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PRT for Airport Applications

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ABSTRACT

Personal Rapid Transit (PRT) systems offer a series of new opportunities for effective solution of airport related transport problems, both on the landside and airside of the airport. A comparative analysis is offered of the potential advantages and disadvantages of this form of transport for airport applications. The work is illustrated by a case study of the application of the ULTra PRT system to serve passenger and staff car parks at Heathrow. The small scale and flexibility of the ULTra infrastructure allows use of the tunnel sidebores and provides unexpectedly simple integration with the complex central terminal area. Detailed comparisons show a benefit of 60% in trip time and 40% in operating cost over current buses. The study shows that such forms of transport are well matched to land side applications for airports. An outline evaluation of possible benefits for airside operations is also presented.

BACKGROUND

Data from the Airports Council International shows that, world wide, over 3.5 billion passengers are carried by aircraft every year. However the total number of trips of all types generated by this passenger flow is considerably larger.

The full passenger trip from starting point to boarding the aircraft has many components

1) From home/hotel/work to the airport. However, except for some public transport trips, these trips will not end at the airport terminal, but at some intermediate location such as the airport parking, or rental car, facility.
2) From intermediate location to the airport terminal proper.
3) Check-in, security and other checks.
4) From terminal to aircraft.
5) Flight.
6) From arrival gate location to terminal building.
7) Immigration /customs / baggage collection (as required).
8) From terminal to intermediate location eg car park/rental car/public transport station, etc.
9) From intermediate location to desired final destination.

The structure of the return flight is identical in principle to the outgoing.

Thus, the 3.5 billion aircraft trips each year world wide generate a need for around double the number of transfers within the terminal and up to this same number of trips for transport to and from the terminal to an intermediate location. For the purposes of the present paper trips between gate and terminal, which are normally on the far side of the checking processes, will be referred to as airside trips, and trips on the near side of this checking process will be called landside trips.

It will be appreciated that the above description is a simplification. However it is not a gross simplification. The description above does not include flights which involve interflight transfer at an airport. This is only a modest proportion of flights overall. London Heathrow airport is believed to have one of the largest proportions of transfer passengers, but even here this only amounts to 27% of all flights. Transfer flights still require an internal transfer within the terminal/airport, although they will not normally require any trips to the intermediate location. A typical hub and spoke flight operation involves both the origin and destination processes as described together with a transfer at the hub.

On the other hand "Kiss and Fly" traffic, ie passengers dropped off or picked up by car users at the terminal, requires two car trips to and from the airport for both drop-off and pick up.

It may also be noted that relatively few airport related trips world wide are undertaken by public mass transport. This is because mass transit is not widely used in most of the cities with the major airport links. Many airports do not have a link to a mass transit system

Most passengers are carried from large airports. Data from ACI is plotted in Figure 1. This shows the cumulative number of passengers carried against airport ranking, starting from the largest. It can be seen that world wide almost half of all passengers are carried from the top 50 airports and nearly 80% of all passengers from the top 150. The 50th size airport (in 2003 London Stansted) carries just under 18 million passengers per year, while the 150th carries almost 5.5 Million. All of these top ranked airports face major issues in passenger transport within the boundaries of the airport, both airside and landside.

The issue addressed in the present paper is the potential for new personalized forms of transport to deal effectively with either airside or landside passenger transfer requirements.

As discussed above the great majority of all passengers arriving at, or leaving from, an airport do so at an intermediate location. Their transport to such locations will normally be by small scale personalized transport, ie automobiles. Thus it is very natural to consider the use of small scale personalized transport for their further transport within the airport. There is an obvious match of automatic personal transport to this landside transport requirement.

The same argument does not apply for the intra-terminal transfers. Flight passengers arrive and leave in large vehicles, ie aircraft. Thus a key question to be answered for airside transport is whether small scale transport can effectively service the needs of passengers arriving or leaving in large groups.

2. AIRPORT TRANSPORT

2.1 Problems Of Bus Transport

In all airports buses are a major form of transport, particularly for landside operations. Many airports also rely on buses for airside operations. However buses suffer from a number of significant deficiencies.

- Transit times are slow due to the extended routings required
- Buses require heavy staffing. Each bus requires 5 or more drivers plus other support staff to provide the necessary full day service every day of the year.
- Landside buses operate against essentially indeterminate passenger arrivals. To provide an adequate service level for passengers requires provision of high frequencies, which in turn means that buses often run with very small loads.
- Waiting times can often be unattractive to the passengers
- Loading and unloading of baggage to and from the bus is a tedious and unattractive element for the trip for many people.

