



A tool to aid redesign of flexible transport services to increase efficiency in rural transport service provision

Richard Mounce, Steve Wright, C. David Emele, Cheng Zeng & John D. Nelson

To cite this article: Richard Mounce, Steve Wright, C. David Emele, Cheng Zeng & John D. Nelson (2018) A tool to aid redesign of flexible transport services to increase efficiency in rural transport service provision, Journal of Intelligent Transportation Systems, 22:2, 175-185, DOI: [10.1080/15472450.2017.1410062](https://doi.org/10.1080/15472450.2017.1410062)

To link to this article: <https://doi.org/10.1080/15472450.2017.1410062>



© 2018 The Author(s). Published with license by Taylor & Francis© Richard Mounce, Steve Wright, C. David Emele, Cheng Zeng, and John D. Nelson



Published online: 29 Dec 2017.



Submit your article to this journal [↗](#)



Article views: 252



View related articles [↗](#)



View Crossmark data [↗](#)

A tool to aid redesign of flexible transport services to increase efficiency in rural transport service provision

Richard Mounce^a, Steve Wright^a, C. David Emele^b, Cheng Zeng^c, and John D. Nelson^a

^aCentre for Transport Research, University of Aberdeen, Aberdeen, United Kingdom; ^bHealth Services Research Unit, University of Aberdeen, Aberdeen, United Kingdom; ^cComputing Science, University of Aberdeen, Aberdeen, United Kingdom

ABSTRACT

Rural areas generally have lower and more dispersed demands for travel which cannot sustain conventional public transport services and consequently have a greater number of flexible and demand responsive transport services operating. These services usually operate on a stand-alone basis, are often subsidized and are typically only accessible by certain passenger types or for specific trip purposes. This generally results in uncoordinated and inefficient transport provision overall. The Flexible integrated transport services (FITS) system featured in this paper has been designed to address this problem. FITS can be used as a planning tool to assess potential benefits from relaxing operating constraints (e.g., a service's operating boundaries), which can potentially suggest service redesign. It also includes the capacity to assign subsidy payments on a trip by trip basis to increase cost efficiency whilst meeting a greater proportion of transport needs. The case study in the paper focusses on transport to health in the Aberdeenshire and Morayshire areas of Scotland in the UK. Despite flexible transport operators receiving public funds to meet passenger needs, this is currently being supplemented by public bodies paying large amounts in taxi fares in instances where there is a statutory obligation to provide travel but where no other suitable transport service exists. The results demonstrate the potential substantial savings which could be realized by allowing transport operators to redesign their services by relaxing constraints and by the reassignment of subsidies: resulting in more passenger demands being met and a reduction in public spending on taxi fares.

ARTICLE HISTORY

Received 4 December 2015
Accepted 23 November 2017

KEYWORDS

constraint relaxation; flexible transport system; rural transport; subsidy; surcharge

1 Introduction

Flexible transport services (FTS) consist of a range of mobility services offering greater flexibility than regular public transport services. Whereas urban flexible transport includes shared taxis, car-pooling, and car-sharing (Nelson & Wright, 2016) which attempt to offer a greener alternative to solo car use, in rural areas where there is limited conventional (fixed-route) public transport, flexible transport providers often fill the gaps providing essential services. This is achieved through demand responsive transport (DRT) for the general public or more commonly through dedicated services (i.e., transport for specific groups of the population, e.g., the elderly). These rural FTS are characterized by flexible routing and scheduling of small to medium-sized vehicles operating in shared-ride mode between pick-up and drop-off locations according to passengers' needs (Mulley et al., 2012), usually resulting in a "door-to-door" service. Dedicated FTS are generally standalone services with

certain eligibility criteria, e.g., only for elderly people or only for people who are disabled. In the UK many services are provided by community transport organizations, health sector funded organizations, or local authority departments involved in social care.

Currently, many flexible transport providers are paid a flat rate subsidy or block grant regardless of the number of the passengers they transport (or are paid the subsidy provided that they fulfill their quota of trips within a given period). This enables these operators to provide a core service to access essential goods, services, and activities (such as local shops, GP surgeries, day care centres) at certain times of day and on certain days of the week. However, a common scenario is that vehicles are underutilized during other periods of the day due to insufficient funds to provide additional services and there is little or no financial incentive available to undertake or accommodate additional trips outside of their core service under the existing funding structure. There may

CONTACT Richard Mounce  r.mounce@abdn.ac.uk  Centre for Transport Research, School of Engineering, University of Aberdeen, Fraser Noble Building, Aberdeen AB24 3UE.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gits.

© 2018 Richard Mounce, Steve Wright, C. David Emele, Cheng Zeng, and John D. Nelson. Published with license by Taylor & Francis.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

then be unmet demand, which is clearly an undesirable situation. In addition, these services are often largely uncoordinated and poorly promoted. In some areas the tight eligibility restrictions lead to multiple services operating in the same places at the same time, each catering for different trip purposes and user categories; this is very costly and inefficient. In other more rural areas the tight eligibility restrictions lead to a much more limited service, in terms of operating area and times, available to only particular users for particular trip purposes: this is ineffective for those whose trips do not fall within these restrictive constraints, resulting in very limited choice for passengers.

