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Loughborough University

The Variable Price and Attribute Transport System

Stage 2 Report:
Scenarios for Market Entry and Evolution

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Tech4all is a charity devoted to reducing poverty, in particular through the use of technology. It runs a very successful Voicemail for the Homeless scheme (together with the leading homeless charity St Mungo's), used by 700 people in 2006. Tech4all has sponsored this research in order to investigate whether modern technology could create a radical improvement in the availability of high-quality transport services for disadvantaged groups, at low or zero incremental cost to the taxpayer, and in a way which fostered integration of disadvantaged and better-off users."

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Contents

Executive summary

1. The report presents illustrative scenarios for the introduction of the Variable Price & Attribute Transport System (VPATS) to the city of Bristol. VPATS is a high-technology transport system capable of operating in varying modalities e.g. ranging from advanced taxi, with exclusive use from door to door, to taxibus or bus-type services with shared use, pre-booking, or hailing on street or from bus stops. Technology is fundamental in keeping productivity high and operating costs low. An element of cross-subsidy from exclusive use to non-exclusive use is expected.

2. The work is based on a comparative supply model which includes the principal costs and resultant outputs for the existing public transport modes and for VPATS. It is intended to indicate:
   - how existing travel demands could be accommodated by VPATS;
   - how existing assets might be reallocated to contribute to the creation of a VPATS system; and
   - the likely levels of absolute and comparative fares that would need to be charged in order to create a near-commercial proposition, with no subsidies other than those already provided to the bus market being assumed.

3. Ten scenarios are considered. Scenarios 1a and 1b consider different levels of taxi and Private Hire Vehicle (PHV) conversion, whilst Scenario 2 adds a proportion of exclusive booking of VPATS services. Scenarios 3-5 all consider a higher level of taxi and PHV conversion, but with varying levels of bus conversion as well. Scenario 3 includes only the conversion of some existing local authority contracts, whilst scenarios four and five examine the conversion of significant proportions of existing commercial services; 4 reflecting partial re-regulation of bus services and 5 representing the adoption of VPATS by a free market bus industry with entrepreneurial leadership. Finally, Scenario 6 considers a significant increase in demand due to the adoption of road user charging.

4. Table ES1 compares the three current public transport modes.

Table ES1: Summary of Current Bristol Public Transport Market

Scenario	Key Assumptions	Fleet sizes	Share of Bus, Taxi and Private Hire market (%)	Operating cost per vehicle-km (£)	Typical fare per lone pass./ km (non	Typical fare per lone pass./ km exclusive
Bus	Current market conditions	538	65	1.17	0.30	-
Taxi	Current market conditions	660	18	0.88	-	1.56
PHV	Current market conditions	675	17	0.81	-	1.45

5. Table ES2 summarises the performance scenarios for VPATS as follows:
   - 1a Modest conversion of taxis/PHVs
   - 1b Moderate conversion of taxis/PHVs
   - 2 Moderate conversion with some exclusive use
   - 3a Institutional acceptance
   - 3b Institutional acceptance with high productivity
   - 4a Institutional promotion
   - 4b Institutional promotion with high productivity
   - 5a Competitive response
   - 5b Competitive response with high productivity
   - 6 Introduction of road user charging

Table ES2: Summary of Scenarios and Key Cost Data

Scenario	Key Assumptions	VPATS fleet size	VPATS share of bus/taxi/PHV market (%)	Cost per vehicle-km (£)	Car market share switching to VPATS (%)	Fare per lone pass./ km (non exclusive use £)	Fare per lone pass./ km exclusive use (£)	Revenue to finance technology (£ mill.)
1a	10% taxi & PHV convert, productivity 4 trips/hr, party size av. 2, no exclusive use	134	8	0.75	0.6	1.11	-	0.61
1b	As 1a but 20% taxi/PHV convert, operating costs slightly lower	267	15	0.74	1.2	1.09	-	0.85
2	As 1b but 20% VPATS vehicles exclusive (productivity 2.7 trips/hr, higher fares)	267	12	0.76	1.1	1.08	1.54	0.84
3a	As 2 but 50% taxi/PHV convert, VPATS wins 25% of local authority bus contracts, eligible for bus subsidy when non-exclusive	681	30	0.74	2.7	0.94	1.54	0.90
3b	As 3a but productivity increased: non-ex = 5 trips/hr, ex = 3 trips/hr	681	35	0.65	4.2	0.84	1.46	0.90
4a	As 3a but 32% bus capacity converted to VPATS	919	42	0.73	2.7	0.94	1.54	1.12
4b	As 4a but productivity as 3b	919	47	0.65	4.6	0.84	1.46	1.34
5a	As 3a but 50% of bus capacity converted to VPATS, each single-deck bus replaced by 3.5 smaller vehicles	1,309	59	0.72	2.8	0.98	1.58	1.47
5b	As 5a but productivity as 3b	1,309	64	0.64	5.6	0.86	1.47	1.79
6	As 5b but productivity 10% higher & dead-running reduced to 25% of vehicle-km	2,421	78	0.64	20.7	0.75	1.47	1.94

6. The key cross-cutting findings from the scenarios are that:-
   - Provided productivity at the level of 4 trips per hour (non-exclusive use) can be achieved, then VPATS can be situated in fare terms between the current bus and taxi/PHV markets.
   - For most bus passengers, VPATS would be perceived as a relatively expensive premium product even in non-exclusive mode, but might well be desirable for certain journeys, particularly given the rise of time-poor travellers prepared to spend more for an enhanced form of 'bus' service (see Stage 1 report for this study). Furthermore, the fare per kilometre does not reflect the stage-boundary and fixed elements of bus fare structures, which means that VPATS would arguably be more attractive for short-range bus journeys, particularly those crossing fare boundaries.
   - Permitting exclusive use reduces capacity (and so in this model market share), quite markedly.
   - Exclusive use fares have been set in the model to compare closely with current taxi and private hire fares. This results in a level of cross-subsidy from exclusive to non-exclusive users. However, VPATS in practice may well provide valuable additional benefits over and above similarly priced taxi fares, in terms of immediacy of availability, and range of vehicle types available. It may be possible to capture these benefits in the fare box. It would be important for fares to reflect such benefits in order to discourage inefficient selection of exclusive mode journeys for the given level of VPATS assets available.
   - Productivity emerges as a very important factor in reducing the cost of non-exclusive use. Economies of scale are also relevant, but Scenario 5 reveals the presence of step-change effects, e.g., in this case due to the conversion of part of the bus fleet which is not suitable for VPATS operation.
   - The operating costs include an element for financing capital costs of the VPATS system which could be sufficient to lever in between £10 and £35 million in investment, particularly if public sector guarantees or funding contributions are available.
   - Due to the dominating role of cars within the overall demand for vehicle use in urban areas, changes within the public transport market will be of a much larger proportion than changes in the private car market. Nonetheless, with the scale achieved in Scenario 5, the system would have the available capacity to accommodate up to 4% of current car movements. Given the popularity of existing taxi services for travellers with a car available, particularly for specific types of journey involving travel to the city centre, expensive parking, or the consumption of alcohol, it seems likely that VPATS would attract such trips both in exclusive and non-exclusive mode. Clearly VPATS would itself generate vehicle-km in providing for these journeys, but system efficiency should result in a reduction in traffic overall, and a substantial reduction in parking demand.
   - Further consideration of practical aspects of implementation will be given in the Stage 3 report to follow.

1. Introduction

The overall purpose of the Stage 2 report is to consider how a Variable Price & Attribute Transport System (VPATS) might operate and perform in practice in a UK context. This is achieved through a desktop case-study approach using a bespoke supply model based on that used by local authority finance officers and spreadsheet modelling of implementation scenarios.

The approach taken in modelling and scenario analysis is informed by Stage 1 of the study. Key observations and findings from that work are:

1. income elasticity is usually positive. As private car use increases and approaches saturation point it is likely that the income effect on bus patronage will show a positive relationship. This positive income effect is assumed to be even more marked for taxis and flexible alternatives where they offer ‘money rich – time poor’ solutions.
2. reducing fares would attract some motorists, this would not be an efficient way to build patronage amongst a group that is relatively price-insensitive; elasticities with respect to quality are more important than those relating to price.
3. different transport modes offering broadly comparable services but with subtle ‘selling points’ have much in common with the concept of brand; where a cheaper brand may provide a basic option, but others offer greater utility, *e.g.*, in terms of luxury or a particular image.
4. higher-income travellers (‘money rich, time poor’) are prepared to trade attributes such as exclusivity for the benefits of immediate availability of a vehicle with spare capacity, with the fare reflecting the perceived value of this ‘between bus and taxi’ bundle.
5. in most established developed country niches the services are medium-to-high specification and appeal to relatively wealthy travellers, using them for specific high-value journeys, or to travellers of more modest means who use them on a more routine basis, but in one way or another receive state subsidy to bridge the affordability gap.
6. consumers choose between modes to achieve different attribute bundles. In the case of VPATS, it is expected that the mode will remain the same, but consumers will select ‘brands’ from within the overall flexible package, in different proportions. It is hypothesised that this will increase operating efficiency and retain any cross-subsidies within the particular operating context.
7. properties that need to be considered in appraising demand for specific market niches include purpose of the journey, the characteristics of the section of the population which is targeted and whether the effects are short or long term. VPATS needs to be efficient, accessible and marketed effectively, using clean, smart vehicles with polite, friendly staff.

