Some observations on the organisation of demand responsive transport services

JF Mageean - JD Nelson

TRANSPORT OPERATIONS RESEARCH GROUP
UNIVERSITY OF NEWCASTLE UPON TYNE, NE17RU, UK

This paper presents new concepts of Demand Responsive Transport (DRT) service provision emphasising the advantages of route flexibility. The paper reviews briefly the development of DRT services world-wide and then focuses on the new service concepts that have been developed as part of the DGXIII-funded SAMPLUS project. Five European demonstration sites are introduced and the experience of the Italian case-study (Florence) is taken as a detailed example. The evaluation of DRT services comprises four assessment categories (economic viability, service provision, technical performance and market projection). In conclusion, discussion centres on the contribution of DRT to future public transport provision and the barriers that must be overcome in order to facilitate widespread adoption.

1 Introduction

Demand Responsive Transport (DRT) provides transport services "on demand" from passengers in which fleets of vehicles are scheduled to pick up and drop off people in accordance with their needs. It is an intermediate form of transport, somewhere between bus and taxi and it covers a wide range of transport services ranging from the 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. This has been further endorsed by the European Conference of Ministers of Transport (ECMT) in its resolution on accessible transport (July 2001).

This paper presents new concepts of DRT service provision emphasising the advantages of route flexibility. The paper is structured as follows. After a brief review of the recent development of DRT services, a number of new service concepts that have been developed as part of the DGXIII-funded SAMPLUS project (1998-2000) are introduced. In the next section, a summary of the demonstrations at five different test sites which implemented the route concepts is given. As a case-study, the main section of the paper presents results of the demonstration in the city of Florence in Italy. The last main section offers discussion in terms of the potential uptake of DRT services across Europe.

2 The development of Demand Responsive Transport Services

DRT services represent an intermediate form of public transport, somewhere between a regular service route that uses small (low floor) buses and special transport services (STS) that typically use a single or shared taxi. DRT services are routed according to the needs of the customers, generally only stopping where passengers request collection or dropping off. 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; and new developments in community transport. For example, 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 the DGXIII-funded SAMPO and SAMPLUS projects (Nelson and Mageean, 1999).

DRT services are undertaken on a variety of modes i.e. buses, coaches, taxis, invataxis (specially equipped vehicles for mobility impaired persons), minibuses and feeder services for both tram and rail services. Services can be integrated between different modes or free-standing. An advantage of a telematics-based DRT system is the opportunity to incorporate some or all of the spectrum of DRT ranging from those based on advance reservation to those 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), schedule (fixed or flexible), method of collecting passengers and quality factors.

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 Figure 1). Automated Vehicle Location (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, 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). Thus, it has been shown clearly that DRT services can offer greater flexibility in time and location than

conventional public transport in meeting some aspects of travel demand.

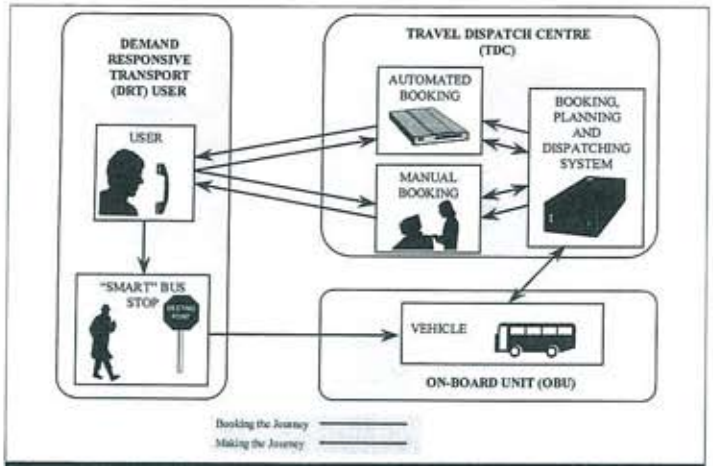

Figure 1 Schematic Representation of Telematics-based DRT Services

The DGXIII SAMPO project ('**S**ystems for the **A**dvanced **M**anagement of **P**ublic transport **O**perations') has assessed the potential and the effectiveness of the introduction of telematics technologies in the provision of DRT services (1996-97). This goal has been evaluated in a demonstration project, developed at test sites in four EU member states (Belgium, rural; Finland, rural; Italy, urban; Sweden, urban). A particular contribution of SAMPO and the successor SAMPLUS project has been the development of DRT traffic concepts and these are described in Section 3.

3 DRT Service Concepts

As noted above DRT services are routed according to the needs of the customers, generally only stopping where passengers request collection or dropping off. Two main types of service operate, namely:

- the service either operates on a corridor between two end points; or
- an area service beginning and ending at the same point or with no end stop points.

In this paper the following definitions are adopted:

(a) *Stopping points*. These comprise: "end stop points" (terminals) which are locations where routes begin and end. "fixed intermediate stop points" are conventional bus stops. "predefined stop points" which are recognised meeting places. "non-predefined stop points" which are generally the doorstep of the user. The vehicle only stops at predefined and non-predefined stop points if requested in advance by pre-booking.

