in rural Scotland 89% of households

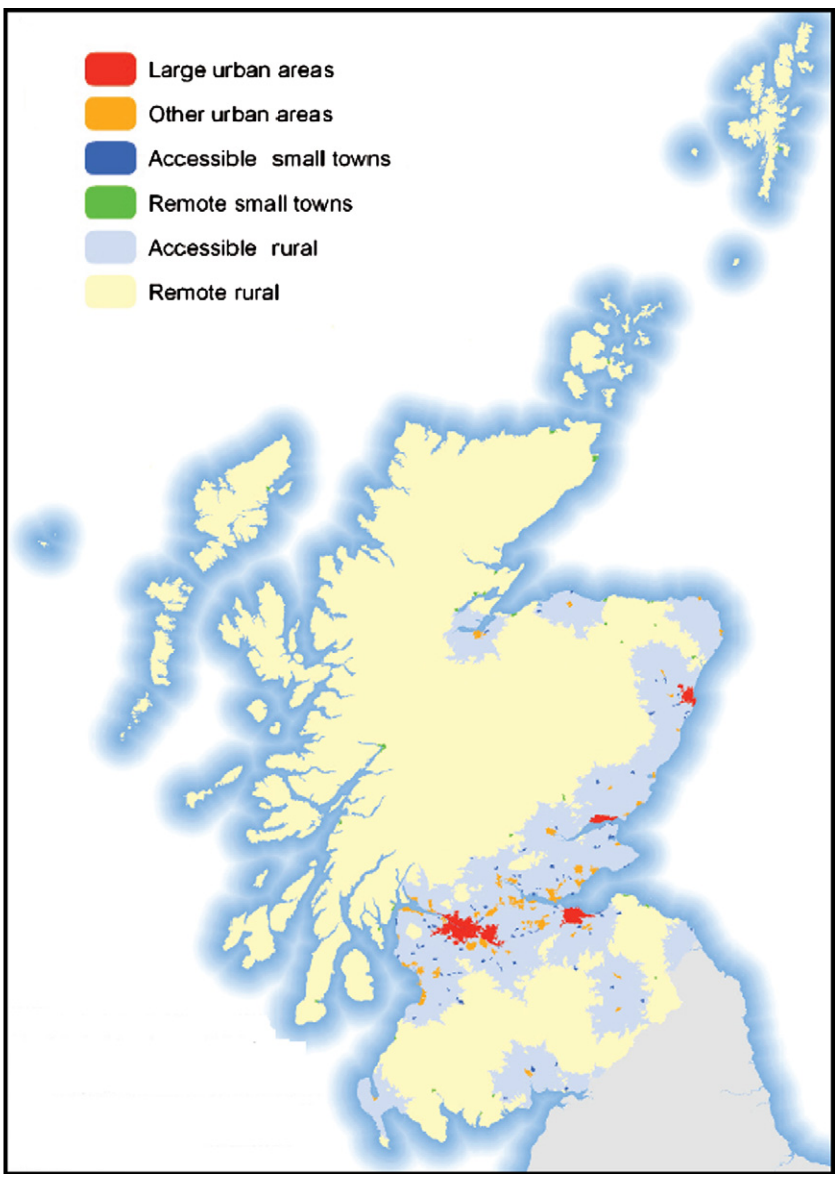

Fig. 1. Map of Scotland showing areal distribution of population. *Source*: National Statistics, 2010.