The model includes estimates of load factors, average fares and subsidy per passenger-kilometre provided for current modes, and contrasts them with load factors, fares and subsidies that might be achieved under VPATS-present scenarios. The scenarios are chosen to represent the evolution of a VPATS system from the current low-technology taxi modes (Hackney Carriages and Private Hire Vehicles), representing in part the conversion of taxi market share and the attraction/creation of trips currently made by other modes, or not at all.

In order to address the research objectives with the limited resources available, the approach is supply-led: resources are allocated within the model and passenger capacities estimated. A cross-check is then made to examine whether the implied modal shifts are of reasonable magnitudes and likely.

A ‘bottom line’ to the scenarios is that the operation should return a 10% profit to a commercial operator, and only rely on identified subsidies, for which the service is likely to be eligible, in achieving this.

The analysis begins with a review of the context in which the scenarios are simulated, including consideration of the chosen case-study context of Bristol. Section 3 then considers the public transport market in Bristol in more detail. The conceptual nature and origins of the model are outlined in Section 4 and it is then applied in Section 5, leading to conclusions and consideration of future work, including Stage 3 of the present project, in Section 6.

2. Contexts to the Study

2.1 UK context

A key element of the second round of Local Transport Plans, which is likely to effect levels of required revenue support for buses, is that each must include an assessment of citizen's accessibility to key public services (healthcare, shops, education) by public transport where they are not directly accessible on foot. An 'Accessibility Planning Approach' must be followed using consistent, agreed methods to map, assess, and monitor accessibility, with the implication that intervention should occur where it is found to be inadequate. This is particularly relevant for the dimension of social exclusion. The assessments will be based on access in time, rather than space, using proprietary software made available by the government to local authorities. Work is likely to focus on the young and the old throughout the LTP area, and on disadvantaged communities, as these groups are least likely to have access to a car. Due to the cost implications of the new policy emphasis, greater attention is likely to be paid to means of widening public transport's scope in an efficient way. It may be an auspicious moment for promoting flexible services.

Variably priced attribute-based transport systems are already in place to some extent in the UK. For instance, prices charged by low cost carriers in the airline sector vary dramatically, with those booking earlier paying far less than those who book later. On the railways and some metro systems too, travellers pay more for:

- the advantage of holding a flexible (or amendable ticket);
- a higher quality of service (e.g. larger, more comfortable seats, complementary food, drinks, newspapers and 'at seat' service) in first class than in second; and
- travelling in the peak as opposed to in the off-peak.

Meanwhile passengers pay less for:

- booking journeys in advance than for paying immediately before (or during) travel;
- the disadvantage of holding an inflexible ticket, or one valid for the off-peak only; and
- for bulk buying of journeys through season tickets or carnets for example.

Such experiences in the road-based public transport sector has always been more limited, even in the post 1986 'deregulated' bus market, which was originally intended to stimulate such competitive practices (Hibbs, 1994). Bluntly, the current position throughout most of the country is that passengers either:

1. pay relatively little for a low quality (shared use of vehicle with strangers, where seats are uncomfortable with no leg room, where one must walk to and from the service at either end and where one must wait for an uncertain amount of time in an unpleasant waiting environment) travel experience on the bus; or else
2. pay substantially more for a higher quality (exclusive use of comfortable vehicle, door-to-door, on-demand) journey by taxi or private hire vehicle.

There are always exceptions though. For instance, the Stagecoach Magicbus brand has offered cheaper services than regular Stagecoach and First services on corridors such as the busy Wilmslow Road corridor in Manchester for a number of years. And, more recently, companies such as Stagecoach through its ‘Megabus’ subsidiary, and Easygroup’s ‘Easybus’, have begun to apply the ‘book early pay less’ principle to interurban corridors on a far larger scale than previously. However, these services also generally offer fewer departure opportunities than established equivalents; so altering other aspects of the attribute bundle.

Finally, it is also the case that some of the new Demand Responsive Transport services have also began to use price as a tool for increasing operating efficiency. One example is that the Nexus U-Call service charges users a supplement of 50p per journey for a door to door service rather than checkpoint to checkpoint.

In summary, travellers making local journeys in the UK have relatively little choice of transport type that they can use, particularly if they have only a low income, and are therefore often unable to access facilities and carry out activities as they would like. With the development of a whole new raft of Demand Responsive Transport systems in the last five years or so, there is a significant potential for transport operators to offer travellers a rather more comprehensive choice of travel options that may help address such issues. The purpose of this study is to investigate the practical feasibility of establishing such a transport system in a UK city environment.

2.2 Chosen Case-study of Bristol

The Bristol City Council authority area has a population of around 400,000, but part of the continuous urban area is within South Gloucestershire (giving a total of roughly 520,000). There are a number of reasons why the city of Bristol was chosen as a model:

- Bristol is very car dependent for a large urban area,
- the local authority structures in the subregion create an interesting context to study barriers to implementation,
- future public transport development is expected to focus on the bus (rather than light or heavy rail),
- Bristol is a free standing city and thus it was easier to examine local travel patterns than a larger polycentric urban area, and in particular to obtain reliable data.
- It is in many ways a typical UK city from which readily transferable lessons may be learnt.

There were practical issues too, most notably that UWE is based in Bristol and the transport group has good links with the City Council and the local public transport operators – vitally important from a data gathering perspective.

3. Background to Public Transport Provision in Bristol

As noted in the Stage 1 report, perhaps the seminal work in deriving the major influences on public transport, is *'The Demand for Public Transport'*, conducted by the Transport and Road Research Laboratory in 1980, and subsequently updated in 2004 (TRRL, 1980; TRL, 2004). From these reports and others (Black, 1995; Simpson, 1994; White, 2002) it was clear these elements can be categorised into three, albeit strongly interdependent, 'types'. These are area characteristics, personal factors and public transport supply features.

3.1 Area characteristics

The crucial area factors that influence public transport use include: size of population, population growth rate, strength of the local economy, distance from town centre, population density, distribution of homes, workplaces and other facilities, and road layout. Less tangible influences too, are important. Enoch (1998) found that cities exhibiting 'good practice' bus operations invariably had local transport authorities and companies that worked well together, combined with complementary land use, environmental, social, fiscal and transport policies all consistent with helping public transport perform at its best. Rather than removing local authorities from the sphere of bus operations, their involvement remains crucial – but as part of a partnership approach.

As discussed further below, the Bristol bus system has had some problems. However, the near-monopoly operator is working in close partnership with a local authority determined to promote public transport. In socioeconomic terms, the area is prosperous and experiencing economic and population growth, with the high technology, aerospace, financial services and education industries leading that growth. As noted in Stage 1, economic growth will tend to result in a wealthier population with high levels of labour force participation. Hence the population will consume more travel overall and tend to exhibit 'money-rich-time-poor' travel choices, which historically have favoured car ownership and use of air, rail and taxi, whilst most bus markets have tended not to be favoured by such changes. There are however exceptions, possibly market niches, where conventional bus services have fared well against growth in wealth, notably in London, Oxford and Brighton. Another market niche is for specialist services. Park and ride services have been provided in a number of towns and cities, including Bristol, and have successfully attracted new patronage, albeit with the application of significant public subsidy. VPATS may be able to exploit similar market niches.

- Bristol's first submission under the Local Transport Plan regime (BCC, 2000) was presented as radical, and showed ambition, with targets to stabilise car traffic growth by 2005 and then reduce it by 20% by 2015 (Target 1). Local bus use was to increase 15% by 2006 (Target 7), with improvements in both reliability and user-satisfaction. Ninety-eight percent of residents were to be brought within 400m of a bus service of 15 min frequency or better, and providing a journey time to the city centre of 25 min or less (Target 4). A further aim was to achieve a 30% increase in public transport use to the city centre by 2015 (Target 24).
- The existence of the Bristol/South Gloucestershire border creates the requirement for inter-authority working on transport issues, without the

coordinating presence of a Passenger Transport Authority[1], as in most other large cities outside London. Hence, these two authorities, together with the unitaries of North Somerset and Bath & North East Somerset will submit a joint Local Transport Plan covering the *West of England Partnership* subregion[2]. The presence of the border plus cooperation agreements provides an interesting context in which to examine rather arbitrary boundaries as potential barriers to VPATS development.

- Two high profile policies discussed in the first LTP were road user charging, and the introduction of a light railway. Having spent a number of years investing political capital and local authority resources in developing proposals for a light rail system, in 2004 it was determined that the project was being suspended, following differences of vision by Bristol and South Gloucestershire and the failure to achieve government funding approval. The future of transport development in Bristol will now be bus-lead, with one proposal being to investigate the possible role for guided buses. Consideration has also been given to demand responsive bus services. By 2005, although the window of opportunity for a light railway had closed, there was still an aspiration for some kind of reserved-alignment public transport investment; possibly a guided busway. At the same time, although investigations had been carried out into the potential for a cordon-based road user charge, and despite the success of the London implementation, the political consensus around the policy had weakened, rather than strengthened, largely for local reasons.

3.2 Person types

Much is also made of the socio-economic characteristics of the population living in an area served by public transport. Whilst bus use tends to decline as income and car availability rises, other factors are also important; more women than men use buses, typically by a factor of 2 to 1. Persons under 17 years old or senior citizens too, are more likely to use the bus. It is therefore, possible to use estimate annual public transport trip rates for each of these categories and factor them up by the relative sizes of population that live in each particular area.