(b) *Route flexibility*. "Semi-fixed routes" are characterised by a DRT service departing from an end stop point (terminal) at prescribed times e.g. every 2 hours. The vehicle will stop at conventional fixed intermediate stop points. In addition there will be deviations to predefined and/or non-predefined stop points on request. "Flexible routes" have a service departing from an end stop point at prescribed times. The vehicle will only call at predefined and/or non-predefined stop points on request. "Virtual flexible routes" have a journey where there are no fixed end or intermediate stop points. This is more like a conventional taxi service (but with shared rides), as it operates for a set number of hours, crossing the DRT service operational area with no scheduled departure times from any stop point. The vehicle will only call at predefined and/or non-predefined stop points on request.

Figure 2 provides several examples of DRT service route concepts.

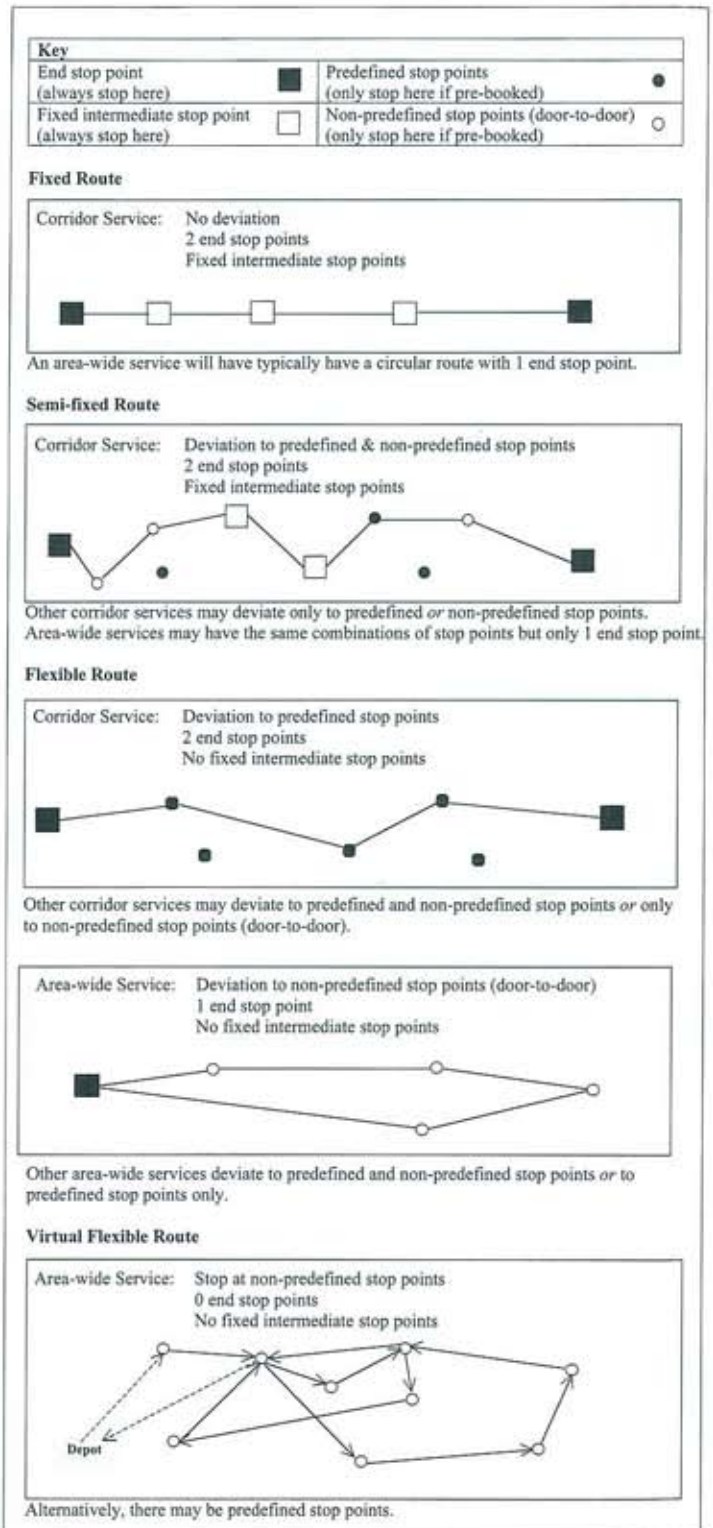

Figure 2 Examples of DRT service route concepts

4 The SAMPLUS demonstrations of DRT

The main goal of the SAMPO project was to assess the potential and effectiveness of introducing telematics technologies to Demand Responsive Transport (DRT) services. This goal was evaluated in a European demonstration project, developed at demonstration sites in four EU member states. The SAMPO project clearly established the benefits of such technologies. A successor project, known as SAMPLUS has built upon the results of SAMPO by providing a set of DRT technologies and operations that have been fully demonstrated and evaluated at urban and rural sites across Europe.

4.1 The demonstration sites

Five demonstration sites were evaluated within SAMPLUS and their characteristics are summarised in Table 1. In addition, there were four follower sites, Surrey and West Sussex (both in the UK), Cavan/Leitrim (Ireland) and Nurmijärvi (Finland).

