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The evaluation of demand responsive transport services in Europe

Jenny Mageean *, John D. Nelson

Transport Operations Research Group, School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, Newcastle upon Tyne NE1 7RU, UK

Abstract

Over the last decade Demand Responsive Transport (DRT) services have grown in popularity for several reasons including: the shortcomings of conventional regular bus and taxi services; shortcomings of special transport services; and new developments in community transport. Traditional dial-a-ride services have often been criticised because of their relatively high cost of provision, their lack of flexibility in route planning and their inability to manage high demand. The potential for overcoming these limitations may be realised through the introduction of telematics-based DRT and this has been widely demonstrated, for example, in recent research funded by the European Commission (e.g. the DGXIII-funded SAMPO and SAMPLUS projects). This paper provides an introduction to the concept of telematics-based DRT services and presents the results of the evaluation of a set of DRT technologies and operations at urban and rural sites across Europe. The paper offers discussion in terms of the key issues that influence the introduction of DRT services.

Keywords: Demand responsive transport; Buses; Telematics; Evaluation

1. Introduction

Demand Responsive Transport (DRT) services provide transport "on demand" from passengers using fleets of vehicles scheduled to pick up and drop off people in accordance with their needs. DRT is an intermediate form of transport, somewhere between bus and taxi which covers a wide range of transport services ranging from less formal community transport through to area-wide service networks. In recent years, the ability of DRT concepts to provide efficient, viable transport services has been greatly enhanced by the use of transport telematics and its successful demonstration in a variety of environments in EC-funded R&D projects such as SAMPO (System for Advanced Management of Public Transport Operations) and SAMPLUS (System for Advanced Management of Public Transport Operations Plus) (see Nelson and Mageean, 1999). The potential of DRT has been further endorsed by the European Conference of Ministers of Transport (ECMT) in its resolution on accessible transport (July 2001). Experience from Europe shows that DRT is more strategically straightforward to implement in more regulated environments as there is less conflict with other public transport modes. Thus it is significant that DRT has progressed more rapidly on the continent than in the UK. In its *Ten Year Plan* for transport the UK Government has pledged to remove or (at least) relax constraints on the development of flexibly routed bus services, e.g. route registration, and to promote a greater role for community-based services (DETR, 2000a). In addition, research commissioned by the (then) DETR (2000b) argues that flexible public transport services—provided by local authorities and bus operators in partnerships with employers, stores and leisure centres—would help to break down social exclusion. Similar findings have been reported in Ireland (ADM, 1999). More recently, the UK Rural White Paper (2001) proposals for the extension of Bus Service Operators Grant (BSOG)—formerly fuel duty rebate (FDR)—to community transport have been adopted. Finally, the recent successes of local authorities in winning substantial funding under the Rural and Urban Bus Challenge programmes for the implementation of DRT confirms this new interest in flexible forms of transport. These developments have been greatly assisted by the publication of the Department for Transport Consultation Paper entitled "The Flexible Future" (August 2002) with new proposals for the registration of flexible transport services (DfT, 2002). These proposals—which

* Corresponding author. Tel.: +44-191-222-7936; fax: +44-191-222-8352.

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have subsequently been approved as of May 2003—will permit the registration of 'many to one', 'one to many' and 'many to many' services. BSOG is also being extended to flexibly routed local bus services. Regulations to implement these changes will be laid before parliament as soon as possible.

This paper provides an introduction to the concept of telematics-based DRT services and presents the results of the evaluation of a set of DRT technologies and operations at urban and rural sites across Europe. The paper is structured as follows. After a brief review of the recent development of DRT services, the evaluation methodology developed as part of the EC-funded SAMPLUS project (1998–2000) is introduced. In the next section, a summary and comparison of the five different sites is given; the main section of the paper then presents results of the demonstrations. The last section offers discussion in terms of the issues that influence the introduction of DRT and the main impacts of these technologies on public transport within the context of Europe.

2. Recent developments in demand responsive transport services

Over the last decade DRT has grown in popularity for several reasons including: the shortcomings of conventional regular bus and taxi services; shortcomings of special transport services; new developments in community transport; and (most recently) an interest in the potential of DRT to combat social exclusion. The original objectives of Dial-A-Ride were to cater for widely dispersed trip-patterns and to provide a service in low-density suburban areas for mainly non-work journeys. Interested users would telephone in their requests some days before they intended to travel and the operator would plan the service the day before the trip. Very few of these initial schemes met with widespread success and traditional dial-a-ride services have often been criticised because of their relatively high cost of provision, their lack of flexibility in route planning and their inability to manage high demand. Some schemes did develop moderate customer bases and considerable international experience in special needs transport was gained (see for example, Ashford and Bell, 1978). This paper argues that the potential for overcoming these limitations may be realised through the introduction of telematics-based DRT and this has been widely demonstrated, for example, in the EC-funded SAMPO and SAMPLUS projects (Nelson and Mageean, 1999).

DRT services are undertaken on a variety of modes, i.e. buses, coaches, taxis, adapted taxis and minibuses and can be supplied by a variety of service providers (including bus, taxi and private hire operators, community transport, local authority and ambulance vehicles and even car-club members). Services can be free-standing or integrated between different modes, for example as feeder services for bus, tram and rail services. The development of communications and optimisation systems has enabled the evolution of new forms of flexible public transport services which can be placed at some point along a continuum between conventional fixed route shared bus services at one end and highly flexible non-shared taxis at the other. A further advantage of a telematics-based DRT system is the opportunity to draw from the spectrum of booking opportunities ranging from those based on advance reservation to those systems which include immediate response to a request for travel. A number of different service dimensions for DRT may be identified and are discussed by D'Este et al. (1994). The key characteristics that delineate service types are the route (by flexibility and density of linkages between origins and destinations), the schedule (fixed or flexible), the method of collecting passengers and quality factors.

Westerlund et al. (2000) have reported a number of DRT service concepts based around careful definition of stopping points and route flexibility. **Stopping points** may be *end stop points* (terminals), *fixed intermediate stop points* such as conventional bus stops, *predefined stop points* (recognised meeting places) and *non-predefined stop points* which are generally the doorstep of the user—the latter two requiring pre-booking. **Route flexibility** is characterised by either *semi-fixed routes* or *flexible routes* for which the DRT service departs from an end stop point (possibly a terminal) at prescribed times; or *virtual flexible routes* with no fixed end or intermediate stop points and no fixed times. Some examples of DRT service route concepts are shown in Fig. 1.