Of course it is also true that where bus supply is right, and where area characteristics are supportive to public transport, then a wider range of people will use the service. For example, in Ottawa, Canada during the mid-late 1980s, 70% of white collar Federal employees used buses to commute to and from work. But, for the purposes of this model it is probably safer to assume that people's propensity to use public transport is fairly average for the region being tested.

- Bristol is perhaps the most car dependent major city in the UK. Bus use for journeys to work was recorded at 12% in the 1991 census, compared with around 20% in the large northern cities and Birmingham (BCC, 2000), whilst rail use was around 3%. By the time of the 2001 census combined rail and bus use for commuting had fallen to 13.5 percent. Bristol's local target, under

[1] The Bristol urban area is one of only two in the UK over 500,000 population not covered by a Passenger Transport Authority, the other being Nottingham.

[2] The LTP is the main means by which local authorities can obtain capital funding from central Government for their transport policies and programmes (maintenance and development). The next five-year plan is due for submission in draft form in July 2005. See http://www.greaterbristoltransportplan.org for details of the Bristol subregion plan.

the national target to achieve a 10 percent increase in bus use 2000-2010, is for there to be 15 percent more passengers by 2001-2006[3]. The 2004 progress report noted no significant change across the whole local authority area for the five-year period. Passenger numbers did rise by 3.9 percent between 2002/03 and 2003/04, but the longer-term trend was not consistent with meeting the target.

- Although walking and cycling to work are somewhat higher in Bristol than in most of the other places, and apparently growing in popularity[4], greater car use explains most of the difference. The number of Bristol households with at least one car rose from 66% at the 1991 census to 71% at the 2001 census, but ranging between 80% of households in some wards, to as few as 35% in others, suggesting considerable variation in travel opportunity according to neighbourhood of residence.

3.3 Quality, level, type and cost of public transport service provision

This final category appears to contain the easiest variables to change. Indeed, a major rationale behind the 1985 Transport Act was that bus operators 'freed from the dead hand of the local authority planner' would be able to manipulate these supply-side variables - safety, reliability, door-to-door speed, cheapness, convenience and comfort - to deliver increased passenger levels and lower costs. In the event, this was proved to be overly optimistic, and while operation costs were dramatically reduced across the country, passenger levels and services continued to decline much as before. Only in places where 'sympathetic' area factors existed (described above), such as Oxford, did on road competition work as envisaged by the proponents of the Act (Enoch, 1998). Ironically, for the most part in the demand responsive sector at least it has been Central Government that has proved to be the catalyst for experiments with high quality innovative services due to the Rural Bus Challenge grants that have been awarded since 1998.

One reason for seeking a high profile guided transport system (tram or guided bus) is that the image of the bus in Bristol has been a weak one. These is a perception by the public that lack of competition has failed to bring any benefits from privatisation and allowing the main operator to place profit before customer service and quality of product. In 2000/01 surveys following the national design showed 40% of respondents to be satisfied with local bus services. This fell to 29 percent in 2003/04. Bristol City Council (2004) thought this was most likely to be due to adverse publicity about the mainly commercial bus services, including the impact of staff shortages, which had particularly coloured public opinion at the time of the triennial survey. Notably, satisfaction with public transport information provision - a council service in which considerable effort has been invested[5], showed a 17 percentage point rise. However, Bristol has a main bus company that is willing to acknowledge its problems and is seeking innovative solutions to try and address these.

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[3] Target 7 of the Bristol Local Transport Plan 2000/1-2004/5.

[4] Cycling increased from 3.3 percent to 4.6 percent and walking from 14.7 percent to 15.6 percent at the two census points. Notably, 'working from home' grew from 3.7 percent to 7.3 percent.

[5] Specific initiatives include the 'traveline' telephone helpline, individual travel marketing, and real time information provision on the web and at bus stops.

Table 1 below indicates how the LTP funds[6] were spent in 2003/04. Apart from maintenance spending, bus schemes were the largest head, and including P&R spending amounted to 28 percent of the whole budget.

Table 1: Allocation of LTP Capital Funds in 2003/04

Scheme type	**Spend £ million**
Bus	2.62
Rail & Other	0.213
Park & Ride	0.378
Walk/ Cycle	0.907
Road Safety (incl. Safer Routes to School)	1.341
Studies	0.107
Demonstration Projects & Promotional Work (incl. Vivaldi, Travel Plans, Car Clubs, Air Quality etc.)	1.163
Road User Charging Investigation	0.245
Traffic Management & Signals	0.627
Maintenance	2.934
All*	10.539

*Adapted from BCC (2004) Figure 4.1. Actual spend slightly above the 2003/04 settlement with supplementary bid funding allocation indicated in Table 2.

The LTP funding is for capital investment. As most public investment in the transport system does not generate net revenues from operations, adequate revenue support for investment is essential. In the five-year period of the plan, subsidy support for local bus services was to increase from £1.6 million to £4.6 million, whilst funding for an enhanced concessionary fares scheme would cost £6.3 million, against an established budget of £1.2 million. In addition, £0.7 million would be provided to subsidise the city's park-and-ride sites. The table below shows the out-turn investment in city council supported programmes for 2003/4 and programmed expenditure for 2004/5, for transport programmes including services (in bold). Expenditure for 'road public transport' support - mainly bus services - is around half the transport revenue support budget.

Table 2: Transport Revenue Expenditure 2003/04 Outturns and 2004/05 Programmed Areas of Revenue expenditure (000s)

	2003/04	2004/05
Night Bus Service	**200**	**160**
Supported Bus Services	**1,663**	**2,000**
Concessionary Fares	**1,432**	**1,550**
Park and Ride support (existing & new sites, net of income)	**573**	**430**
Community Transport	**817**	**780**
Rail Services support	123	140
Water Transport (support for ferry operations)	15	13
Transport surveys	41	60
Road Safety including Education, Training, Publicity	102	150
Highway Maintenance (routine maintenance of footways, carriageways, gully emptying, verge maintenance, lighting, cycleways, public rights of way etc.)	4,931	5,370
Total for road public transport services	4,685	4,920
Total	9,897	10,653

Adapted from BCC (2004), Table 4.3, staff overheads not included.

[6] LTP funds making up nearly 80% of investment funds in 2004-5.

4. Development of Costing Model

Bearing these factors in mind, in developing a basic model, the first stage is to forecast the likely aggregate public transport demand for the chosen area. However, this is not as easy a task as it might first appear. In developing any model, the limiting factor is often the availability of data. Data are particularly difficult to obtain when time and finances are constrained, and where issues of commercial confidentiality are concerned, as in this study. Accordingly, it was decided to use city-wide figures where available, and to use national norms where they were not. A further consequence of the limited data, was that it limited the type of model. Crucially, it made the task of predicting demand levels rather difficult. Instead, it was decided to devise a model that assumed a range of fixed demand levels based on existing public transport usage, and then analyse how these demands might be served, and how much they would cost.

To be useful, the basic model needed to generate outputs such as:

> number of vehicle trips; total vehicle kilometres; total vehicle hours; total passenger trips; total passenger kilometres; total passenger hours; cost per vehicle trip; cost per vehicle kilometre; cost per vehicle hour; cost per passenger trip; cost per passenger hour; and cost per head of population.

The major concerns of the service operators can be assumed to centre on usage, revenue and cost measures.

4.1 Data relating to bus services in Bristol urban area

The majority of bus services in the city are provided by First Bristol (formerly First City Line), and as First Avon (formerly First Badgerline) which runs routes into the city from the surrounding area, and local networks in neighbouring towns (JUTS, 2004). In addition, a small number of operators run some commercial and subsidised routes into the city, including Buglers of Brislington, Crown Coaches of St Phillips, South Gloucestershire Bus Company of Patchway and Turners Coachways of St Phillips.

Bristol City Council (2004) reports that there were around 33.3 million bus boardings in Bristol in 2003-4, whilst the Greater Bristol area has of the order of 55 million (JUTS, 2004). Allowing for the part of the urban area in South Gloucestershire, it can be estimated that the total for the whole urban area was somewhat more than 43 million. Another key input is bus-km operated. According to Janes' Urban Transport, in 1996 there were 48.5 million vehicle km operated on 98 routes by the two main First subsidiaries across the greater Bristol area - an area much larger than the urban area. Assuming that bus boardings are in proportion to bus-km operated, then around 36 million bus-km are operated in the Bristol urban area. Overall, with an average trip length of 2.5 km, this implies an average ridership of around 3 passengers/km[7], which is possibly somewhat lower than the national average of around 5 passengers/km in metropolitan areas[8].

The Bristol allocation of bus-km is also assumed to involve a proportionate share of buses and staff. Hence, of a total of 727 vehicles (including 11 coaches operated) by the two companies and 1800 staff employed, 538 vehicles and 1,350 staff were allocated to the Bristol urban area.

Fares (80% of which were collected on the vehicle) covered 92% of operating costs, and were structured on a zonal basis. One Person Operation applied to all routes. Average peak-hour vehicle speed was 16.1kmh, with the average somewhat higher in the off-peak. The most intensive operation was a bus every six minutes.

Other contextual data from Bristol City Council (2004) indicate that there are 1,560 bus stops within the city boundary, and 14 city bus services with a frequency of every 15 minutes or better during the day and 20 with a frequency of 30 minutes or better. Local authority investment in the bus system has included the provision of 16.4km of bus lanes and three park and ride sites with a total of 3,100 spaces and associated bus services. The first of a programme of 'Showcase' bus routes was completed in 2004, involving a coordinated upgrade of vehicles, roadside infrastructure, priority, customer service, and information provision on a corridor or route-length basis. Initial monitoring shows a 16 percent increase in weekday passengers, once transfers between routes is discounted.