Many airports have sought to improve their passenger handling, especially on the airside, by the installation of Automatic People Movers (APMs). 25 of the top 50 airports and a further 7 of the next 100 ranked airports have installed one or more systems. Nearly all of these systems serve the airside of the airport. In many cases the APM system is a critical link in the whole airport operation, so that very high reliability is required.

There are a few airports which have installed APM systems for landside operations. Examples known to the author are the recent San Francisco and JFK links to a consolidated rental car area, Minneapolis St Paul and the much older Houston Inter Terminal Train. Interestingly, the lowest ranked airport with an APM system, ie Birmingham England, has installed this to deal with a landside rather than an airside requirement. This indicates that there could be potential for further use of automatic systems for landside passenger transport, even in airports which do not have a need for an airside system, especially if the cost of such systems could be significantly reduced.

A second, and for many airports more significant, issue is transport of staff. Staff have to be in position before passengers and in all airports operate on a multiple shift system. For the majority of airports staff arrive at the airport predominantly by personal transport. Further although the passengers average 3 days between arriving at the airport for a flight and departing to return home, staff arrive and depart every day. This means that staff car parking and terminal transport is an important issue for all airports. For modest scale airports it may be possible to locate staff car parks sufficiently close to permit staff to walk to the terminal. But in any airport of even modest scale, which includes all 150 top ranked airports discussed above, it will be impractical to offer staff parking close to the airport terminal on simple commercial grounds. Land close to the terminal is too valuable in terms of its revenue generation for premium parking, hotels etc., to be considered for use by staff. Thus staff parking will normally be located at some distance from the terminal, possibly several km. In turn this generates a need for a substantial staff transport operation.

In essentially all cases, staff transport is by bus. But again all staff will mostly arrive at the airport either individually or in small groups. This is mismatched to bus transport for reasons which are parallel to those discussed earlier. There appears to be an excellent case for considering the use of small scale automatic transport for this application.

2.2. Issues with Conventional Transport Modes

As noted for most airports the service for passengers and staff is provided by buses. Alternatives that can be considered include light rail and Automatic People Mover (APM) systems. However such transport systems are in principle very similar to buses. They require gathering people together in groups, making them wait for service and restricting access to relatively few stations. Providing acceptable access, especially in the landside car park areas, requires frequent stops, which severely reduces average trip speed.

This is shown in Figure 2. For a stop spacing of 250 m, which is necessary to provide acceptable service in the landside car park areas, average speed is below 20 kph. In addition, passengers have to wait. For a car park, the relatively low load means that service is likely to be infrequent, at the best 15 minutes, so that overall trip times including walk, wait and journey are bound to be high. This is a fundamental difficulty in any application of conventional corridor-collective transport in landside applications. A second major problem with current APM or light rail approaches is their scale. Even a “small” scale system will use trains with gross weights of 40 tonnes or more. These require large-scale infrastructure, which is difficult to fit into a congested terminal area.

An alternative approach can be found by the use of small scale transport system, specifically Personal Rapid Transit (PRT). This paper uses the ULTra system as an example.

2.3 PRT

PRT is a public transport system intended to offer an equivalent capability to that offered by cars. In the case of ULTra, it offers transport on demand on four-seat battery-electric vehicles, automatically guided on 2m-wide concrete guideways, either at grade or elevated. Elevated guideways have a depth of only 0.45m and supporting columns at 18m spacing to minimize visual intrusion. Vehicles wait at a series of off-line stations, which can be spaced to provide any desired level of service without leading to problems in average speed. The vehicles operate at a maximum speed of 40 km/h. They carry individuals or individual groups and travel non-stop from the origin to destination, so they can maintain average speeds well above buses, matching APM or Light Rail, (see Figure 2). Guidance is by automatic location and there is a separate vehicle headway control system to ensure safe separation between the vehicles. Empty vehicles wait at stations until boarded by the next passenger, or vehicles can be run empty to a station where a passenger has arrived but no vehicle is waiting. Stations can be at grade or elevated: stations on the ground are low cost and can be placed at a small spacing to reduce passengers' walking time.

The ULTra system (*1*) (Figure 3) has completed its first stage of prototype testing using four vehicles and two test tracks, the larger being of almost 1 km guideway length in Cardiff, Wales. The testing culminated in very successful passenger trials, for which permission was received from the Rail Inspectorate to carry the public.