Telematics-based systems are based upon organisation via Travel Dispatch Centres (TDCs) using booking and reservation systems which have the capacity to dynamically assign passengers to vehicles and optimise the routes (see Fig. 2). Automated Vehicle Locationing (AVL) systems are used to provide real-time information on the status and location of the fleet for the route optimising software. Integrated DRT services are achieved when multi-modal options can be generated and managed for passengers. The application of advanced technologies to DRT has been considered by Glazebrook (1993), Glazebrook and McCombie (1995) and Teal (1994) whilst case studies of telematics-based DRT services may be found in Australia (Radbone et al., 1994) and the USA (White, 1995). European examples include the SAMPLUS demonstrations in Belgium, Finland, Italy and Sweden which are described in this paper. Recent UK experience is witnessing the introduction of DRT applications in rural areas as diverse as Gloucester, Wiltshire, Lincolnshire, Northumberland, West Sussex and Surrey (Jones, 2002; Grosso et al., 2002). There is also widespread interest within the UK in potential urban applications (see Nelson, 2002). This shows that there is clear potential for DRT services to offer greater flexibility in time and location than conventional public

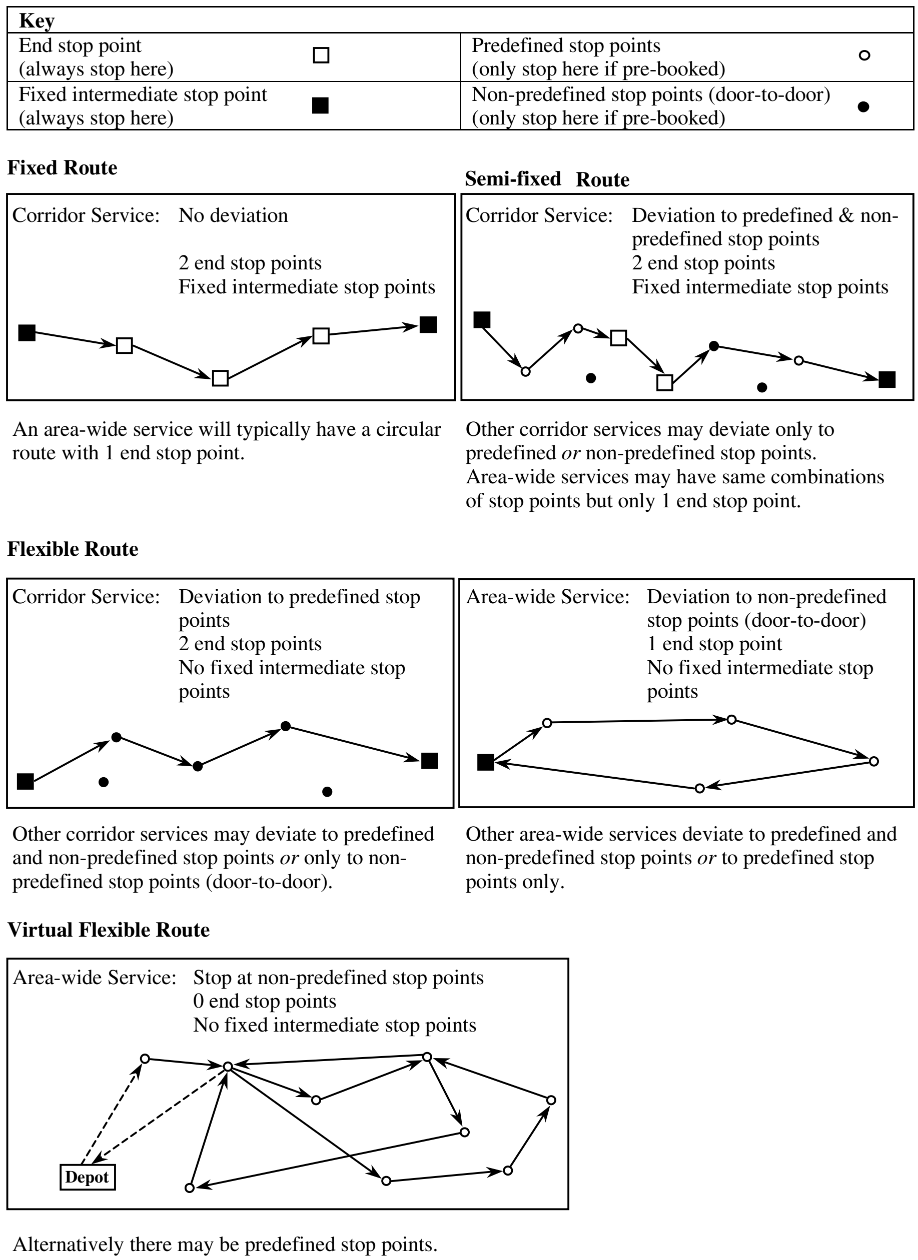

Fig. 1. Examples of DRT service route concepts.

transport in meeting many aspects of travel demand. Indeed current EC-funded research (the FAMS and EMIRES projects) is developing the next generation of DRT services which will offer a package of value-added services through the collaboration of multiple service providers (see Finn and Ambrosino, 2002).

3. The SAMPLUS evaluation methodology

The SAMPLUS *Evaluation and Verification Plan* (Nelson and Mageean, 1998) describes the methodology adopted in the evaluation which is summarised below:

- The *evaluation framework and analysis* followed a number of steps. The assessment objectives and priorities were identified for the user groups at each site, i.e. public authorities, transport operators, the general travelling public and special user groups such as the disabled and elderly. This was followed by an estimate of the impact and effectiveness of SAMPLUS technology upon the user groups at each site. The evaluation indicators for three Assessment Categories were defined: *economic viability* (considering operational efficiency and financial performance), *service provision* (behavioural evaluation and distributional costs and benefits), and *technical performance*. In

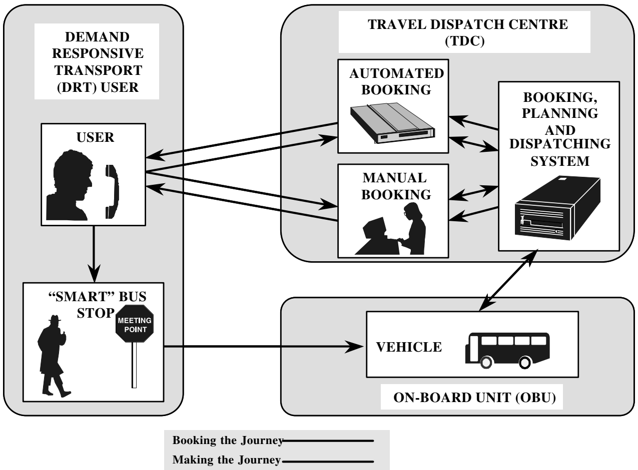

Fig. 2. Schematic representation of telematics-based DRT services.

particular, the evaluation assessed the effectiveness of DRT operations in achieving intermodality and system integration and carried out a technical evaluation to check the integration potential of different telematics systems, especially at the European level. A variety of techniques were employed for data collection including questionnaires, focus groups and manual and automated observations. The emphasis was on common methods of data collection and common evaluation indicators between sites.

- *Individual site evaluation* was achieved by the continued evaluation of demonstrations developed during the earlier SAMPO project for which each site retained responsibility for its own detailed evaluation objectives and contributions to the Evaluation Plan.
- *Common European evaluation* was necessary in order to achieve strong commonality between the SAMPLUS national demonstration sites (thereby guaranteeing a strong level of European analysis, transferability and recommendations) and this was achieved by a number of approaches. The context of each demonstration site (organisation, administration, financial, legal etc.) was described. As noted above common methods of data collection and common evaluation indicators were collected from demonstration sites for analysis. The standard of data collection and analysis was ensured by adherence to *CONVERGE* guidelines (Zhang et al., 1996).
- *Future markets* for SAMPLUS technology were investigated by ensuring that the technology would extend to all EU member states and other non-EU countries. These markets were identified by building upon extensive DRT contacts; and by analysing the benefits to service providers and operators following the implementation of SAMPLUS systems, e.g. expected increase in patronage and cost-effectiveness of operations.

As described in the next section, the SAMPLUS demonstrations took place at five sites in four EU member states that covered northern and southern Europe, urban and rural environments, and conventional and special needs operating environments. They also contained a variety of organisational frameworks for operating DRT services which influenced the results of the evaluation.

4. The SAMPLUS demand responsive transport service sites

Five demonstration sites were evaluated within SAMPLUS and their characteristics are summarised in Table 1. All but one of these sites were extensions of the SAMPO project thereby strengthening the authority of the results obtained from SAMPLUS. In addition, there were four follower (feasibility) sites. Fig. 3 shows the location of all the demonstration and feasibility sites.