DfT (2003a) reports that the average staff earnings for bus drivers were £290 a week, while the average staff cost per passenger journey was 60p (but with a wide range). Average total costs per vehicle operating kilometre in the English Metropolitan regions was £1.05, while in the Shire Counties it was 93p in 2001-2002.

Table 3: Summary of annualised bus data for Bristol urban area

Variable	Value
Passenger boardings	43.3 million
User-cost/boarding	£1
Bus-km operated	36.4 million
Operating cost/ buskm	£1
Buses utilised in Bristol	538
- double deck	- 160
- single deck	- 150
- midi	- 120
- mini	- 108
Staff utilised	1,350

[7] In practice the bus-km figure for Bristol urban area may be somewhat lower, as boardings/km are likely to be higher in the population-dense urban area. However, supply will be matched to demand by the commercial bus sector. In any case, around three-quarters of boardings in the wider area will be in Bristol and some of the other journeys will also be urban.
[8] Tables 6.9 and 6.13 of Transport Statistics Great Britain show that there were around 1 billion boardings and around 600 million bus-km operated, giving just under 5 passengers/km with a trip length of 2.5km.

4.2 Data relating to taxi services in Bristol urban area

Information about taxi services in Bristol and South Gloucestershire is more limited. This is due in part to the nature of the generally small-business nature of the suppliers, who generally do not provide annual data returns to local authorities or central government. However, 600 hackney carriages (taxis operating from ranks or hailed on street) were licensed by Bristol City Council in 2001-2; 350 of these were wheelchair accessible in that year, all must be by 2008 (Bristol City Council, 2000). These vehicles were driven by 1030 registered drivers (DfT, 2003b). Bristol City does not apply maximum quotas to taxi licenses, so market demand can be assumed to be being met. Taxis must have a maximum age of 3.5 years at first licensing, however.

Aside from the part of South Gloucestershire within the Bristol urban area, much of the authority is rural, and the hackney carriage fleet reflects those conditions. Less than half as many hackney carriages are registered, with fewer driving licences issued for the number of taxis. Very few vehicles were wheelchair accessible. Only a subset of this fleet would be allocated to the Bristol urban area, although the most important rank is at Bristol Parkway station, and Bristol-registered taxis are not permitted or licensed to ply for trade here. By the same token, though, hackney carriage journeys begun in Bristol and terminating in South Gloucestershire would be made in Bristol-registered taxis.

Bristol City Council sets the principal elements of taxi fares as

- Circa £2.50 for the first 265m of a journey (depending on departure time/date)
- Circa £0.25 for subsequent 265m stages at all times.

In addition there are other minor charges for luggage and additional passengers over the first passenger. The DfT found that, in the Bristol City area during August 2002, the average taxi fare was £7.30 for a four mile journey, and around 5% higher in South Gloucestershire, at £7.70 in January 2001 (DfT, 2003b: chosen sample length, not the actual average length).

Private hire fares are not regulated although, in practice, are likely to be charged at similar rates. A rather similar number - 662 - of private hire vehicles (obtained via pre-arranged telephone bookings only) were registered in Bristol in 2001-2, and these were operated by 1,353 drivers for 58 operators. Only 43 private hire vehicles were registered in the whole of South Gloucestershire, where there were 31 operators and 101 drivers licensed.

Lack of data about passenger numbers and trip lengths in the city every year meant that these figures had to be estimated within the model.

Table 4: Summary of annualised taxi assumptions for Bristol urban area:

Variable	Assumption
Fare (taxi)	£2.50/pick up + £1/km
Taxis/PHVs utilised	1,320
- taxi	660
- PSV	675
Drivers utilised	2,485
- taxi	1,110
- PSV	1,375

4.3 Conceptual structure of model

The typical cost structure, in simplest terms, for bus public transport systems is as follows[9]:

Table 5: Overview of Cost Structure of Local Bus Operations

Cost Class	Cost Type	Typical share
Variable	Crew, fuel, tyres, oil	55%
Semi-variable	Vehicle maintenance, depreciation	25%
Fixed	Garages, overheads	20%

For bus, a full- allocated method known as the CIPFA (Chartered Institute of Public Finance and Accountancy) Formula or the National Bus Company Model developed this further (CIPFA, 1974), distinguishing three types of cost: per vehicle hour (VH), per vehicle mile (VM), and per vehicle (V). The main expenditure heads are shown in Table 6 by type and frequency of occurrence.

Table 6: CIPFA Approach to Bus Cost Allocation

	Variable Costs	Semi-Variable Costs	Fixed Costs
Time (VH)/ Bus hours	Crew costs, vehicle servicing (45%)	Traffic and maintenance staff, vehicle maintenance, miscellaneous expenses (15%)	Administration staff, educational, medical and welfare benefits (15%)
Distance (VM)/ Bus km	Fuel oil and duty, tyres, hire charges, insurance, compensation (10%)		
Peak Vehicles (V) /maximum number of vehicles on the road		Tickets, publicity, vehicle licence, leasing charges, vehicle depreciation (10%)	Rent, rates, building insurance, maintenance and depreciation, staff vehicles, miscellaneous expenses (5%)

Hence, Total Cost (TC) is given by the formula:

$$TC = aVH + bVM + cV$$

and Average Cost (AC) by:

$$AC = \frac{TC}{VM} = a\frac{VH}{VM} + b + c\frac{V}{VH}$$

where a = time-related allocated costs,
b = distance-related allocated cost, and
c = vehicle-related allocated cost.

[9] Based on TRRL (1980).

Further information on how this model operates can be found in White (2002). There is no reason in principle why this model cannot be adapted to describe the various VPATS options, and this approach is followed here.

5. Bristol VPATS Scenarios

5.1 Modelling assumptions

When building scenarios, the following general assumptions were made.

1. All scenarios assume average routes (although different for each mode) – i.e. buses have average fare and service levels, as do taxis, minicabs etc.
2. All scenarios assume constant contextual factors – i.e. same social, physical, political, demographic and economic circumstances, same traffic conditions etc.
3. The base-case scenario assumes current aggregate levels of bus, minicab and taxi passenger trips is total public transport demand. Index of demand is 100.
4. The base-case scenario assumes current aggregate levels of bus, minicab and taxi vehicle trips is total public transport supply. Index of supply is 100.
5. All operators seek a 10 percent profit margin over turnover.

Bus service inputs

In addition, to model the bus supply and demand the average bus trip is indicated as 2.5 km (although this value does not influence the base-case model) and the average fare assumed to be £0.85. The latter figure takes into consideration the discounts offered by bulk-purchase tickets, but treats concessionary fare tickets as in effect full price, as the difference is fully refunded by the local authorities.

Bus service operating costs are based on estimates by a House of Commons study; updated to £1.06/km. The service subsidy inputs are derived from the relevant data noted in Table 2 above: £2.6 million direct support including P&R and night bus services in the last year. In addition, it is estimated that the bus operators receive £4.7 million annually in Bus Service Operators' Grant.[10] Together these amount to a total of £7.25 million[11]. Including an estimate of £2 million for concessionary fares payments from Bristol City Council and South Gloucestershire, the model suggests that just over 20% of bus company revenues are from public sector sources.

Taxi inputs

The assumptions for the hackney carriage and private hire services are greater in number. The limited reliable data have been combined with estimates informed by discussions with taxi drivers.

As a result it was concluded that the typical taxi or private hire vehicle is:

- out of service 5 days per year for maintenance etc.,
- in service for an average of 12 hours in 24 on the other 360 days,
- operated by 2 drivers working an average of 6 hours per day each,

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[10] Until recently this was known as Fuel Duty Rebate. Currently, the rebate is worth 80% of the 47.1p per litre duty paid on diesel. An average bus fuel consumption figure of 3 km/l is assumed, which covers the range of vehicles from minibus up to double-decker.

[11] This total would be increased to £8 million if community transport schemes could be served by DRT, and the funds instead allocated to supporting DRT.

- provides an average of 2 party-journeys per hour of service, allowing for dead running and awaiting demand[12].

Hence, hackneys and PHVs combined are estimated to provide around 23 million one-way party journeys per annum

Whilst in service the vehicle will be stationary, awaiting fares/bookings for 50% of the time. Whilst in motion, taxis will be operating ‘dead’ kilometres, moving to pick up fares, for 45% of the time and ‘live’ kilometres, with passengers on board, for 55% of the time. The figure is better than 50% because efforts will be made to optimise pick-ups and drop-offs, but given the limited technology available, often there will not be a more optimal strategy than returning to a rank or depot.

Both hackney and private hire passenger trips are assumed to average 4 km. Applying the Bristol City Council fare structure for hackney carriages, the average party fare will cost £6.50, whilst the average party size is assumed to be 2. The fare regulations only apply to hackney carriage journeys, and the operating costs will be somewhat lower for PHVs, as the vehicles are less specialised. For the model it is assumed that operating costs are 20% lower, and fares 10% lower.

The 2002 New Earnings Survey, used by the DfT in calculating values for time lost or gained in calculations of the generalised cost of journeys indicates that taxi drivers earned £8.08 per hour (including non-wage costs). That figure is a national average, including London. Bristol figures are likely to have been somewhat lower in 2002, although all taxi driver wages will have risen in line with inflation. A figure of £8.00 per hour has been adopted for hackney drivers and £7.80 for PH drivers.

