THREE FINANCIAL AND SOCIO-ECONOMIC ASSESSMENTS OF A PERSONAL RAPID TRANSIT SYSTEM

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1. INTRODUCTION

The principles of public transport are the same today as in the stagecoach era. Vehicles operate according to a published schedule, passengers go to a designated stop and wait for the vehicle to arrive. Their journey is interrupted by periodic stops as the vehicle picks up or drops off passengers. If the passenger is lucky the service will have a stop near the desired destination. If not, it will be necessary to transfer to another service or services. The waiting and interchange components of the journey are generally regarded as inconvenient (and, in generalised cost terms, costly).

A Personal Rapid Transit (PRT) system uses automatically-driven small vehicles to carry individuals or small groups non-stop from the origin station to the destination station, wherever the stations lie on the network of guideways. Because vehicles can be parked off-line at stations to be immediately available when passengers arrive, or if no vehicle is at the station one can be called up automatically from nearby, waiting times are very short or zero, and since all stations are off-line there are no intermediate stops. Several such systems reached advanced stages of design and development in the UK, Europe and the USA in the early 1970s, but none were put into public operation, though a larger vehicle derivative still operates as a small automated tram to serve a university campus in Morgantown, Virginia, USA.

The 1970s proposals were too advanced for the available technology. Such systems could have been made operable, but they were too complex and expensive, and the guideway and infrastructure tended to be large and too visually intrusive to be aesthetically acceptable. Thirty years later, technology has moved on. Control systems which required a room of mainframe computer then can now be run from a laptop. Proposals for PRT are back. The particular system described here has been developed by Advanced Transport Systems Ltd of Bristol. Development of the prototype test track and vehicles was funded in part by the Department for Transport, and the assessments of the PRT system described here were made for DfT and for the European Commission as part of the EDICT project.

2. THE ULTra PRT SYSTEM

The ULTra system (Lowson, 2002) uses small four-seater electric vehicles automatically controlled on a concrete or steel guideway, with a maximum speed of 25 mph (40 kph). The prototype ULTra vehicle is illustrated in Figure 1. It is based on conventional automotive technologies and battery powered.

The vehicle is equipped with two permanent and two flip-down seats and has level entry from the station: it has room for, and is accessible by, wheelchairs, shopping carts or pushchairs.

Figure 1 The prototype vehicles operating on the test track

The segregated track is low weight, since it is supporting a small scale vehicle, and the loadings from the vehicle, at 2000 Pa, are less than the design loadings for building floors at 5000 Pa, meaning that the infrastructure can be run through any building built to modern codes without the need for structural alteration. Considerable attention was given to minimising visual intrusion during the design, and in questionnaire studies less than 1% of people interviewed felt that it would be an unacceptable intrusion in their city.

ULTra Vehicle: Principal Parameters	
Gross Weight	800kg
Empty weight	400kg
Max speed	40kph
Length	3.7m
Width	1.45m
Height	1.6m
Passengers	4
Continuous power	2kW

ULTra Guideway Principal Parameters	
Overhead or At-grade	
Width	2.1m
Overhead	
Depth	0.45m
Column spacing	18m
Column diameter	0.7m
columns able to withstand vehicle impact	

The cost of elevated construction is lower than an equivalent footbridge. The smaller-scale structure facilitates running the guideway as mostly single track in interconnected loops. The network is able to penetrate built-up areas more closely than the larger-scale public transport. Stations are low-cost whether at grade or elevated, and can be relatively closely spaced to reduce walking distances to the service without affecting journey speed or capacity of the other parts of the system.

The vehicles can operate at 3 second headways or better, giving a lane capacity of 4800 seats per hour, considerably higher than either bus or rail at typical frequencies. Vehicles are controlled by two independent protection systems, with built-in redundancy. Computer simulation of the operating and control systems in the case studies suggest that passenger waiting times would average around 20 seconds, since most passengers find a vehicle waiting for them.

ULTra has completed prototype system testing on a 1 km track in Cardiff. Many Local Authorities and Airports have expressed serious interest in the system and negotiations leading to the first application are in progress.

3. THE CASE STUDIES

Although the system is operating in prototype form, it is not yet in public operation, and any assessment of it must necessarily be in the form of a desk exercise. Nevertheless, development of the prototype has provided a good basis for estimation of its costs and operating characteristics. Standard modelling techniques have been used to predict demand. The assessments described here are of three very different applications of ULTra:

- **within a large city** (Cardiff)
- **in a "New Town" context** (Corby)
- **an airport** (London Heathrow)

In each case the general approach was similar.

i) First, the general needs and policies of the area were discussed with its authorities, to establish what was expected from the PRT system and to identify major centres of activity and potential demand.

ii) On the basis of what was learnt in i), potential routes were identified and the physical practicality of constructing guideways and stations examined.

iii) Data was collected on current travel patterns to provide the basis for demand estimates for the PRT network. This was tackled differently in each study, since the nature of the available data was different in each case. Some limited surveying was necessary for Heathrow and Cardiff, but Colin Buchanan and Partners made available the demand database they had recently used to examine proposals for an LRT system in Corby (CBP, 2002).