The flexible integrated transport services (FITS) system has been designed to address this problem of inefficient transport service provision in rural areas. The FITS tool affords the opportunity to identify flexible transport services which could fulfill currently unmet passenger trip requests if certain constraints were to be relaxed. Such an approach is of potential benefit to flexible transport operators looking to extend their services and generate additional revenues. It is also of potential benefit to public sector organizations with an obligation to provide equal access to individuals for key services (e.g., access to education, social care, and health services). In cases when there is no existing public transport which is suitable, these organizations have an obligation to pay for, or at least subsidize using public funds, the use of taxis by individuals. In addition, public sector organizations may pay block subsidies to transport operators to operate their services. The FITS system can be used to demonstrate the effects of restructuring this system of subsidy payments: in place of only block subsidy payments, a more incentive-based structure is proposed where a lower block subsidy is received to retain the basic service, but is supplemented by additional subsidy payments to transport operators for operating outside of their usual operating constraints, e.g., operating outside of their usual operating times and areas, or transporting additional types of passengers. The FITS tool can estimate the net savings through reductions in taxi fares that are possible through the relaxation of constraints.

Flexible transport operators can utilize the FITS tool to specify the extent to which they are prepared to relax their core service constraints on when, where, and who they are prepared to carry and it also allows them to stipulate the financial compensation (within legislative boundaries) they would require to make these relaxations. This provides a mechanism by which flexible transport operators (including community transport providers) can generate additional revenues for accommodating transport to health passengers who otherwise would need to be carried by taxi.

The benefits of FITS detailed above can be realized through the use of the offline version of the FITS tool. The FITS system can also operate in an online mode, interfacing between passengers and transport operators in real-time (Emele et al., 2013). This is conceptualized as a multiagent system (Ferber, 1999) comprising a virtual marketplace with three types of agents:

1. Passenger agents, operating on behalf of passengers,
2. Transport operator agents, operating on behalf of transport operators,
3. The marketplace agent, which mediates between the passenger and transport operator agents.

The paper is organized as follows: Section 2 provides a detailed overview of the FITS system, including the data requirements as well as the modes of operation. Section 3 is on the case study area and includes detail of the local context and results from the test runs. Finally, Section 4 discusses the benefits and future uses of the FITS tool and provides conclusions.

2 The FITS system

2.1 Data requirements

FITS requires data about passenger trips to ascertain whether passengers are both physically able and eligible to use given transport services. The following data is required for each trip:

1. Journey origin and destination address.
2. Expected time of departure or desired arrival time.
3. Age group, chosen from: under 16, 16–21, 22–54, 55–59, and 60+.
4. Mobility status, chosen from: able-bodied, disabled (wheelchair user), disabled (other). In addition there is an option to choose “unable to use regular public transport,” which includes the case where this is due to lack of provision or of frequency). Wheelchair users are further categorized as “electric,” “nonelectric nonfolding” and “nonelectric folding (and able to sit in car/bus seat).”
5. Journey purpose, chosen from: health appointment, shopping, social care, leisure/visiting friends, school/education and work/commuting.
6. Whether there is a clinical need for ambulance service transport.
7. Whether there is a need for an escort (e.g., a carer or other assistant) to accompany the passenger (to assist them).
8. The relative weightings of the value of travel time, money, and number of vehicle changes (for the online operation of FITS only).

Figure 1. FITS operator data input tool.

Clearly there are certain restrictions that are placed on services that should not be violated if a service is to remain legitimate and reputable, e.g., government regulations, vehicle capacity etc. However, there are other discretionary constraints that operators assign to their services as they choose. Figure 1 shows the FITS operator data input tool. The operating area can be drawn as a polygon in Google maps and the accompanying data entered into a web template. All this data is then imported into the FITS system. The following information needs to be provided to the FITS tool for each service: (note that if there are day-to-day variations, such as to the hours of operation, then these need to be defined as separate services):

1. Operating times: days of the week and hours of operation.
2. Operating area.
3. Fare structure (including concessions).
4. Vehicle specifications (including seat /wheelchair capacities and vehicle access).
5. Passenger type (age, mobility status, journey purpose) eligibility information.
6. Penalty surcharges for operating outside defined operating area (in bands).

7. Penalty surcharges for operating outside defined operating hours (in bands).
8. Passenger type eligibility penalty surcharges for those passenger types who are normally ineligible (these are optional in that the operator has the option to keep these types as ineligible regardless of any surcharge).

The fare structure information consists of the following:

1. Whether the service charges fares.
2. Fares within mileage bands.
3. Return fare multiplier.
4. Percentage discounts for over 60s and under 16s.
5. Whether escorts are charged a fare.
6. Whether the service charges for dead mileage and the location for this to be calculated from.

2.2 Searching and ranking of transport options

If the passenger can use conventional public transport, the FITS tool generates conventional fixed-route public transport options using the Google Maps Transit¹ journey planner via the Google Directions application

¹ <http://www.google.com/transit>

programming interface² (API): parameters for this API include desired arrival/departure time, mode, whether to minimize transfers etc. The distance that different categories of passenger (e.g., able-bodied, disabled, elderly, etc.) are assumed to be able and willing to walk to access public transport is set to a maximum value in order to limit the number of options returned from Google Transit.

Flexible transport options are also generated in the FITS tool by searching the available flexible transport services (details of which are input to FITS by operators as described in Section 2.1). These potential transport options are deemed suitable if the journey origin and destination are within the service's operating area (which can be established using the ray method (Shimrat, 1962) since the operating area is defined by a polygon); the journey is within the operating times of the services; and also if the passenger meets the service's other eligibility criteria (e.g., age, mobility status etc.). The travel time for voluntary car services (which involve volunteers driving their own cars) is assumed to be the same as for a taxi, whereas travel times for door-to-door bus services are multiplied by a penalty factor (or travel time ratio) of 1.5 to reflect the fact that they may need to divert for additional passenger pick-ups (the value of 1.5 is based on our experience of DRT services in rural areas). Simulation studies have shown this penalty factor to range from one, where only one passenger is carried, to over five when there are a high number of trip requests that each vehicle needs to accommodate. In rural areas, when responding to trip requests for mainly health purposes there are likely to be relatively few diversions to pick up additional passengers and hence a relatively low value of travel time ratio is reasonable.