However, in practice, taxi drivers only earn when carrying passengers; non-owner drivers in fact earn a percentage of takings. Hence, the effective hourly wage rate will be derived according to how effectively drivers and operators choose when to be on duty; decisions that are made on a trial and error and experience basis in a competitive marketplace with scarce information. In practice, most taxis will be in service and utilised at peak times, most will be in service, with poorer levels of utilisation in the day. Vehicles in service at night will reflect demand and drivers’ willingness to work antisocial hours, with better utilisation as a consequence.

5.2 Base Case Model Outputs & Accuracy

Given that some real-world data were not available for input into the model, there will be some level of inaccuracy in the extent to which the model describes the Bristol transport system. However, the critical tests of robustness are whether the model is nonetheless reasonably realistic, and whether the operating costs are aligned with the revenues. Calibration of the model enabled the latter to be achieved for both bus and taxi, and it is believed that the model is reasonable representative of a large city transport market (Table 7).

[12] This data point is supported also by evidence from Chelmsford, where overall productivity was 1.84 journeys per hour.

Table 7: Summary of Modelled Public Transport Supply and Demand in Bristol

Mode	Total Passenger-km travelled p.a.	Vehicle Km p.a.	Operating Costs (£ including profit)	Operating cost per passenger-km (£)
Bus	108,290,000	37,117,347	43,278,827	0.40
Hackney	45,619,200	38,016,000	36,276,768	0.80
Private Hire	46,656,000	42,414,545	34,350,480	0.74
All	200,565,200	154,665,239	157,184,901	0.57

A specific cross-check is available in the case of bus subsidy. A House of Commons investigation found that, overall, national subsidy for bus services was in the region of 30% of revenues. The modelled figure of 20% is likely to be accurate for an urban area outside London, where networks are mainly commercially operated and supported journeys are relatively short.

5.3 Evidence from Polybus trials

The closest near-market DRT prototype with VPATS characteristics is the proprietary *Polybus* technology. The system proposes a many-to-many operating pattern with real-time request and response scheduling enabling response times to rival (or better) taxi services, but with 2 to 3 times greater productivity than achieved by a hackney carriage or PHV 3, so allowing lower fares per km.

The developer of Polybus reports that a fleet of 20-100 vehicles could provide for 1.1-3.8 million party journeys per annum plus deliver 0.2-1 million items of light goods[13]. Hence, assuming a party size of 1.5 travellers (possibly cautious) then 1.7-5.7 million passenger-trips could be served.

The Polybus system does not, however, seek to provide exclusive use options; indeed, *"the average load level may well be between 1 and 2 [groups of 1+ passengers] for the system to have an optimum balance of income and service level"* (Ephraim, 2003). Nor does Polybus seek to offer differentiated levels of comfort etc..

A field trial was conducted in Chelmsford, covering 80,000 people in a 64km2 area. The trial involved simulated journeys for 85 minutes using one vehicle (routes driven but no actual passengers carried). During the period it is reported that:

- 7 party journeys were driven with an average distance of 4.4 km;
- the assumed fares levels of £0.62 per km for passenger 1 and £0.16 per km for subsequent passengers, yielded £31.64 in fares and £4.50 average per trip;
- the average time elapse between travel request and pick-up was estimated to be 2.6 minutes (min 1.5, max 4.1).

Further analysis of the trial leads to the observations that:

- the level of service simulated was in fact equivalent to 5 party journeys per hour;

[13] Elsewhere, Ephraim argues that, with a focus on efficiency, a 15-vehicle fleet could offer 120 party journeys per hour in urban conditions, equivalent to 8 journeys per vehicle.

- the average party size simulated was 2.7, rather than 1.5 - the main effect being higher income for the given number of trips driven;
- the average journey length is also possibly high for an urban context, probably leading to an underestimation of the total number of trips that could potentially be provided;
- the average estimated in-vehicle time for a traveller group was simulated to be 10.8 minutes, which given the average trip length suggests the service level offered was equivalent to a vehicle travelling at 24 km/h following the shortest route;
- the ratio of passenger-desired distance travelled ('live' mileage') to total vehicle distance travelled was 1:1.5, suggesting that 'dead mileage' was optimised at 33%.

Notably, the fares structure simulated is hybrid between taxi (second and subsequent passengers virtually 'free') and bus (second and subsequent passengers usually cost as first passenger). This is a logical choice given the hybrid nature of the mode in public transport terms, but the structure may need to be more like a taxi fare to attract parties with a car available.

The claims for efficiency advantage over existing taxi operations are supported by the use of optimisation technology. However, the efficiency of the system also relies on being able to introduce and eliminate vehicles from the pool to reflect peaking and troughing in demand. However, this is in effect what taxi firms do already, although in a less efficient way. Although the Polybus approach will reduce inefficiencies, they will occur to some extent; for example when demand increases to require additional vehicles, but they are not fully utilised for the hours they are in service.

A specific limitation due to the scale of the trial in terms of the assessment of efficiency is also that the system was able to select the most appropriate journeys to provide out of the total pool. It was assumed that each other unit in the system was also selecting most appropriate journeys. In practice when the other units are real rather than notional, conflicts may arise in optimising the allocations between vehicles. The conflicts may not have been fully simulated in the trial.

5.4 Model Scenarios including VPATS

The nature of bus and taxi provision in urban transport markets is competitive, indeed aggressive; sometimes literally so. For the present analysis it has to be assumed that the system seamlessly supplants existing capacity and has equivalent ease of access as existing modes to the types of demand which are efficient and inefficient to serve. As the proposed system is closer in design to existing many-to-many taxi services it is assumed that players in the hackney and private hire trades are recruited to provide the VPATS system, at least in the first instance.

Were a VPATS to take a 10% market share of the taxi sector in Bristol it would need to provide for around 2.5 million party trips per annum (around 5 million passenger trips). However, it can be expected that it would:

- generate additional trips from taxi users, to the extent that it was more efficient and cheaper than existing taxi services;
- attract trips from other modes, including bus, cycle, walk, rail and car, according to the perceived generalised cost of those different modes;

- generate travel more generally, to the extent that it creates travel opportunities for some specific groups e.g. those without cars, not currently well served by buses, with limited facilities in walking range and for whom taxis are expensive.

Attracting trips from other modes may be important in creating an economy of scale for the system given that it will have some fixed investments in infrastructure, which could possibly be large. It would be particularly desirable to attract trips from car use and to create wider economic and environmental benefits from reduced car use (which would also mean VPATS and the other road transport systems would suffer from less congestion).

The flexible *mode* of operation, as opposed to the flexible scheduling and routing of operation is a specific feature of VPATS, enabling it to operate in exclusive use or shared use modality. This is likely to be a feature which particularly attracts car users. Whilst flexible modality can be made to operate efficiently in economic terms, through the fare box, it will require additional resources over a Polybus-type system and the assets will be utilised somewhat less intensively in terms of vehicle occupancy. For the purposes of comparison, the first scenario considered is for VPATS operating in non-exclusive mode.

Scenario 1a: Modest conversion of Taxi/PSV fleet (10%, no exclusive use)

Assumptions:

- 10% of hackney carriages and 10% of PHVs are converted to VPATS operation (134 vehicles);
- other taxi and all bus services operate as at present, offering journey attribute bundles on a low-tech basis
- average party size is the same as for taxi travel, at 2 persons;
- the average trip distance travelled is between bus (2.5 km) and taxi (4 km) at 3.5 km;
- productivity over taxi operation is doubled to 4 trips per hour;
- share of total mileage which is ‘dead’ mileage is 33%;
- operating costs 10% higher than for hackney carriages, to reflect the costs of technology and the use of minibus vehicles;
- labour costs at similar rates to hackney carriages (minimum necessary in order to attract drivers);
- no direct local authority subsidy, although any use by subsidised users e.g. mobility impaired, those eligible for concessionary fares are assumed to be fully refunded;
- fare structure a cheaper version of taxi fares i.e. £1.25 per group per pickup plus £0.75 per group per kilometre travelled.

Table 8: Results of Scenario 1a ('10% Taxi Share No Exclusive Use')

Attribute	Value
VPATS vehicles in circulation	134
Annual capacity for passenger trips @ average party size 2 (trips)	4,665,600
- demanded by modal transfers from taxi	2,332,800
- demanded from other sources e.g. transfer from car	2,332,800
Passenger-trip capacity per annum	16,329,600
Share of public transport passenger-km (%)	8
Maximum transfer by car passengers required to fill capacity (%)	0.6
Maximum interception of car trips resulting from transfer	0.4
Fare per group per 3.5km journey (£)	3.88
Typical fare per passenger per km (£)	1.11
Total fare revenue per annum (£)	9,039,600
All vehicle-km operated	12,247,200
Revenue available to finance investment in technology (£)	605,556
All costs + profit margin (£)	9,237,888
Cost/vehicle-km	0.75
Cost/passenger-km	0.57

Key findings of the scenario run are that the conversion of 10% of the taxi fleet to VPATS would result in the new mode having an 8% share of a somewhat increased supply of public transport capacity. Around £0.6 million would be available to finance investment in the necessary technology. Depending on the financing arrangements, and the availability of public sector guarantees, this might lever in £6-12 million in funds.

If the new capacity were to be solely filled by transfers from private cars, it would require less than 1% of current car trips to be attracted for viability to be achieved at the suggested fare levels. (By the same token, any decongestion benefit from this level of transfer would be small.)