Country	Localities	Population Density	Service Type	User Restriction
Belgium	Limbourg, W & E Flanders	Moderate	Regional	None
Finland	Tuusula, Järvenpää & Kerava	Low – Moderate	Regional & Urban	Special Transport None
Italy	Florence, Porto Romana & Campi	Moderate – High	Regional & Urban	Special Transport None
Sweden	Gothenburg (Högsbo)	High	Urban	Special Transport None
Sweden	Stockholm (Märsta)	Low	Rural	None

Table 1 Characteristics of Five DRT Demonstration Sites

The Belgian test site was located in three provinces of Belgium (Limburg, West and East Flanders), the regional service having rural and suburban characteristics. DRT services have replaced conventional services which were expensive to operate. 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 demonstration operated and evaluated 20 DRT services in 17 separate areas. The services were provided by one operator (De Lijn) and were controlled through three local Travel Dispatch Centres (TDC). Interactive Voice Response System (IVRS) and Internet booking were available as well as manual booking.

The Finnish site consisted of the Municipality of Tuusula and the towns of Kerava and Järvenpää managed by one TDC. The demonstration proved the use of telematics for DRT from a remote TDC. The test site incorporated all modes of public transport (taxi, bus, train, invataxi and minibuses equipped for mobility impaired people) and a large number of independent companies were involved. The DRT services operated on a "many-to-many" basis (i.e. area-wide virtual flexible route with predefined and, in the case of special users, non-predefined stop points).

In Italy, the demonstration supported the DRT service at three main 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 Florence metropolitan area. Porta Romana (30,510 inhabitants) 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 (28.6 km^2, 34,444 inhabitants) 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 were as follows: a many-to-many service in the Campi area, with the possibility of interchange to the regular lines (area-wide virtual flexible with predefined stopping points); a one-to-many service in Porta Romana (area-wide flexible with predefined stop points), characterised by a number of fixed trips from Monday to Saturday; and a door-to-door service in the entire urban network of Florence for disabled people (area-wide virtual flexible with non-predefined stop points).

The Swedish demonstration was in Högsbo, an urban district of Gothenburg. The 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 who are not eligible for STS but still have difficulty using regular public transport. The DRT solution comprised: accessible low-floor minibuses (12-14 passengers); two fixed end-points with scheduled departures (every 30 or 60 minutes 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 < 150 m for other elderly persons; and friendly drivers for a very personal service.

A second Swedish site in Stockholm demonstrated DRT in the semi-rural area of Märsta, having a flexible corridor service with predefined stop points. Additional flexibility was achieved by not using the most rural end stop point if there was no demand.

4.2 The evaluation methodology

The evaluation of the DRT demonstrations followed a robust methodology which is described in full in Nelson and Mageean (1998). The evaluation framework and analysis was developed as follows. The assessment objectives and priorities were identified for the user groups at each site, i.e. public authorities, transport operators, the general travelling public, 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 four Assessment Categories (*economic viability, service provision, technical performance and market projection*) were defined. In 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 system architectures, especially at the European level.

Individual site evaluation was achieved by continued evaluation of demonstrations developed during SAMPO together with common methods of evaluation at new demonstration sites in SAMPLUS. Each site retained responsibility for its own detailed evaluation objectives and contributions to the Evaluation Plan. Common European

evaluation was necessary so that there was strong commonality between the SAMPLUS national demonstration sites, which guaranteed a strong level of European analysis, transferability and recommendations. Commonality was brought about by several means. Firstly, the context of each demonstration site (organisation, administration, financial, legal etc.) was described. Common methods of data collection and common analysis of data were followed. Common evaluation indicators were collected from demonstration sites. The standard of data collection and analysis was ensured by adherence to *CONVERGE* guidelines.

4.3 Results from the Italian demonstration

This section is divided into three parts. First there is a description of the operational characteristics of the DRT services. This is followed by a consideration of the telematics applications necessary to deliver this level of service. Finally, the results of the evaluation are presented.

Operational characteristics

As described above three different implementations of DRT were demonstrated at the Florence test site. At the Porta Romana and Campi sites, the users were able to access the service (trip booking) by calling the TDC on a toll-free telephone number. In addition, the users could directly contact drivers at the bus terminals asking for the next vehicle departure. In both cases, the user requests were submitted to TDC operators (at bus terminals, the driver calls the TDC operator using a standard radio link). The users have to specify the desired departure or arrival time and should specify the predefined stop point identification names for the requested trip origin and destination. Supported by the *PersonalBus* booking and trip planning software, the TDC operator is able to manage the request even when the user is not able to give complete and correct identification of the required stop points. Pick-up/delivery points for the Campi and Porta Romana services are characterised by two main requirements: they are located at points easily accessible by both the vehicles and the users; and there is a short distance between two stop points (<300 metres in built-up areas). All the bus stops for regular services located on the Campi and Porta Romana sites are used as meeting points for the DRT service and some other bus stops have been installed in order to satisfy the above requirements. The DRT service for disabled people is a door-to-door service. The users can access the service by calling the same toll-free number as the Campi and Porta Romana sites.

The on-board equipment is limited to a chip card ticketing machine and standard Advanced Vehicle Location (AVL) equipment (radio system, on-board computer and driver's keyboard, TDC-drivers communication and vehicle location). Two low floor 8 metre vehicles working at Campi are equipped with wheel chair carrying capability to allow bus access to elderly and disabled people. In Porta Romana, two 10 metre vehicles are operated during morning peak hours (until 09.00) and one vehicle for the rest of the day. Five minibuses are operated on the DRT disabled service, with low floor and wheel chair capabilities.

