AN ASSESSMENT OF CITY-WIDE APPLICATIONS OF NEW AUTOMATED TRANSPORT TECHNOLOGIES

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Abstract

There is renewed interest in Europe in the potential role of new automated technologies for urban transport. Such systems include personal rapid transit (PRT), cybercars and high-tech buses, which have been studied in the European programme CityMobil. In the absence of empirical evidence on their performance, a common predictive modelling method has been used to predict the impacts of three comparable applications of these technologies in four case study cities. The design of the applications and the modelling assumptions were based on earlier research in the programme. The model results and a business case tool have been used to assess the contributions such systems make and their financial justification.

Impacts on car use were often small, but were greater for city centre PRT schemes and cybercar feeder schemes. However, these schemes also attracted patronage from conventional public transport and from walking and cycling. Financial benefit cost ratios were often positive, reflecting the low costs of operation, and were particularly high in cities with high fare regimes and in areas with previously poorer levels of service. These results suggest appropriate conditions for a full scale trial of such technologies.

INTRODUCTION

Automated transport systems are ones which require no driver or other on board personnel, thus reducing substantially their operating costs and enabling them to be applied more intensively than conventional public transport services. Some systems go further, and offer an on-demand service rather than a conventional timetabled service, thus substantially reducing waiting times. There has been interest for several decades in the development of such automated transport systems for urban areas, given their potential to improve public transport services, reduce their costs and encourage a switch away from private car use (*1*).

Several new automated technologies for urban passenger transport are now being developed and tested as small scale demonstrations, but their site-specific application makes it difficult to generalise their results. It is likely to be some considerable time before cities are willing to take the risk of being the first to implement full scale applications. In the meantime, predictive modelling offers the most dependable way of assessing the likely contributions of such technologies to urban transport policy.

These recent technological advances have led the European Commission to finance a major investigation into the design and application of such technologies, CityMobil (*2*). A key element in CityMobil has been to bring together expertise in technology and in urban transport to assess the potential of such technologies when applied on a large scale in urban areas. Early work involved categorising the technologies available and identifying their most promising applications. Subsequently a research method was developed for assessing the performance and contribution of these technologies in such applications (*3*).

That method involved specifying in more detail four particularly promising applications; selecting four representative European cities in which to test them; determining the contexts in which they should be tested and the complementary policy instruments with which they might be tested; choosing a common modelling platform with which to test them; collecting data to understand behavioural responses to them; and creating a Business Case Tool to evaluate their impacts (*3*). In this paper we summarise the applications specified, the cities selected, the modelling platform chosen and the Business Case Tool developed. We then report the results, limiting them in the interest of space to three of the four applications, in a medium growth scenario, and without complementary policy measures. This allows us to draw important comparisons between technologies and between cities. These results are presented in terms of peak mode shares and financial benefit cost ratios. We then use these results to discuss implications for full scale field trials. Further results are available in the full project report (*4*).

THE TECHNOLOGIES AND APPLICATIONS

Within the context of the study the term automated transport technologies is used to describe the vehicles and any associated infrastructure to enable vehicles to operate. The automated transport technologies modelled include cybercars, personal rapid transit (PRT) and high-tech buses. The specifications of these automated modes can vary between different types of system, so those reported here will not necessarily apply to all other similar modes but are used as the basis for the modelling work. The term applications is used to describe the context in which the new automated transport technologies are used, and the design of the system within a particular location is referred to as the scheme. The types of application modelled are common across all four case study cities, though the individual schemes differ between cities due to variations in size, geography and existing road and transport networks.

The cybercar system specification is similar in concept to the ParkShuttle system operating in Rotterdam (*5*). The vehicles run on a lane segregated from other traffic at a maximum speed of 25 km/h, with a maximum capacity of 20 passengers. The fully automated vehicles operate without a driver and have a battery powered energy supply. Two types of cybercar applications have been modelled: the first is an inner city network; the second includes several suburban feeder systems linking low density residential areas to existing high quality public transport systems. Both services are scheduled rather than on demand. Only the second of these is presented in detail in this paper, since the inner city application mirrored that for the PRT system.

