Personal Rapid Transit, an Airport Panacea?

Can Personal Rapid Transit Alleviate the Widespread Surface Transportation Problems Faced by Modern Large Airports?

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Abstract. Personal rapid transit (PRT) appears to be emerging as a viable technology. PRT vehicles typically function as automated taxis on demand carrying small groups of one to six people who are traveling together. Initially conceived to solve urban transportation problems, PRT may be well suited to also solving large airport surface transportation problems.

Present airport solutions for surface transportation involve most of the following modes: shuttle buses, walking, moving sidewalks, automated people movers (APM), escalators, elevators and electric carts. This paper examines PRT's ability to replace these modes of transportation.

Using Denver International Airport (DIA) as a case study, the paper explores how the airport could have been built had PRT been available ten years ago. Three levels of innovation are examined: conventional - replacing existing wheeled modes (shuttle buses and APMs), unconventional - using PRT within long concourses and to provide continuous service from the main terminal to individual gates, and novel - opportunities for PRT to improve airport layout and functionality including widely separated runways served by remote concourses, improved security screening opportunities and consolidated waiting and concession areas.

PRT has the potential to provide improved airport surface transportation - often at less cost than existing systems. In addition it could mitigate many of the aggravations of air travel such as waiting in line, losing one's way and the continual barrage of public address announcements. PRT thus could potentially be an airport panacea.

INTRODUCTION

A 2001 Airport Consultants Council initiative identified personal rapid transit (PRT) as having the potential to alleviate airport surface transportation problems. PRT also appeared to have the ability to allow reinvention of the way in which airports are designed and operated in much the same way that automated people movers (APM) did. A very preliminary attempt to explore these (unpublished) concepts is presented. Cost comparisons (necessarily constrained by the lack of hard PRT cost data) are followed by a brief discussion of more futuristic, novel applications. Finally, some potential barriers to entry are described.

PRT appears to be emerging as a viable technology. It is defined as follows (*1*):

- Direct origin-to-destination service with no need to transfer or stop at intermediate stations.
- Small vehicles (called transportation pods or T-Pods in this paper) available for the exclusive use of an individual or small group traveling together by choice.
- Service available on demand by the user rather than on fixed schedules.
- Fully automated vehicles (no human drivers) which can be available for use 24 hours a day, 7 days a week.
- Vehicles captive to a guideway that is reserved for their exclusive use.
- Small (narrow and light) guideways are usually elevated but also can be at or near ground level or underground.
- Vehicles able to use all guideways and stations on a fully connected PRT network.

More than a dozen PRT systems are in various stages of development around the world. A transit system with many PRT characteristics has been successfully operating in Morgantown, WV, USA for some thirty years. The 2getthere system (see Figure 1) has been serving parking lots at Schiphol Airport in Holland since December 1997 with a system meeting all the definitions of PRT except that the vehicles accommodate slightly larger groups of passengers. Advanced Transit Systems Ltd. has been successfully operating a prototype of the ULTra PRT system (see Figures 2 and 3) in the United Kingdom for about three years now. In the United States of America the Taxi 2000 SkyWeb Express prototype vehicle (see Figure 4) has operated regularly for thousands of public groups since April 10, 2003 under automatic control. At least three UK and one US airports are seriously investigating airport PRT applications. London's Heathrow Airport plans to have a PRT system installed and operating by the end of 2006.

Denver International Airport (DIA), the most recent new large US Airport, will be used as a basis for this investigation. PRT applications that could have been incorporated in DIA, had PRT been available at the time, are explored. Conventional and unconventional applications are constrained to fit within the existing facilities and layout. Novel applications are explored without constraint.

Where possible, the actual capital cost of the various existing surface transportation systems has been obtained. These costs have been adjusted to 2004 Dollars. In addition, DIA has been most cooperative in providing the actual current operating and maintenance costs of their systems. In most cases DIA data has been compared to that provided by system vendors to ensure that DIA costs are reasonably representative of the industry. Passenger traffic volumes have been assumed to remain constant at the highest levels experienced to date at DIA. Infrastructure such as stations, tunnels and guideways has been assumed to have a useful life of thirty years.

PRT system costs and operating parameters are based on an average of costs provided for the ULTra, 2getthere and SkyWebExpress systems. Advanced Transportation Systems Limited (ATS) cooperated by costing out the ULTra systems replacing the shuttle buses and the APM layouts. They indicate that the costs figures provided are representative of the costs they would quote for turnkey installation, operation and maintenance of the systems. Their costs were very comparable to the average costs provided here.