3. CASE STUDY: HEATHROW AIRPORT

Detailed studies of the ability of PRT to meet transport needs have been completed for Heathrow airport. These were reported in Lowson, Gibbs and Bly (*2*)

3.1 Transport Demand

The flows of passengers and staff to and from Heathrow airport, ignoring transfer passengers, are illustrated in Table 1. The base data was provided by BAA, supported by detailed gate counts at the car parks, from which daily and peak hour totals were estimated. The figure indicates the large scale of people movements to and from London Heathrow (LHR).

	Non-transfer passengers			**Staff**		
	% by mode	**Per day**	**Peak hour**	**% by mode**	**Per day**	**Peak hour**
Car	39%	43,230	3,242	76%	28,120	5,624
Taxi/Minicab	27%	29,637	2,223	1%	370	74
Bus/Coach	13%	14,484	1,086	11%	4,070	814
Underground rail	13%	14,596	1,095	6%	2,220	444
Mainline rail	8%	9,359	702		-	-
Other	0.2%	223	17	3%	1,110	222
Total	100%	111,419	8,356	100%	37,000	7,400

Table 1 Modal Split of Travelers and Staff for Heathrow (2001)

Only 35 percent of passengers, and less than 25 percent of the staff, currently arrive other than by car (including taxi). LHR is committed to increasing these proportions to 50 percent - a major task. For many airports, passengers arriving or departing by taxi would simplify transport requirements because they would be arrive or leave the airport at a location close to the terminal. For Heathrow the situation is different because road traffic to the Central Terminal Area (CTA) is limited by the capacity of the access tunnel. Thus for Heathrow transferring passengers from car or taxi to an alternative system can provide substantial benefits.

3.2 Overall Description Of Routes

The detailed assessment of this case study relates to the network shown in Figure 4, which connects the large Pink Elephant long-term business car park (4950 spaces and 1 km in length), and the smaller premium car park Park 1 (781 spaces), both on the north perimeter road, with the Central Terminal Area. The two parks form an obvious pair for an initial consideration. N4 is a staff car park with 1675 spaces neighboring the Pink Elephant site. Service to N4 requires little or no further network than serving Pink Elephant and Park 1 alone.

In addition three other routes have been assessed in less detail. These include an initial scheme connecting the CTA with Park 1 which might provide a natural first opportunity for commissioning a new scheme, and extended schemes serving additional car parks, along the whole northern edge and northeast corner of the airport, and eventually the complete airport.

3.3 The Tunnel

The CTA is served by a 650 m tunnel from the north. The main part of this tunnel consists of two double track main bore sections. However the tunnel complex also includes two smaller side bore tunnels, which are less intensely used. BAA suggested that it would be acceptable to use one or possibly both side bore tunnel tunnels to carry the system. ULTra's small physical size made it possible to take full advantage of this opportunity. Two guideways can be constructed within the width of each side-bore, providing capacity for 2,700 vehicles per hour or 10,800 seats per hour, in each direction without the loss of primary tunnel capacity. If the average vehicle occupancy were 1.4, the same as that of cars using the long-term car parks, the system would carry 3,780 passengers per hour in and out of the CTA [1]. This is far more than would be required to service the long-term and staff car parks, and could accommodate wider strategies for the future development of the airport. Bearing in mind that each vehicle can carry four passengers, this capacity is parallel to that offered by many light rail or APM systems.

Even more intense use of the side bores could be obtained by using the space below the side bore roadbeds. This currently carries several services (eg gas and water mains), but in principle these could be repositioned. Use of all side bores would permit a total of eight tracks, four in and four out. This would mean that using ULTra the side bores alone would provide more passenger capacity than is currently provided by the whole tunnel complex.

This provides more than adequate capacity not only to service all other LHR car parks but also for the transfer of all "Kiss and Fly" traffic in the CTA to a PRT interchange north of the tunnel. Currently this traffic requires two car trips through the tunnel for both drop-off and pick up, but is reduced by a factor of two by the use of PRT. Overall this would require four ULTra guideways to accommodate it, to give a total capacity of 5,400 vehicles per hour, or 7,560 passengers per hour at an average occupancy of 1.4 (and substantially more if staff shared vehicles at a greater occupancy), or a total of 21,600 seats per hour. The four

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[1] This assumes a minimum headway of 2 two seconds between ULTra vehicles providing a maximum 1,800 vehicles per hour in each direction for each lane. This headway easily meets brick wall stopping criteria at the max operating speed of 40 kph using APM standard emergency decelerations for seated passengers.