A generalized cost g can be calculated for each possible transport option using the formula:

$$g(t, f, t_f, c, t_c) = t + ft_f + ct_c \quad (1)$$

where t is the travel time, f is the fare paid, t_f is the value of fare in terms of travel time, c is the number of interchanges, and t_c is the average value of an interchange in terms of travel time (note that t_f and t_c are requested from the passenger in the booking entry form). Note firstly that for public transport options the travel time can be split up into in-vehicle travel time, waiting time, and walking time with suitable value-of-time weighting factors applied to each³. Note also that the generalized cost defined in Eq. (1) is in time units; this is appropriate since we generally do not have any information available regarding an individual passenger's value of time in terms of money. For the offline version of the FITS tool, each trip demand is assigned its transport option which has the

lowest generalized cost. For the online version of the FITS tool, the transport options with the lowest generalized cost are presented to the user to choose from.

2.3 Constraint relaxation and surcharges

Sections 2.1 and 2.2 describe how FITS provides a tool which checks the operating criteria and constraints of all existing transport services in an area to identify suitable transport options for specific trip demands. For trip demands which cannot be fulfilled by current transport services, the FITS tool provides the option to identify the flexible transport services which could fulfill the passenger request if certain constraints were relaxed. This constraint relaxation takes into account the preferences of the operators themselves as well as the compensation payments a flexible transport operator would be prepared to accept for a given relaxation request. These compensation costs can be thought of as surcharges imposed by the flexible transport operator to extend their core funded service. Relevant legislative restrictions which place limits on relaxations and compensation payments are also considered in the process.

Three types of surcharge, as identified in Section 2.1 are:

1. Penalty surcharges for operating outside defined operating area (in bands).
2. Penalty surcharges for operating outside defined operating hours (in bands).
3. Passenger type surcharges for those passenger types who are normally ineligible

In the instances where constraint relaxation is necessary to fulfill a passenger demand, the total fare f charged by an operator is given by:

$$f = f_p + d_p \quad (2)$$

where f_p is the standard fare for the operator to take passenger p and d_p is the surcharge for the operator to take passenger p . The standard fare will depend on the passenger's journey origin and destination and may include dead mileage. The surcharge will be the sum of all the penalty surcharges identified above. Note that these surcharges are additive, e.g., if the passenger's origin and destination are both 5 miles outside of the usual operating area then the surcharge will be twice that for operating 5 miles outside of the usual operating area. In the case of the origin or destination being outside of the operating area the distance outside of the operating area can be calculated as the minimum distance to any of the line segments which constitute the boundary (since the boundary is defined by a polygon). The generalized costs of the options are calculated using Eq. (1) but with the revised fare defined in Eq. (2). Allowing these relaxations will obviously result in more transport options being available to passengers

² <https://developers.google.com/maps>

³ <https://www.gov.uk/government/publications/webtag-tag-unit-m3-2-public-transport-assignment-modelling>