iv) Demand was estimated. For Heathrow this was straightforward, since car park use and staff numbers, and their likely future trends, were known, and use of PRT was part of the car parking package. Demand for the Cardiff and Corby systems was estimated on the basis of conventional logit mode split modelling: in Cardiff the parameters were calibrated on a Stated Preference survey, while in Corby the Colin Buchanan model was made available, enabling a direct comparison between PRT and LRT.

v) The number of PRT vehicles needed was estimated on the basis of peak demand, and a simulation of the control system for the PRT network was used to ensure that capacity was adequate, network flows could be properly managed, and to estimate mean waiting times and travel times.

vi) The PRT system was costed. Obviously, for these desk studies, and in the absence of a proper engineering assessment of the system, these costs are uncertain, but they have been estimated on the basis of a very detailed spreadsheet, with each component identified in detail, and both guideway and vehicle costs are supported by experience gained in construction of the test track and prototypes. Contingencies of 20% have been added to the base costs. Costs might be viewed somewhat sceptically on the grounds that any innovation generally costs more in outturn than the estimates (a precept which also applies to conventional transport systems). However, as part of the EDICT project Ove Arup and Partners, who were responsible for the infrastructure design and costing, commissioned two experienced construction companies to estimate the costs of infrastructure for the Cardiff network on the basis of detailed specifications. Both companies arrived at estimates substantially less (by 30% or more) than those made by Arup originally (EDICT, 2004). Similarly, the assumed vehicle costs have been criticised as being unduly pessimistic, but it seems sensible to adopt a cautious approach to cost estimation and the original costing is retained in these case studies.

vii) On the basis of the estimated costs and demand, detailed financial and socio-economic appraisals have been made. These analyses are consistent with DfT's New Approach to Transport Appraisal (NATA) and the tabulated results given in this paper are selections from those original analyses.

4. CARDIFF

The Cardiff case study was made originally for the Department for Transport, but a much more detailed examination and appraisal of the installation of ULTra in Cardiff has been made recently for the European EDICT study (EDICT, 2004). The PRT network studied connects the city centre rail stations (Central and Queens Street), and the shopping area around them, with the rapidly developing Cardiff Bay area about 1.5km to the south. The new waterfront developments contain new offices, shops and leisure facilities, and a substantial amount of new residential development between the waterfront and the central area. The Bay area also contains the Welsh National Assembly building, the new opera house under construction, and the Cardiff County Council offices.

4.1 The network

As proposed, the system is to be developed in three Stages, with an initial pilot loop to demonstrate the practicality and reliability of the concept, then a second phase connecting the Bay Area loop with the city centre and two railway stations as shown in Figure 2: the third phase would extend the network to the north of the central area. The EDICT study examines the second phase, which has 7.7kms of single-track guideway, 80% of it elevated, and 12 stations. 134 vehicles are required to meet the predicted demand for 2006, rising to 176 by 2036.

The demand model used to predict the system's usage and transfer from existing modes of travel is a conventional logit modal split model, depending on the relative costs of travel in both time and money by the different modes (car, taxi, walk, bus, rail and ULTra). The model parameters which relate to PRT have been estimated from a "Stated Preference" survey of 358 potential users, who were each asked to choose between alternative modes for particular journeys on the basis of realistically estimated travel times and costs. Although the study is unavoidably hypothetical, confidence in this approach is given by the estimated "Values of Time" implied by the analysis, which were consistent with accepted values obtained from many previous studies (Ove Arup and Partners, 2002). The model was applied to Cardiff City's estimates of current trip-making between 330 zones into which the whole city area had been divided, based on traffic counts and transport surveys made in 2002 and extrapolated into the future on the basis of predicted demographic changes and expected new development. The latter is obviously very important to this study, where PRT is intended to serve the rapidly-developing Bay Area.