guideways could be accommodated at two levels within the tunnel sidebores. Obviously, this would lose road capacity and reduce the total road capacity of the tunnel to about 3,400 vehicles per hour from the present 4,800, all now running through the main tunnel, but it would greatly increase the total *passenger* carrying capacity of the tunnel system. Since a previous study by W S Atkins estimated that Kiss and Fly accounts for 80 percent of the peak morning flow, this would leave less than a thousand vehicles requiring to use the tunnel. Naturally, these estimates are uncertain and a more detailed examination would be required, but it is clear that the potential of PRT to solve the access problems of the CTA is at least as great as that of an LRT system, since the sidebore tunnels can accommodate four ULTra guideways at two levels, while a single rail line needs the entire cross section of the side bore.

3.4 Evaluation

Current Bus Services

A comparison was also made of cost and performance of the new system versus the current shuttle bus services to the car parks. BAA provided detailed bus schedules for the staff car parks, and gave an overall figure for the cost of services, though commercial confidentiality precluded any more detailed cost information. The service in Park 1 is on demand, with limousines taking passengers to their terminal as they arrive, though on return they must request a pickup when they arrive in the terminal. The service in Pink Elephant is notionally at five-minute intervals from 06.00 in the morning to 23.00 at night, with service at 10-minute intervals between 05.00 and 06.00 and on demand (with the unavoidable delay in response) at other times. Data from the overall cost for staff services provided by BAA were interpolated and applied to the driver shift patterns estimated for each type of service.

Travel times from the car parks to the various destinations were surveyed. At peak times, especially in the mornings, traffic congestion increased these substantially and disrupted the bus schedules. Sample estimates indicated that this could increase trip times by a factor of two. In the interests of a conservative assessment, however, the journey times and waiting times used in the assessment refer to the services when operated without appreciable traffic congestion, since this is variable from day to day. Mostly, Pink Elephant buses circulated past all three terminals on a circuitous route, causing long travel times. Walking times to the shuttle buses from the cars in the car park were estimated on the basis of the mean distances. At the terminal end, it was assumed that business passengers had zero walking time into the terminals from the bus drop-off, but generally staff had to walk appreciable distances from the drop-off points. Since the actual distribution of staff destinations is not known the assumption of a three-minute walk for N4 staff and four minutes for all staff (both ends of the journey) is uncertain, but it is likely to be an underestimate of the time involved.

		Shuttle Bus Times in Minutes			**ULTra Times in minutes**		
Car park	**Users per day**	**Walk**	**Wait**	**In-Vehicle**	**Walk**	**Wait**	**In-Vehicle**
Pink Elephant	3590	1.0	3.0	12.0	0.6	0.2	5.3
Park 1	532	0.5	1.5	7.0	0.6	0.2	4.5
Staff N1/N2	3014	4.0	4.0	10.0	0.6	0.2	5.8
Staff N4	4143	3.0	3.0	8.0	0.6	0.2	5.3

Table 2 Time Comparison Bus vs PRT

The data permitted a full comparison of the times of travel by bus and PRT respectively, shown in Table 2. In every case (except Park 1 walk) PRT reduces time on each part of the journey.

The PRT system would provide 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. A comprehensive appraisal shows that the average time saving over buses is 60 percent.

Costs

The system has been costed in considerable detail, but costing at an initial stage of any project is subject to error. This is particularly true when, as in the case of ULTra, no system has been put into service. A conservative approach was adopted to estimating costs and contingencies. However, most of the components which make up the system are "off-the-shelf", and have an established cost basis. Further, a test track and prototype vehicles have already been built. These costs were found to be on target, and experience from operation of the prototype system provides confidence that uncertainties lie within the applied contingencies. It is estimated that an ULTra system connecting the Pink Elephant and Park 1 business car parks, and the N4 staff car park, to the Central Terminal Area, with 7.6km of guideway (2.4km elevated) and 78 vehicles, could be built for £23 million, and have an operating cost of £1.07 million per year.

Operation of the PRT system has been compared with the present operation of shuttle buses between the car parks and the CTA. Although the initial investment is obviously much greater with PRT than for the existing shuttle bus systems, the annual operating cost of the buses is estimated to be 65% larger than for PRT.