In practice, other sources of patronage will also demand the capacity, in particular existing taxi users travelling more due to the lower fares. However, the fares would be considerably higher than bus fares, so would only attract bus users travelling alone at the margin i.e. those journeys that a sole traveller currently makes by bus, but existing taxi services would be a close second choice. Similarly, the shorter wait times and higher comfort of the vehicle might attract a small number of less price sensitive bus travellers. Where groups travel by bus, VPATS would offer a cheaper than taxi alternative which could be expected to attract custom.

Car users would be in a similar position. Whilst being more affordable than current taxis, the notional per kilometre cost of VPATS would remain higher than even the fully allocated (fixed and running[14]) costs of car use, except where parking fees at

[14] Private costs will include variable costs of the order of 20p per kilometre. Fixed costs will vary according to intensity of use of the vehicle and its value, but will usually be of the order of another 5-20p per km.

the destination add considerably to these costs for specific journeys[15]. Some trips, mainly to the city centre, would be attracted from car use, then, where car is currently the least-cost option of car and taxi use, but VPATS pricing would create a third, cheaper, option.

Scenario 1b: Moderate conversion of taxi/PSV fleet (20%, no exclusive use)

Assumptions:
This scenario is identical to the previous one, except that twice as many taxis join the system, creating an economy of scale in funding the technology costs, so that operating costs reduce by £0.015/vehicle-km. This in turn enables a very minor reduction in fares, implemented by reducing the fixed element to £1.20.

Table 9: Results of Scenario1b ('20% Taxi Share No Exclusive Use')

Attribute	Value
VPATS vehicles in circulation	267
Annual capacity for passenger trips @ average party size 2 (trips)	9,227,520
- demanded by modal transfers from taxi	4,613,760
- demanded from other sources e.g. transfer from car	4,613,760
Passenger-trip capacity per annum	32,296,320
Share of public transport passenger-km (%)	15
Maximum transfer by car passengers required to fill capacity (%)	1.2
Maximum interception of car trips resulting from transfer	0.8
Fare per group per 3.5km journey (£)	3.83
Typical fare per passenger per km (£)	1.09
Total fare revenue per annum (£)	17,647,632
All vehicle-km operated	24,222,240
Revenue available to finance investment in technology (£)	847,778
All costs + profit margin (£)	17,870,823
Cost/vehicle-km	0.74
Cost/passenger-km	0.55

The implied modal shift from car (or other modes) is doubled, although the modal trade-offs that would be experienced by travellers are effectively identical.
A further sensitivity test was also included in this scenario: supposing VPATS vehicle operating costs could be reduced to current hackney carriage costs of £0.25/km, the reduction in costs would fund a further £0.15 reduction in the VPATS 'boarding fee' to £1.05.

[15] The additional cost of parking, expressed per km of the return journey to the car park, will depend on the length of journey and length of stay. However, a relatively long stay, attracting a charge of £5-10 in a major city would add a cost of 20p per km to a 25 km round trip. Hence the combined fully allocated private costs of car use and parking could approach or exceed the per km cost of VPATS use.

Scenario 2: Conversion of 20% of taxi/PSV fleet with 20% exclusive use

Assumptions: In this scenario, the range of attribute bundles is increased to four:

- fixed route, fixed schedule, non-exclusive, low-tech (current bus)
- many-to-many, exclusive, low-tech (current taxi)
- many-to-many, non-exclusive, high-tech (VPATS shared-use mode)
- many-to-many, exclusive, high-tech (VPATS exclusive-use mode)

The key difference in this scenario, is that users have the option to specify exclusive use on pick-up, so that the scheduling system will need to identify the nearest empty (or due to be empty) vehicle, and the system scale and level of service must be great enough for there to be a suitable vehicle within appropriate range. The user will pay a premium for this facility. It is assumed that most travellers will be prepared to accept sharing some journeys with other groups, and the deviation implied, so that only 20% of VPATS trips are requested on an exclusive basis.

In practice the scenario is modelled by dividing the VPATS fleet into two, with 80% of vehicles operating as in the previous scenario, and 20% operating on an exclusive basis. The exclusive vehicles no longer carry an average of, say, 1.5 parties at any given time, but are fixed at 1 party. Therefore the productivity falls to 2.67 party trips per hour. In effect, the exclusive vehicles are running as high-tech taxis in this modality, with the efficiency advantage over current taxis of somewhat higher productivity and less dead running.

The other key change is to implement a degree of cross-subsidy in the fare regime. This is achieved by charging levels of fare slightly lower than hackney carriage use for the exclusive trips, *i.e.* £2.40 pick-up charge (double the non-exclusive rate) and £0.85 per km, and reducing the costs of non-exclusive use through a 'yield management' strategy to ensure the system covers costs. In principle the system remains attractive as a whole as exclusive users get a higher level of service (door-to-door but shorter wait time) than a taxi service for a similar level of price, whilst non-exclusive users enjoy a higher level of service for a substantially lower fare.

Table 10: Results of Scenario 2 ('20% taxi share with 20% exclusive use')

Attribute	Value
VPATS vehicles in circulation	267
Annual capacity for passenger trips @ average party size 2 (trips)	8,612,352
- demanded by modal transfers from taxi	4,613,760
- demanded from other sources e.g. transfer from car	4,000,130
Passenger-trip capacity per annum	30,148,615
Share of public transport passenger-km (%)	12
Maximum transfer by car passengers required to fill capacity (%)	1.1
Maximum interception of car trips resulting from transfer	0.7
Fare per group per 3.5km journey (£)	5.38/3.78
Typical fare per exclusive/non-exclusive passenger per km (£)	1.54/1.08
Total fare revenue per annum (£)	35,273,879
All vehicle-km operated	22,611,461
Revenue available to finance investment in technology (£)	839,906
All costs + profit margin (£)	17,292,321
Cost/vehicle-km - non-exclusive/ exclusive/combined	0.73/0.96/0.76
Cost/passenger- km - non-exclusive/ exclusive/combined	0.55/0.72/0.57

The scenario shows - as would be expected, due to productivity changes - a reduction in the total VPATS capacity offered for the given number of vehicles and a slightly lower potential market share of public transport journeys. Another outcome is that the total VPATS distance operated and total operating cost falls[16], whilst the operating costs per kilometre are naturally higher for exclusive use operation.

Also, due to lower productivity, a larger contribution per kilometre of operation is required to cover the costs of technology, so for VPATS exclusive mode only, the rate/km increases to £0.30. This allows the revenue available for financing needs to remain similar to the non-exclusive only scenario.

Fares for non-exclusive users can be cut to £1.15 for boarding (with per-km charge remaining at £0.75). The small reduction in fare levels will contribute to system viability by competing with bus use, but the main viability benefits derive from adding an exclusive option which will compete with taxi and car use.

A sensitivity test showed that if exclusive use falls to 10% then the higher fares charged to these users pay for the additional costs incurred, but do not offer any cross-subsidy benefit to shared-use travellers.

Scenario 3a: Institutional acceptance

This scenario represents a more mature stage of VPATS development under which it has achieved 'institutional acceptance', which is defined as:

- 50% of taxis become part of the system, more than doubling capacity;
- VPATS is declared eligible for BSOG when operating in non-exclusive mode, worth £0.38/litre of diesel consumed;
- VPATS wins 25% of local authority tenders for supported bus services and the support for nightbus services, bringing an annual income of around £700,000, transferring 1.5% of current bus revenues to VPATS. Given that these are by definition low patronage services the share of bus patronage transferred will not be equivalent, and is assumed to be 1% from this change alone.
- Due to the nature of the subsidies, the financial benefits enable fare reductions for shared-use travellers only.

[16] It is not completely clear if this is solely an artefact of the model, which derives vehicle-km travelled from the trip rate. It may be a real-world effect as well; if a VPATS vehicle is in exclusive mode operation it will not make detours to collect additional parties, so will travel less kilometres per trip. Once reaching the exclusive-party's destination it is more likely to experience 'down-time' as it will not have a second party on board, and so by definition must seek a new journey from the notified demands, and a good scheduling match may or may not be immediately available. Non-exclusive vehicles may have a second party on board, so are more likely to remain in productive use.

Table 11: Results of Scenario 3a ('Institutional acceptance')

Attribute	Value
VPATS vehicles in circulation	681
Annual capacity for passenger trips @ average party size 2 (trips)	21,984,005
- demanded by modal transfers from taxi	11,534,400
- resulting from substitution of DRT for conventional bus	433,160
- demanded from other sources e.g. transfer from car	10,016,445
Passenger-trip capacity per annum	76,944,017
Share of public transport passenger-km (%)	30
Maximum transfer by car passengers required to fill capacity (%)	2.7
Maximum interception of car trips resulting from transfer (%)	1.8
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.38/3.28
Typical fare per exclusive/non-exclusive passenger per km (£)	1.54/0.94
Total VPATS fare revenue per annum (£)	39,206,080
Total VPATS revenue including subsidy (£)	41,762,303
All VPATS vehicle-km operated	57,708,013
Revenue available to finance investment in technology (£)	895,911
All costs + profit margin (£)	42,410,274
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.71/0.96/0.74
Cost/passenger- km - non-exclusive/ exclusive/combined	0.53/0.72/0.56

The effect of subsidies, particularly eligibility for BSOG, has a significant effect on fares, reducing the average fare by £0.50 and bringing the effective fare/km below £1.00. The availability of subsidy is likely to provoke both modest and step-change effects:

- Thirteen vehicles in the city bus fleet are converted to VPATS, for use mainly on the tendered services, including 7 minibuses and 6 minibuses (equivalent to 1.5% of total bus seating capacity).
- With fares for non-exclusive use approaching half the typical taxi fare, but with shorter wait-times than typical for private hire arrangements, the pressure for taxi companies and drivers to join VPATS would be significant. The scenario assumes 50% conversion, but there may be a snowball effect whereby conventional taxis become the niche market.
- At this scale, VPATS may now have a limited traffic reduction relevance, although the magnitude has not been tested, and will depend upon the actual extent of sharing of VPATS vehicles. The reduction due to sharing would need to at least offset the 'dead' VPATS distance operated.
- Given the scale - 30% of public transport trips, albeit on a larger total - effects on the bus market would emerge, particularly given the level of fares and the winning of local authority contracts. For pairs or larger groups of travellers, the benefits of VPATS use over bus use may tend to justify the fare difference. Competitive responses by the bus industry may occur.