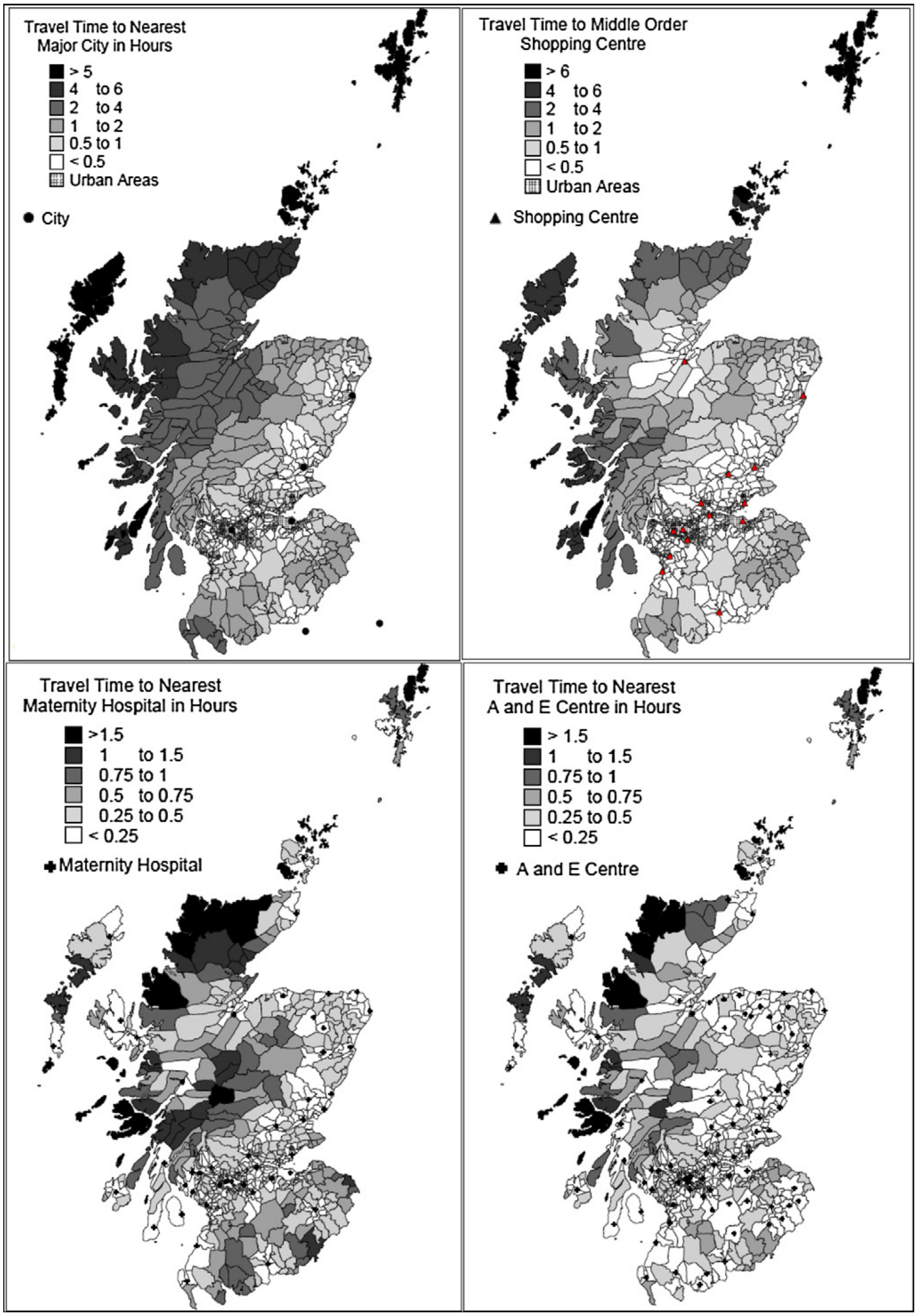

Fig. 2. Road travel time to basic amenities by postcode sector in Scotland. *Source*: modified from Halden et al., 2002.

had access to a car; moreover, cars were the mode of transport for 77% of journeys; most rural areas were not connected by trains; and buses were used for 2% of journeys. Most non-car owning households (9% of rural households) lived within 'walkable' distance of amenities such as shops, services and employment. Figs. 3 and 4 highlight the limitations of public transport provision in rural areas compared to the rest of Scotland in terms of accessibility to bus stops and connectivity to key services.

The most commonly cited reason for not using public transport in rural areas is lack of convenience. This could be due to lack of service availability, inefficient or inadequate passenger information provision and bad journey experiences (e.g., unexpected delays, crowded vehicles, etc.) (Scottish Executive, 2006). Fig. 5 shows passenger views on the convenience of public transport in Scotland. About 50% of urban dwellers regarded public transport as being very convenient compared with about 20% of rural residents.

Advanced technologies and telematics could play a significant role in mitigating inconvenience associated with public transport use in rural areas (Golob and Regan, 2001; Rieck, 2003; Giannopoulos, 2004). However, the degree of mitigation possible is influenced by transport technology coverage and infrastructure

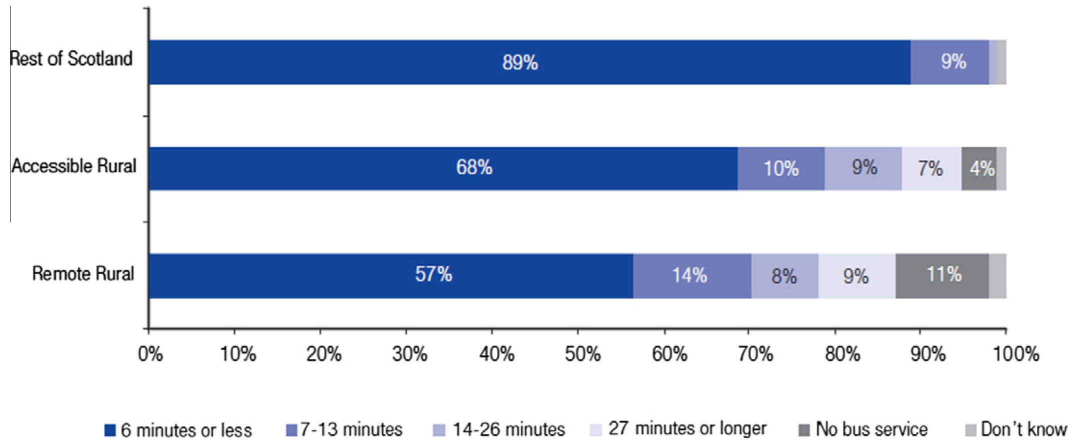

Fig. 3. Distance to nearest bus stop by geographic area, 2009. *Source*: National Statistics, 2010.