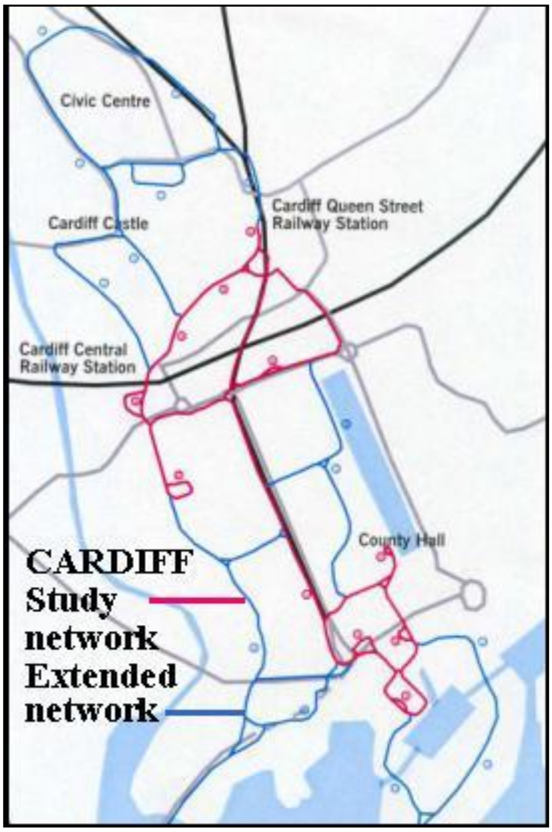

Figure 2 The proposed Cardiff network

The fare proposed is £1 (€1.50) per vehicle, about 70p per passenger at average occupancies. Focus Group studies under EDICT with people who have ridden on ULTra at the test track suggest that they would be willing to pay two or three times this amount. The demand model predicts that in the base year, 2006, the ULTra system will attract 5.67 million person trips per year, or 4.30 million vehicle trips at an average occupancy of 1.32. Demand is predicted to grow as both commercial and residential development increases in the Bay Area, rising to 5.62 million vehicle trips by 2036, the end of the assessment period.

4.2 System performance

ULTra is very competitive with bus travel, and with walk over longer distances, attracting 61% of present bus users, though only 9% of all walkers since the average walk distance is very short. However, ULTra also benefits bus and rail services by attracting 8% of present car commuters to the Bay Area to use the combination of rail or bus into the centre and then onward by ULTra, an additional 2 million passengers per year. Note that this assumes current availability and cost of car parking: parking may become more constrained in future, increasing the demand for ULTra. Although ULTra's speed is relatively low, at 40 kph, it is non-stop and provides a much faster journey then do average road speeds in the congested centre. For public transport users, ULTra has the important advantage of involving almost no waiting time, compared with a random mean wait time of 7.5 minutes for the infrequent bus services to the Bay Area, and typically 5 minutes even for more frequent services. Simulation of the ULTra operation suggests that its mean wait time is only 0.3 minutes, because most passengers do not have to wait at all.

Obviously, there are practical and aesthetic problems in running the system through existing built development, but it is potentially much easier to do this with ULTra than with any larger-scale form of tracked public transport. Installing the guideway amongst the new development in the Bay is relatively straightforward, and there are no serious impediments to constructing the infrastructure within the existing town centre along the routes indicated. Indeed, discussion with the planning authorities met a very positive response.

Safety and security have been high priority issues during focus group discussions with the public, and consultations have been undertaken with HM Rail Inspectorate from the early stages of the project, supported by independent safety experts. The Inspectorate have issued a 'letter of no-objection' to ULTra's safety case, and have authorised the carriage of the general public for the trials. The system can also offer significant benefits in personal security since travellers spend little time waiting in potentially insecure places because the immediate availability of a vehicle can be virtually guaranteed at times when few people are around. At all times, trips are only undertaken either individually or with companions chosen by the traveller. All stations will be well lit and under continuous coverage by CCTV, which will also monitor the guideway against intrusion. Direct links to the controller, including CCTV, will be available from all vehicles and from all stations.

In a Focus Group survey of people who had ridden on the trial system, all respondents found the ULTra system 'Very Easy' or 'Easy' to use, and over three quarters of respondents felt either 'Very Secure' or 'Secure' using the system. Nobody felt 'Insecure' or 'Very Insecure'. The response to all aspects of the system was very positive, with 70% or more rating each aspect as "excellent" or "good", and hardly any ratings below "average". Three-quarters of the passengers thought the elevated sections of track were "not a problem" or "probably OK", though a quarter were unsure. The ULTra system has been tested by 8 mobility-impaired people and six elderly people in two of the Focus

Groups, who considered the system to be easier to use than any other form of public transport, including taxis. An Access Audit has been made of the ULTra vehicle and station in the trial system, and this assessed accessibility for mobility-impaired people to be better than the regulatory requirements for taxis and railways. There were a number of minor criticisms connected with lack of colour discrimination for the partially-sighted, and positioning and size of control buttons in the vehicle and station, but the necessary improvements can be made easily in the final designs. The only concern which is not easily remedied is that, although the DfT "standard" wheelchair has been successfully tested within the vehicle, particularly large types of wheelchair are more difficult to manoeuvre.

4.3 Financial and social assessment

The total capital cost for the Cardiff system is estimated at £34.3M, with an annual operating cost in 2006 of £2.05M, rising thereafter as demand increases. Revenue is estimated at £4.30M in 2006, rising to £5.62M in 2036. Over the 30-year period of the assessment, the Net Present Value of the revenue less costs is +2.71M at a 3.5% discount rate (a rate considered appropriate to public investment in innovative systems provided measures have been taken to reduce risk), and -£8.27M at 6% (the standard public investment discount rate). The demand forecasts are considered to be conservative, and the out-turn performance seems likely to be better than this, especially so since a system which provides such an improved level of service will encourage entirely new trip making. Thus the system easily covers its operating costs, and seems likely to cover its capital costs in full at public project discount rates, but does not provide the higher rates of return demanded for purely commercial operation. It is likely to require some public subsidy for its infrastructure, but at a level which is very small in comparison with conventional tracked public transport. ULTra track is substantially cheaper than conventional LRT track, as is illustrated by a comparison of ULTra with five recent UK LRT systems which showed a mean cost per one-way LRT route-km some 70% higher than for ULTra (EDICT, 2004), yet ULTra has a passenger-carrying capacity as great as LRT at 4800 seats per hour one-way at a 3 second headway.