Cost-benefit analysis

Cost benefit analysis makes a very robust economic case for PRT. Analysis of the economic efficiency has been made in accordance with the Department for Transport's standard appraisal process that provides an estimate of wider social benefits of a transport scheme. This shows a Net Present Value (NPV) after 30 years, at a discount rate of six percent per year, of £73 million. The majority of the benefit stems from the user benefits, with an NPV of £88 million, but there is also an operating benefit to the operator over the use of buses with an NPV of £12.5 million. The overall benefit/cost ratio is 6.1:1, and first year rates of return are 22 percent in user benefits and three percent in operator benefits. Although the user benefits do not accrue to the operator, they are a measure of the users' satisfaction with the system, and if required it would be possible to recoup extra revenue because of them. There are inevitably uncertainties in estimating the costs of a new system. Although the calculations have been conservative, a 20percent over-run on infrastructure costs would only reduce the NPV to £68M, and even a doubling of the infrastructure costs would still produce an NPV of £49M. Operating costs would have to increase by 65 percent before they equate to those of the shuttle buses, and there would be a gradually increasing saving into the future as staff costs increase in real terms, since they form a larger proportion of the bus costs than of ULTra costs.

Environmental

ULTra vehicles are battery electric, making them quiet and pollution free at the point of operation, and they have substantially lower energy requirements than the shuttle buses. It is estimated that 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 per year. Although the absence of carbon dioxide emissions at the vehicle is offset to some extent by emissions at the power station, it is estimated that there would be a net saving of 311 tonnes of CO_2 per year.

Once the network is installed within the tunnel and CTA, further expansion of the system can be made at modest cost and good rates of economic return. Initial study has shown that expansion to other staff and passenger car parks would be very cost effective. PRT connections between all the terminals would give journey times which better current bus links.

4. Comparative Summary

	APM	LRT	Bus	PRT
Walking Time	Moderate	Moderate	Moderate	Good
Waiting Time	Bad	Bad	Bad	Good
Trip Time	Good	Good	Bad	Good
Flexibility	Bad	Bad	Good	Moderate
Disruption	Bad	Bad	Good	Good
Cost	Bad	Bad	Good	Moderate
Innovation	Moderate	Moderate	Good	Bad

Table 3 Comparison of Transport modes

Table 3 summarizes the relative benefits of various transport modes in an airport application. This is discussed in detail below.

Walking Time

For a landside application, especially in a car park, it is impractical to locate stations very close together for conventional forms of transport. For APM/Light Rail this is an issue of cost, since additional stations can add significantly to overall system cost. But for all conventional forms of transport, as was shown by Figure 2, frequent stop location reduces trip speed. Thus for conventional forms of transport walk times are likely to be longer than preferred by the passenger. In contrast, the low cost of PRT stops, especially if these are at ground level means that additional stops can be introduced without severe penalties of overall cost. This means that walk times can be reduced to a minimum.

Waiting Time

For landside operations wait times are liable to be long for all conventional forms of transport. This is because of the low local demand in the landside areas, which means that it is not practical on cost grounds to offer high service frequency. This problem is bypassed by PRT, since vehicles can readily be made available on demand. Studies for the ULTra application at Heathrow, using a simulation tool developed in depth by ATS, show that average wait times are reduced to below 20 seconds with the 78 vehicles used in the cost-benefit estimates.

Trip times

Trip times for APM, LRT and PRT are all low. Although APM and LRT have a reduced mean velocity because of the need to stop at every station, the delivered trip times will normally be enough to satisfy passenger service requirements. PRT has a lower maximum speed but will deliver excellent trip times because it has no need to stop at intermediate stations.

Flexibility

There are two aspects to flexibility, viz the ability to fit within the demanding space constraints of an airport and the ability for reconfiguration after installation. Buses are extremely flexible, and cause few constraints on the airport. In contrast the large scale infrastructure of APM/LRT systems can cause major problems, and force major rebuilding of other airport structures. Flexibility is also an important issue in airport development. All airports have undergone extensive and extended growth, which can be expected to continue for some time into the future. Thus the flexibility to easily reconfigure a transport system to meet new airport needs is an important aspect. By far the most flexible form of transport is the bus, which requires minimal additional infrastructure and can be reorganized at zero notice to undertake new tasks. In contrast APM/LRT systems require heavy and costly infrastructure, which is extremely difficult to change once it, is in position. PRT systems have significant flexibility benefits, with infrastructure which is easily installed and repositioned. Structure is small scale, low cost, and modular. The small scale of PRT systems provides major installation benefits. If required radius of curvature for PRT system can be as low as 5m. PRT cannot compare with the bus in flexibility, but has very major benefits over APM/LRT systems.