4.1. The demonstration sites

The Belgian test site is located in three Belgian provinces (Limbourg, West and East Flanders), the regional services having rural and suburban characteristics. The DRT services have no user restrictions, having

Table 1
Characteristics of the SAMPLUS DRT demonstration and feasibility sites

Type of site	Country	Localities	Population density	Type of service area	User restriction
Demonstration	Belgium	Limbourg, W. and E. Flanders	Moderate	Regional	None
	Finland	Tuusula, Järvenpää and Kerava	Low–moderate	Regional and urban	Special transport and none
	Italy	Florence, Porto Romana and Campi	Moderate–high	Regional and urban	Special transport and none
	Sweden	Gothenburg (Högsbo)	High	Urban	Special transport and none
	Sweden	Stockholm (Märsta)	Low	Rural	None
Feasibility	Finland	Nurmijärvi	Low–moderate	Regional and urban	Special transport and none
	UK	Surrey	Moderate	Rural	Special transport
	UK	West Sussex	Low–moderate	Rural	None
	Ireland	Cavan/Leitrim	Very low	Rural	None

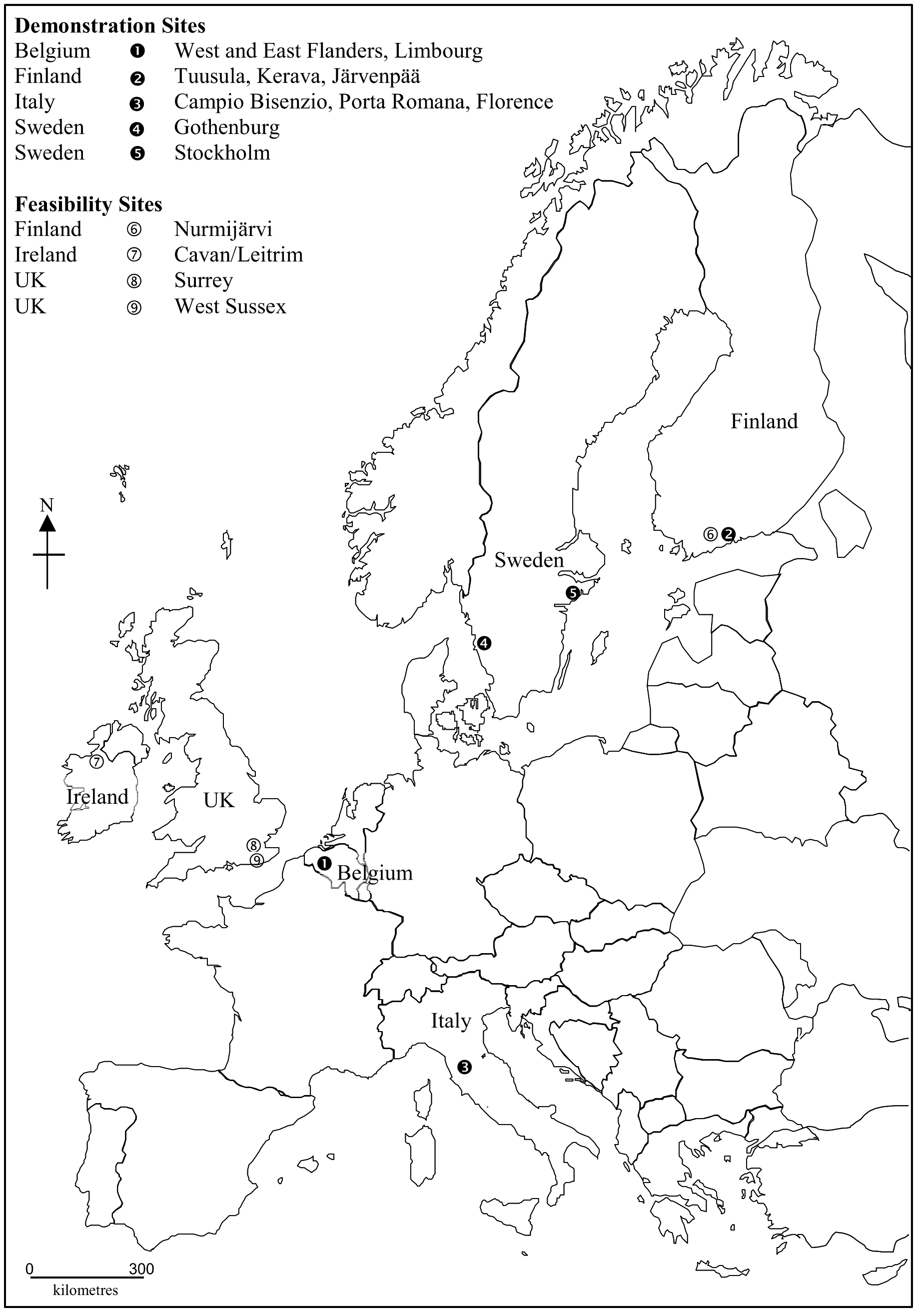

Fig. 3. The SAMPLUS DRT sites.

replaced conventional services which were expensive to operate and provided a low service quality level for passengers. DRT services have been designed to act as feeder services to main trunk-lines, as well as meeting local demands (corridor-based, flexible route with predefined stop points). The services operate every hour in Limbourg and East Flanders and every 2 h in West Flanders, the users having to walk no more than 500 m to the stop point in urban locations and 1 km elsewhere. The SAMPLUS demonstration operated and evaluated 20 DRT services in 17 separate areas. The services are provided by one operator (De Lijn who have a monopoly and receive public subsidy) or their contractors and are controlled through three local Travel Dispatch Centres (TDC). Interactive Voice Response System (IVRS) and Internet booking are available as well as manual booking.

The Finnish site consists of the Municipality of Tuusula and the towns of Kerava and Järvenpää which are all managed by one TDC. The test site incorporates all modes of public transport (taxi, bus, train, invataxi and minibuses equipped for mobility impaired people) and a large number of independent companies are involved. The DRT service operates on a "many-to-many" basis (i.e. area-wide virtual flexible services with predefined stop points at a maximum of 900 m from origins/destinations and, in the case of special users, non-predefined stop points). DRT feeder services operate outside the urban areas, whilst within the urban areas DRT services operate in low demand locations. A privately owned company, Korsisaari, operates the DRT buses and the Travel Dispatch Centre.

In Italy, the demonstration supports the DRT service at three sites in the Florence metropolitan area: the peripheral rural area of Campi Bisenzio; Porta Romana, a part of the urban area in Florence; and the service network for disabled people in the entire Florence metropolitan area. The main evaluation objectives were to improve the quality and level of public transport services, whilst improving cost-effectiveness. Porta Romana is an urban quarter with a low demand, the users group being mostly residents. The Campi Bisenzio site is located in the western part of the Florence metropolitan area. The Campi area is characterised by a low public transport demand with a significant number of mobility origins and destinations (shops, factories, shopping centre, schools, public offices, banks etc.). The route concepts are as follows: a many-to-many service in the Campi area available for any users, with the possibility of interchange to the regular lines (area-wide virtual flexible service with predefined stopping points 300 m apart); a one-to-many service in Porta Romana without user restrictions (area-wide flexible routes with predefined stop points 300 m apart; a few services have fixed departure times, the rest being on-demand); and a door-to-door service in the entire urban network of Florence for disabled people (an area-wide virtual flexible service with non-predefined stop points). Services are provided by the (dominant) publicly owned operator (ATAF), which also operates the Travel Dispatch Centre.