The PRT system specification is similar in concept to the ULTra system (*6*), operating on a segregated guideway at a maximum speed of 40km/h. The vehicles have a maximum capacity of four seats, are automatically controlled and battery powered. This is a demand responsive mode in which passengers at the off line PRT station ‘summon’ a vehicle to take just them or their party to the requested destination. An inner city PRT network linking key facilities such as existing transport interchanges, universities and hospitals has been modelled.

High-tech buses are similar to regular buses in terms of appearance and specifications, but are able to run automatically, without a driver on guideways. The high-tech bus application includes services on several major routes from the suburbs to the city centre, and at least one route linking the city centre to a major facility, such as an airport or out-of-town shopping centre.

CITIES AND SCHEME DESIGNS

New automated transport technology schemes were modelled in four case study cities: Madrid, Trondheim, Tyne and Wear (a city region) and Vienna. FIGURE 1 shows an example of the PRT city centre scheme as modelled in Tyne and Wear. A full set of scheme plans can be found in (*4*). TABLE 1 provides an overview of the scale of the case study cities, modal split and transport conditions.

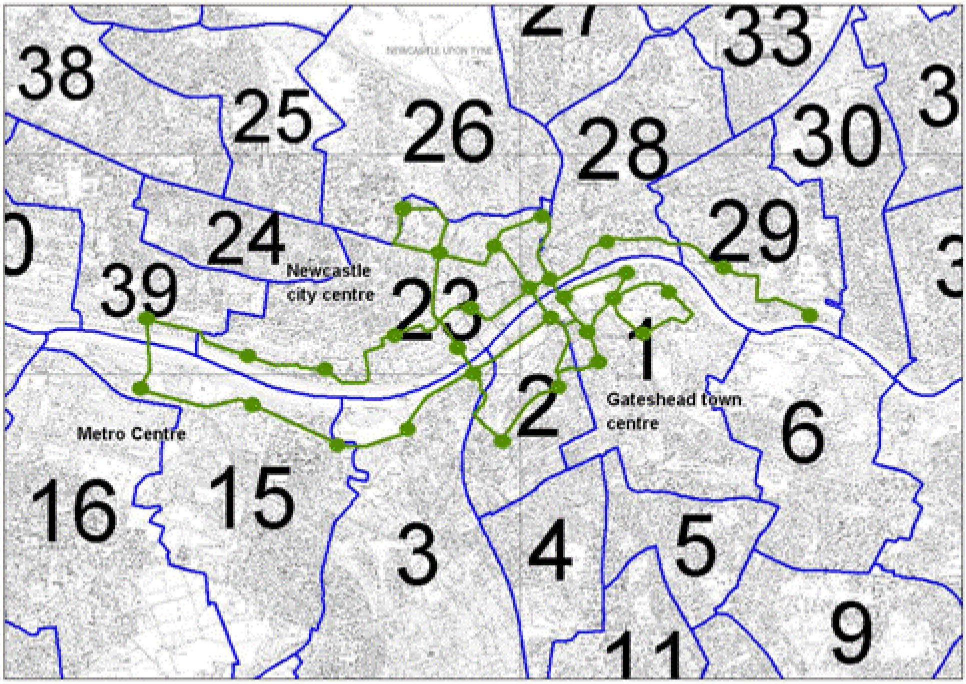

FIGURE 1 Tyne and Wear PRT city centre network

TABLE 1 Overview of case study cities

	Madrid	**Trondheim**	**Tyne and Wear**	**Vienna**
2005 population	5,846,473	150,000	1,451,872	2,755,000
2035 population (medium growth forecast)	8,502,867	192,000	1,400,438	2,859,000
Modal split 2005	55% public transport, 12% car, 33% walking and cycling	11% public transport, 58% car, 31% walking and cycling	23% public transport, 65% car, 12% walking and cycling	34% public transport, 36% car, 30% walking and cycling
Public transport provision	Bus, metro, LRT, rail	Bus, tram line	Bus, metro, limited intra-urban rail	Bus, metro, LRT, tram
Transport issues	Low levels of public transport provision in the suburbs which leads to high car usage compared to central areas	Hills surrounding the city create challenges for transport provision, making it difficult to connect the east and west parts of the city	River Tyne acts as a geographical barrier. High traffic flows across the river create bottlenecks at crossing points	Good level of public transport provision throughout the city

Of the tests undertaken, those that assumed no additional measures were introduced alongside the new schemes, and a "medium growth" context for population growth, ageing, fuel price rises and urbanisation, are reported here. The full range of tests undertaken in the project is reported in (*4*). The impacts of schemes were modelled over a total of 30 years, with 2005 as the base year. In all cases the new technologies were modelled as being introduced in 2010. The details of the schemes for each of the three applications in reported here are as follows:

- ***Cybercar public transport feeder:*** this system is modelled as an enhancement to the existing public transport system. In all cities a number of suburban areas with relatively poor access to main line public transport systems were selected for the implementation of feeder systems. The detailed assumptions about the performance characteristics that are made when modelling this system are shown in TABLE 3.

- ***PRT:*** this mode is modelled as an enhancement to the local public transport system. This varies by city: Madrid's feed the local metro; Trondheim's links to the local bus service; Tyne and Wear's serves as a stand-alone system in addition to feeding the metro and rail systems (see FIGURE 1), while Vienna's feeds both the metro and tram system. The detailed assumptions about the performance characteristics that are made when modelling this system are shown in TABLE 5.
- ***High tech bus:*** this system is modelled as an enhancement to the existing bus system, and is assumed to replace the existing bus service on all high tech bus corridors. The detailed assumptions about the performance characteristics that are made when modelling this system are shown in TABLE 7.

THE STRATEGIC TRANSPORT MODEL AND BUSINESS CASE TOOL

The strategic modelling of the new technologies transport schemes was undertaken using MARS (*7*), (*8*), (*9*). MARS is a dynamic Land Use and Transport Integrated model. The basic underlying hypothesis of MARS is that settlements and activities within them are self organising systems. MARS is based on the principles of systems dynamics (*10*) and synergetics (*11*). The present version of MARS is implemented in Vensim®, a System Dynamics programming environment and the model has been applied in 19 cities world-wide.

MARS includes a transport model which simulates the travel behaviour of the population related to their housing and workplace location, a housing development model, a household location choice model, a workplace development model, a workplace location choice model, and a fuel consumption and emission model. All these models are interconnected as shown in FIGURE 2. The sub-models are run iteratively over a 30 year time period. They are linked on the one hand by accessibility as an output of the transport model and input to the land use model, and on the other hand by the population and workplace distribution as an output of the land use model and input to the transport model.

MARS has two distinguishing characteristics that enable it to operate rapidly. Firstly it contains no detailed network, but instead represents the modes available between O-D pairs and the interaction between demand and supply for each. Secondly it assumes a constant travel budget so that if time is saved on commute trips then more time can be spent on “other” trips.