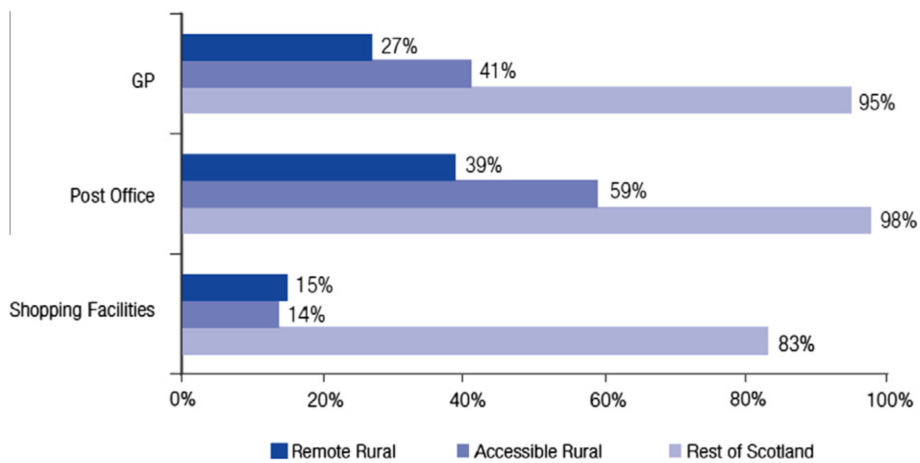

Fig. 4. Percentage of population within 15 min drive time by public transport of service, by geographic area, 2009. *Source*: National Statistics, 2010.

provision in rural areas. These issues are discussed in the following section.

3. Transport technology issues in rural areas

Digital technologies are often used to make mainstream public services (such as education, health care and transport) more effective and efficient (Boulton, 2010). Examples of such digital technologies include broadband internet access, smart mobile phones and personal computers. Varying levels of access to digital infrastructure, technologies, knowledge and the skills required to use digital systems have led to notions of 'digital divide' with gender, age, income, race and location being identified as significant factors in identifying 'haves' and 'have nots' in the digital sphere (Digital Britain, 2009; Boulton, 2010).

Scottish rural communities have been identified as being particularly vulnerable to digital exclusion (Scottish Executive, 2002). People who live in rural locations across the UK are less likely to have access to super-fast broadband, a 3G phone signal, or a choice of suppliers through their local fixed telephone exchange than urban residents. Average broadband speeds are typically lower in rural than in urban areas (Ofcom, 2010). A recent consultation by the Scottish Government on rural Scotland identified broadband coverage as the key issue for rural communities and a vital measure to support economic growth in rural areas (Scottish Government, 2011). Fig. 6, presents broadband coverage across Scotland, highlighting differences between urban and rural areas.

Advanced technologies can significantly influence lifestyle changes, particularly in rural areas (Wilson and Edwards, 2008). For example, lack of public transport service availability and efficiency can provide conditions which are highly suited to the development of more flexible, demand responsive transport services which are often supported by transport telematics. Such services may develop more readily in social contexts notable for high levels of community involvement and support e.g., concerns about traveller information in rural areas are leading to passengers sharing information about their journeys using the latest mobile and IT technologies through social networks, media sharing and blogging (Maclean and Dailey, 2001; Politis et al., 2010).

However, there has been a strong urban bias in the application of new technologies; this is particularly true within the transport industry (Malecki, 2003). Whilst this may be due to severity of transport problems in urban areas, the transport industry faces particular challenges in the deployment of transport telematics in rural areas:

(1) *Service area:* Rural transport agencies often serve large areas with long trips. As a result, assisting passengers needs is not easy and attending immediately to a problem that arises on the road is difficult (e.g., rescheduling trips when an incident occurs).

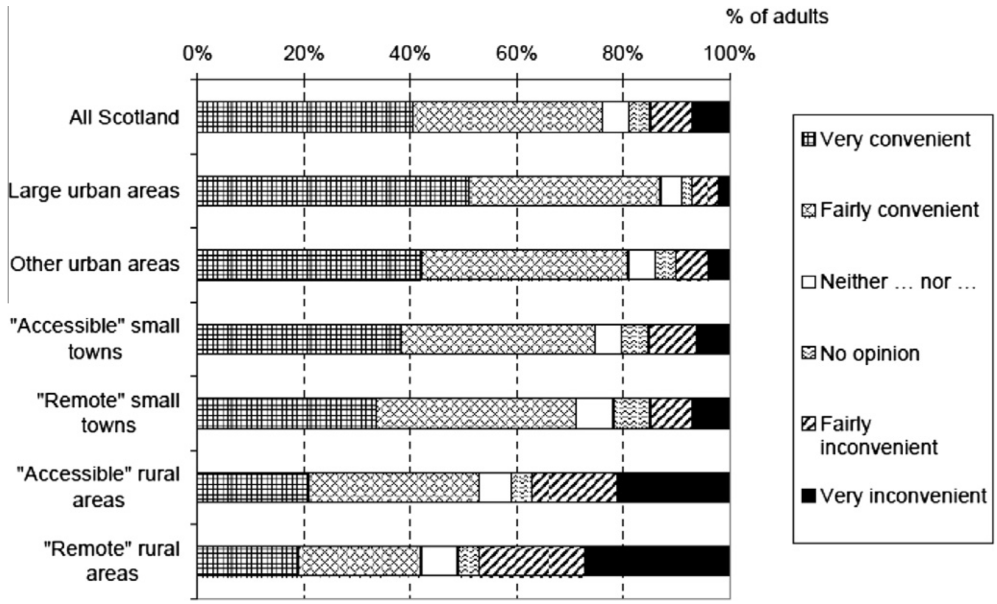

Fig. 5. Views on the convenience of public transport in Scotland. *Source*: Scottish Executive, 2006.