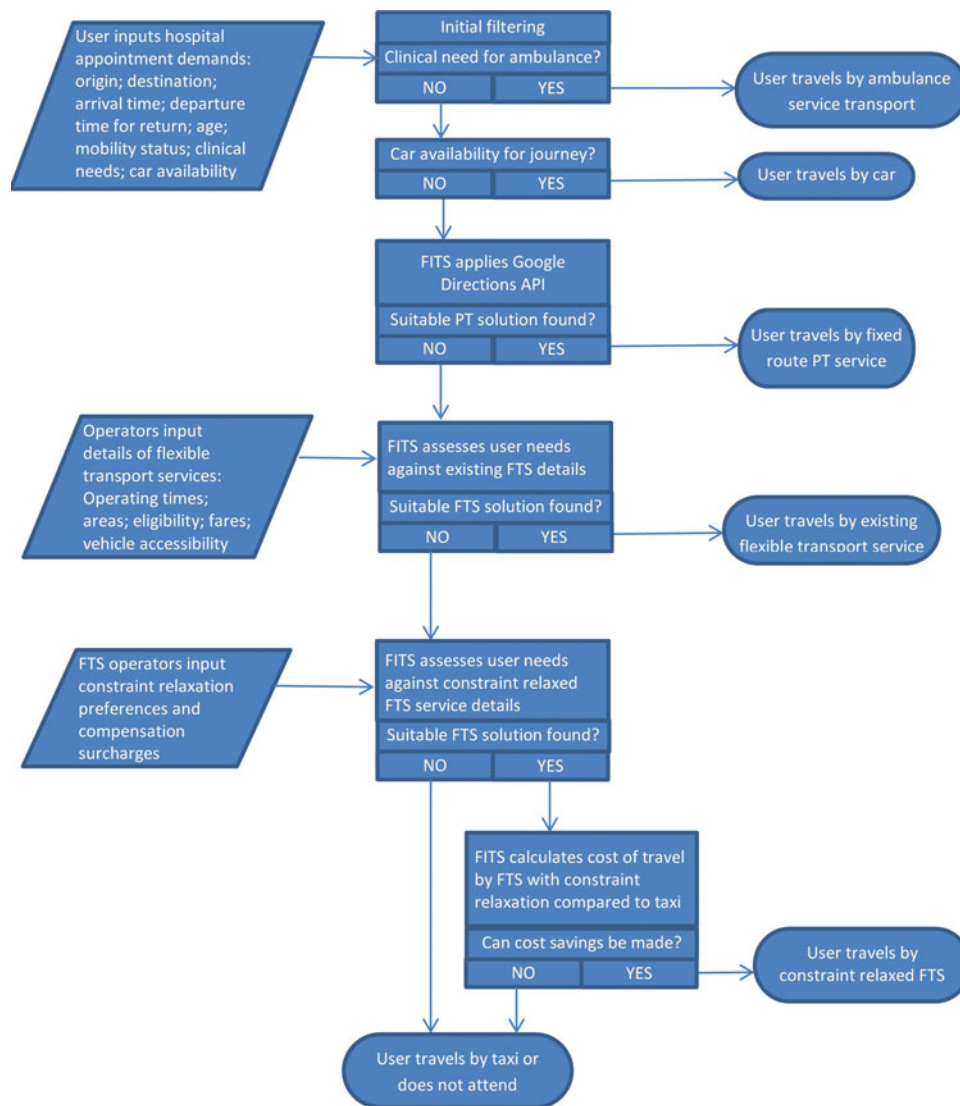


Figure 2. Flow of data through the FITS system in the case of hospital appointment demands.

overall, but with the accompanying cost incurred through the operator surcharges.

Figure 2 presents the flow of data through the FITS system in the case of hospital appointment demands.

3 Case study

The FITS planning tool has been applied in the rural case study setting of Morayshire and Aberdeenshire in North East Scotland to explore how flexible transport service redesign can lead to potential increases in efficiency when providing transport to health trips. Before discussing the results we briefly describe the national transport to health context.

3.1 Context

To set this work in context it is necessary to understand who is responsible for providing transport to health in

the UK. The UK's National Health Service (NHS) has a statutory duty to provide transport to get nonemergency patients, but who have a medical need while being transported, to hospital for treatment. In many areas it is the Ambulance Trust that provides this service. For patients not deemed to have a medical need whilst being transported the responsibilities for transport are less clear. In the UK, local authorities are obliged to assess whether people living in their area, particularly households on low incomes and people without cars, are able to reach key services and activities safely, reliably, affordably, and with relative ease by public transport. Each local authority must then produce an action plan to identify how they and their partner organizations will improve any gaps in accessibility (for example, in our case study area the transport to health agenda is shaped by the Grampian Health Transport Action Plan team which is a consortium of local authorities, NHS and transport agencies). This involves financially supporting bus operators (commercial or community) to provide necessary services, or filling the

Table 1. Journeys by mode of travel to attend hospital and other health appointments in Scotland.

| Travel Mode | Walk | Car Driver | Car Passenger | Public Transport + Other | Taxi |
|-------------|-------|------------|---------------|--------------------------|------|
| Proportion | 13.9% | 41.9% | 22.2% | 17.3% | 4.7% |

Source: Scottish Household Survey (2008–2012)

gaps with local authority in-house bus services. Whilst this can be planned to some degree for certain types of regular trip it is more difficult for hospital appointments which are largely unpredictable and are often one-off demands. As a result, local authorities often resort to using taxis to meet their responsibilities in providing access to health appointments. Whilst health boards and Trusts, understandably, wish to concentrate their efforts and funding into advancements in clinical care, poor access means that whilst those patients who have access can enjoy improving clinical care, others without access frequently may not enjoy even basic levels of health care, let alone any advancement. As a result, they also support transport to health to ensure equal access. The result is often an uncoordinated system of funding transport to health resulting in inefficient, poorly planned, and uncoordinated transport services. Whilst there have been several initiatives to better integrate funding and service provision (DfT, 2009), these have often struggled to get agreement on shared funding and establish joint commissioning for transport services. It remains the case that apart from the Ambulance Trusts' non-emergency patient transport services, taxis are a mainstay for patients accessing health appointments from rural areas when limited or no public transport is available or suitable.

We see from Table 1 that 78% of health appointments in Scotland are accessed by foot or as a car passenger or driver; the remaining 22% are by bus, taxi, or other public transport. Table 1 relates to hospital and other health appointments including GP surgery visits. The data also relates to the whole of Scotland. As such the distances involved will tend to be shorter than for the hospital-only appointments in the generally rural area of our example. As a result, in our test (described in Section 3.2) we consider a slightly lower proportion of access by walking (10.9%) and a similarly higher proportion accessing by public transport and taxi (25%). Table 2 gives the expected weekly journeys by mode to outpatient appointments in the study area, based on these slightly adjusted mode share proportions.

3.2 Results

The FITS system was tested offline in order to assess its potential. The trial was done using a set of typical health-related passenger trip demands along with transport operator data (as detailed in Section 2.1) for the Morayshire and North-West Aberdeenshire area. The passenger trip demands were produced using a simulated demand generator, which was based on actual annual outpatient appointment data from nine origin districts (electoral wards) to five destination hospitals in the Morayshire and North-West Aberdeenshire area (the Hospital locations and ward boundaries are illustrated in Figure 3).

In total there were 107,120 annual outpatient appointments at the five destination hospitals originating in the nine origin districts. This generates 214,240 annual trip demands, or 4120 trip demands per week. The distribution of the origin locations (passenger pick-up points) within each ward was generated by random selection from the full set of postcodes in each ward (the postcode locations give a reasonable representation of the spatial distribution of population across the ward, and each postcode provides a good proxy for the location of the patient's address). Note that simulated passenger age was added to the postcode dataset for each ward based on patient age profiles for outpatient appointments and simulated mobility status was added based on simulated age. Therefore the selection of a postcode provides the simulated origin pickup point, passenger age, and mobility status.