The first Swedish demonstration was in Högsbo, an urban district of Gothenburg. The evaluation objective was to provide an efficient door-to-door special transport service (STS) for the elderly population, and to reduce the STS cost with a minimum of service reduction, whilst also increasing mobility (at a reasonable cost) for elderly people who are not eligible for STS but still have difficulty using regular public transport. The DRT solution comprises: two fixed end-points with scheduled departures (every 30 or 60 min in each direction), a fully flexible corridor service between end-points according to requests for pick-up and drop-off, door-to-door for STS eligible persons and generously distributed predefined stop points to assure a walking distance of less than 150 m for other elderly persons. Services are provided by the city authority's special transport services division.

A second Swedish site in Stockholm demonstrated DRT in the low demand semi-rural area of Märsta, having a flexible corridor service with predefined stop points less than 400 m from the doorstep. Additional flexibility and cost savings have been achieved by not using the most rural end stop point if there is no demand. The objectives were to encourage modal shift from the car by providing an increased level of public transport mobility. There are no user restrictions. This site was not a continuation from the SAMPO project.

4.2. The feasibility sites

The Feasibility sites have come into operation since the end of the SAMPLUS project. At Nurmijärvi (Finland) the objective was to improve the level and accessibility of services in a sparsely populated area and to reduce transport costs. The DRT services operate on a "many-to-many" basis (i.e. area-wide virtual flexible services with predefined stop points at a maximum of 900 m from origins/destinations and, in the case of special users, non-predefined stop points). It uses the same TDC as the Finnish demonstration site.

The Surrey (UK) service operates for disabled and elderly users throughout the rural districts of Haslemere and Chiddingfold. This is a virtual flexible service with non-predefined stop points. The main objectives were to reduce the cost of service provision and provide a superior service to the dial-a-ride service it replaced. Further details are given in Grosso et al. (2002).

West Sussex (UK) is another rural area for which DRT can provide improved accessibility to public transport services whilst minimising cost-effectiveness. These requirements are being addressed with the provision of evening services, particularly at weekends. There are no user restrictions on the five semi-fixed routes with predefined stop points, running three times each way per day. The services in Surrey and West Sussex are operated by ACCORD (the former in-house West Sussex County Council service provider). Although the TDC booking hours do not extend beyond operating hours, it is possible to make a request for a booking by telephone answering machine or an on-line booking form. Initially, a single TDC at Midhurst was used for the Surrey and West Sussex services but a separate TDC is now being established in Surrey (see Grosso et al., 2002).

The Cavan/Leitrim area of Ireland has a very low population density and the objective was to improve accessibility to public transport. There are no user restrictions on the four services, some of which are semi-fixed whilst others are flexible. All services use non-predefined stop points. These services do not permit same day booking and pick-up time is considered to be more important than drop-off time.

4.3. Overview and comparison of sites

The nature of a site, the service and the operational characteristics can vary considerably. One of the strengths of DRT in general, and SAMPLUS in particular, is the ability to operate successfully in these varying environments. This section summarises these differences, thereby providing a portfolio for potential DRT sites to examine and ascertain possible similarities and differences with existing DRT sites (see Table 2). Linked with the results of the evaluation of the indicators (discussed in the next section), this contributes to the assessment of DRT technologies.

Table 2 shows that the size of the SAMPLUS DRT service areas is reflected by the type of DRT service that has been established. At one extreme the Belgian site covers three provinces which are not densely populated, although the total population is quite large: this has led to the provision of many services covering the provinces. Conversely the Italian and Gothenburg (Sweden) sites are densely populated over a small area, and only a few DRT services have been established. Where population density is very low, varying solutions have been used, e.g. in Ireland several routes are used to cover a wide area; at the Finnish demonstration and feasibility sites only one route is used over a small area but the coverage is much more flexible; and at the Stockholm site a fairly flexible service covers a very small area (Fig. 4).

There are generally one or two DRT buses per route (Table 2). The exceptions are Florence, Campi and Hogsbo, where there are more vehicles per route and the Finnish sites, where taxis are an integral part of the DRT service, thereby providing a role model for future intermodal co-operation. The number of SAMPLUS DRT operators (Table 2) reflects the legal and organisational environments of the sites. Thus, in Belgium and Italy there is little scope for more than one bus operator to be involved, due to the highly regulated planning and operation of public transport. In Sweden, the operation of routes is subject to off-the-road competition: as only single routes were established, there was no scope for more than one operator. In the UK and Finland, on-the-road competition is permitted: in these cases the number of bus operators is limited by the natural caution concerning relatively expensive technologies in an open market.

Many variables can be used to describe the operating characteristics of a site. The minimum pre-travel booking time (Table 2) shows a wide variation. Whilst the Italian and Gothenburg sites have a short period (15 min), the other sites require at least 1 h. Not surprisingly, it has been found that longer booking periods are

Table 2
Overview of site, service and operational characteristics

Country and site	Socio-economic characteristics			Operational characteristics			
	Area (km^2)	Population	Population density (per km^2)	Number of DRT:			Pre-travel booking time by passengers (min)
				Services	Vehicles	Operators	
Belgium							
Limbourg	2427	917,577	378	21	20	1	60
W. Flanders	3161	1,301,330	412	6	5		60
E. Flanders	3008	1,583,743	527	2	2		120
Finland							
Tuusula	225	28,677	127	1	2 + 30 taxis	1 + 60 taxi	60
Järvenpää	40	34,282	857			operators	60
Kerava	31	29,298	945				60
Nurmijärvi	367	30,880	84	1	2 + 30 taxis		120
Italy							
Florence	102.4	383,611 D: 600	3746 D: 6	1	5	1	15
Porto Romana	8.4	30,510	3624	1	2		10
Campi	28.6	34,444	1204	1	4		15
Sweden							
Gothenburg (Högsbo)	8	20,000 D and E 6700	2500 D and E: 837	1	4	1	15
Stockholm (Märsta)	44	1100	25	1	1	1	60
UK							
Surrey	4000	1,057,100 E: 195,800	264 E: 49	1	2	1	120
West Sussex	263.4	20,840	79	5		1	At start: 120[a]
Ireland							
Cavan/Leitrim	1500	21,000 (+Fermanagh)	14	7	7	15	180

Key: D = disabled; E = elderly; Start = start of DRT service; later = adjustment after service operational for a few months.
[a] Later: 60 min.

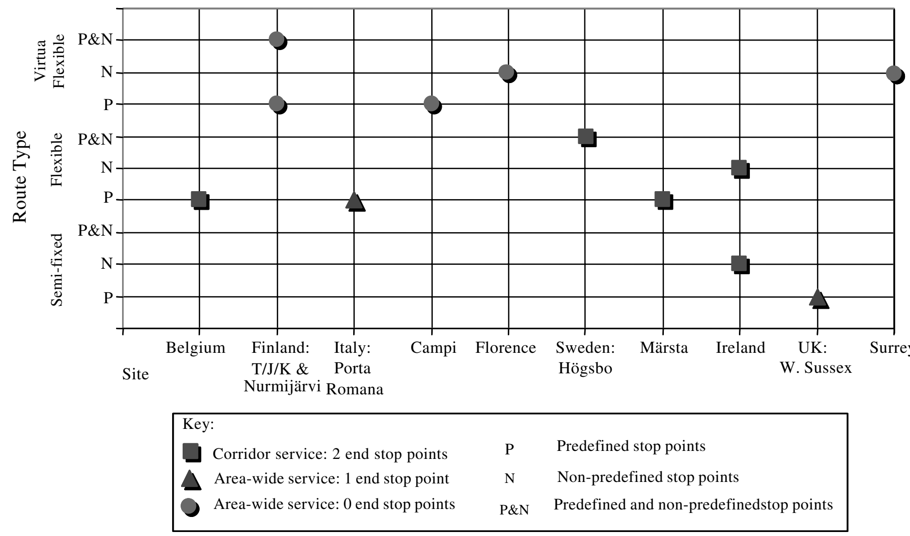

Fig. 4. DRT service journey patterns at SAMPLUS sites.

more beneficial to TDC operators, but are less flexible for passengers.