(2) *Service coordination*: There are different basic public services (e.g., health care, education) with overlapping areas of service provision. It is challenging to co-ordinate services and resources among the agencies and other providers.
(3) *Infrastructure*: Rural areas often suffer a lack communication infrastructure (e.g., wireless communications services). Real-time communication from and to rural passengers is one of the major issues.
(4) *Fleet size*: Although technologies can solve several transportation problems in remote rural areas, it might be difficult to fund and develop at a small scale (for example, funding and establishing mobile data terminals in a remote rural area). (Schweiger, 2003).

Since the 1990s, technology has been seen as a key driver of rural economic growth in the UK and within this context there has been an increasing emphasis on the application of ICT (e.g., e-ticket booking, smaller hospitality business) in rural Scotland (Grimes, 1992; Irvine and Anderson, 2008). A parallel trend has also been identified throughout Scotland in the provision of flexible types of transport services to enhance accessibility, including various community transport initiatives e.g., community buses and dial-a-ride services to car schemes, postbuses and taxibuses (Scottish Executive, 2001; Scottish Executive Social Research, 2006; Juffs, 2010). However, despite these developments, rural Scotland still suffers a lack of accessibility and connectivity. The role and potential of ICT in rural areas remains poorly understood. This has contributed to the slow rate of diffusion of new technologies in these areas (Grimes, 1992).

4. Real-time passenger information systems in rural areas

Transport users generally look for accessible, accurate, user-friendly, dynamic and consistent information about their travel and transport (Kenyon and Lyons, 2003; Molin and Timmermans, 2006). When planning and undertaking a trip, travellers have different stages in their journey. Each stage demands different information requirements. Pre-trip, en-route and post-trip are broad stages of any journey (Hine and Scott, 2000; Grotenhuis et al., 2007). The general information requirements at these three stages of a public transport journey are illustrated in Table 1.

Any real-time dynamic passenger information system generally incorporates three broad stages: (1) Data collection, primarily from vehicle positioning systems; (2) data integration/fusion/analysis; and (3) delivery of passenger information to displays (Cathey and Dailey, 2003; Kim et al., 2010). The primary information required for any traditional passenger information system is: (1) real-time automatic vehicle location/positioning information; (2) a GIS map; and (3) information about traffic conditions and delays (Koncz and Greenfeld, 1995; Wall and Dailey, 1999). If a geo-referenced vehicle location is known on a GIS map the vehicle arrival time to the downstream stops can be predicted using GIS software or an algorithm. Often, real-time traffic conditions and delays in the network are considered in predicting vehicle arrival time to the stops. Technologies used in a conventional real-time passenger information system are:

(1) *Automatic vehicle positioning system*: Real-time automatic vehicle location (AVL) or positioning information is a primary data requirement in a passenger information system. A number of positioning systems/sensors are normally used to obtain vehicle location information (Kaplan and Hegarty, 2006; Chang et al., 2010; Leung et al., 2011; Shen et al., 2011). These are:
   (a) Dead reckoning (DR) system;
   (b) Ground based beacon/signpost system; and
   (c) Global Navigation Satellite System (GNSS)

(2) *Information and communication technologies (ICTs)*: mobile communication systems such as Global System for Mobile Communications (GSM) and General Packet Radio Service (GPRS)
(3) *Information dissemination technologies: web-based,* display boards (e.g., Light Emitting Diodes (LED) single lines, LED matrix, LED lines and Thin Film Transistor (TFT) screens), enquiry office terminals, personal digital assistant (PDA) such as mobile phones, etc.

Examples of rural real-time passenger information systems include: a rural transit passenger information service at Amador