From Table 2 we see there are an estimated 25% of hospital appointment trips made by public transport and taxi. This 25% multiplier was applied to the total number of outpatient appointments to get the simulated daily passenger demand to be run through FITS; this was done five times to give five different passenger demand sets for one week, i.e., five week days. In total this produced 515 passengers, each making an outward and return trip, giving a total of 1030 trips.

The transport operator service data was sourced from publicly available data as well as directly from the operators. This provided operating area boundaries, fare

Table 2. Estimated weekly journeys by mode to attend hospital appointments in the study area.

| Travel Mode | Walk | Car Driver | Car Passenger | Public Transport + Other | Taxi |
|--------------|-------|------------|---------------|--------------------------|------|
| Proportion | 10.9% | 41.9% | 22.2% | 20.3% | 4.7% |
| Weekly Trips | 449 | 1726 | 915 | 836 | 194 |

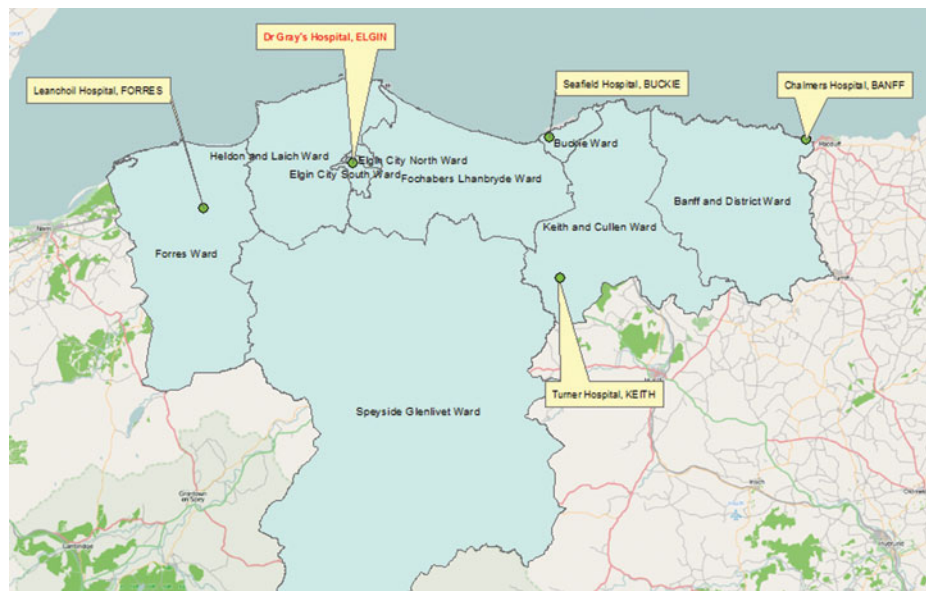


Figure 3. Map showing the districts (electoral wards) and hospital locations used in the testing.

information, eligibility criteria, and core operating times (09:30–11:30 and 13:30–15:30) for seven flexible bus services across the study area. Operator surcharges for constraint relaxation were estimated from information provided from the operators.

First, the FITS tool was run using this data without any constraint relaxation (i.e., as the services currently operate). In this first run, approximately 80% of the simulated trips were found to have at least one potentially suitable transport option (either a conventional fixed-route service or an existing flexible service). However, there remained a substantial number of passenger trip demands for which the passenger did not have a suitable non-taxi travel option, e.g., because they required a door-to-door service and there was no suitable flexible transport provider operating at that time and/or within that area. There were 194 such trips (counting the outward and return trips as separate trips since passengers could have an option for one but not the other). At present, use of a taxi is the only transport option available to these passengers to be able to access their appointment. It is assumed therefore that they will all access the hospital by taxi. This is a reasonable assumption since this level of taxi use is consistent with the estimated use of taxis in the study area based on the Scottish Household Survey data detailed in [Table 1](#). These 194 passenger trip demands were noted and then a second run was carried out with constraint relaxation: in this case, it was just the flexible transport providers' operating times and areas that were relaxed in exchange for surcharge payments. This resulted in over two thirds (132 out of 194) of the originally unmet passenger trip demands having suitable travel options using flexible bus services. In each of these cases, there is a potential

saving if the overall fare charged by the flexible bus operator (including the penalty surcharges) is cheaper than the equivalent taxi fare (calculated using £2.40 flag drop plus £1.80 per mile). These potential savings were the taxi fare that would be paid minus the total fare that would be paid to the flexible bus operator. Whilst the beneficiary of these savings may be the private individual if they are prepared and able to meet the high costs of a taxi trip, in most cases it will be the local authority or health board which meets most of the cost of the taxi on behalf of the passenger. [Table 3](#) shows these potential savings for a single day (Day 1) of simulated demand data and [Figure 4](#) shows the location of each passenger trip demand. For passengers whose total fare (including operator surcharges) is less than the taxi fare there are potential savings, e.g., for the outward trip of passenger 1 the trip distance is 26.4 miles, the taxi fare would be £49.92 and the flexible bus cost including surcharge would be £23.60 (£7.60 basic fare plus £12 for picking up 8.9 miles outside their normal area and £4.50 for extending their normal operating hours by 0.5 hours) resulting in a saving of £26.32 compared to using a taxi. Note that there were a small number of passengers whose relaxation was unrealistic because the ratio of relaxation distance to relaxation time was too high, i.e., above 40 miles of relaxation distance per hour of relaxation time, and these passengers were filtered out from the savings.