The DRT journey pattern is developed according to many criteria, e.g. the distribution and density of population and the resulting potential demand; the amount of capital available for investment in vehicles and scheduling programmes and operators; and the analysis of user needs will guide the investors towards the most

Method of booking											
Return journey	Non-predefined		λ			λ	$\lambda\sigma$		λ		λ
	Predefined	$\lambda\sigma\upsilon$	λ	$\lambda\nu$	$\lambda\nu$		$\lambda\sigma$	λ		λ	
	Fixed intermediate								$\lambda\nu 9$	λ	
	End	$\lambda\sigma\upsilon$		$\lambda\nu$	$\lambda\nu$	λ	$\lambda\sigma\Psi$	λ	$\lambda\nu 9$	$\lambda\leftrightarrow$	λ
Outward journey	Non-predefined		λ	$\lambda\nu$		λ	$\lambda\sigma$		λ		λ
	Predefined	$\lambda\sigma\upsilon$	λ		$\lambda\nu$		$\lambda\sigma$	λ		λ	
	Fixed intermediate								$\lambda\nu 9$	λ	
	End	$\lambda\sigma\upsilon$		$\lambda\nu$	$\lambda\nu$	λ	$\lambda\sigma$	λ	$\lambda\nu 9$	λ	λ
Stop point		**Belgium:** W/E Flanders/ Limbourg	**Finland:** T/J/K[1]/ Nurmijärvi	**Italy:** Porta Romana	Campi	Florence	**Sweden:** Högsbo	Märsta	**Ireland:** Cavan/Leitrim	**UK:** West Sussex	Surrey

[1] Tuusula/Järvenpää/Kerava

Key:

ν	Driver	υ	Internet
λ	Manual (TDC)	Ψ	Magnetic swipe card
σ	IVRS (TDC)	$\leftrightarrow$	Touch screen
		9	No pre-booking needed

Fig. 5. Method of booking DRT services at SAMPLUS sites.

appropriate solution. Semi-fixed routing is easier to schedule: these are used or planned at Stockholm (Sweden), Ireland and West Sussex (UK). More flexible routing is used in Belgium, Porta Romana (Italy) and Gothenburg (Sweden), whilst virtual flexible routing is found on the remaining two Italian services and in Finland (Fig. 4).

Lastly, the method of booking the DRT trip (Fig. 5) is partly dependent upon the journey pattern. For example, pre-booking is necessary at non-predefined and predefined stop points, as there is no guarantee that the vehicle will pass those locations. Manual booking with the TDC is always available. The use of an Interactive Voice Response System (IVRS) has had varying success: whilst it continues to be used in Stockholm and Belgium, experiments have not shown it to be worth continuing at present in Finland. Similarly, Internet booking has only been pursued in Stockholm and Belgium. Return booking raises a number of complications leading to innovative, different booking solutions: in Gothenburg magnetic card readers are used, whilst in West Sussex a touch screen system is planned.

5. Results of the evaluation

The evaluation of the SAMPLUS demonstration sites took place over varying periods of time, according to the objectives of each site. All but the Märsta site in Sweden continued from the SAMPO project, enabling a relatively long-term profile of the success of DRT services to be made. Information concerning the feasibility sites largely relates to defining the areas and the probable service provision.

There were two main priorities for evaluation, despite differences in the operating context between the sites:

- the use of telematics enhanced DRT services to improve cost-effectiveness by reducing public expenditure (e.g. Finland, Italy) or improving fleet operations (e.g. Belgium, Sweden);
- the use of DRT systems to improve social conditions by increasing service levels and access to facilities (e.g. Finland, both UK sites).

The results in this section are organised according to the assessment categories developed for the evaluation which were described above and draw on the experience at the five SAMPLUS demonstration sites.

5.1. Economic viability

The results of the evaluation are described under the following headings: operating costs; TDC cost; vehicle usage; route directness; and passenger usage. In completing the evaluation indicators were drawn on a site-by-site basis from the full list of indicators. It should be noted that direct cost savings are not easy to calculate, due to the restructuring of public transport services that often accompanies the introduction of DRT services. Nevertheless, two main economic benefits have been noted: (a) the ability to support services on low demand routes that would be too expensive with regular services (Belgium)—although the DRT services still require a subsidy it is less than required for the conventional services; and (b) the provision of STS leading to a saving in authority costs (Sweden).

- *Operating costs:* although *operating costs per vehicle revenue hour* can be rather high in comparison with regular services, there are opportunities to offset costs, e.g. in Belgium drivers are used for other duties when not required for driving; and in Italy fewer drivers are needed to run DRT in comparison with equivalent conventional services. Operating costs per vehicle revenue hour varies between sites: in Finland the service purchaser's costs are used which are less than the true operator costs; and costs are low in Belgium due to subcontracting to lower cost operators. Similarly, *operating cost per ride* is high when compared to conventional services, e.g. in Finland (€14.4/trip and €7/trip respectively). In Sweden (Gothenburg) operating cost per ride was €5/trip which is about three quarters of the corresponding taxi trip. Operating cost per ride is lowest in areas of greatest population density: the more densely populated Belgium province of East Flanders cost €10.24/trip compared to €26.25/trip in Limbourg; in Italy Porta Romana is more densely populated than Campi, with costs of €1.69/trip and €7.61/trip respectively (see Table 2) (as with all public transport services). The *operating cost per ride kilometre* was least at Porta Romana (0.85 compared to 2.4 in Finland, Limbourg and Campi), due to the high number of rides in a densely populated area. For *fare revenue per operating cost* it is difficult to differentiate between fares derived from regular and DRT services when through ticketing is available, e.g. Belgium. Current evidence suggests that DRT fare revenues do not cover costs, despite the increased patronage. This is not a particular issue in regulated environments, e.g. in Belgium, where the operator is required to provide basic mobility for all, but in deregulated environments such as the UK, operators are less likely to consider DRT as a viable proposition. Therefore, the benefit of DRT lies not in direct but in relative savings derived through cross-sector benefits, e.g. by comparing DRT with single ride STS taxis in Sweden.
- *TDC cost:* results show that the *method of booking* (see Fig. 5) has a strong impact on TDC costs. No pre-booking is the least costly method—but pre-booking is the preferred option for DRT services,

as it leads to the most efficient scheduling. At present manual booking is the least costly method of pre-booking, but it is anticipated in Belgium and Gothenburg that as bookings increase, IVRS and Internet booking will offset operator costs. They have the added advantage of being available 24 h per day, which virtually eliminates the possibility of a call not being answered—which can lead to a lost booking. Touch screens and magnetic swipe cards are not cheap options, but they do improve the quality of service for return booking. There are wide variations in *fare revenue per transport cost* even in sites with similar market environments. This confirms that TDC costs decrease as patronage increases, e.g. the low unit cost at Porta Romana (€0.60) compared to Campi (€2.19) in Italy. In Finland the authority wished to see *booking and dispatch costs* of less than €1.50/trip—at the end of the project they were 3.15. In Italy these costs vary from 0.60 in Porta Romana, to 2.19 in Campi, and 4.48 for the disabled service in Florence: it is generally accepted that STS do incur high costs, but they are regarded as a social necessity. A key issue is the level of patronage needed to justify the fixed costs incurred by the TDC: post-demonstration Finland has simplified the system in order to reduce (successfully) TDC costs.