DRT System Architecture

The system architecture developed for the demonstration is shown in Figure 3. The architecture ensures flexibility in route planning (there is no fixed route for *PersonalBus*, enabling all the routes to be modified to satisfy customer requests); automated management and control; off-line and on-line booking procedures. All of the DRT service management operations are supported by the *PersonalBus* software[1]. In particular, the main functionalities of *PersonalBus* include: user's request management; booking and cancellation of requested trips; DRT service planning and optimisation: journey and route formation; journey editing and tuning; resource optimisation; drivers information management (journey plan); customer information management; service management and statistics; fine tuning of the operational parameters (maximum trip duration, maximum delays at pick-up/delivery points, number of vehicles, etc.); configuration management for the service network (road structure, stops, parking places, etc.).

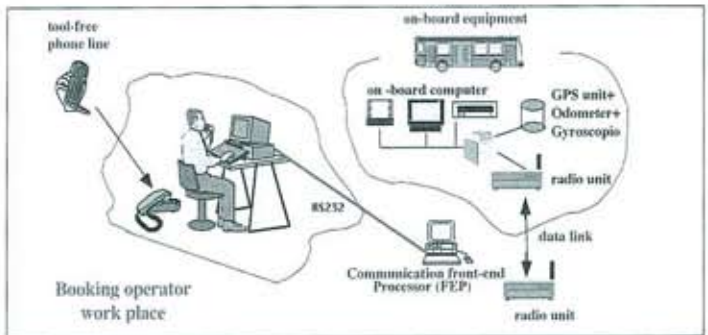

Figure 3 Florence DRT System Architecture

The system includes three main technological and operational components: the control room (TDC); the telephone communication line for connecting the users and the TDC operators; and the radio-based communication network for connecting the TDC operators and the service drivers. The dialogue between DRT vehicles and the TDC is ensured by the communication network of the AVL system currently operated by ATAF (the public transport operator). The DRT and AVL systems are integrated at the first level of the communication network (voice) while the second level (data/voice) has already been designed. The TDC is physically located in the AVL control room, in order to simplify the integration with the AVL system, allowing the DRT operators to communicate with the DRT vehicles.

Results of the evaluation

The main objective of SAMPLUS in Florence was to gain experience in co-ordinating operations over a number of sites and to cover a number of specific issues including: technical extension in terms of priority of users requests, vehicle availability management, and optimisation of ATAF resources. In the remainder of this section results are drawn

from the evaluation indicators for three Assessment Categories (*economic viability, service provision, and technical performance*).

A number of indicators were used to investigate *Economic Viability*. Operating costs have been calculated considering two kinds of costs classes: (a) total operating cost = labour, fuel, maintenance, insurance, depreciation, general cost; (b) total operating cost = labour, fuel, maintenance, insurance, depreciation, but no general cost. On a "before" and "after" basis the results showed that in Campi (which from September 1998 became the first town in Italy with all public transport services operating as DRT) the DRT service is generally more expensive, but this difference is compensated by the higher number of advantages brought by the introduction of *PersonalBus* in the Campi area. Moreover, all three services guaranteed a higher coverage in terms of area and users, with a more cost-effective service. This is a result of a) its flexibility, allowing a better coincidence with user needs; and b) the creation of a common TDC for the management of all the flexible services. However, any cost/benefit analysis is partial if it does not take into account the funds that the authorities have available in order to guarantee the mobility advantages to the community and the consequent overall increase in the number of "potential users" – it is then possible to consider the "overall improvement of the perceived service quality".

The *PersonalBus* service at Campi changed many operational aspects (Table 2): the number of km/year increased from 50,729 (before DRT) to 120,576 (after DRT); the number of stop points increased from 29 to 161; as a result there has been a decrease in the number of drivers utilised for the services, due to the better organisation allowed by the new *PersonalBus* system; on the other hand, the extension of the services led to an increase in the number of TDC operators, from one to three, in order to cover all three DRT services. The STS has the highest cost per passenger trip, which is compensated for by the higher amount of resources received by ATAF to guarantee this social service. Fare revenue/transport cost varies considerably between the three services, ranging from 0.60 Euro per passenger (Porta Romana) to 4.48 Euro per passenger for the STS.

Economic Viability Indicator		Before SAMPLUS	After SAMPLUS
Km/year		50,729	120,576
Number of bus stops		29	161
Labour cost		More drivers 1 TDC staff	Fewer drivers 3 TDC staff
Campi			
Operating cost/km (Euro):	Including general costs	4.09	4.42
	Excluding general costs	3.63	3.95
Operating cost/ride (Euro):	Including general costs	8.68	7.61
	Excluding general costs	7.72	6.80
Porta Romana			
Operating cost/km (Euro):	Including general costs	3.04	2.99
	Excluding general costs	2.58	2.51
Operating cost/ride (Euro):	Including general costs	1.90	1.69
	Excluding general costs	1.62	1.42
Florence (STS)			
Operating cost/km (Euro):	Including general costs	4.08	4.01
	Excluding general costs	3.63	3.54
Operating cost/ride (Euro):	Including general costs	34.84	29.88
	Excluding general costs	30.98	26.36

Table 2 Operating costs before and after SAMPLUS for the Italian site

The load factor recorded at the Campi and Porta Romana services represented a big increase in comparison with the ordinary lines substituted by the two services. This achievement is more evident in Campi (31.6 seat km/ride km). For total actual trip kilometres/total vehicle hours the results obtained are similar for the whole ATAF network, except for the Porta Romana service (16.12), which has a higher value due to the absence of traffic congestion in the zones served. The rate of passenger usage per vehicle hour varied considerably, being least efficient for the STS (1.7) and most efficient for the flexible route at Porta Romana (36.44).