In addition to the financial returns described above, an assessment of this public scheme needs to include various other social benefits accruing to both users and non-users of the system. These cannot all be monetarised, but they are important because they may contribute to the local policy objectives. The monetarised benefits include:

- the savings in travel time and money accruing to the ULTra users compared with their previous journeys, estimated as the change in the weighted costs of the time components of travel when ULTra is introduced, plus the saving in car operating cost of those car users who transfer. In 2006, this is £3.29M.
- the reduction in congestion, whereby those travellers who continue using the roads benefit from reduced delays as some car users transfer to ULTra. By applying the predicted reduction in total car-kms to the mean speed/flow relationships applicable to Cardiff's roads it is

estimated that 953 passenger-hours will be saved each day (in 2006), or 348,000 per year, with a value of £1.67M per year. In practice the reduction in congestion will encourage some travellers to drive into the city when before they used other modes or went to more local destinations, and this will erode the time savings (though giving benefit to the new travellers), but the extent to which this happens will depend on the City's policies towards traffic restraint.

- ULTra is a safer mode of transport than either car or foot, and the consequent reduction in accidents can be estimated on the basis of broad average accident rates, and the saving in fatalities, severe and minor injuries costed at standard UK rates. The value of this is £0.52M in 2006.
- The saving in energy, at 9.4 GWhr in 2006, can be costed at the current price of electricity in the UK of £0.08/kWhr to obtain a benefit of £0.92M per year in 2006.

These costs and benefits are summarised in Table 1.

Table 1 Summary of benefits and costs estimated from 2006 to 2036 for the proposed Cardiff network

	in first year		**NPV over 30 years at 3.5% pa**		**NPV over 30 years at 6.0% pa**	
	£M	***€M***	**£M**	***€M***	**£M**	***€M***
Financial assessment						
Total capital cost	34.3	*51.5*	48.2	*72.2*	45.6	*68.3*
Operating cost	2.05	*3.08*	44.6	*66.9*	32.6	*48.9*
Revenue	4.30	*6.45*	95.5	*143.2*	69.9	*104.8*
Revenue – op cost	2.25	*3.38*	50.9	*76.3*	37.3	*56.0*
Net NPV			**+2.71**	***+4.07***	**-8.27**	***-12.41***
Social cost-benefit assessment						
Passenger time/ car operating costs saved*	3.96	*5.94*	115.8	*173.7*	81.5	*122.2*
Congestion time saved*	1.67	*2.51*	48.9	*73.3*	34.4	*51.6*
Energy saved	0.92	*1.38*	20.5	*30.8*	15.0	*22.5*
Accidents saved	0.52	*0.78*	15.3	*23.0*	10.8	*16.2*
Total net NPV			**+203**	***+305***	**+133**	***+200***
Benefit/Cost Ratio	**27.2%***		**521%**		**392%**	

* *First year rate of return*

The ULTra vehicle is battery electric and lightweight: its energy consumption per passenger-km is about a fifth that of a car, one third that of rail, and about half that of a heavily laden urban bus. Consequently there are substantial savings in energy use, estimated at the equivalent of 3 million litres of fuel per year in 2006, and parallel savings in emissions. The effects of air pollution on health are serious, and there is evidence to suggest that particulate emissions from traffic may cause more premature deaths than road accidents, but there is no accepted basis for monetarising these benefits. After allowing for the pollutants emitted by the power stations which generate the electricity to recharge the vehicles' batteries, it is estimated that, over the base year 2006, installation of the ULTra system reduces total emissions by 45 tonnes of carbon monoxide, 3.6 tonnes of volatile organic compounds (VOCs, or hydrocarbons), 5.7 tonnes of nitrogen oxides (NO_x) and 0.30 tonnes of particulates or black smoke. The saving in energy also corresponds to a reduction in the greenhouse gas carbon dioxide (CO_2) of 3750 tonnes.

Ecological effects are small, since the footprint of the guideway is small, and in the Cardiff application there is no appreciable loss of habitat. The use of de-icing agents in winter may cause some nuisance, however, and will require careful management. ULTra offers noise levels which are likely to be undistinguishable from the background noise, and will cause no vibration problems in the buildings it passes. The guideway has to be segregated, and there are potential problems of community severance here, but in practice much of the track is elevated so that footpaths can pass underneath, and it will pass over all roads it crosses. The design intention is to cause no added severance. There are unavoidable problems of visual intrusion, but these can be minimised by the small scale of the infrastructure and careful design, and will be far less severe than with other forms of tracked public transport. In some aspects the system can add positively to the cityscape, creating an exciting and dynamic addition, especially where it can be integrated directly into new development.