- *Vehicle usage:* the higher the *load factor* the more flexibly the service is being used. To some extent this is determined by the type of service installed, e.g. the virtual flexible routes in Campi and Finland have a high load factor. Before and after SAMPLUS comparison at these sites shows an increase in the load factor. The *active revenue hours per total revenue hours* [time spent transporting passengers] varies between sites: 35% in Finland, 56% in Belgium, and over 78% in Italy.
- *Route directness:* Belgium reports only a 7% increase in distance travelled compared to the previous conventional routes.
- *Passenger usage:* is variable, e.g. Campi has 10 *rides per vehicle revenue hour* compared to 36 in Porta Romana. A good guide is the change following the introduction of DRT e.g. Belgium: 4 compared to 0 on some conventional services previously. In Gothenburg an average productivity of >7 rides per vehicle revenue hour was achieved in the first two years of operation. The Finnish site has achieved almost 9 rides per vehicle revenue hour but this is skewed by the supplementary use of taxis.

Table 3 summarises the positive and negative outcomes of the evaluation of economic viability, together with the outcomes which varied between the demonstration sites.

5.2. Service provision

The results of the evaluation are described under the following headings: core background information; trip purpose; operator indices; coverage of service; service reliability; ease of making reservations; and passenger convenience. Overall, users are satisfied with the DRT services offered and their mobility has improved.

- *Core background information:* Females are the dominant users of the DRT services (over 80% in Belgium and 70% in Gothenburg), which is not surprising as they are less likely to have access to a car, e.g. in Bel-

Table 3
Summary of economic viability evaluation for the SAMPLUS DRT demonstration sites

Indicator	Positive outcomes	Negative outcomes	Variable outcomes
Operating costs	Cost savings are made: relative not direct	Direct comparison between sites is difficult	High compared to regular services
		Costs are not covered by fare revenue	Vary between sites Lower in areas of high population density DRT is less likely in deregulated open access markets
TDC cost	Simplification of procedures reduces costs		Level of patronage is critical
	IVRS and Internet booking will help reduce costs		Wide variations even in similar market environments
	Economies of scale possible		STS costs are regarded as a social necessity
Vehicle usage	High load factors on virtual flexible routes Increased since DRT introduced		
Route directness	Small increase in distance travelled		
Passenger usage	Increased since DRT introduced		

gium only 10% of all users would have access to a car for the trip, leading to a large captive user group. The modal age group varies between sites from less than 15 years in Finland to 15–30 years in Campi and Porta Romana, 31–45 years for the Florence STS, with 44 years being the mean age in Belgium; as the Gothenburg service is restricted to the disabled and elderly the mean age is 77 years. These age distributions are reflected in the composition of the users: 65% of Belgian users are retired, house persons and students, whereas in Campi and Porta Romana students and workers constitute the largest group (84%); the eligibility requirements of the Florence STS lead to 80% of the users being unemployed or students.

- The *trip purpose* reflects the type of users (shopping dominates in Limbourg and West Flanders, social visits in East Flanders, work and shopping in Campi and Porta Romana).
- *Operator indices: multiple reservations* are made by less than 30% of users in Limbourg and West Flanders, this rises to 45% in East Flanders, reflecting the use of DRT for work-related trips. In theory all trips are *pre-booked* in Belgium and Finland, but 3% of passengers are let on by Belgian drivers without pre-booking and schoolchildren make use of non-booked space in Finland.
- *Coverage of service: daily services* are regarded favourably in East Flanders and have been requested in Finland, but this is unlikely due to the low demand. Similarly, passengers in Gothenburg wish to have weekend services and longer hours; in Campi a 24-h service has been suggested. Passengers in West Flanders would like a service of more than 3 days a week. The *rejection rate* of requests is variable: less than 1% in Finland and Belgium, rising to 10% in Italy. The reasons for this included: vehicles fully booked (Belgium); inappropriate stop point requested (Belgium, Finland); an alternative regular service was available (Finland).
- *Service reliability:* 80% of Belgian passengers are satisfied with the actual stop point time. In Italy only 2% of trips failed, which were due to mechanical rather than soft/hardware problems. Congestion frequently accounted for delays in Italy. Finnish passengers were more critical of lateness, even though punctuality improved following SAMPO (when passengers were less critical): therefore, familiarity can lead to more discerning users. Finnish delays were usually due to inexperienced drivers, particularly taxi drivers. Service reliability improved when the TDC was moved closer than a site 200 km from the DRT service area.
- *Ease of making reservations:* there is scope for improvement, e.g. in Italy only 45% considered booking to be good or better. Finnish passengers wish to see better response times. The majority of Belgian users make the reservation in the morning, leading to delays, which should be reduced by IVRS and Internet booking, if passengers can be encouraged to overcome their resistance to these services which lack human interaction. Return booking causes problems, e.g. in Gothenburg, following the replacement of driver issued return booking with card reader booking, elderly users faced ergonomic difficulties in using the magnetic swipe card. Dissatisfaction with the system may relate to passenger inexperience and/or the technical problems, and this has led to the consideration of contactless cards. Increased mobile phone coverage should also reduce this problem.
- *Passenger convenience:* the *time spent in transit* becomes less satisfactory as the service area increases (see Table 2). The need for *intermodal transfers* varies between sites, e.g. ranging from 40% of passengers in West Flanders to 62% in East Flanders. Dissatisfaction with the transfer wait time increased from 14% in West Flanders to 25% in East Flanders leading to the conclusion that more flexible services do not seem to enable well timed transfers. Although *passenger comfort* is one of the most satisfactory elements of DRT services, there is room for improvement (e.g. waiting environment, older vehicles, space for prams, TDC staff not noting the STS status of some passengers). *Satisfaction with the TDC* was good, but operators still seek to improve the service. *Driver satisfaction* is universally high, although some Finnish STS passengers preferred the single ride taxis. *Willingness to pay* is a good measure of user satisfaction: e.g. 72% in Finland, 83% in Porta Romana and 90% in Florence STS considered it good and/or cheap. The stronger appreciation of the STS in Florence than in Finland may be related to the alternatives available to the passengers: taxis in Finland, whereas in Florence it is conventional services and their attendant difficulties for those requiring STS. *Walking time* to the stop point was thought to be good by most users, e.g. 82% in Finland, 90% in Italy. Satisfaction is linked to the actual dispersal of stop points (see Fig. 4), e.g. in Belgium the frequency of using DRT decreases as the walking time increases. The type of stop point strongly influences satisfaction with the walking distance: as non-predefined stop points provide a door-to-door service, this naturally is more satisfying to the customer than predefined stop points which may be up to 400 m away. Door-to-door is generally only available to STS and elderly users. Satisfaction with the *TDC opening hours* was good. *Call-back* is not always successful: in Gothenburg 25% of customers leave home without waiting for the call-back, leading to avoidable increases in waiting times and dissatisfaction with the service.