In terms of *Service Provision* the three DRT services in Florence have been evaluated on the basis of data collected directly from the service provider (ATAF) and its operators; by automatic operational data collection provided by the controlling system; and by a passenger survey of 100 passengers for Campi *PersonalBus*, and 50 passengers each for Porta Romana and Florence (STS).

Due to the initial success of *PersonalBus*, the Campi Municipality pushed for the extension of the service to the entire network, in order to supply the increasing needs and requests of the citizens. The principal commercial outlets (Coop, I Gigli) interested into the *PersonalBus* DRT service in the area (Coop, I Gigli) required an agreement with ATAF to ensure the *PersonalBus* service was in their zone of influence.

Core background information for service utilisation is shown in Table 3 from where it can be seen:

- The results obtained show that for the Florence STS there is a prevalence of users in the 31-45 age group (the differences are not very great in the under 45 age categories).
- In Porta Romana there is a high percentage both of young and elderly customers (the service reaches a high number of schools, while the entire zone is characterised by a high concentration of elderly residents).
- In Campi the numbers are quite similar to Porta Romana, with a particular difference in the total amount of young users: 86% under 46 years as opposed to 78%.
- The Campi service is being used increasingly for school and work purposes.
- The Campi service is being used to reach the more peripheral zones.

Also relevant is the car availability indicator: the higher rate of young/elderly users is affected by the rate of car ownership in Porta Romana, which is lower than in Campi (in the area of Florence there is an average of 1 car per 1.6 inhabitants). The results for the socio-economic group indicators confirm the other service utilisation data:

- half of the Campi users are workers/employees;
- in Porta Romana there are many students and retired people;
- for the disabled the situation is different as in order to qualify, they must be unable to work;
- disabled service users are mainly people with wheel chairs.

The service coverage has been described in terms of hours of service offered to the customers and to the potential users. In Porta Romana and Campi the service operates from Monday

Service Provision (SP) Indicator			Response (%)						
			<15	15-30	31-45	46-60	>60		
SP8a	Age (years):	Campi	11.5	47.8	26.5	9.7	4.5		
		Porta Romana	12.6	44.1	21.4	11.8	10.1		
		Florence (STS)	20.0	32.0	44.0	4.0	0.0		
SP8b	Car availability:	Campi	42.2% drive a car						
		Porta Romana	38.1% drive a car						
		Florence (STS)	0% drive a car						
			Worker	Employee	Professional	Trader	Student	Housewife	Retired	Other
SP8c	Socio-economic group:	Campi	44.5	10.9	1.8	0.9	29.1	5.5	4.6	2.7
		Porta Romana	38.7	9.8	0.9	0.2	35.1	4.9	8.8	1.6
		Florence (STS)	0.0	16.0	4.0	0.0	44.0	0.0	0.0	36.0
	Service utilisation:		Mean (years)				Mode (years)			
	Age:	Campi	31				26			
		Florence (STS)	29				40			
			Male (%)				Female (%)			
	Gender:	Campi	44				56			
		Florence (STS)	52				48			

Table 3 Core background information for the Italian site

to Saturday between 06:30 and 19:30 hours, whilst the STS operates slightly longer (06:00 to 22:00). The indicators have been obtained directly from the service operators involved, by collecting the operational data related to the areas covered. Good results have been achieved in terms of the served population, especially for the *PersonalBus* service carried out in Campi (Table 4). With the most recent Campi network extension, the service now covers the entire area of Campi. The number of passengers in Campi increased by more than 50% between September-October 1997 (3,693) and September-October 1998 (5,963). An interesting result, which confirms *PersonalBus* as a powerful tool for the management of flexible services, is that it assures most users of having the trip guaranteed, even for "last-minute" bookings (made less than one hour before the requested trip): less than 10% of all the users had their request rejected during the period of system testing. In terms of choice of origins and destinations the only customers that cannot have a trip guaranteed are those who call within 30 minutes before the requested trip: in this situation it is not always possible to provide a trip that fits the requirements of the caller, given the maximum number of buses and drivers available for the services.

Service Provision (SP) Indicator			Response	
			Before SAMPLUS	After SAMPLUS
SP1	Campi	Service hours	06.30-19.30 Mon.-Sat.	06.30-19.30 Mon.-Sat.
		Kilometres/year	50,729	120,576 (+137%)
		Stop points	29	161
	Porta Romana	Service hours	06.00-20.00 Mon.-Sun.	06.00-20.00 Mon.-Sun.
		Kilometres/year	71,894	72,397
		Stop points	40	40
	Florence (STS)	Service hours	07.00-20.30 Mon.-Sun.	07.00-20.30 Mon.-Sun.
		Kilometres/year	180,350	180,168
		Stop points	70	80
Service Provision (SP) Indicator		No. of passengers/year	% population served in area	Rejection rate of callers requesting service (%)
SP2	Campi	70,000 in 1998 85,000 in 1999	100	10
	Porta Romana	127,000 in 1998	100	6
	Florence (STS)	24,160 in 1998	100	4

Table 4 Coverage of service for the Italian site

The service reliability has been assessed through the automatic collection of the operational data provided by the system. The results are very good in terms of correspondence between scheduled and actual arrivals and departures, with 2% of failed trips which were caused by mechanical problems of buses, rather than hardware/software components. Late arrivals were usually due to traffic congestion.