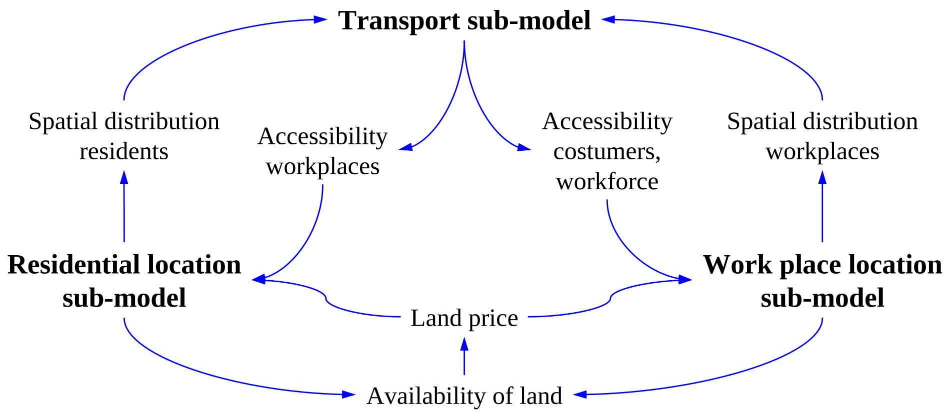

FIGURE 2 Basic structure of the MARS sub-models.

Incorporating New Public Transport Technologies

MARS models the mode choice between public transport, private car and slow modes (walking and cycling) via the concept of friction factors, which reflect the impedance of travelling between each origin-destination pair for each mode. For example, a trip by public transport consists of the following individual (cost) parts:

1. Average walking time to the next PT stop from origin
2. Average waiting time for the PT service
3. In vehicle time (OD)
4. Changing time (OD pair dependent)
5. Egress time to destination, and
6. Fare costs

Each of these parts is perceived and valued differently by the user. MARS uses perceived values derived by a previous study (*12*) that defines separate friction factors for the public transport modes bus, tram and rail, as well as for car. As will be seen later the use of these perceived values tended to favour schemes which reduce access/egress times over those which improve in-vehicle times. MARS makes a distinction as to whether public transport is separated from individual road traffic or not.

To include a new technology such as a PRT system, it is necessary to characterise the supply factors such as average speeds, access/egress times, headways, fares and changing times. The approach will depend on whether the new technology will be perceived as a completely new mode or as similar to an existing mode. This will determine which of the subjective valuation factors should be applied in the first instance.

We specifically chose to apply the same generic model within the four case studies so that we could evaluate the impact of the systems and their context in terms of city and existing infrastructure without worrying about differences in modelling approaches. However, some local calibration of the aggregate and OD-specific mode shares is possible by adjusting the relative subjective values between modes at the area level and for OD pairs.

The Madrid and Tyne and Wear models represent four modes: car, bus, rail and slow, with the new mode added to bus or rail as appropriate. Trondheim has no rail, and the Vienna model has a combined public transport mode.

Standard policy tests for fuel price and fare changes showed the output elasticities to be -0.1 for fuel price and -0.16 for fares which are in line with the mean value for fuel price elasticity reported in Goodwin et al (13) and within the range for fare elasticities in urban areas, see TRL Report 593 (14). The main response to the schemes was seen to be a change of mode, with very little relocation in response to the schemes tested.

A business case is the basis for the economic justification of any new scheme. The Business Case Tool (BCT) has been developed and is designed to provide a quick and simple means for assessing the economic case for a new transportation system. It is based on the results of a literature review from which a list of the relevant factors has been determined together with a preferred methodology for taking them into account. The BCT is a spreadsheet comprising a number of interlinked worksheets. When these are used in sequence, they take the user through a structured set of questions that are designed to elicit the information and data needed to build up the business cases for two alternative schemes, for example, a PRT versus a conventional bus scheme. The structure of these worksheets is described more fully in (*3*).

In the exercise reported here, the BCT has been applied to the MARS model outputs for the three proposed schemes in each of the four cities. In each case, the MARS model results have provided the length of the route, the number of stations/stops, the average fare, the peak and off-peak demand figures (passengers/hour) for a 16 hour/day operating period, the growth in demand over a 25 year period, and the number of buses needed in the HTB schemes. A sensitivity test was included to show the effects of a ‘worst case’ scenario made up from a 20% reduction in demand and a 20% increase in costs, and a ‘best case’ made up from a 20% increase in demand and a 20% decrease in costs.