Table 4 summarises the positive and negative outcomes of the evaluation of service provision, together

Table 4
Summary of service provision evaluation for the SAMPLUS DRT demonstration sites

Indicator	Positive outcomes	Negative outcomes	Variable outcomes
Core background information			Users mostly female Age and social profile varies between sites
Operator indices	Good use of multiple reservations		Not 100% pre-booking
Coverage of service			Requests for more hours and days Rejection rate is variable between sites
Service reliability	Overall user satisfaction Good soft/hardware reliability	Remote TDCs are less reliable	Passengers become more critical as knowledge increases
Ease of making reservations	IVRS and Internet should reduce delays	Scope for improvement in procedures and response times Need to improve return booking	
Passenger convenience	Passenger comfort is high—but with room for improvement Walking time to the stop point good High satisfaction with drivers High willingness to pay Good satisfaction with TDC	Frequency of using DRT decreases as walking time increases Dissatisfaction with intermodal wait time Call-back is not always satisfactory	Service area size is important Need for intermodal transfers varies

with the outcomes which varied between the demonstration sites.

5.3. Technical performance

The results of the evaluation are described under the following headings: system performance; system capacity; loss of potential customers; and data reliability. Overall, the technical performance of SAMPLUS has been successful, giving reassurance that reliable DRT systems can be developed by different suppliers of soft and hardware.

- *System performance: dispatch reliability* has been acceptable at all sites, reflecting the period of operation. The provision of well-trained TDC staff (Italy) is particularly important. The use of SMS (Short Message Service) has reduced route and client information errors. The use of widely available soft- and hardware will enable rapid standardisation of DRT products, yet still permit flexible service architecture. This was demonstrated in Italy where the same system was used to schedule three different types of services. However, complex scheduling issues require further refinement in Finland, e.g. the avoidance of conflict with regular public transport services. At Gothenburg the calculation of driver times needs to be improved; research suggests that virtual flexible routes—as used in Campi, Florence, Finland—are most likely to permit efficient scheduling. Initial problems were found with magnetic swipe card return booking (Sweden) and procedures IVRS (Belgium). TDC operators were extensively questioned concerning their attitudes to the *Travel Dispatch system*. Key outcomes included the need to involve TDC staff with development, the availability of on-line information (e.g. customer address, nearest stop point, other public transport services) and thorough testing of new modules. Conflict with regular services is difficult to avoid in Finland, particularly as the number of DRT services increases. The speed of the system is now largely restricted by the speed of the operator. In Finland taxi drivers are becoming more accepting of the system, although negative attitudes remain. There are fears about the effect of IVRS and Internet booking on job security in Belgium, as it is known that these reservation systems are a means of reducing the TDC's fixed costs. The *size of the operating area* was considered to be satisfactory in Finland and Italy, allowing users reasonable access to the DRT service. Stop points are sparser in rural areas, leading to less satisfaction. Potential DRT installations should be wary of attempting to provide a service over a large area with few vehicles and stop points.
- *System capacity:* the user *pre-trip booking time* (see Table 2) varies from less than 15 min in Italy, to 1 h in Finland and West Flanders, to 2 h in East Flanders. The longer the time, the less stressful it is for TDC staff and drivers, but it is less flexible for passengers. Post-demonstration Finland has seen an increase to 2 h, balancing commercial reality with the most efficient service. *Call-back* is not necessary for a successful scheduling system, e.g. Belgium. Call-

back time varies: 15 min in Finland, 30 min in Sweden. The *time taken to make a booking* is short: in Belgium 75% of calls take less than 2 min; in Finland the mean time is 1 1/2 min, and in Italy it is 1 min. *Trip cancellation* is rapid, e.g. 20 s in Belgium. *Scheduling delays* are almost all due to unforeseen events, e.g. congestion in Italy. Routine updates take place outside TDC opening hours in order to maximise *system uptime*.

- *Loss of potential customers:* the capacity of the reservation system was not reached in normal conditions. The limiting factor was the capacity of the TDC operator, which in turn depends upon customer knowledge of the procedures. The limited number of operators in peak hours led to some lost bookings, which should be alleviated by IVRS and Internet booking. 12% of calls were unanswered in Finland, 10% in Campi (where there is a very high number of customers) and 4% in Florence. Some callers ring less than 30 min before the desired trip time, in which case a slot is less likely to be available.
- *Data reliability:* the database for regular public transport services is unreliable in Finland—reflecting the problems of a deregulated market—making timed transfers difficult.

Table 5 summarises the positive and negative outcomes of the evaluation of technical performance, together with the outcomes which varied between the demonstration sites.

6. Discussion: factors influencing the introduction of demand responsive transport services in Europe

The results from the SAMPLUS demonstrations and experience elsewhere supports the contention that DRT services can offer greater flexibility in time and location than conventional public transport in meeting many aspects of travel demand. Detailed findings from the SAMPLUS demonstrations and from subsequent research have been reported elsewhere (e.g. Nelson and Mageean, 1999; Nelson, 2002). The experience gained in the SAMPLUS project suggests that there are a number of issues that authorities and operators planning to enter the DRT market need to be aware of. Three key areas that will strongly influence the development of DRT services in Europe—the market environment, economic barriers and the pursuit of public transport system integration—are discussed below.

6.1. The market environment: institutional and legal barriers

In terms of the relationship between DRT and scheduled and other public transport, experience shows that the more regulated the environment (e.g. Belgium, Italy), the less conflict there is between DRT and other public transport modes making DRT strategically more easy to implement. Operators with a monopoly can plan services as they see fit, which should lead to a service without duplication, gaps and the fear of losing

Table 5
Summary of technical performance evaluation for the SAMPLUS DRT demonstration sites

Indicator	Positive outcomes	Negative outcomes	Variable outcomes
System performance	Dispatch reliability is generally good	Problems with calculating accurate driver times	
	Provision of well-trained TDC staff	Problems with IVRS	
	SMS reduces route and client information errors	Problems with return booking	
	Good potential to standardise DRT products	Conflict with regular services	
	Staff involvement in development of procedures	Taxi driver and TDC staff concerns	
	Testing procedures		
	Speed of the system is good		
	Satisfactory operating area size		
System capacity	Call-back not necessary for successful scheduling		Scheduling delays due to unforeseen events
	System uptime is maximised		Length of pre-trip booking time has varying consequences
	Rapid booking time		
	Rapid trip cancellation		
Loss of potential customers		Customer awareness is a restriction	
		Loss of customers in peak hours	
Data reliability			Regular public transport database may be not be available, limiting intermodality with DRT

customers to competitors. The operator can demonstrate improved public accountability as ridership and customer satisfaction increase, whilst reducing operating costs. However, an innovative authority is required, taking a long-term view of the service. If only a short-term view is taken (as in the Ireland feasibility site), DRT is unlikely to be implemented.

In a deregulated (franchise) environment (e.g. Sweden) off-road competition promotes innovation, as DRT investment can be specified by the authority and there is protection from competition for the duration of the franchise.

In a deregulated (open access) environment (e.g. UK outside London, Finland) there are few incentives for operators competing on the road to introduce DRT, due to the high investment required and the possibility of other operators benefiting from the capital outlay. DRT is most likely to be implemented where one operator is extremely dominant in an area. DRT will therefore (normally) only be a niche opportunity for private operators and is more likely to be procured by local authorities as socially desirable services, which are associated with long-term funding issues. DRT may be considered to impinge upon taxi operations, as in Finland. Historically, there has been great competition between bus and taxi operators. However, the Finnish demonstration provides a role model for improving co-operation, to the mutual benefit of bus and taxi operators. In particular, the introduction of compatible software systems is a vital step forward.