By using a set of on-board interviews, the indicators chosen to describe the customers' perception of the three services in terms of ease of booking, speed and safety of the trips, etc., have been evaluated. The results obtained (see Table 5) show that the service is considered positively by a high percentage of users including the point of view of trip planning. The results are quite similar for all the three services provided, except for the willingness to pay: the focus groups carried out with the disabled people revealed that they are willing to pay higher fares in order to obtain a better service, more suited to their specific needs. The results for number of transfers per week show that most of the customers use the service 5 days a week. For Porta Romana and Campi services it is also important to notice that there is a significant percentage of 1 day/week transfers, thus demonstrating that the system is suitable also for occasional users. The disabled are quite a different category of users that need the transportation service almost every day, as shown by the 68% percentage of 5 days/week users. 8% of all the users judged the transfer ease to be very positive in comparison with the regular service. Passengers were willing to pay higher fares for this service, as the alternative to the ATAF service was not appreciated for various reasons (high price of private operators, difficulty of booking of the journey, barriers to the regular services). 92% of passengers found the vehicle comfort to be good or very good in Campi; falling to 89% on the other services. Over 90% of passengers considered the walking time taken to reach the stop point as good or very good at Campi and Porta Romana (Table 5).

Service Provision (SP) Indicator			Response (%)					
			Once		2-4 times	5 times	Other	
SP5	No. of transfers per week:	Campi	26		15	51	8	
		Porta Romana	27		16	48	9	
		Florence (STS)	0		12	68	20	
SP6	Perception of transfer ease		8% of users thought that this was very positive in comparison to the regular line					
			Very good	Good	Sufficient	Insufficient	Bad	Don't know
SP3	Service reliability:	Campi	56	24	12	4	4	0
SP4	Perceived trip time:	Campi	40	48	8	4	0	0
		Porta Romana	38	47	10	5	0	0
		Florence (STS)	35	51	9	5	0	0
SP9	Comfort:	Campi	40	52	0	8	0	0
		Porta Romana	39	50	4	7	0	0
		Florence (STS)	37	52	6	5	0	0
SP10	Walking time taken to stop:	Campi	8	84	8	0	0	0
		Porta Romana	7	82	11	0	0	0
SP12	Safety, security:	Campi	36	48	4	12	0	0
		Porta Romana	38	49	3	10	0	0
		Florence (STS)	40	50	4	6	0	0
SP13	Control and independence:	Campi	37	42	4	17	0	0
		Porta Romana	35	41	8	16	0	0
		Florence (STS)	37	41	12	10	0	0
SP14	Willingness to pay:	Campi	8	80	0	8	4	0
		Porta Romana	6	77	7	7	3	0
		Florence (STS)	15	75	9	1	0	0

Table 5 Passenger convenience for the Italian site

In terms of convenience for STS users, there was a high level of satisfaction with the service. Actual and potential users would like to see an extension of the service to 24 hours due to the wish (and right) to obtain a transport service without asking for help from family or friends. Personnel were held in high regard. The service regularity was considered good.

Special vehicles and accessibility support is required. For all three services about 40% considered the reservation procedure to be adequate, whilst another 45% felt it was good or very good.

For the trip purpose indicators, it is seen that in Campi the most frequent trip motivation is work, followed by shopping (due to the presence in Campi of "I Gigli", the biggest shopping centre in Italy). In Porta Romana, during the school term students also frequently use the service. For the disabled service, the most frequent trip motivation is the need to visit rehabilitation centres, but it is important to notice that the service is also utilised for house/work/school trips, thus contributing to letting them live an ordinary every-day life.

The evaluation of the system *Technical Performance* was carried out extensively, through the collection of the data (and opinions) available from all the actors involved (operators, drivers and technical developers) in the services and by automatic collection of the operational data provided by the system for all the three experimental DRT services (Campi, Porta Romana and Florence (STS)). Most of the results for these indicators are aggregated and not differentiated for the three services, since the *PersonalBus* system with its components (hardware and software) is a common tool to support all the flexible services.

Technical Performance (TP) Indicator		% of Respondents (Florence (STS), Porta Romana and Campi)					
		Very good	Good	Sufficient	Insufficient	Bad	Don't know
TP1	Driver's perception of the importance of on-board messages	0	21	79	0	0	0
TP2	Driver's attitude towards ATT	9	54	37	0	0	0
TP3/MP5	*Operator's attitudes toward the travel dispatch system*						
	Reliability	0	67	33	0	0	0
	Speed of the system: searching for customer addresses	25	25	50	0	0	0
	Speed of the system: providing scheduled line based service information	12	44	44	0	0	0
	Speed of programme and hardware repair	0	29	71	0	0	0
	System quality	0	75	25	0	0	0
TP3/MP6	*Operator's attitudes and acceptance levels towards test area*						
	Number of stops	25	63	12	0	0	0
	Suitability of distance to stops for customers	12	50	38	0	0	0
	Size of operating area	0	100	0	0	0	0
	Cost of tickets	75	25	0	0	0	0
TP14	Voice Communication Quality	0	65	35	0	0	0