5. CORBY

This case study of the application of PRT to a "New Town", where it would connect extensive new "greenfield" development with the town centre, was made as part of a project for the DfT, but with interest and support from Corby Council and the Catalyst Corby Urban Regeneration Company. However, it also offered a valuable opportunity to compare PRT with LRT, because Colin Buchanan and Partners (CBP) had recently made a feasibility study for LRT (ie a "supertram") linking the town centre with the new development areas. CBP were particularly helpful in providing the data on which their feasibility study was based, and the mathematical model they used to predict demand.

5.1 The network

CBP identified an alignment and described an LRT system consisting of two lines, with Line 1 running from an area designated for new development to the southwest, through the town centre and via an industrial zone into an area planned for substantial new growth in the northeast. Line 2, which would not be opened until 2016 when new development was beginning in the areas served, runs east from the town centre through two industrial areas to new developments to the east. The whole system required 14.2 kms of two-way track, and 17 stops. The ULTra network examined uses six large open loops of guideway, occupying the same SW to NE corridor as LRT's Line 1, and the west-east corridor of Line 2, but servicing a much broader area of access. Both LRT and PRT networks are shown in Figure 3.

It is obviously straightforward to integrate the infrastructure with new construction in the development areas, but it is also the case that even the older areas of Corby offer adequate space for the ULTra guideway, though there are potential concerns about visual intrusion and vandalism in a few places. The pedestrianised shopping centre is planned for redevelopment and is ideally suited to accommodating PRT at first-floor level, with stations inside the shops. There are 30 kms of ULTra guideway and 31 stations, and overall 44% of the guideway's length is elevated. The system is designed for construction in two phases, beginning operations in 2008 on the SW to NE network and in 2016 on an additional loop to the east, paralleling CBP's Line 1 and Line 2.

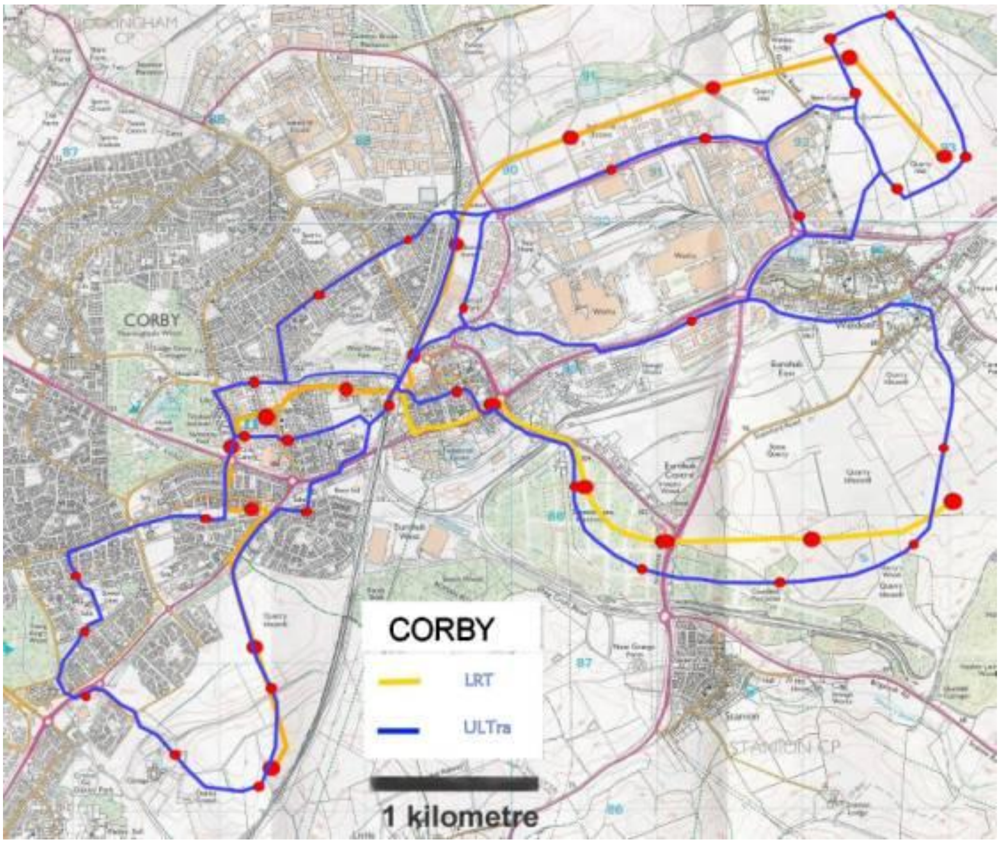

Figure 3 The proposed Corby PRT and LRT routes

The dispersal and control of the PRT vehicles is crucial, and the system must have sufficient vehicles to ensure that it can always meet the peak demand at any point on the network. Detailed computer simulation shows that the system will require 365 vehicles initially, rising to 895 at the start of Phase 2 and a maximum of 967 in 2021 when the system would carry over 38,000 passengers per day. The average wait time is only 17 seconds.