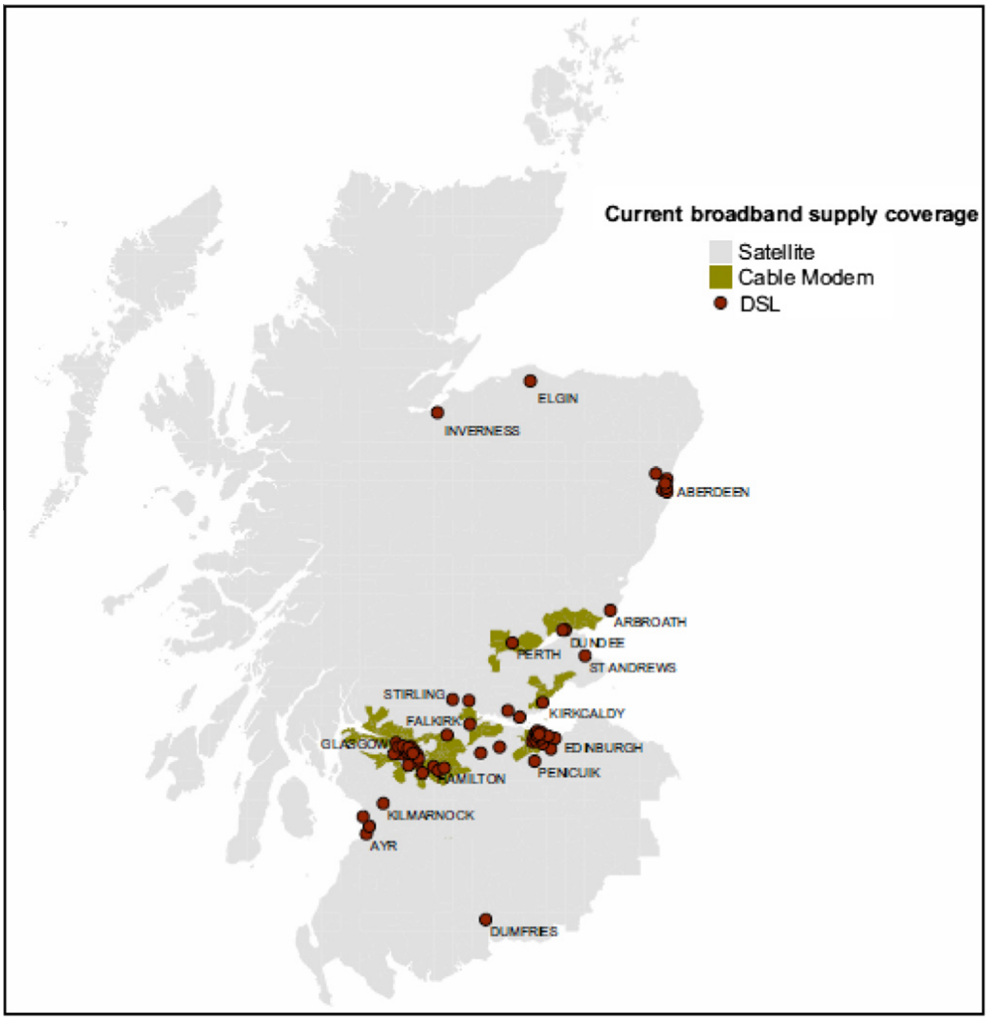

Fig. 6. Broadband coverage in Scotland. *Source*: BT Scotland, www.btplc.com.

Table 1
Information requirements of travellers using public transport.

Journey stage		Information required
Pre-trip	During travel planning stage	• Time tables (scheduled times) • Itineraries • Waiting time • Travel time • Number of changes • Possible time window for any delays (generally in case of flexible transport systems) • Tourist information • Type of vehicle • Availability of luggage racks/bicycle racks
	Before starting a trip	• Expected vehicle arrival time/delay (and scheduled terminals) • Vehicle occupancy information (number of seats available) • Information for any special needs for disabled passengers
En-route		• Expected delays during journeys • Information about connection journeys • Information about way side amenities and tourist places
Post-trip		• Information about car parking/renting • Connection journeys/schedules/delays of other modes of information • Tourist information • Information about walking and cycling • Park and rides facilities

County, California, USA; passenger information systems at bus stops in Warrington Borough; and a bus passenger information system into rural areas of South East Scotland (Hofacker and Mustard, 1999; SEStran, 2009). Often the provision of a passenger information system in rural areas suffers from many problems due to:

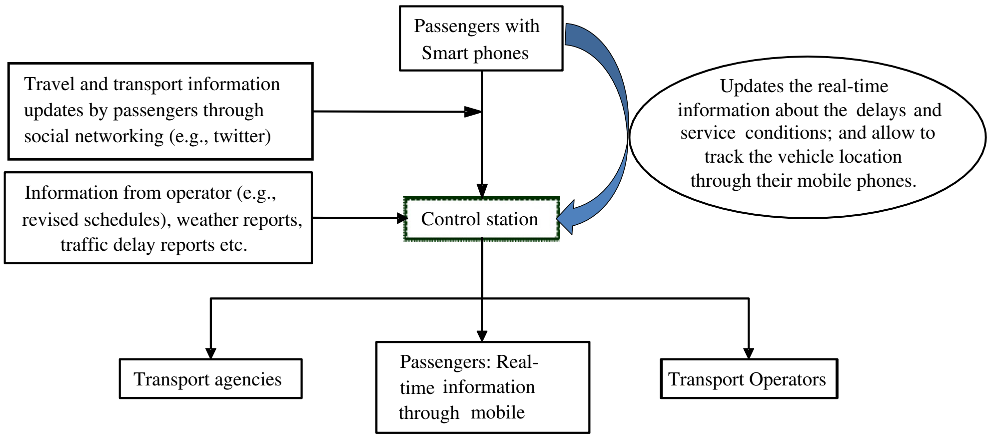

Fig. 7. System architecture for passenger centric passenger information system in rural areas.