[Table 4](#) gives these potential savings (compared to taxi costs) for each of the five days of simulated demand as well as the total (weekly) savings. Note that these savings are after accounting for the total cost of the trip (including the surcharges) paid to the flexible bus operator; hence the total surcharges listed in [Table 4](#) are for information only. It should also be noted that the savings in [Table 4](#) were the

Table 3. Potential savings for day 1.

| Passenger Trip No. | Hospital destination | Flexible Bus Service | | | | | | | | | | Total fare (£) | Taxi fare (£) | Saving (£) |
|--------------------|----------------------|----------------------|----------------------|-------------------|---------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|----------------|---------------|------------|
| | | Dist. (miles) | Relax. dist. (miles) | Relax. time (hrs) | Base fare (£) | Operating area surcharge (£) | Operating time surcharge (£) | Operating time surcharge (£) | Operating time surcharge (£) | Operating time surcharge (£) | Operating time surcharge (£) | | | |
| 1 | Dr. Gray's | 26.4 | 8.9 | 0.5 | 7.1 | 12 | 4.5 | 23.6 | 49.92 | 26.32 | | | | |
| 2 | Dr. Gray's | 26.4 | 8.9 | 1 | 7.1 | 12 | 9 | 28.1 | 49.92 | 21.82 | | | | |
| 3 | Dr. Gray's | 20.5 | 8.9 | 0.5 | 7.1 | 9 | 4.5 | 20.6 | 39.3 | 18.7 | | | | |
| 4 | Dr. Gray's | 18.7 | 7.4 | 0.5 | 7.1 | 8 | 4.5 | 19.6 | 36.06 | 16.46 | | | | |
| 5 | Dr. Gray's | 1.5 | 0 | 0.5 | 1.55 | 0 | 4.5 | 6.05 | 5.1 | 0 | | | | |
| 6 | Dr. Gray's | 3.6 | 0 | 0.5 | 2.35 | 0 | 4.5 | 6.85 | 8.88 | 2.03 | | | | |
| 7 | Dr. Gray's | 9.8 | 20.5 | 0 | 4.26 | 47.5 | 0 | 51.76 | 20.04 | 0 | | | | |
| 8 | Dr. Gray's | 9.8 | 20.5 | 0 | 4.26 | 47.5 | 0 | 51.76 | 20.04 | 0 | | | | |
| 9 | Dr. Gray's | 12.1 | 31.3 | 0 | 4.72 | 76 | 0 | 80.72 | 24.18 | 0 | | | | |
| 10 | Dr. Gray's | 11.4 | 30.4 | 0 | 4.58 | 74.5 | 0 | 79.08 | 22.92 | 0 | | | | |
| 11 | Dr. Gray's | 18.1 | 4.2 | 0.5 | 7.1 | 5 | 4.5 | 16.6 | 34.98 | 18.38 | | | | |
| 12 | Dr. Gray's | 11.4 | 30.3 | 0 | 4.58 | 74.5 | 0 | 79.08 | 22.92 | 0 | | | | |
| 13 | Dr. Gray's | 11.6 | 31.1 | 0 | 4.62 | 76 | 0 | 80.62 | 23.28 | 0 | | | | |
| 14 | Dr. Gray's | 6.1 | 0 | 0.5 | 3.6 | 0 | 4.5 | 8.1 | 13.38 | 5.28 | | | | |
| 15 | Dr. Gray's | 31.4 | 9.1 | 1 | 7.1 | 10 | 9 | 26.1 | 58.92 | 32.82 | | | | |
| 16 | Dr. Gray's | 24.2 | 9.1 | 0.5 | 7.1 | 10 | 4.5 | 21.6 | 45.96 | 24.36 | | | | |
| 17 | Dr. Gray's | 24.2 | 9.1 | 0.5 | 7.1 | 10 | 4.5 | 21.6 | 45.96 | 24.36 | | | | |
| 18 | Dr. Gray's | 17.5 | 7.1 | 0.5 | 7.1 | 8 | 4.5 | 19.6 | 33.9 | 14.3 | | | | |
| 19 | Dr. Gray's | 17.3 | 6.5 | 0.5 | 7.1 | 7 | 4.5 | 18.6 | 33.54 | 14.94 | | | | |
| 20 | Dr. Gray's | 17.5 | 6.6 | 0.5 | 7.1 | 7 | 4.5 | 18.6 | 33.9 | 15.3 | | | | |
| 21 | Turner | 16.6 | 4.3 | 0.5 | 7.1 | 5 | 4.5 | 16.6 | 32.28 | 15.68 | | | | |
| 22 | Chalmers | 16 | 3.3 | 0 | 5.5 | 6 | 0 | 11.5 | 31.2 | 19.7 | | | | |
| 23 | Chalmers | 16 | 3.3 | 0 | 5.5 | 6 | 0 | 11.5 | 31.2 | 19.7 | | | | |
| 24 | Dr. Gray's | 40.1 | 6.7 | 0.5 | 7.1 | 7 | 4.5 | 18.6 | 74.58 | 55.98 | | | | |
| Total | | | | | | | | | 792.36 | 346.13 | | | | |



Figure 4. Distribution of currently unmet demands which could be met through constraint relaxation at lower cost than using a taxi: 1 day of simulated data.

maximum, since not necessarily all this cost will be met by the public authorities as noted above.

Table 4 suggests that the potential savings to the public authorities (due to a reduction in expenditure on trips by taxi) are up to £2196 per week, or equivalently £114,000 per annum.

Table 5 shows the percentage of the total potential savings per week for different levels of constraint relaxation for both time and distance together, and illustrates clearly the necessity for time and distance constraints to be relaxed together in order to allow significant savings to be made. In addition to the level of constraint relaxation, the potential savings when applying the FITS tool in a particular instance will depend also on the particulars of the transport demands (i.e., if they are close to existing operating times and areas).