5.2 Financial and social assessment

At the start of operation in 2008, the infrastructure of Phase 1 has 13 kms of guideway at grade and 10 kms elevated, with 25 stations. The capital cost is £68.2M, including vehicles. Operating costs would be £3.3M per year. The vehicle requirement and operating costs increase with demand, until Phase 2 opens in 2016, adding 7.3 kms of track and another 6 stations, plus additional vehicles, to a cost of £25.2M. The combined operating cost of both Phase 1 and Phase 2 is £5.1M, and the total capital costs of the system at 2016 are £97.6M, rather higher than the £93.5M of the LRT system, which is shorter and has fewer stations, but the main difference is due to the large number of PRT vehicles required to carry many more passengers than for LRT. It is also the case that the LRT cost estimates for Corby are substantially lower than the mean of recent LRT systems, as surveyed in EDICT (2004).

The CBP modal split model was applied to the ULTra network using seven fairly coarse zones and the CBP trip matrices. At the start of the 20-year period modelled these zones accounted for 69% of trips in the town, and by 2027, after much new development, for 76% of trips. Although this study uses the CBP model and data, some details of the trips between the seven zones were no longer available and had to be synthesized from the zonal trip totals. The present study showed excellent agreement with the CBP study for patronage and revenues on LRT in 2027, but in earlier years it predicted slightly greater usage of LRT than the CBP study. Consequently, the results are not directly comparable with those of the CBP study. Treatment of ULTra and LRT within this study is exactly comparable, however. It is assumed that ULTra will charge a flat fare of £1.50 *per vehicle*, because at the assumed average occupancy of 1.33 the mean fare per passenger is £1.13, close to the mean LRT fare of £1.09.

The CBP demand model predicts that ULTra would attract 19.3% of trips made in the seven zones, compared with 11.4% for LRT (when the full systems are operating). In particular, ULTra would capture 17% of existing car driver trips in this area (though only 8% of the mileage) and 37% of car passenger trips, compared with 10% and 21% for LRT. Overall, ULTra would carry 13.0M passengers per year, gaining revenue of £14.7M, compared with 7.7M passengers and £8.4M revenue for LRT.

Financial and social assessments of the two transport schemes over 30 years at a 6% discount rate are summarised in Table 3. Both cover their operating costs easily, but LRT revenues are insufficient to cover the capital costs, and the NPV is -£68.6M, while PRT has a positive NPV of £3.5M. However, neither of these analyses makes allowance for vehicle renewal. When this is included for ULTra the NPV falls to -£13.9M. The effect on the LRT assessment is not known. Additionally, though, the ULTra network runs close to areas outside the seven zones served by LRT, and would attract extra demand. The LRT lines are too far from these areas to benefit from additional patronage, but it is estimated that they would increase the start-up demand for ULTra by 27%. This additional demand could be estimated only crudely, but with appropriate adjustments made to the vehicle requirements and operating costs to cover it the 30-year NPV becomes +£3.8M. The network studied here has not been optimised to maximise the financial return: it is very likely that further examination of the trade-offs involved would improve its performance. There is also scope for a higher fare: a £2 flat fare (ie a mean of £1.50 per passenger) gives a 30-year NPV of +£27M.

Social benefits, comprising passenger time and cost savings (halved according to the standard “rule of a half” for modal transfer), accident and energy savings have been calculated in a similar way to those for the Cardiff study. No benefits from reduced congestion are assumed, since traffic congestion causes few problems in Corby. As Table 3 shows, these increase the NPV to £188M, excluding the additional demand from neighbouring zones. ULTra has substantial environmental benefits, and would reduce total emissions by 62 tonnes of carbon monoxide, 5 tonnes of hydrocarbons, 10 tonnes of nitrogen oxides and 1 tonne of particulates per year. It also shows a net saving of 3600 tonnes of the greenhouse gas carbon dioxide per year after allowing for emissions from the generating stations which power ULTra.

Table 2 Summary of costs and benefits of Corby PRT and LRT

	ULTra				**LRT**			
	In first year of full system, 2016		**NPV over 30 years @ 6%**		**In first year of full system, 2016**		**NPV over 30 years @ 6%**	
	£M	***€M***	**£M**	***€M***	**£M**	***€M***	**£M**	***€M***
Financial analysis								
Total capital cost	97.5	*146*	-99.6	*-149*	93.5	*140*	-93.5	***-140***
Operating cost	5.1	*7.7*	-61.0	*-92*	5.8	*8.7*	-171.3	*-272*
Revenue	15.1	*22.7*	+164.1	*+246*	8.5	*12.8*	+219.4	*+329*
Net NPV			**+3.5**	***+5.3***			**-68.6**	***-103***
Social analysis								
Passenger benefits	16.9	*25.4*	+180	*+270*	5.0	*7.5*	+51	*+77*
Energy saved	0.4	*0.6*	+14	*+21*				
Accidents saved	0.2	*0.3*	+8	*+12*				
Vehicle renewal	44.9		-17.4	*-26*				
Total net NPV			**+188**	***+282***				
Benefit/Cost Ratio*	**0.19**		**2.6**					