(1) lack of transportation infrastructure (vehicle tracking system, bus stop displays)
(2) fewer passengers; therefore no encouragement to operators to provide current transport information.
(3) rural areas being sparsely populated; making it difficult to collect travel/traffic information from the system.
(4) problems with mobile communication systems

The lack of efficient passenger information systems in rural areas may reduce the use of public transport and increase car ownership. Therefore, a sophisticated passenger information system, which can take into account the above mentioned problems, is required. It is a challenge to provide accurate, current information on arrival and departure times particularly in rural areas. Passengers from suburban, rural and remote areas need more reliable and sophisticated travel information compared to urban areas; because, unlike in urban areas, passengers in rural areas are provided with very limited transport facilities, generally make longer journeys, have problems with social exclusion and limited exposure to media and other communications (Farrington and Farrington, 2005).

The Informed Rural Passenger (IRP) research activity being undertaken in the dot.rural Research Hub (www.dotrural.ac.uk/irp) is exploring how advanced technologies might help in developing and enhancing passenger information systems in rural areas where basic transport technology infrastructures are not available; the objective is to demonstrate how passengers may become producers as well as consumers of passenger information. A simple system architecture is shown in Fig. 7. In rural areas, vehicle positioning/tracking systems are not always available as many rural buses are not fitted with GPS devices due to cost and even traditional information dissemination technologies (e.g., bus stop display boards) can be scarce. Advances in mobile technology and ICT offer the prospect of addressing these gaps and diminishing the problem of poor information provision.

In this scenario, passengers with smart mobile phones can update real-time information about the public transport vehicle delays and service conditions; and they can also permit the control station to track location (i.e., vehicle location information) during their journey using the GPS in their smart phone. This real-time vehicle location and delay information is transferred to a control station where other information (such as revised schedules) and weather reports are available. At the control centre this information is analysed and further passenger information will be disseminated to all users through mobile devices. Moreover, information on transport service conditions (e.g., noisy, crowded, etc.), provided by users (e.g., at the time of travel or subsequently including by social networking media), could be used by transport operators and government agencies to improve public transport services.

It should be acknowledged that when seeking to utilise mobile platforms for public transport information provision there are particular challenges in relation to the use of mobile phones in rural areas (and in Scotland more generally) which need to be recognised and addressed:

- Scottish rural dwellers are less likely to have a mobile phone (80% compared to 86% for urban residents) and to buy a 3G handset (17% compared to 27% for urban residents).
- 40% of Scottish adults who own a mobile phone experience regular reception problems (compared to a UK average of 33%).
- 87% of people in Scotland are able to receive 2G mobile phone coverage, (compared to a UK average of 97%) (Ofcom, 2010).

The above statistics have clear implications for acquiring data from and providing data to passengers in rural areas: the reduced signal coverage inhibits communications with the device, meaning there could be a delay in data being received from the device, and the device receiving data; while the reduced number of smart phones (as indicated by the number of 3G handsets), limits the type of information that can be obtained from the mobile device (for example, smart phones often feature GPS sensors which can be used to determine location, while non-smart phones do not).

5. Flexible integrated transport services for rural areas

To improve the efficiency and performance of a transport service a flexible integrated transport system (FITS) is identified as one of the more promising solutions (Palmer et al., 2004). The FITS concept builds on the principles of demand responsive transport (DRT) and can provide flexibility in choosing route, time, mode of transport, service provider, payment system, etc.

A well-designed FITS aims to integrate different modes of transport to provide more sophisticated, comfortable and cost effective transport options. The flexibility of such a transport service could be in terms of space (i.e., the route), time (i.e., the schedule that includes start time, waiting time and travel time), type of vehicle, booking system, payment system, etc. (Mageean and Nelson, 2003; Zografos et al., 2008). Early studies concentrated on single-vehicle multiple-passengers solutions in which a single vehicle is designed for a set of customers whose pickup and drop-off points are known prior to a trip (Sexton, 1979; Sexton and Bodin, 1985a, 1985b; Psaraftis, 1980, 1983). Later studies report multiple-vehicle multiple-passenger flexible transport services, (see for