Table 6 System performance for the Italian site

The first results of the TDC operators and driver surveys, carried out in September-October 1998 showed considerable receptiveness towards the system. Driver perception of the importance of on-board messages and attitudes towards telematics were evaluated through a set of interviews with operators and drivers: answers were summarised in a qualitative scale (from very good to very bad). The results showed quite a good approach and attitude from operators and drivers, who understood the utility of the new system and its capabilities. It is clear that it has been necessary to provide them with a training period, in order to become familiar with the new *PersonalBus* technologies. Voice communication quality and despatch reliability are indicators of the quality and reliability of the system, and were determined through interviews with passengers and the automatic collection of the operational data provided by the system. The TDC was shown to be quite reliable in all its components, after the initial phase of testing, especially the software component. This impression has been confirmed by the operators, who added positive comments on the step-by-step improvements made at the level of managing software (considerable efforts have been made at the level of the operator interface to improve the ability to understand and use *PersonalBus* software). The end-user is largely concerned with the ease of trip booking. The percentage of late arrivals resulted from on-going traffic congestion. In terms of potential for use of standardised systems, the *PersonalBus* package is implemented using standard, off-the-shelf software technology.

With the latest extensions, the *PersonalBus* covers the entire area of Campi. The three test areas in Florence have very different characteristics, but the system showed a high level of flexibility managing the services with no basic operational differences, confirming *PersonalBus* capabilities as a common supporting tool for all flexible services. The opinion offered by the operators on the size of the operating area is good, in terms of the capability of the system to guarantee the use of collective transport to an adequate number of citizens.

System capacity indicators, obtained through an automatic collection of the operational data provided by the system, showed a high speed in the phase of creating new trips following users' requests. The length of an average phone call is 1 minute; 20 to 40 phone calls are handled by the dispatcher in 1 hour; the trip is generated directly during the period of the phone call, which takes about 45 seconds. Trip cancellation is immediate upon the operator receiving the phone call and applying the appropriate procedures of the *PersonalBus* software. Since its definitive set-up the system has not had any inconvenience due to hardware/software failures, but only due to problems that involved the whole of ATAF (loss of energy, problems with the telephone line, etc.). The conventional mean time between component failures is 3 months.

The speed of the system gives the same satisfactory results found in the system capacity-testing phase. The capacity of the reservation system is demonstrated by the fact that no more than 10% of the users could not obtain an answer from the booking system. The correlated indicator has been automatically collected by the system confirming the first impression given by the operators. The number of unanswered calls (10%) for Campi is due to the very high number of customers, which sometimes causes congestion in the telephone lines. The service reliability has been assessed through the automatic collection of the operational data provided by the system.

4.4 Overview of findings from the other SAMPLUS demonstrations

The full results from the evaluation of the five DRT demonstrations are given in Nelson and Mageean (1999) and the results from Gothenburg have also been reported in Westerlund *et al* (2000). The remainder of this section briefly

describes the salient results of the analysis for three assessment categories (economic viability, service provision and technical performance) and provides an overview and comparison between the various sites.

For the assessment of *Economic Viability*, direct cost savings as a result of implementing DRT services are not easy to calculate, due to the restructuring of public transport services that often accompanies DRT, e.g. in the Belgian demonstration. The two main economic benefits of DRT services are: firstly, the ability to support services on low demand routes that would be too expensive with regular lines, as in Belgium; secondly, the provision of special transport services (STS) using DRT has produced clear economies, e.g. in Finland. Furthermore, there are also administrative savings to be made in the operation of STS, e.g. at the Gothenburg site. Otherwise the improvements which result from the introduction of DRT services are frequently only measurable in a qualitative rather than a quantitative manner, e.g. increased access for the disabled and elderly, and the improved matching of customer route requirements with the available services. Operating a TDC leads to relatively high fixed costs: as patronage increases, the significance of these costs lessens.

High levels of passenger satisfaction, a major characteristic of *Service Provision*, has been one of the outstanding successes of SAMPLUS – although in Finland as familiarity with the system increased, there was a more critical appraisal by passengers. The passenger profiles vary between the sites – in some cases the type of passengers was restricted, e.g. disabled and elderly. At present DRT is mainly used to increase the mobility of those without access to private transport, rather than as an agent of modal shift. Service coverage is highly variable, and there are frequent requests to extend the daily and weekly operating hours: clearly, economic viability will determine whether this is possible. The opinion of service reliability is generally high, as is the ease of making reservations. The use of an Interactive Voice Response System (IVRS) is regarded as less satisfactory, particularly for the elderly who tend to be less able to deal with advanced technology. Various measures of passenger convenience, e.g. time in transit, wait times, on-board comfort, time taken to book a trip, distance to the vehicle and willingness to pay, are rated as satisfactory or better at all sites.

The *Technical Performance* has been successful. The future for reliable DRT systems therefore looks assured: the SAMPLUS project has demonstrated the development of high performance systems by different soft- and hardware suppliers. Despite early problems with complex scheduling issues, dispatch reliability is high. Problem areas are IVRS reservation procedures, avoiding conflict with regular public transport services, and integration of taxis (where they are part of the DRT service). Nonetheless, IVRS (and Internet booking) are a valuable tool for enhancing the booking capacity. The system is most easily managed when a passenger makes a booking least 2 hours prior to travel. Conversely, passengers favour the flexibility offered by systems with only a 15 minute pre-booking requirement.