The DRT tariff is unlikely to cover the cost of the service in any market. Instead, it is regarded by the authority as fulfilling a public obligation, and by the operator as a means of increasing passenger numbers, including a beneficial effect on regular services as a result of interchange opportunities. Subsidies are most likely in regulated environments, whereas in deregulated environments, subsidies are service specific.

The optimal operational area is variable, being determined by geographical, political and existing operational boundaries. Overall, in order to maximise customer needs, route flexibility and route directness, the optimal area is small.

In regulated environments the TDC is part of the operator organisation, which generally does not need to demonstrate TDC profitability on its own. In less regulated systems, there are no obvious patterns. If more than one operator is involved, an independent TDC is viewed favourably by operators, but financial problems remain. A successful TDC will demonstrate economies of scale, although the Finnish demonstration suggested that diseconomies occur if TDC operators lack local knowledge. Economies could be achieved as a result of integration with other potential TDC functions, such as journey planning, brokerage and transport services provided by other public authorities.

As a relatively new form of public transport, the legal and organisational framework for DRT is unclear, even in more regulated environments like Belgium and Italy. The UK Government in its *Ten Year Plan* for transport has pledged to remove or (at least) relax constraints on the development of flexibly routed bus services and to promote a greater role for community-based services (DETR, 2000a).

The rules for compulsory competition and bidding vary considerably. Obviously, in regulated environments there is no competition. Elsewhere, the rules vary according to the type of service (STS or no restriction), the legal status of DRT, and the type of competition (off- or on-road). Off-road competition is successful as there is no competition until the next round of franchises, but on-road competition can deter heavy investments. In existing regional models for co-operation the responsibility for DRT services varies. It may be the authority fulfilling its public duties or a private operator utilising a gap in the market. In fully deregulated environments, the authority is particularly aware of the need to co-operate with private operators.

The influence of health, welfare and pensions arrangements on DRT provision shows no pattern. In some countries there is an obligation to provide public transport access for everyone (e.g. Sweden) whereas elsewhere disabled people may be entitled to free public transport, but there is no duty to provide the appropriate transport (e.g. Ireland). Where more than one operator trade union exists, conflict is more likely when establishing working practices, e.g. the taxi unions in Finland were an impediment to the introduction of DRT services. Elsewhere, drivers' unions fear the loss of jobs.

Major investment can only be justified if high patronage can be confidently predicted; therefore more regulated environments are more likely to sustain high investment, due to the flexibility of resources.

6.2. Economic barriers

In urban areas there is a demand for a high level of mobility. The public transport network is a response to political forces, e.g. the need to reduce congestion and pollution, and because operators can operate cost effective services. DRT successfully supports conventional services in areas of low demand and by providing STS. Highly regulated markets are most likely to support DRT services, due to the high subsidies available. Beyond the major conurbations, regional mobility between rural and urban areas is an important issue. DRT has the potential to be a significant transport mode, providing local and feeder services. Subsidy levels are moderate. In rural areas available subsidies may be lower, but DRT remains a realistic way of improving mobility for those without access to a private vehicle. In areas of open competition, capital investment needs some protection, so DRT schemes are more likely to be in response to authority initiatives. As the population density decreases, so does the level of STS; DRT can provide a valuable supplement for people who would, in urban areas, receive STS.

The viability of DRT services as a self-supporting system has not yet been demonstrated. Viability is therefore measured in terms of citizen mobility and providing the cheapest public transport solution. Modal shift could be viable if costs are discounted against travel time-savings and environmental degradation. Public transport patronage has increased as a result of DRT services. However, the best method of building up the market may be through staged technological development, commencing with low-tech solutions. The attractiveness of DRT services is clearly demonstrated: this flexible application adapts to local physical, economic and organisational conditions. Subsidies will encourage operators in competitive markets. Customers report increased mobility and intermodality; drivers have greater job satisfaction.

6.3. Impact on intermodality and system integration

At present the main objectives of DRT services are (generally) to improve access to public transport in areas of low demand and for particular groups of disadvantaged users (e.g. disabled and elderly). The next stage is to extend mobility by improved intermodality. It has been shown above that the nature of the market environment strongly influences the feasibility of establishing DRT services. The more regulated the market (Belgium, Italy), the easier it is to integrate DRT with conventional services. Open access markets are not easy to integrate, as seen in Finland, where even the provision of up-to-date timetables is not always forthcoming. The West Sussex feasibility site also demonstrated the danger of introducing a subsidised services, which could lead to the withdrawal of regular services by the existing operators if any competitive infringement was perceived.

In addition, vehicle design may impede intermodality: in this case it is the regular service that is most likely to be the weak link in the provision of low floors, wheelchair access and buggy storage areas. The removal of this impediment depends upon national legislation regarding vehicle design and the attitude of operators.

Within any market environment, the service journey pattern selected for the DRT service influences intermodality. Whilst non-predefined stop points are most desirable for customers, they produce greater scheduling complexity. Therefore, predefined stop points are most likely to promote intermodality. The more flexible the route itself, the more difficult it becomes to guarantee connections with other services. Thus, routes which are semi-fixed are easier to schedule for intermodal change—but this is at the expense of individual passenger flexibility.

Little research has been carried out on system integration and scope for further work lies in several areas. In large conurbations fringes are frequently poorly served and orbital services are poorly developed. Strong commuter movements to conurbations from small to medium-sized towns need to be served by local services.

7. Conclusion

This paper has introduced the concept of telematics-based DRT services and has presented the results of an extensive evaluation of DRT at five demonstration sites across Europe. The following conclusions are offered:

- Whilst the integration of DRT services into a network provides greater transport cohesion through flexible routing of services which allows access throughout an area rather than on specific corridors, it is arguable that the adoption of DRT services is not yet as widespread as one might expect.
- The potential for reducing transport costs and improving or sustaining citizen mobility through the introduction of DRT services are not yet fully established. It is likely that such policy objectives could be fulfilled by integrating DRT scheduling systems with Internet journey planners, community transport brokerage schemes and other transport services available as public services, such as educational transfers, social services and patient transport services. However, as has been discussed, a number of pressing institutional, legal and economic barriers must be overcome if the DRT market is to be consolidated. Institutionally, the potential for conflict between different potential service providers (e.g. bus and taxis) and between DRT and other public transport modes is very real, perhaps more so in urban areas. Questions of ownership and control with respect to the TDC may relate to the degree of regulation pertaining. As a relatively new form of public transport the legal and organisational status of DRT is unclear and, without exception, the UK applications to date are hampered by issues of route registration and eligibility for BSOG—which in turn influences the levels of subsidy required.
- Crucially, the viability of DRT services as a self-supporting system has not yet been demonstrated. At most sites issues of fares, cost of phone calls, subsidy, bus and TDC operating costs all pose challenges. However, for financial and scheduling reasons, DRT services (with the possible exception of niche services, e.g. feeders to airports) do not aim to be the dominant public transport supplier in a market, although the SAMPLUS results show they should be regarded

as a vital supplier of services where conventional solutions are untenable, e.g. low demand areas, special transport services.
- There are potential new markets for DRT to assist with modal shift since DRT offers scope for full integration with conventional services.

Although the SAMPLUS results must be viewed within the context of the operating environment, particularly with regard to reported costs, this paper has identified a number of generic factors that future applications should consider. Governments will continue to grapple with the need to deliver good quality public transport within the context of mobility for all. Telematics-based DRT services, by incorporating individual customer preferences, offers the possibility of greater reliability and punctuality than is often available to public transport users. The next generation of DRT services is likely to embrace the concept of flexible, mobile agencies providing a variety of business services with DRT at the core.

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