Disruption
The disturbance to airport operations caused by major rebuilding programs is a fact of life at most airports, but nevertheless remains a major issue both for the passengers and for the airport management. A significant negative factor for APM/LRT systems is the major disruption imposed on the airport for extended periods, typically two years, during their installation. By comparison disruption caused by PRT is minimal. This is due to the far smaller scale of the infrastructure which can be largely prefabricated as modules off-site. Although some small scale ground works are inevitable the infrastructure as a whole can be installed in months. In the case of Heathrow it is planned that installation would occur entirely during the night.

Cost
APM and LRT systems have very high overall costs. Recent APM installations have exceeded an overall system cost of $100 million per km. LRT and smaller scale monorail systems usually have lower overall costs, but these are still high in absolute terms, around $20 – $40 million per km. Buses are very low cost, since they require no additional infrastructure. This low cost is slightly artificial since there is a need for infrastructure, such as roads, parking areas etc., to support the buses. However it is unusual for this expenditure to be explicitly costed. PRT has significant cost attractions over LRT and especially APM systems. Costs can be less than $10 million per km, although the special circumstances of airport applications may add to this. For Heathrow recent cost studies, supported by detail evaluations by contractors with substantial experience of construction at Heathrow, have given overall costs of around $7 million /km of track. There are significant potential cost benefits in PRT applications for airports.

Innovation
Bus systems are most unlikely to feature any significant innovation. APM/LRT systems are normally regarded as well proven, but most systems will have a number of application specific features which will not have been previously proven in service. Poor experiences on recent installations, which has frequently led to in-service delays, reinforces this point. However, no PRT system is yet in service. The innovative issues in PRT are widely perceived as a major negative factor in the choice of PRT for an airport application and justify special discussion.

5. Risk Management for PRT

Any PRT system will be new. Adoption of a novel system obviously offers some risk to the airport, but on the available timescale this can be managed in an acceptable way. The aims of the risk management strategy are to ensure reliable and safe passenger service from day one, and to commission operation of an initial small network or pilot to confirm the operating conditions and solve the inevitable teething problems. Risk management is a critical element of the successful implementation of a PRT system and is discussed here in terms of the approach to the ULTra system

The main categories of risk reduction are:

1. Safety

The ULTra system does not fall formally within any of the existing procedures for approval of public transport systems. ATS Ltd has worked closely with HM Railways Inspectorate to establish a set of procedures for the approval of ULTra. The system has been designed with a target for safety that is better than the target adopted by the rail network for achievement by 2009. The resulting approval procedures were developed from current railway procedures and have been endorsed by HMRI. ATS has received a 'letter of no objection' from HMRI to the ULTra concept safety case. In support of the Type Approval ATS Ltd has produced an 'Intermediate Safety Case' for HMRI. ATS have been complimented by HMRI on the thoroughness of the Company's approach to safety. ATS has received permission to carry the public on the system for passenger trials. This is an important milestone for the project.

2. Reliability

ATS expects to provide aircraft levels of reliability, using experience gained in the aerospace industry. Reliability depends on adequate redundancy in the various control and communication systems and components. Compared with conventional APM systems any PRT system is inherently more reliable due to higher redundancy in the network and the use of multiple small vehicles. ULTra vehicles will be equipped with performance monitoring capability to ensure that vehicles are removed from service should key parameters fall outside set operating limits. This will minimize possible breakdowns in service. Contingency and back-up operations are planned and strategies for quick recovery have been developed.

3. Minimum disruption to the existing operations at the airport

During construction:

PRT's small footprint guideway and its modular, prefabricated construction with short assembly times will minimize disruption in the CTA;

PRT's short assembly times will also minimize disruption in the car park areas, and it can be done in a way which allows continued operation at all times.

During start-up of the PRT operation there will be:

Extensive commissioning trials over an extended period;

Extensive back up transport options.

It is considered that this combination of approaches to risk management will deliver a system which can be introduced without incurring unacceptable risk.

6 AIRSIDE APPLICATIONS

The present study is oriented purely at landside connectivity between terminal and car parks. However the passenger-carrying capacity of the PRT system is equivalent to that of many larger scale APM systems. The smaller size of the PRT system is more than balanced by the very high service frequency, in effect seconds. This raises the possibility that the system could find wide application for airside use. Key ideas in this area have been presented by Muller (*3*).

Airside application can also be associated with modern computing/information technologies to provide fully personalized treatment of each passenger. This opens up a series of new opportunities for improving the level of both the service to the passenger and the quality of the security delivered. This fully flexible approach also offers new opportunities to reshape airports, for example by using boarding areas remote from the terminal. In principle this could also eliminate the need for costly structures which are only required for boarding.