In order to accommodate the particular requirements of the exercise, and to facilitate cross-site comparisons, only a financial Benefit-Cost Ratio was calculated, as:

$$BCR = (PVB - PVC)/PVC$$

Where PVB and PVC are the Present Value of Benefits and the Present Value of Costs, on the assumptions that:

- scheme benefits derive from fare revenues only
- costs of systems are in 2008 prices
- costs and benefits are computed using a discounted cash flow analysis performed over a 30 year period starting in 2009, using a 3% discount rate
- scheme operation and fare collection starts in 2010
- generic costs, in 2008 prices are based on evidence from manufacturers and consultants.

RESULTS

Cybercar feeder system

TABLE 2 shows the index for changes in trips in the peak within the implementation area when a cybercar feeder scheme is implemented in a number of suburban zones in each city. With the exception of Trondheim, where the scheme feeds the bus service, all schemes feed tram, light rail or rail systems. Cybercar trips are included within the rail mode, except in Trondheim, where they are added to the bus mode.

TABLE 2 Index of 2010 peak trips following cybercar feeder introduction (2005 = 100)

2010 peak	Madrid	Trondheim	Tyne and Wear	Vienna
Car	91.9	99.6	91.7	98.1
Bus	88.1	111.7	74.2	N/A
Rail	149.6	N/A	290.6	103.8
Total PT	129.7	111.7	111.8	103.8
Slow	55.1	97.4	78.3	95.5

Both the Tyne and Wear and Madrid feeder systems have a significant impact in terms of reducing car use on their respective public transport corridors. For Tyne and Wear this is due to the relatively large reduction in access/egress times; for Madrid the results are due to improved access but also because the system is developed in high growth areas. However it should be noted that within the feeder zones there is also a high transfer from bus and from slow modes. The high increase in rail share for Tyne and Wear is explained by the relatively low mode share in the base.

For Trondheim and Vienna the impacts are more modest. In Trondheim the bus services which are fed have relatively low patronage. In Vienna the high level of service for public transport makes it difficult to find zones with poor access. In summary the feeder system works well in Tyne and Wear and Madrid where initial access times were poor and there was an opportunity to link to a good main line service.

TABLE 3 shows the performance characteristics assumed in the model, the key model outputs and the resulting Business Case Tool results.

TABLE 3 Assumed characteristics of the cybercar feeder schemes and BCT results

	Madrid	**Trondheim**	**Tyne and Wear**	**Vienna**
Route length (km)	90	22.8	22.8	110
No.stops	140	36	36	500
Peak demand (pph)	17772	115	2655	2465
Off peak demand (pph)	3686	2	860	2262
Annual demand (Mppy)	47.2	0.18	7.6	13.5
Growth in demand (%pa)	1.19	0.7	0.7	0.1
No. vehicles	287	2	43	40
Average veh speed (kph)	14.7	14	14.4	14.1
Average trip time in peak (mins)	5.9	5.9	5.9	5.9
Average waiting time in peak (mins)	3.1	3.1	3.1	3.1
Average veh spacing (m)	313.6	11400	530	2750
Fare (€)	0.7	2.53	2.2	0.3
Capital costs (€M)	195	17.2	34.6	94.6
Base year op costs (€M)	17	1.8	3.3	6.4
PV cost (€M)	539	53.6	102	224
Base year benefits €M)	33.1	0.45	16.8	4.05
PV benefit (€M)	743	9.4	354	78.8
Business BCR	**0.38**	**-0.82**	**2.48**	**-0.65**
BCR Sensitivity analysis:				
-20% demand, + 20% cost	0.08	-0.88	1.6	-0.75
+20% demand, -20% cost	0.81	-0.74	3.66	-0.5

It can be seen that the schemes differ substantially in size and patronage. That in Madrid has many more vehicles, reflecting the size of the area covered. Vienna, despite its size, has far fewer vehicles, while the Trondheim system is too small to be viable.