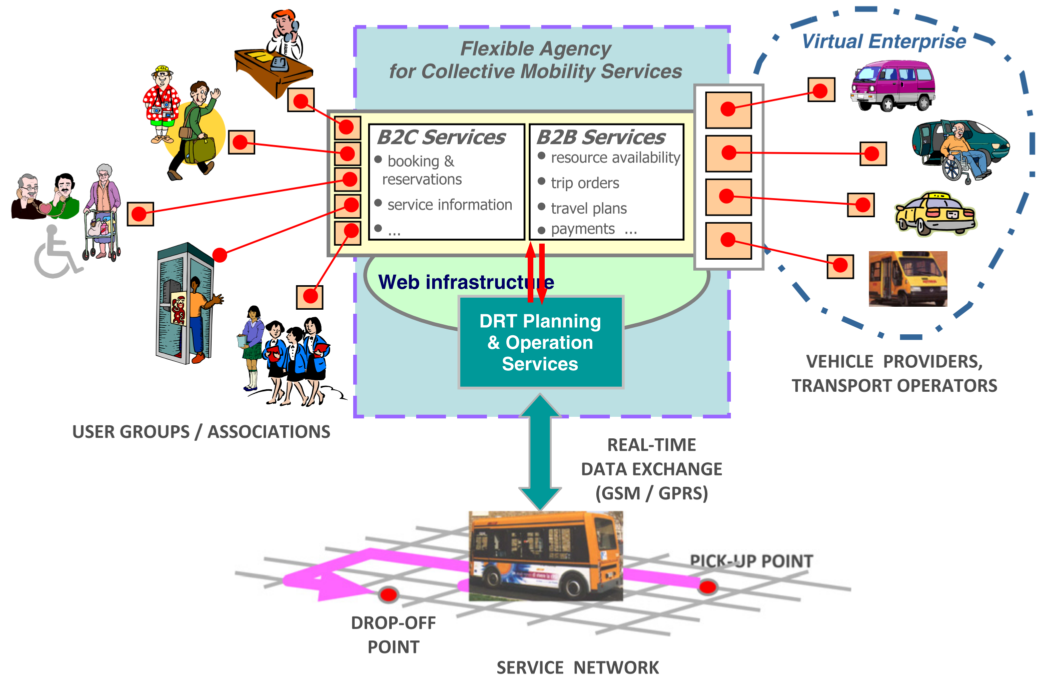

Fig. 8. Virtual agency for flexible transport services (FAMS, 2004).

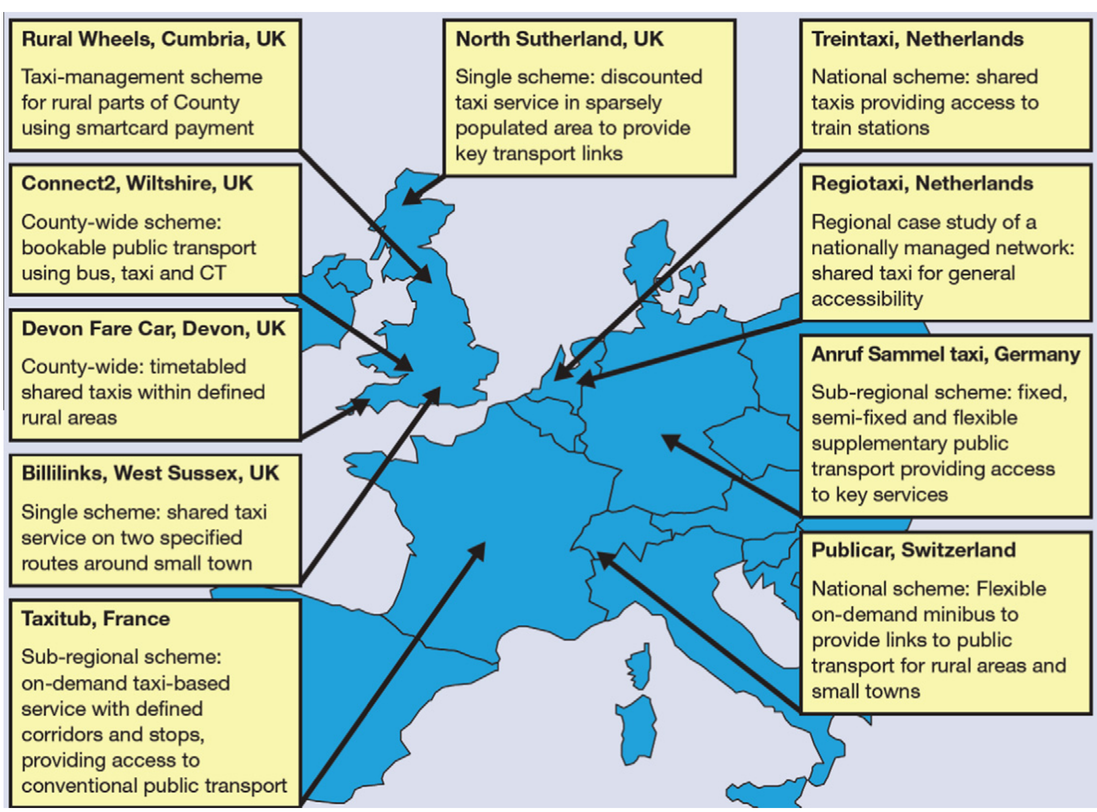

Fig. 9. Case studies of flexible transport systems from Great Britain and mainland Europe (Sloman and Hendy, 2008).

example Cordeau, 2006; Bent and Van Hentenryck, 2006; Ropke and Pisinger, 2006; Xiang et al., 2006; Melachrinoudis et al., 2007; Parragh et al., 2010; Garaix et al., 2010).

An example of a virtual agency approach to flexible transport systems is shown in Fig. 8. FAMS, the Flexible Agency for Collective Mobility Services (FAMS), established an organisational structure and business model for flexible transport that manages the entire service chain – from customer booking to service planning, monitoring and control – operating as unique entity, through a dedicated Management Centre. FAMS (an EU funded project) tested

Table 2
Flexible transport systems in Scotland.