From the point of view of the passenger there are many benefits

- no standing in line;
- no extended walking or waiting;

- major improvement in the airport experience ;
- opportunity for extended in-vehicle screening of passengers without impinging on passenger time;
- passengers leave from any gate to arrive at any aircraft;
- separate bag handling possible.

A key issue is the ability to service large numbers of passengers as they leave the aircraft. This is far less difficult than might be anticipated. Measurements of passengers leaving an aircraft by the author show that rates average around 24 per minute per exit. For this application it is reasonable to suppose that passengers would fill the vehicle, ie an occupancy of 4. Thus the requirement is to provide 6 vehicles per minute. Typical loading times for four passengers for the ULTra vehicle have been measured at 16 seconds from start of door open to end of door close. (For calibration it may be noted that most elevators have door cycle time of less than 10 seconds.) Thus it is reasonable to assume that 3 vehicles can be loaded per minute per berth. This means that aircraft could be cleared at present rates by providing two berths per aircraft. It is a simple matter to provide three or more berths per aircraft if required. Although the layout, aircraft interactions, detailed passenger handling and other features require considerably more study, these initial figures demonstrate that there is no major issue of capacity.

9 CONCLUSIONS

PRT can offer a variety of benefits in application for connection of the passenger and staff car parks to the airport terminal areas. PRT offers:

- passengers the immediacy, privacy and comfort of the private car;
- the capacity of mass transport;
- little or no waiting time and closer stops;
- a system which is non-polluting and quiet;
- a guideway which is small in scale, unobtrusive, accepts small radii, turns, and steep gradients;
- a modular and flexible system for low cost and quick construction, with minimum disruption and relatively easily relocated;
- infrastructure that can be readily integrated into the airport in an aesthetically pleasing and exciting way, with stations situated inside the terminal buildings.

PRT is considered to be well suited to the landside transport needs of airports:

- it offers a saving in operating cost of 40% over current shuttle bus services;
- the estimated mean passenger time saving for Heathrow is 8.4 minutes, or 60 percent of current transfer times;
- the system is projected to have modest capital cost, especially compared to Light Rail/APM, and offers a 22 percent first year rate of return, primarily in passenger benefits;
- there are risks in any new system. For ULTra it is believed that these are manageable.

In the longer term the system could offer similar benefits for airside operations.

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Corus. This support has been fundamental in getting the project to its present stage. ULTra is a registered trademark.

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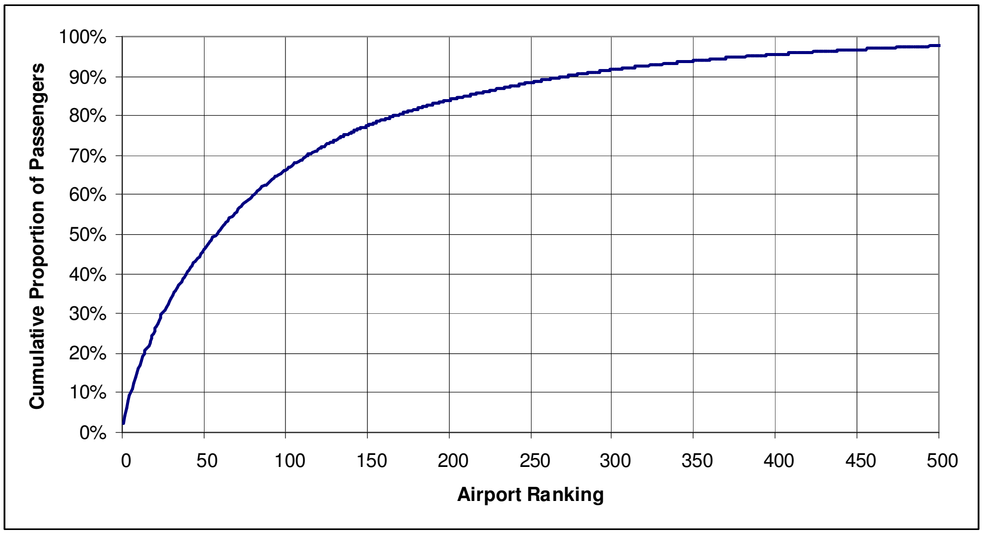