The Tyne and Wear system produces a very respectable BCR suggesting the fare revenues should substantially cover the costs. The Madrid system has a small positive BCR, while those for Trondheim and

Vienna are negative. The low fares in Vienna make it difficult to make a financial case for the scheme. Further tests showed that a fare of around €2 would provide a better than break even case in Vienna.

PRT system

TABLE 4 shows the index for changes in trips in the peak within the implementation area when a PRT scheme is implemented in each city. Vienna and Madrid are contained within large central zones but act as feeders to the main transport systems. The Tyne and Wear PRT network covers a few central zones and acts as a feeder to rail/METRO and also as a stand-alone system. PRT trips are included within the rail mode, except in Trondheim, where they are added to the bus mode.

TABLE 4 Index of 2010 peak trips following PRT introduction (2005 = 100)

2010 peak	Madrid	Trondheim	Tyne and Wear	Vienna
Car	98.3	98.7	95.8	91.9
Bus	96.4	95.4	88.9	N/A
Rail	106.6	N/A	258.8	102.7
Total PT	102.6	126.1	146.9	102.7
Slow	90.6	92.5	91.4	99.8

The Tyne and Wear and Vienna schemes have a significant impact on car use. It should be noted however that the Vienna scheme also included some additional measures to remove cars from the central zone in order to reallocate capacity for the PRT track. Cars were effectively restricted to the use of ring-roads within the zone and only allowed to park at certain parking locations. For Madrid and Trondheim reductions in car use are smaller. Except in Vienna there is a notable reduction in bus and slow mode trips. The significant reduction in slow mode trips is due to the new opportunities to replace short within zone walk trips with short PRT trips. This should be taken into account when considering the design of such systems.

FIGURE 3 shows the "local" mode share trajectories over time for the Tyne and Wear case. Here we can see that as the scheme is implemented in year 2010 there is a one off mode shift towards rail, taken from car, bus and slow modes. As there are no other schemes introduced beyond 2010, the previous trend in mode share i.e. a growth in car share remains. The scheme is unable to reverse the base trend for an increasing car share over time. This result was mirrored in all cities and for all schemes.

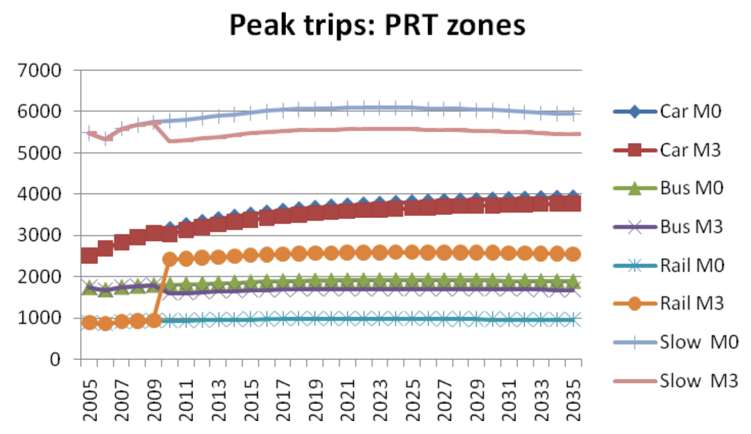

FIGURE 3 Peak trips for inner PRT (M3) versus Do-nothing (M0) over time

TABLE 5 shows the performance characteristics assumed in the model, the key model outputs and the resulting Business Case Tool results.