The analyses of costs and benefits which follow should not be considered rigorous since they were based on numerous assumptions and averages of costs provided by vendors who had little knowledge of the different proposed systems. Since the proportion of operating to capital costs varies widely across the systems evaluated, all amounts have been converted to net present value using a 7% discount rate (*2*).

Travel time is valuable, especially to those traveling by air. The cost of time is accounted for at the FAA's cost of time ($28.60 per hour) (*3*). Systems cost comparisons are provided both with and without the cost of time.

AIRPORT SURFACE TRANSPORTATION PROBLEMS

Typical airport solutions for surface transportation involve most of the following modes: shuttle buses, walking, moving sidewalks, automated people movers (APM), escalators, elevators, electric carts and wheelchairs. In addition to being expensive (even walking is expensive if time is valuable as it is to air travelers), most of these modes contribute to the following problems:

- Waiting for transportation (usually while standing, sometimes out of doors)
- Difficulty of way finding (ease of getting lost)
- Frequent mode changes
- Total trip times not much quicker than walking
- Travel is accomplished while standing
- Travel is accomplished in crowded conditions

Other problems include: shuttle buses and escalators are not easy to use while accompanied by luggage, and APMs, escalators, elevators and moving sidewalks are commonly restricted to linear travel along a corridor with a mode change being required to move in a direction perpendicular to the corridor.

SYSTEM PARAMETERS

In order to compare PRT with other systems, vendors were contacted and asked to provide system parameters. The PRT vendors contacted were those who were likely to be capable of suitable systems for airport use. These included those with a T-Pod seating capacity of 2 to 6 people and a turning radius of less than 40 feet. The range of operating parameters gathered from responsive vendors is provided in Table 1 along with the parameters used in this study.

The Study Values shown in Table 1 can all be met or exceeded by the ULTra PRT system which has therefore been used as the reference system for this study. The minimum headway (time between vehicles) used is critical to system capacity. While some systems claim 0.5 seconds and ULTra is anticipated to be able to achieve 1 second, two seconds has been used in this study. The British Rail Authority has already approved ULTra to carry members of the public at three seconds and two seconds should be readily achievable. Failure-modes-and-effects analysis (FMEA) has shown that it is practical to design a PRT system with a minimum safe headway under one second (*4*).

The capacity of the ULTra PRT system is therefore 4 seats x 60 minutes x 60/2 seconds = 7,200 seats per hour. In peak periods two or more passengers at a station are likely to discuss their destinations and share rides rather than wait for the next T-Pod. This is particularly true for travel in a secure airport environment and for most scenarios studied herein that have relatively few stations arranged more or less linearly. Thus it seems reasonable to use a 2.0 occupancy (passengers per T-Pod) factor for peak periods yielding an hourly capacity of 3,750 passengers per one-way guideway. Note that this figure doubles should one second headways be achievable.

APM parameters are provided in Table 2. The Study Values used are those for the existing DIA APM. It can be seen that they are not unusual compared to the vendor responses. The hourly capacity of the DIA APM is 62 passengers x 4 vehicles x 60 minutes x 60/160 seconds = 5,600 passengers per hour per direction (pphpd) with a 160 second headway.

CONVENTIONAL APPLICATIONS

The costs and benefits of PRT are compared to shuttle buses and APMs.

Shuttle Buses

The shuttle bus system serving the DIA long-term parking lot west of the western short-term parking garage was used as a basis for comparison. It was assumed the PRT system would operate 24-7, provide a similar or better level of service and thus carry the same number of passengers as the existing shuttle bus system does.

Shuttle Bus Operations and Costs

The capital costs of the shuttle bus system that were considered include the buses and stations. Operating costs included the vehicles and personnel. Operating times and characteristics were determined by limited on-site observations and verified as reasonable in discussions with DIA.

PRT Operations and Costs

The PRT guideways would be elevated to keep them separate from automobiles even though some PRT systems do not require this separation. Elevated guideways provide a minimum clearance of 10’ over parking access routes and 16’ over roads.

All stations are off-line and at ground level. In all cases the guideway up and down ramps connecting the stations to the overhead guideways have maximum slopes of 10% or less.

It was found that the existing parking lot layout could easily accommodate a PRT system with little disruption. Had the lot been originally designed for PRT service, it could have accommodated at least as many automobiles as it does presently.

Table 3 provides the comparative numbers obtained for the shuttle bus/PRT parking lot systems. It is apparent that the PRT system costs more to build than the shuttle bus system. Operating costs are almost identical. While passengers save time with PRT, this system carries too few passengers to offset the additional capital cost.