Figure 1 Cumulative passengers vs airport ranking

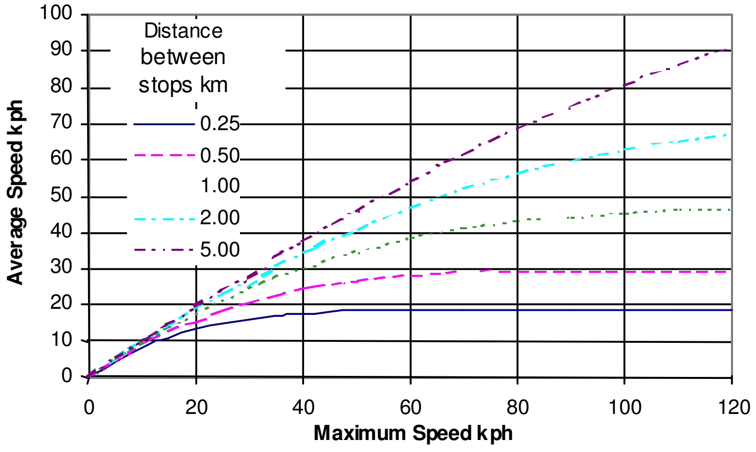

Figure 2 Average vs Maximum speed for a Collective-Corridor Transport System
(Based on 0.125g acceleration 20 second stops)

Figure 3 ULTra Vehicle on Elevated Track

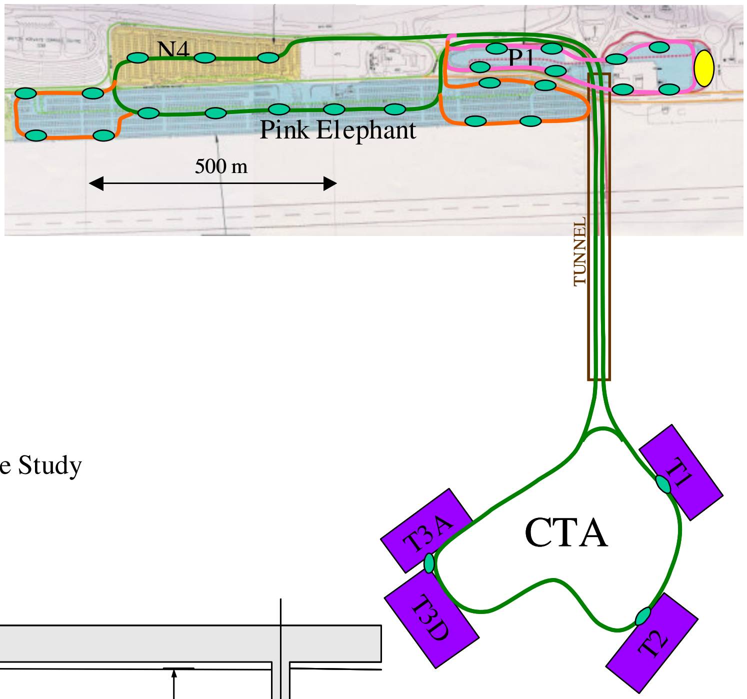

Figure 4 Route Examined for Case Study

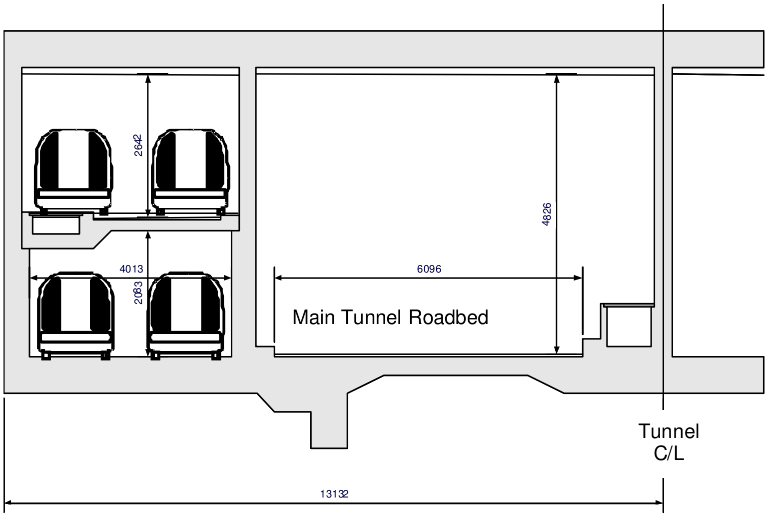

Figure 5   Potential Use of the Tunnel Side Bores by the ULTra system