TABLE 5 Assumed characteristics of the PRT schemes and BCT results

	Madrid	**Trondheim**	**Tyne and Wear**	**Vienna**
Route length (km)	42	18.5	20.7	11
No.stops	84	34	56	49
Peak demand (pph)	27427	580	5580	744
Off peak demand (pph)	11278	1624	3776	485
Annual demand (Mppy)	95.3	8	24.7	3.2
Growth in demand (%pa)	-0.72	0.8	0.11	0.02
No. vehicles	1960	43	406	55
Average veh speed (kph)	30.4	30.8	30.7	30.8
Average trip time in peak (mins)	5.8	5.8	5.8	4.8
Average waiting time in peak (mins)	1.4	1.4	1.4	1.4
Average veh spacing (m)	21.4	430	51	200
Fare (€)	0.6	2.53	2.21	0.3
Capital costs (€M)	351	75.4	123	47.7
Base year op costs (€M)	25.8	2.7	6.9	2.3
PV cost (€M)	872	130	263	95
Base year benefits €M)	57.2	20.1	54.6	0.96
PV benefit (€M)	1001	429	1062	18.5
Business BCR	**0.15**	**2.30**	**3.04**	**-0.81**
BCR Sensitivity analysis:				
-20% demand, + 20% cost	-0.11	1.24	2	-0.86
+20% demand, -20% cost	0.51	3.83	4.51	-0.72

The schemes differ substantially in size and patronage. That in Madrid has many more vehicles, reflecting the size of the area covered. The Tyne and Wear scheme also justifies a substantial vehicle fleet, resulting from its success in attracting patronage from all other modes. The Trondheim and Vienna schemes are much smaller.

The Tyne and Wear and Trondheim systems produce very respectable BCRs suggesting the fare revenues should substantially cover the costs. The Madrid system has a small positive BCR, but is susceptible to becoming negative under certain assumptions, while that for Vienna is negative. The low fares in Vienna make it difficult to make a financial case for the scheme.

Equivalent cybercar systems were tested in all except Trondheim; the principal differences were lower operating speeds in the range of 14 to 16km/h and, in Vienna, no restriction on car use. The BCRs in Tyne and Wear and Vienna were lower than for PRT at 2.58 and -0.61 respectively. That for Madrid was higher at 0.49.

High Tech Bus

TABLE 6 shows the index for changes in trips in the peak within the implementation area when a High Tech Bus scheme is implemented on a number of corridors in each city.

TABLE 6 Index of 2010 peak trips following introduction of high-tech bus (2005 = 100)

2010 peak	**Madrid**	**Trondheim**	**Tyne and Wear**	**Vienna**
Car	98.4	99.7	99.3	99.4
Bus	126.4	106.1	145.2	101.0
Rail	94.8	N/A	97.9	N/A
Total PT	105.8	106.1	128.4	101.0
Slow	97.8	98.3	96.3	98.4

These High Tech Bus schemes have little impact on car use in any of the four cities. Impacts on the slow modes are also typically small, as might be expected for longer distance services. The main impact is to transfer trips between public transport services.

TABLE 7 shows the performance characteristics assumed in the model, the key model outputs and the resulting Business Case Tool results.

TABLE 7 Assumed characteristics of the high-tech bus schemes and BCT results

	Madrid	**Trondheim**	**Tyne and Wear**	**Vienna**
Route length (km)	143	25	50.9	34
No.stops	60	20	18	108
Peak demand (pph)	115782	3091	3273	609
Off peak demand (pph)	94492	2445	931	984
Annual demand (Mppy)	591	15.2	8.9	5.2
Growth in demand (%pa)	-0.56	0.44	0.2	0.04
No. vehicles	1800	35	30	73
Average veh speed (kph)	40.6	29	30	26
Average trip time in peak (mins)	24.4	21.11	38.37	15
Average waiting time in peak (mins)	5	4.07	4.81	0.6
Average veh spacing (m)		1450		
Fare (€)	0.75	2.53	3.15	0.3
Capital costs (€M)	3622	255	453	381
Base year op costs (€M)	481	9.9	9.9	20.4
PV cost (€M)	13329	455	652	792
Base year benefits €M)	443	38.5	27.9	1.56
PV benefit (€M)	7813	783	549	30.1
Business BCR	**-0.41**	**0.72**	**-0.16**	**-0.96**
BCR Sensitivity analysis:				
-20% demand, + 20% cost	-0.52	0.28	-0.4	-0.97
+20% demand, -20% cost	-0.25	1.33	0.19	-0.95

The Madrid scheme is very much larger than the others, reflecting the route length and the intensity of demand in the chosen corridors.