5 Concluding Discussion

This concluding section identifies some key issues which have emerged from the detailed investigation of DRT which has been reported in this paper.

The SAMPLUS project has demonstrated clearly that integration of DRT services into a network provides greater transport cohesion. Flexible routing services allows access throughout an area rather than on specific corridors. There is improved access to local services, and to some extent to larger centres. Improved mobility increases the level of economic activity and, in the case of socially excluded groups, allows them to participate more fully in their communities and reduce barriers to being treated on an equal basis with other citizens. Improved mobility and access to services helps retain people in areas of declining population and DRT can encourage tourism without cars, assisting growth in a sustainable fashion.

The potential market for DRT services is defined by raising the awareness of local authorities and operators about the flexibility of DRT in solving problems, mainly the reduction of transport costs and improving or sustaining citizen mobility. A number of institutional, legal and economic barriers must however be overcome. Institutionally, the more regulated the environment, the less conflict there is likely to be between DRT and other public transport modes. 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 juridical status of DRT is unclear. 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).

Customer awareness is improved by local and national networks which have a common approach to economical, physical and cultural issues, particularly in the planning of feasibility studies. 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. 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 juridical conditions. Subsidies will encourage operators in competitive markets. Customers report increased mobility and intermodality; drivers have greater job satisfaction. There are potential new markets for DRT to assist with modal shift since DRT offers scope for full integration with conventional services.

In terms of technologies for DRT services the level of ITS support available is a critical factor. Major investment can

only be justified if high patronage can be confidently predicted; more regulated environments are more likely to sustain high investment, due to the flexibility of resources. The telematics solutions developed by SAMPLUS are highly transferable, to rural and urban areas with varying complexity, route requirements and time/distance criteria.

For future transport policy procurers of public transport should regard DRT services as a means of improving intermodality and system integration, as they provide another link in the public transport objective of seamless journeys for the citizen. However, for financial and scheduling reasons, DRT services do not aim to be the dominant public transport supplier in a market. But they should be regarded as a vital supplier of services where conventional solutions are untenable, e.g. low demand areas, special transport services. Therefore, awareness raising needs to be directed towards central as well as local government institutions. In terms of the link between transport policy and rural/community development policies attention is increasingly being given to the rural areas, which contain some of the most socially excluded members of society. In addition, there are pockets of exclusion in urban areas. Links need to be strengthened with organisations that specifically deal with these issues (e.g. the Community Transport Association and Rural Development Commission in the UK) and have a history of supporting Dial-a-Ride services in the voluntary and local government sectors. Recently-published research commissioned by the 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 break down social exclusion.

Finally, the case for DRT services for special needs services has been demonstrated by SAMPLUS. Cost savings have been made at little or no disadvantage to the customers. It is recommended that providers of social services should be high on the list of DRT target groups.

References

Department of the Environment Transport and the Regions (2000a) Transport 2010: the 10 year plan. DETR, London.

Department of the Environment Transport and the Regions (2000b) Social Exclusion and the provision and availability of public transport. DETR: London.

D'Este, G., Taylor, M.A.P. and Radbone, I.G. (1994) Demand-Responsive Public Transport for Australia: 1. The Trade-Offs. Papers of the Australasian Transport Research Forum 19.

ECMT (2001) Consolidated Resolution No 2001/3 on Accessible Transport. CEMT/CM(2001)15/FINAL/CORR1.

Glazebrook, G. (1993) Innovations in personal public transport: concept and applications. Planning, co-ordinating and funding urban transport. Sydney.

Glazebrook, G. and McCombie, K. (1995) New technologies for personalising public transport. Traffic Technology International.

Nelson, J.D. and Mageean, J.F. (Eds) (1998) Evaluation and Verification Plan. Telematics Application Programme Transport Sector Project TR3321 Contract Report No. 7.1. Commission of the European Communities, Bruxelles, October.

Nelson, J.D. and Mageean, J.F. (Eds) (1999) Results of the Evaluation and Market Assessment of SAMPLUS Technologies. Telematics Application Programme Transport Sector Project TR3321 Contract Report No. 7.2. Commission of the European Communities, Bruxelles, November.

Radbone, I.G., D'Este, G. and Taylor, M.A.P. (1994) Demand-Responsive Public Transport for Australia: 2. Meeting the needs. Papers of the Australasian Transport Research Forum 19.

Teal, R.F. (1994) Using Smart Technologies to Revitalize Demand Responsive Transit. IVHS Journal, 1(3), 275-293.

Westerlund, Y., Stahl, A., Nelson, J. and Mageean, J. (2000) Transport Telematics for Elderly Users: Successful use of automated booking and call-back for DRT in Gothenburg. Proc. 7th ITS World Congress, Torino, November.

White, C. (1995) Multimodal Public Transit System Routing and Scheduling. In VERTIS (Ed) Steps Forward. Tokyo: VERTIS.

Footnote

[1] PersonalBus is the general TDC support software package developed by Softeco Sismat SpA (Genova) for the public transport operator ATAF.

Acknowldgements

The work reported in this paper was funded by the EC (DGXIII) and completed during the SAMPLUS project. The contribution of the SAMPLUS partners to discussions on DRT concepts is acknowledged.