Table 4. Potential savings by day.

| Day | Direction of travel | No. of passengers | No. of savings | Total surcharges paid (£) | Total savings (£) |
|-------|---------------------|-------------------|----------------|---------------------------|-------------------|
| Day 1 | Outward | 18 | 12 | 169 | 294.76 |
| | Return | 6 | 4 | 29.5 | 51.37 |
| | Total | 24 | 17 | 198.5 | 346.13 |
| Day 2 | Outward | 27 | 16 | 213.25 | 305.87 |
| | Return | 16 | 10 | 90.75 | 140.59 |
| | Total | 43 | 26 | 304 | 446.46 |
| Day 3 | Outward | 27 | 21 | 271.75 | 403.15 |
| | Return | 14 | 8 | 89.25 | 124.46 |
| | Total | 41 | 29 | 361 | 527.61 |
| Day 4 | Outward | 25 | 19 | 234 | 344.99 |
| | Return | 14 | 10 | 141.75 | 127.26 |
| | Total | 39 | 29 | 375.75 | 472.25 |
| Day 5 | Outward | 26 | 18 | 207.25 | 277.61 |
| | Return | 20 | 13 | 131 | 126.1 |
| | Total | 46 | 31 | 338.25 | 403.71 |
| Total | Outward | 124 | 87 | 1095.3 | 1626.38 |
| | Return | 70 | 45 | 482.25 | 569.78 |
| | Total | 194 | 132 | 1577.5 | 2196.16 |

Table 5. Total weekly savings (% of maximum possible) for different levels of constraint relaxation of time and distance.

| Relaxation distance (miles) | Relaxation time (hours) | | | |
|-----------------------------|-------------------------|------|------|-------|
| | 0 | 0.5 | 1 | 1.5 |
| 0 | 0.0 | 2.3 | 2.3 | 2.3 |
| 2 | 3.1 | 6.1 | 6.1 | 6.1 |
| 4 | 6.2 | 9.2 | 9.2 | 9.2 |
| 6 | 8.3 | 32.4 | 32.4 | 32.4 |
| 8 | 12.1 | 65.5 | 66.6 | 66.6 |
| 10 | 12.1 | 88.0 | 97.2 | 98.5 |
| 12 | 12.1 | 88.0 | 97.2 | 98.5 |
| 14 | 12.1 | 88.0 | 97.2 | 98.5 |
| 16 | 12.1 | 88.0 | 97.2 | 98.5 |
| 18 | 12.1 | 88.0 | 97.2 | 98.5 |
| 20 | 12.1 | 88.0 | 97.2 | 98.5 |
| 22 | 13.5 | 89.4 | 98.6 | 100.0 |

4. Discussion and conclusions

4.1 Immediate benefits from the use of FITS as a planning tool

The main beneficiaries of the savings calculated in Section 3.2 are a) individuals who may pay all or part of the taxi fare; and b) public sector organizations which pay all or part of the taxi fare where there is an obligation to provide transport to health. In rural areas where there are no other transport alternatives the latter case is prevalent.

If the £114,000 annual savings are extrapolated from the case study area to the whole of rural Scotland (i.e., scaling up proportional to rural population) there are estimated potential savings of up to £1.8 million per annum. Although not all these estimated potential savings should be attributed to spending by public authorities (since some of these taxi costs will be met by passengers themselves) it is likely that a large proportion should be. The possible savings are significant since the total spend on

transport for patients by NHS boards in Scotland was £4.5 million (Audit Scotland, 2011). This figure includes reimbursement of £2.5 million for the Healthcare Travel Costs Scheme, much of which is spent on taxis in rural areas.

The surcharges in Table 4 are payments that would be made to the flexible transport providers, potentially on behalf of the passenger by the public authorities. These surcharges are significant (up to £1577 per week or £82,000 per annum) and hence potentially provide a valuable revenue stream for these operators. This could be up to £1.3 million per annum across rural Scotland. This is equivalent to over 40% of the £3 million in total grants received annually by the community transport sector (the main providers of flexible transport services in rural areas) in Scotland from statutory bodies (CTA, 2012) and more than *three times* the level of funding that the community transport sector currently receives from health bodies (Audit Scotland, 2011).

4.2 Longer term benefits for transport to health

Part of the savings identified above for local authorities and NHS boards could be used to fund more patient transport to reduce the number of “Did Not Attends” (DNAs). There is little research on what proportion of these are attributable to transport issues, but figures ranging from 20% (PCC and CC, 2013) up to 69% (Countryside Agency, 2004) in more rural areas have been reported. The number of DNAs stands at over 7600 per annum in our case-study region alone. Each DNA was estimated to cost the NHS in Scotland approximately £112 (Audit Scotland, 2011). If only 20% of these can be avoided by offering additional door-to-door flexible transport through FITS constraint relaxation, this would reduce DNAs in the case study area by 1520 per annum, with an associated cost saving of £170,240 per annum (£2.7 million per annum if scaled up to the whole of rural Scotland). In addition to this are patient-cancelled appointments, which is an even higher number and which also incurs a cost to the NHS. Some of these cancellations could also potentially be avoided with more extensive door-to-door transport provision. As well as the financial cost of missed appointments, one must also factor in the benefits to health of patients being able to attend their appointments.

Over time, if shifting demands suggest a different core service provision then this can be specified in future contracts with flexible transport providers in return for the statutory grants received. With improved knowledge of the spatio-temporal distribution of health and social care related demands which the system captures (through data on unmet trip requests and requests requiring additional subsidy payments) the commissioners of transport

services can ensure the core services evolve to incorporate changing health and social care demands, thereby keeping the additional subsidy payments within manageable levels.