* *(Social benefit + revenue)/Capital cost*

6. LONDON HEATHROW AIRPORT

This case study was made as part of a project for the Department for Transport, with the collaboration of the British Airports Authority. The new Terminal 5 is scheduled to open in 2008, and this will provide a window of opportunity for redevelopment of the Central Terminal Area, since activity at Terminals 1, 2 and 3 will decline because of transfer to T5, though it is expected to grow back to current levels within a few years. The application studied was of a PRT network linking the Pink Elephant and Park1 business car parks north of the CTA access tunnel, plus the N4 staff car park, with the three terminals plus the Queens Building for administration staff. At present the car parks are linked to the CTA by shuttle bus services: Park1 has a dedicated limousine service to Terminal 1 only, Pink Elephant has a 5-minute bus services which drops passengers at the three terminals in turn and then reverses the process to pick up passengers, while N4 staff buses call at the central bus station and, at some periods of the day, at Queen's Building.

The network is shown in Figure 4. It has several stations in each of the Pink Elephant and Park 1 business car parks, and in the staff N4 car park, on the perimeter road north and northwest of the main Heathrow access tunnel. These are then connected by a guideway running through the access tunnel into a loop around the three airline Terminals of the CTA. The access tunnel has two full-height road lanes in each direction, but also a single lane on each side running in a sidebore which is too low for vehicles taller than cars or taxis. Each sidebore is wide enough to accommodate two ULTra guideways, and the lesser-used west sidebore is proposed for the system. It seems practicable to install the guideway at mezzanine level between departure and arrivals halls in all three Terminals, and if required to integrate some of the stations within the buildings, which it is planned to redevelop in conjunction with the opening of Terminal 5 in 2008.

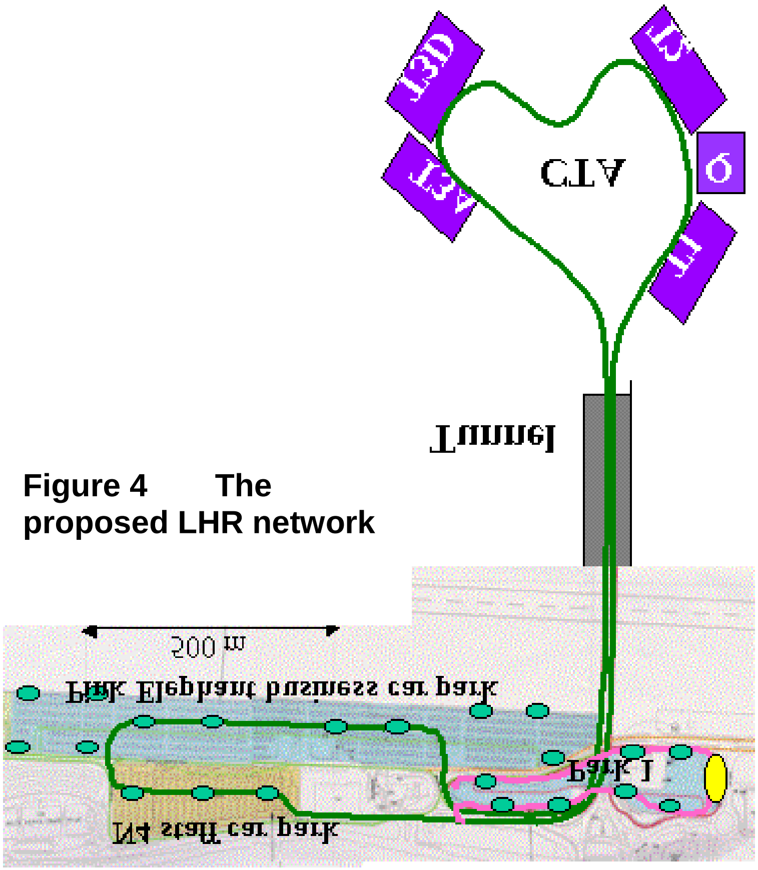

Figure 4 The proposed LHR network

Data on passenger demand to and from the car was obtained from BAA and from Atkins Planning, who are currently studying a number of redevelopment options for the CTA. Limited surveys were carried out of arrivals at the car parks to establish the shape of peak demand, and to measure passenger travel times on the shuttle buses: the journey times and waiting times assumed in the appraisal refer to relatively uncongested times of day, and are therefore favourable to the existing bus services.

The system studied has 7.6km of single-track guideway, and uses 78 vehicles to carry 8,300 passengers per day to and from the CTA. Since one guideway offers a capacity of 4800 seats per hour the system operates well below capacity. There are 24 at-grade stations in the car parks and one station per Terminal in the CTA, though these could be expanded at relatively little cost to bring passengers closer to their actual destinations, at their check-in desks, for example. Simulation of the system suggests an average waiting time of only 12 seconds.