City or council	Scheme	Level of flexibility	Operator(s)	Start date	End date
Aberdeen	*A2B dial-a-ride*	Fully flexible	Stagecoach bluebird	2004	Still operating in rural areas
Angus	*Flexible transport agency/ community transport development*	Destination specific	Angus transport forum	2002 April	2007 April
Dundee	*Shopper service for elderly the friendly bus*	Fixed route	Strathtay Scottish/ dundee accessible transport action group	2004	Still operating
Edinburgh	*Community transport development*	Fully flexible	Edinburgh Community Transport Operators group	1970s	Still operating
Fife	*Subsidised service with diversions*	Destination specific and flexible route	Stagecoach	2004	Still operating
Highland	*Network of taxis offering access to work DRT*	Fully flexible	Local taxi firms	–	–
Glasgow	*Hospital visiting service*	Fully flexible	Community transport glasgow	2007	Still operating

the concept of a "Virtual Agency" to co-ordinate, multi-modal DRT service delivery at sites in the Angus region of Scotland and in Florence in Italy (FAMS, 2004).

The main architectural components of any technology-based flexible transport system are (Ambrosino et al., 2001):

(1) Control centre (also known as the travel dispatch centre)
(2) Customer devices
(3) In vehicle on-board unit and equipment
(4) Communication devices.

The main functionalities are handled by the travel dispatch centre (TDC) which acts as a mediator between customers (passengers) and operators; and deals with a wide range of activities such as trip reservation, travel planning (i.e., optimal route search, vehicle assignment, travel time and delay estimates, etc.) and vehicle dispatch and control. Integration of the appropriate technologies is used to carry out the above activities (Ambrosino et al., 2001; Fu, 2002; Palmer et al., 2004).

The flexible transport system is not a new concept; examples of existing systems include shared taxicabs, shuttle vans, dial-a-ride services and car-clubs (Li and Quadrifoglio, 2010). Telematics-based demand responsive flexible transport systems started in Europe more than a decade ago. Examples of such European Commission funded R&D projects include SAMPO (1996–1997), SAMPLUS (1998–2000), INVETE (2000–2001) and FAMS (2002–2004) (Ambrosino et al., 2004; SAMPO Project 1996, 1997; SAMPLUS, 1999; INVETE, 2000; Nelson et al., 2010). The characteristics of several flexible transport systems from across Europe are depicted in Fig. 9.

Some examples of current and previous flexible and demand responsive transport schemes in Scotland are listed in Table 2.

Most of these schemes operate in urban and suburban areas with few or no defined stopping points, resulting in maximum flexibility. Most existing services are on a small scale, isolated from other modes of transport (e.g., rail) and targeted at specific population groups; allow only advanced booking; and use very little or no ICT support. This often leads to ineffective flexible transport systems, particularly in rural areas. An example of a successful low-tech system is the transport to employment (T2E) shared transport services in rural Highland Scotland (Wright et al., 2009).

The Flexible Integrated Transport Services (FITS) research activity being undertaken in the dot.rural Research Hub (www.dotrural.ac.uk/fits) is exploring how to overcome some of the challenges with flexible transport systems in rural areas (e.g., scalability issues, challenges of transport service co-ordination, technological issues and economic viability). A local level flexible and demand responsive virtual transport market place with a focus on passenger centric scheduling could be a solution.

In this scenario, the virtual transport market would be characterised by principles of trust management, data sharing and privacy to facilitate matching of transport offers by operators and trip requests by passengers. The "market" would seek an efficient match between the demand for and supply of transport services. The FITS research is addressing the specification of a platform to enable such a virtual transport marketplace which would be based on supporting autonomous agents acting on behalf of stakeholders to solve their individual (or collective) transport goals. This approach could optimise the use of the available transport resource and reduce unmet demands in rural areas, where population density is low and transport demand is very uncertain, by opening up an opportunity for a much wider breadth of transport supply (e.g., shared taxis, taxibuses and car sharing) to become market participants thus improving accessibility.

6. Conclusion

Providing accessibility and connectivity to rural communities presents significant challenges. These challenges are formidable because they combine the problems of transport poverty and digital exclusion. Alongside social and economic aspects, these problems include a strong technological/technical component common to both the transport and digital spheres in terms of the quality and availability of infrastructure and services.

Innovations orientated around advanced technologies and transport telematics such as a passenger information system with the capability to incorporate user generated information and a local level flexible and demand responsive virtual transport market place aiming to better utilise the available transport resource can make a significant contribution to addressing these problems. In particular, by better gathering and communicating information they offer the prospect of enhanced quality of service, more closely aligned to user needs and expectations.

However, it must be realised that these innovations, reliant as they are on the quality and availability of technology, generate additional challenges and secondary effects that need to be recognised and sometimes mitigated. Examples of these challenges and effects include: (1) understanding basic technological infrastructure requirements in rural areas; (2) considering trust and reliability issues with the crowd-sourced information provided by passengers during their journeys; and (3) understanding and anticipating passenger behaviour change in response to technological innovations. Addressing these challenges and mitigating negative effects will require both technical adaptation and innovation by service providers and a supportive policy agenda pursued by decision-makers.

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.

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