4.3 Future uses of the tool

As mentioned above, the FITS tool has been developed to operate in both online and offline modes. In its online mode it is a tool which utilizes the operating requirements and constraints of all existing transport services in a defined area to identify the transport services which potentially could fulfill passenger trip requests. It then presents these to the passenger as a list of transport options, ranked according to their preferences. There is clearly the potential to build constraint relaxation into the online operation of FITS. This would open the possibility of incorporating the FITS constraint relaxation approach into emerging *Mobility-as-a-service* (MaaS) systems (Heikkilä, 2014; Hietanen, 2014; Kamaragianni, Matyas, Li, & Schafer, 2015; Transport Systems Catapult, 2016). Within MaaS, an individual’s travel needs (usually satisfied by owning a car), are met by a range of services that include car leasing, car clubs, carpooling, community transport, cycle, and taxi services in combination with “traditional” public transport. Arguably, this could remove the need and cost of running a second car, or even remove the need for owning any car at all. If community transport services could adapt their service offering, through suitable constraint relaxation, in response to passenger requests then these community transport services and other flexible transport services could offer a much stronger component within MaaS solutions in rural as well as urban environments.

4.4 Conclusions

The paper showed how the FITS tool could help increase efficiency in transport provision to health appointments in rural areas, by demonstrating its benefits in a case study. The flexible transport services in the case study area of Aberdeenshire and Morayshire, which is typical of rural areas across the UK and many developed countries worldwide, are highly subsidized and have strict eligibility criteria; this has resulted overall in an inefficient patchwork of transport provision. The FITS system allows the relaxation of transport operators’ constraints in exchange for operators receiving surcharge payments. The FITS tool was applied to a simulated demand set and substantial potential savings were identified by relaxing operating constraints. Additional benefits were also identified in the form of increased revenue to transport operators and the potential to reduce the number of missed appointments.

As well as identifying such benefits, FITS is also useful as a tool for decision makers to consider modifying funding mechanisms in a way which motivates operators to amend their service provision in order to better meet passengers' transport to health needs.

Funding

This research was supported by the Research Councils UK Digital Economy programme award (reference: EP/G066051/1) to the dot.rural Digital Economy Hub, at the University of Aberdeen.

References

- Audit Scotland. (2011). *Transport for Health and Social Care*. Available at: http://www.audit-scotland.gov.uk/docs/health/2011/nr_110804_transport_health.pdf
- CTA. (2012). *State of the Sector Report for Scotland 2012*. Available at: <http://www.ctauk.org/UserFiles/Documents/In%20Your%20Area/Scotland/State%20of%20the%20Sector%20Scotland%202012.pdf>
- Countryside Agency. (2004). *The benefits of providing transport to Health-Care in Rural Areas*. Final Report to The Countryside Agency, prepared by CAG Consultants and the TAS Partnership Ltd, UK.
- DfT. (2009). *Providing Transport in Partnership – a guide for health agencies and local authorities*. Available at: <http://www.gov.scot/Resource/Doc/935/0085701.pdf>
- Emele, C. D., Oren, N., Zeng, C., Wright, S., Velaga, N., Nelson, J., Norman, T. J., & Farrington, J. (2013). Agent-driven variable pricing in flexible rural transport services. In J. Corchado, J. Bajo, J. Kozlak, P. Pawlewski, J. Molina, V. Julian, R. Silveira, R. Unland, & S. Giroux *Highlights on practical applications of agents and multi-agent systems* (eds.). (pp. 24–35). Vol. 365 of *Communications in Computer and Information Science*, Heidelberg: Springer Berlin.
- Ferber, J. (1999). *Multi-agent systems: An introduction to distributed artificial intelligence*. New York: Addison Wesley Longman.
- Heikkilä, S. (2014). *Mobility as a service – A proposal for action for the public administration, Case Helsinki* (MSc dissertation), Helsinki, Finland: Aalto University.
- Hietanen, S. (2014). 'Mobility as a Service' – the new transport model? *Eurotransport*, 12(2), 15 2–4.
- Kamargianni, M., Matyas, M., Li, W., & Schafer, A. (2015). *Feasibility Study for "Mobility as a Service" concept in London*. Report – London, UK: UCL Energy Institute and Department for Transport.
- Mulley, C., Nelson, J., Teal, R., Wright, S., & Daniels, R. (2012). Barriers to implementing flexible transport services: An international comparison of the experiences in Australia, Europe and USA. *Research in Transportation Business and Management*, 3, 3–11. doi: 10.1016/j.rtbm.2012.04.001.
- Nelson, J. D., & Wright, S. (2016). Flexible transport management. In M., Bliemer, C. Mulley, & C. Moutou *Handbook on Transport and Urban planning in the developed world* (Eds.). (pp. 709–742). Cheltenham, Gloucester, UK and Massachusetts, USA: Edward Elgar.
- PCC and CC. (2013). *Transport Issues in Accessing Health and Social Care Services*. The Patient and Client Council & the Consumer Council, Northern Ireland. Available at: http://www.consumercouncil.org.uk/filestore/documents/TRANSPORT_ISSUES_IN_ACCESSING_HEALTH_AND_SOCIAL_CARE_SERVICES_REPORT_FINAL.pdf
- Shimrat, M. (1962). Algorithm 112: Position of point relative to polygon. *Communications of the ACM*, 5(8), 434. doi:10.1145/368637.368653.
- Transport Systems Catapult. (2016). *Mobility as a service: Exploring the opportunity for Mobility as a Service in the UK*. Transport Systems Catapult, July. Available at: https://ts.catapult.org.uk/wp-content/uploads/2016/07/Mobility-as-a-Service_Exploring-the-Opportunity-for-MaaS-in-the-UK-Web.pdf