Although the existing shuttle bus system has low capital costs, its operating costs are estimated to exceed the ULTra operating costs, providing a Net Present Saving on operating costs over 30 years at a 6% discount rate of £12.5M (€19M). The PRT system provides both business passengers and staff with a much higher level of service, cutting in-vehicle times by an average of 4.4 minutes, walking times by 1.3 minutes and waiting times by 2.7 minutes. These passenger benefits have a 30-year Net Present Value of £88M (€132M), providing a total Net Present Value of £73M (€110M). Note that here, unlike the other case studies, there is no direct revenue, since passengers pay as part of their parking package. However, the large user benefits imply that, if necessary, passenger would be willing to pay more for the improved level of service.

Environmentally, the system will reduce the local air burden by 2.9 tonnes of carbon monoxide, 0.9 tonnes of hydrocarbons, 12.9 tonnes of oxides of nitrogen, and 1.7 tonnes of particulates. Although the absence of carbon dioxide emissions at the vehicle is compensated to some extent by emissions at the power station, there is a net saving of 311 tonnes of CO_2 per year.

6. IN CONCLUSION

The three case studies reported here involve very different applications of PRT. In the case of Cardiff and Corby, where passenger revenue is compared with capital and operating costs, ULTra easily covers its operating costs and is able to make a contribution to the capital costs which is close to the 6% public investment discount rate. This performance in purely financial terms is substantially better than has been obtained from conventional public transport systems, which sometimes fail to cover the operating costs, and where subsidy is invariably required for the capital costs. The social benefits in terms of reduced travel times and better levels of service (with negligible waiting times), the attraction of substantial numbers of people from car travel, with the consequent reductions in road congestion, accidents and energy use, and reduced pollution and noise, all make a very robust socio-economic case for PRT. In the case of LHR, where PRT replaces the existing shuttle buses and there is no allocated revenue, savings in operating costs and the improved levels of passenger service, together with the flexibility and modern image of the system, make it attractive for an airport local transport system. Table 4 summarises the findings for the three applications, and includes the CBP estimates for LRT in Corby.

Table 4 Summary of the case study assessments

	Cardiff	**LHR airport**	**Corby PRT**	***Corby LRT***
Length, kms	7.7	7.6	30.3*	*14.2 two-way*
Capital cost	£34M *€51M*	-	£98M *€147M*	*£94M €141M*
Passengers/day	13,900	8,300	38,500	*22,800*
Operating cost pa	£2.1M *€3.1M*	-	£5.6M *€8.4M*	*£6.4M €9.6M*
Revenue	£4.3M *€6.5M*	NA	£15.4M *€23M*	*£8.8M €13M*
Total cost per passenger+	£0.53 *€0.79*	-	£0.52 *€0.78*	*£0.73 €1.10*
Financial NPV	**-£8.3M** *-€12.5M*	**NA***	**+£3.8M** *+€5.7M*	**-£72.1M** *-€108M*
NPV Passenger benefits	+£82M *+€123M*	+£88M *+€132M*	+£180M *+€270M*	+£51M *+€77M*
NPV Other benefits	+£60M *+€90M*	*Not calc*	+£22M +€33M	*Not calc*
Net NPV	**+£133M** *+€200M*	**+£73M** *+€110M*	**+£188M** *+€282M*	***Not calc***
Reduction in emissions: tonnes/year				
CO	45	2.9	60	
VOC	3.6	0.9	4.5	
NOx	5.7	12.9	9.7	
Particulates	0.3	1.7	0.6	
CO2	3750	311	5380	

** Phase 2*
+ Operating cost + 6% capital cost per passenger per year
♦ No revenue attributed to LHR operation

Clearly PRT has progressed from being a high-tech dream in the early 1970's to become a practical, and surprisingly economical, transport system for the twenty-first century. The ULTra system is predicted to be cheaper and better than conventional public transport, and the infrastructure costs have been checked as far as possible and seem conservative. The passenger-carrying prototype vehicle has been operating for a year now without problems.

Nevertheless, despite the robust financial and economic case which can be made for PRT, the adoption of any innovative system carries risk, in that there is no existing system on which to base experience. The Cardiff system was not intended as merely a case-study, but as a working system to be installed in the city. It has still not been installed because commissioning has become embroiled in difficulties connected with European regulations for competitive purchase, and with problems of funding and decision-making between Cardiff County Council and the National Welsh Assembly. Several other Local Authorities are interested in installing it in their towns, and have formed a PRT Interest Group which now has 15 members. Understandably, there are plenty of interested potential purchasers, but they would all rather be second than first. The Interest Group sees the need to set up a joint pilot project to demonstrate the practicality of the system in an urban context.

It seems likely that the first application will be in an airport, where the attractions are obvious. Several are interested. This would certainly be easier than an urban installation, for the system would operate in a secure environment, and potential problems of vandalism would be less. If the system can do what it promises, however, it seems likely that once it can be demonstrated in an airport environment, an urban public transport application will rapidly follow.

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