Scenario 3b: Institutional acceptance with productivity maximised

This variant of the scenario is essentially a sensitivity test which examines what would happen if the productivity of VPATS could be further enhanced. The Polybus trial suggested that five trips per vehicle per hour might be achieved. Although that trial was limited, higher-capacity systems may bring economies of scope, as well as scale, whereby the likelihood of an available vehicle being proximate to a user origin is increased with market penetration. In this scenario, then, it is assumed that

- Non-exclusive VPATS productivity is increased to 5 journeys per hour
- Exclusive VPATS productivity is increased to 3 journeys per hour
- Both fare types are consequently reduced to reflect the better financial performance, although a cross-subsidy from exclusive to non-exclusive use is retained at around 10% of revenues from exclusive use.

Under this scenario, the cheapest VPATS journey (assumed to be 1 km in length) for a shared-use, lone traveller would be £0.84, whilst those for exclusive-use travellers would also reduce.

Regarding the operation of the VPATS system itself, it is notable that the vehicles would now be operating extremely intensively; covering 115,000 kms p.a. each in shared-use mode. This is probably around the maximum conceivable distance coverable in urban conditions in a year, suggesting that 5 trips per hour at this trip length would be a reasonable maximum. Further, at this intensity of use it may not be possible to keep the vehicle on the road for 360 days a year. However, the high replacement cycle implied means that VPATS operators would be able to upgrade technology, vehicle image, and vehicle specification frequently, enabling the service to be responsive to market needs and fashion trends.

Table 12: Results of Scenario 3b ('Institutional acceptance with productivity maximised')

Attribute	Value
VPATS vehicles in circulation	681
Annual capacity for passenger trips @ average party size 2 (trips)	27,523,880
- demanded by modal transfers from taxi	11,534,400
- resulting from substitution of DRT for conventional bus	433,160
- demanded from other sources e.g. transfer from car	15,556,320
Passenger-trip capacity per annum	81,941,120
Share of public transport passenger-km (%)	35
Maximum transfer by car passengers required to fill capacity (%)	4.2
Maximum interception of car trips resulting from transfer (%)	2.8
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.10/2.93
Typical fare per exclusive/non-exclusive passenger per km (£)	1.46/0.84
Total VPATS fare revenue per annum (£)	44,076,931
Total VPATS revenue including subsidy (£)	47,117,058
All VPATS vehicle-km operated	72,250,185
Revenue available to finance investment in technology (£)	904,169
All costs + profit margin (£)	46,733,274
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.62/0.87/0.65
Cost/passenger- km - non-exclusive/ exclusive/combined	0.46/0.65/0.49

Scenario 4a: Institutional promotion

The scenario extends the concept of institutional acceptance in *3a* to one of institutional promotion. It is assumed that the provisions in the White Paper of 2004 (DfT, 2004) for local exclusive contracts are implemented for specific routes, with the agreement with the private sector based on a demand-responsive approach. In practice this would amount to limited re-regulation in specific zones of the city. It is assumed that:

- The routes selected for operation as VPATS under public-private sector contracts would be the least appropriate ones for current conventional bus operation (but are nonetheless routes which currently operate commercially during weekdays).
- Twenty percent of bus trips are assumed to transfer to VPATS
- Around thirty percent of the bus capacity is converted to VPATS mode, with all minibuses and midibuses converted, as well as 23 single-deck buses, amounting to just under half the vehicle stock.
- For the purposes of the current analysis, these vehicles are assumed to have similar operating costs and operating efficiency as smaller VPATS vehicles. In practice fuel consumption and maintenance costs will be somewhat higher but, depending on how they are deployed, may have greater operating efficiency. Further, over time, they may be substituted at the time of fleet renewal with smaller vehicles, as appropriate.
- The VPATS system receives same amount of local authority subsidy support as in Scenario 3a/b (hence no additional support for operating these commercial services).

Table 13: Results of Scenario 4a (Institutional promotion)

Attribute	Value
VPATS vehicles in circulation	919
Annual capacity for passenger trips @ average party size 2 (trips)	30,209,285
- demanded by modal transfers from taxi	9,368,600
- resulting from substitution of DRT for conventional bus	8,663,200
- demanded from other sources e.g. transfer from car	10,011,685
Passenger-trip capacity per annum	76,394,485
Share of public transport passenger-km (%)	42
Maximum transfer by car passengers required to fill capacity (%)	2.7
Maximum interception of car trips resulting from transfer (%)	1.8
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.38/3.28
Typical fare per exclusive/non-exclusive passenger per km (£)	1.54/0.94
Total VPATS fare revenue per annum (£)	52,701,373
Total VPATS revenue including subsidy (£)	56,044,762
All VPATS vehicle-km operated	79,299,373
Revenue available to finance investment in technology (£)	1,116,361
All costs + profit margin(£)	57,953,020
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.71/0.96/0.73
Cost/passenger- km - non-exclusive/ exclusive/combined	0.53/0.72/0.55

Overall the public transport system has slightly lower resulting capacity than in Scenario 3b (due to lower productivity), hence the implied transfer from private car to PT is lower, although still considerably higher than base case. Further, the market share of VPATS within the PT market is still higher than in other scenarios.

Scenario 4b: Institutional promotion with productivity maximised

The scenario is identical to 4a, but with productivity and fare changes as described in 3b.

Table 14: Results of Scenario 4b (Institutional promotion with productivity maximised)

Attribute	Value
VPATS vehicles in circulation	919
Annual capacity for passenger trips @ average party size 2 (trips)	37,372,320
- demanded by modal transfers from taxi	11,534,400
- resulting from substitution of DRT for conventional bus	8,663,200
- demanded from other sources e.g. transfer from car	17,174,720
Passenger-trip capacity per annum	83,559,520
Share of public transport passenger-km (%)	47
Maximum transfer by car passengers required to fill capacity (%)	4.6
Maximum interception of car trips resulting from transfer (%)	3.1
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.10/2.93
Typical fare per exclusive/non-exclusive passenger per km (£)	1.46/0.84
Total VPATS fare revenue per annum (£)	58,504,896
Total VPATS revenue including subsidy (£)	62,519,132
All VPATS vehicle-km operated	98,102,340
Revenue available to finance investment in technology (£)	1,344,357
All costs + profit margin(£)	63,374,632
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.62/0.87/0.65
Cost/passenger- km - non-exclusive/ exclusive/combined	0.46/0.65/0.49

As with Scenario 3 a/b, the effects of productivity and economy of scale are demonstrated as significant.

Scenario 5a: Competitive response

The scenario represents reaction from the private sector in response to demand-responsive services representing a significant threat to traditional bus patronage. Clearly, the industry might respond in a range of ways, including cutting fares to retain patronage, with the risk of a 'fare war' being a significant one. Consideration of the full range of possible responses is beyond the scope of the present work, but the present scenario does consider the more 'benign' scenario of a bus company deciding to convert a number of its own services to demand responsive mode in order to compete. The willingness of bus companies to pursue DRT operations on a commercial basis has already been demonstrated by Stagecoach in Scotland. The scenario assumes that:

- 50% of bus capacity is converted to VPATS,
- whilst mini and midi buses are suitable for VPATS operation, single deck 118 vehicles must be substituted with smaller vehicles at a rate of 3.5 new smaller units per old, in order to provide sufficient flexible capacity,
- double deck vehicles and a few single deck vehicles continue to operate in traditional mode on the main corridors,
- due to the higher resulting operating costs (mainly labour) from replacing one larger vehicle with 3.5 smaller ones, all VPATS fares must be increased by a fixed amount of 15p, in order to maintain profitability.

Table 15: Results of Scenario 5a ('Competitive Response')

Attribute	Value
VPATS vehicles in circulation	1,309
Annual capacity for passenger trips @ average party size 2 (trips)	43,687,685
- demanded by modal transfers from taxi	11,534,400
- resulting from substitution of DRT for conventional bus	21,658,000
- demanded from other sources e.g. transfer from car	10,495,285
Passenger-trip capacity per annum	76,880,085
Share of public transport passenger-km (%)	59
Maximum transfer by car passengers required to fill capacity (%)	2.8
Maximum interception of car trips resulting from transfer (%)	1.9
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.53/3.43
Typical fare per exclusive/non-exclusive passenger per km (£)	1.58/0.98
Total VPATS fare revenue per annum (£)	78,048,829
Total VPATS revenue including subsidy (£)	82,725,367
All VPATS vehicle-km operated	114,680,173
Revenue available to finance investment in technology (£)	1,470,169
All costs + profit margin(£)	82,898,169
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.71/0.96/0.72
Cost/passenger- km - non-exclusive/ exclusive/combined	0.53/0.72/0.54

The scenario results in a major increase in the VPATS fleet and an increase in the total number of PT vehicles in the city, in order to maintain passenger-trip capacity. VPATS is now the majority provider of public transport, although in practice market growth will be partly restrained by the modest fares increases needed to reconfigure and expand the bus fleet, leading to a step increase in operating costs.