Only Trondheim generates a positive BCR, and even this is small.

CONCLUSIONS

Several new automated technologies for urban passenger transport are now being developed and tested as small scale demonstrations. However, it is likely to be some considerable time before cities are willing to take the risk of being the first to implement full scale applications. In the meantime, predictive modelling offers the most dependable way of assessing the likely contributions of such technologies to urban transport policy.

In this paper, we have presented some results from a comparative study of three technologies as used in three applications in four European cities. The study has used a common modelling and appraisal framework, building on assumptions described fully in an earlier paper (3). While the common framework will have avoided some of the differences which arise when trying to compare predictive results in different cities, it is important to bear in mind that the schemes tested are those which were agreed with the city authorities in each case study, and may well not represent the optimal application of a given technology. Moreover, lack of space has precluded the presentation of results for these technologies when combined with other policy instruments or tested in the context of high economic growth. These fuller results are available in (*4*). Bearing in mind these caveats, a number of conclusions can be drawn from the results presented above.

The impacts of all the technologies tested arise principally in terms of modal change; relocation impacts were typically small. Even so, the impact of many of the schemes on car use, even within the areas in which they are applied, are modest. Those in Trondheim, a small city where walking and travelling by bus are attractive, and in Vienna, which has a well developed public transport network and low fares, are particularly small. Moreover, the new technologies will extract patronage from conventional public transport and from walking and cycling as well as from the car, and this needs to be borne in mind in considering their contribution to sustainability.

Despite this rather negative overview, some applications have proved more successful in influencing car modal shares in some cities. On this criterion, the cybercar feeder service in Madrid and Tyne and Wear and the city centre PRT scheme in Vienna and Tyne and Wear were particularly effective, although it should be noted that the Vienna application of PRT included some reduction in road capacity to accommodate the segregated track. The city centre cybercar in Madrid and Tyne and Wear (not presented in detail in this paper), the cybercar feeder in Vienna, the city centre PRT in Madrid and Trondheim, and the High Tech Bus in Madrid also had a useful impact on car use.

At the time of writing, only a financial benefit cost ratio has been calculated. Even so, many of the tested schemes have generated positive BCR values. In the case of the city centre cybercar, cybercar feeder and city centre PRT in Tyne and Wear and the city centre PRT in Trondheim, the present cost of revenues was more than double the present value of costs, reflecting the high fares in both cities, and the substantial cost savings accruing from the use of driverless systems. Conversely, no scheme in Vienna, which has a particularly low fare regime, generated a positive BCR.

Overall, the city centre PRT system and the cybercar feeder system performed best in terms of impacts on car use and financial return. The success of PRT can be attributed to its high operating speed and the avoidance of waiting time. The success of the feeder systems arises from the improved access time to high speed modes, and improvements in their patronage. As mentioned previously this is partly because access time carries with it a higher value of time than in-vehicle time and so any scheme which reduces access time is expected to perform well. It may well be that a PRT system applied to these feeder services would have proved even more effective. The principal messages from this study are that new technologies do have a role to play in an urban transport strategy, both because they can attract users from the car and because they offer a much lower cost means of operating public transport services. However, they are clearly not a panacea. Rather, they will have a role to play in certain niche markets in a city, and those niches will differ from city to city.

The next and most important step in their development will be the funding and facilitation of a full scale trial, which will help cities to assess the risks which they will be taking in pursuing such technologies, and enable the public and business to gain objective experience of their performance. The results of this study help indicate the types of context in which such trials might take place. Feeder services to conventional high speed public transport routes, using cybercar or PRT, in cities with high fare regimes and in areas with relatively poor levels of public transport service, offer a particularly promising testbed.

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