Scenario 5b: Competitive response with productivity maximised

The following represents a sensitivity test with productivity as in 3b and fares reduced over 5a to reflect greater operating efficiency. In other respect the scenario follows 5a.

Table 16: Results of Scenario 5b ('Competitive response with productivity maximised')

Attribute	Value
VPATS vehicles in circulation	1,309
Annual capacity for passenger trips @ average party size 2 (trips)	54,220,320
- demanded by modal transfers from taxi	11,534,400
- resulting from substitution of DRT for conventional bus	21,658,000
- demanded from other sources e.g. transfer from car	21,027,920
Passenger-trip capacity per annum	87,412,720
Share of public transport passenger-km (%)	64
Maximum transfer by car passengers required to fill capacity (%)	5.6
Maximum interception of car trips resulting from transfer (%)	3.8
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.15/3.02
Typical fare per exclusive/non-exclusive passenger per km (£)	1.47/0.86
Total VPATS fare revenue per annum (£)	85,431,024
Total VPATS revenue including subsidy (£)	91,111,696
All VPATS vehicle-km operated	142,328,340
Revenue available to finance investment in technology (£)	1,786,617
All costs + profit margin(£)	90,849,508
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.62/0.89/0.64
Cost/passenger- km - non-exclusive/ exclusive/combined	0.47/0.67/0.48

With higher productivity, VPATS would have the capacity and potential to provide two-thirds of public transport in Bristol, with 4% of car trips being transferred to the system (resulting in some reduction of traffic due to higher vehicle occupancy).

Scenario 6: Introduction of road user charging

Bristol has, for a number of years, considered adopting some form of road user charging (RUC). The London scheme focuses on trips to the central area for which there are very good public transport alternatives and high congestion. As a result, around 15% of former private vehicle trips to (or through) the central area were no longer made.

The scenario for Bristol assumes a citywide restraint policy (perhaps part of a national scheme), or a very stringent city-centre focussed policy) results in 15% of baseline car trips transferring to VPATS (bringing total modal transfer given pre-RUC shifts to 20%). Such an outcome would require both strong 'sticks' and 'carrots' as some trips might also switch to walk, cycle, bus and car sharing rather than VPATS as a result of the introduction of RUC, or be entirely suppressed. Total modal shift as a result of RUC might then have to be greater to achieve 15% shift to VPATS. However, VPATS would be an attractive option for relatively wealthy car users, particularly if an overall reduction in traffic would reduce congestion and journey times. There would be a positive feedback from growth in demand, and that the average proximity of a VPATS vehicle to the point of demand would increase with density of operation.

Indeed, the key assumption for this scenario, however, is the extent to which a doubling in the density of demand and supply for VPATS across the city would reduce dead running and increase productivity further over Scenario 5b. The effect of reducing dead running is likely to be a more significant effect than that of increasing productivity, as additional picking up and setting down imposes time penalties which limit productivity gains. Hence, it is assumed that:

- dead running reduces from 33% of distance travelled to 25%, whilst
- productivity increases by 10%

for both exclusive and non-exclusive modes.

As a result of economies of scale and productivity:

- an 85% increase in VPATS vehicles can provide for a 100% increase in patronage,
- the element of operating costs per kilometre covering the fixed cost of technology reduces slightly, and
- greater efficiency allows fares to be reduced slightly in the non-exclusive mode of operation.

Hence, a number of generalised cost attributes, including fare, wait time, and in-vehicle time would all move in such a way to encourage an increasing in demand.

Table 17: Results of Scenario 6 ('Introduction of road user charging)

Attribute	Value
VPATS vehicles in circulation	2,421
Annual capacity for passenger trips @ average party size 2 (trips)	110,338,351
- demanded by modal transfers from taxi	11,534,400
- resulting from substitution of DRT for conventional bus	21,658,000
- demanded from other sources e.g. transfer from car	77,145,951
Passenger-trip capacity per annum	143,530,751
Share of public transport passenger-km (%)	78
Maximum transfer by car passengers required to fill capacity (%)	20.7
Maximum interception of car movements resulting from transfer (%)	13.8
Fare per group per 3.5km journey (£) exclusive/non-exclusive	5.15/2.64
Typical fare per exclusive/non-exclusive passenger per km (£)	1.47/0.75
Total VPATS fare revenue per annum (£)	85,431,024
Total VPATS revenue including subsidy (£)	91,111,696
All VPATS vehicle-km operated	142,328,340
Revenue available to finance investment in technology (£)	1,944,511
All costs + profit margin (£)	164,225,858
Cost/vehicle-km – non-exclusive/ exclusive/combined	0.62/0.89/0.64
Cost/passenger- km - non-exclusive/ exclusive/combined	0.42/0.59/0.43

Notable findings are that:

- with the higher level of productivity and reduced dead-running, VPATS manages to reduce overall traffic, despite essentially replacing car journeys with VPATS movements, so that around 20 million net car-km are avoided per annum,

- although the changes in operating cost per vehicle-km are very low, per passenger-km they are significant, resulting in VPATS non-exclusive fares per kilometre being reduced by 10%,
- the requirement for BSOG is now more than £17 million per annum (a £10 million increase over the base case), which suggests that the revenue from RUC would need to be hypothecated to provide this subsidy, and
- VPATS would have more than 20% share of all trips in Bristol, and 78% of the public transport market[17].

[17] Although note that the figures do not allow for any change in the overall trip rate or growth in the demand for other public transport modes as a result of RUC implementation.

6 Conclusions

The present study has appraised VPATS as a special case of high-technology public transport provision which would mainly attract current taxi and car users by offering better quality for low fares, and would mainly attract bus passengers dissatisfied by the range of bus services and willing to pay significantly more for a much improved service. Car users can be expected to use both exclusive and non-exclusive VPATS services in order to take advantage of convenience benefits, but in some cases a lower cost than taxis. Classes of journey that would fit in the latter category would be journeys attracting a high parking fee (or congestion charge), or journeys for activities involving alcohol consumption. This is seen as the most likely market scenario. Other scenarios are possible, but it has not been possible to explore these within the present resource constraints.

The findings reported above support the principle that VPATS can operate profitably in a low-subsidy, deregulated environment. Notably, however, the operating environment of the scenarios is one of 'complementarity', with the competitive response modelled in Scenario 5 not being of an aggressive, protectionist nature. The real world operating environment would be expected to involve a wider range of responses from other market actors; most obviously from bus operators satisfied with the performance of the bus market as it stands and willing to defend it through short term fares cuts or service increases. In the past, in a range of places, these responses have tested the boundaries of the competition legislation, and in some cases broken them.

In essence VPATS works because, like systems such as Polybus, technology gives it a productivity advantage over lower-technology taxi systems. Notably, this increases the intensity of the operation in terms of passenger-kilometres served, but costs per kilometre are reduced by the elimination of 'dead' or empty running. Costs per passenger kilometre are also similar to those achieved with buses; the main reason for this is that vehicle occupancy levels are of a similar order (1-3 passengers per vehicle kilometre), but bus operating costs per vehicle kilometre are around double, due to the larger size of vehicle.

Notably, however, the bus traveller meets the cost of accessing the bus route through his/her time and perhaps physical effort and comfort. The critical question perhaps to be answered – which could not be tested by the present study - is how much bus users would be prepared to pay in fares to obtain a door-to-door service, and how many they would number. The fare at which VPATS can be offered will clearly be critical. The latter scenarios assume that VPATS is legally a flexible bus service in shared mode of operation, and so eligible for fuel duty rebate, and this assists in bringing the fare levels towards half of the cost of taxi travel.

Even without significant transfer from the main bus routes, however, VPATS is likely to be particularly attractive for specific bus markets such as night-time travel, and travel from parts of the urban area not well served by the current bus network.

Introducing a radical policy such as RUC could have a fundamental effect on transfer from car, combining greater restraint with hypothecated subsidy to support a mode which is closer to car use than any of the existing offers but able, in shared-use mode, to reduce traffic overall.

Finally, the key principle of VPATS that differential rates be charged for service levels (attribute bundles) is found to be worthy of further development: the study suggests that technology can make sufficient difference in terms of productively to enable VPATS to be competitive with current taxis when used in exclusive mode, whilst still creating a fare premium over costs. These additional revenues can then result in moderate fare reduction for non-exclusive users, making VPATS more attractive for current bus travellers, or those excluded from access to mechanised transport currently through a combination of proximity to services and/or their cost.

6.1 Future work

Issues of implementation and relevance for social inclusion objectives will be the subject of the third stage of the present project.

In terms of the technical work in this report, there are several areas where a small scale scooping study such as this might be extended in the future. Most obviously, there are a number of tools that are becoming available to local authorities through the Local Transport Plan Guidance that may allow demand forecasts to be made for public transport systems.

More detailed and sophisticated modelling work would be appropriate ahead of any field trials, although it is notable that many initiatives in the bus market have been trialled based on intuition and low cost straight-to-public experiment's, such as the low-tech Fife taxibus in Scotland. Indeed, demand-responsive services have arguably already now received above-average attention. Nonetheless, the special nature of VPATS suggests that more detailed demand-side modelling be carried out, to complement the supply-side focus of the above work. The technical challenges of such a project, however, would be significant.

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