Automated People Movers (APM)

Table 4 compares the costs and benefits of using PRT vs. the APM to link the DIA terminal to Concourses A, B and C – a total one-way distance of 5,050 feet. The travel times from the Terminal to Concourse B have been assumed representative of the average system travel times.

APM Operations and Costs

The capital costs of the APM system that were considered include the trains, guideways, stations, tunnels and the maintenance facility. Operating and maintenance costs include the vehicles and personnel. Operating times and characteristics were provided by DIA and verified by limited on-site observations and comparison with information provided by various APM vendors.

The two tunnels constituted a significant portion of the APM costs. They are each 17'-10" wide by 18'-0" high and include emergency walkways.

PRT Operations and Costs

PRT stations could be accommodated in a slightly smaller space than the APM stations (see Figure 5). In order to match the APM capacity, four PRT guideways are required. The PRT guideways were laid out in pairs with each pair occupying a tunnel of similar width to that required for one APM guidway. This still leaves enough room for a walkway between each pair of guideways. The tunnel height required by the T-Pods is only 8 feet. This provides significant tunnel and station savings since it allows the total depth of the system to be reduced by 10 feet. PRT tunnel costs have been conservatively assumed to be 50% of the actual APM tunnel costs.

Vertical stacking allows four (or possibly even six) PRT guideways to fit in one existing APM tunnel. PRT could more than double the existing tunnel capacity. Alternatively it could provide increased capacity as well as an emergency pedestrian walkway located above or below the guideways.

While all stations are off-line they have been kept consolidated at the center of the terminal and concourses reflective of the way the APM operates. They would be served by a similar system of escalators and elevators. The number of elevators and escalators has been assumed to be the same although the PRT system would deliver people in a mostly steady stream thus potentially allowing a reduction in these systems.

The somewhat complex station guideway layout allows any T-Pod to quickly bypass the station or stop at the station and proceed in either direction. It also allows each tunnel to have bi-directional flow. In this way the system could continue to operate despite one of the tunnels being closed by an incident. A simplified station layout is achievable if the redundancy of bi-directional tunnel flow is not required.

Table 4 provides the comparative numbers obtained for the APM/PRT Terminal to Concourses A, B and C system. The PRT system reduces all relevant system performance parameters (trip times, capital and operating costs as well as net present values) by 50% or more, in addition to providing a seated ride for all passengers and to reducing the need to intermingle with other passengers.

UNCONVENTIONAL APPLICATIONS

PRT has the potential to replace existing non-wheeled forms of transportation such as walking, moving sidewalks or even elevators. These are applications generally considered unsuitable for wheeled transportation. In the two examples which follow, the PRT systems are designed to function within existing airport infrastructure without significant impacts on the way the airport operates. While they would expedite surface transportation they would not change the routes or flows.

Intra Concourse Surface Transportation

Many modern airports require significant walking distances within their long concourse buildings. Typically these buildings are as long as one mile and are served by one centrally-located APM station connecting the concourse to the terminal. Walking is often facilitated by moving sidewalks. Handicap transportation is typically provided by wheelchair and/or electric cart, both of which are labor-intensive. Detroit Metropolitan Airport and Minneapolis-St. Paul International Airport are the only airports known to the author to have installed an APM within a concourse to facilitate passenger movement from the central APM station to the gates. These APMs are elevated above the concourse floor level and must be accessed by escalator or elevator. This is a deterrent to their use.

The costs and benefits of an in-concourse PRT system are compared to the existing system of moving sidewalks and electric carts operating in DIA's 3,500 foot long concourse B. Figure 6 shows the layout of an in-concourse station. The PRT stations would be at concourse level and would be connected to elevated guideways (the original concourse design anticipated potential future elevated guideways) by up- and down-ramps sloping no steeper than 10%. Each station and its ramps would occupy a footprint shorter and generally narrower than the footprint of the existing moving sidewalks which are approximately 24 feet wide and 200 feet long. Since each of the six moving sidewalks would be replaced by one PRT station, the system would occupy less concourse floor space and would not significantly change existing traffic flows. An additional station would be located in the center of the concourse directly above the APM station.

Ridership on the system has been assumed to be 75%. Another assumption is that the PRT system would eliminate the requirement for electric carts and reduce the number of wheel chairs by 80%.

Table 5 provides the comparative numbers obtained for the Moving Sidewalk/PRT Concourse B system. While the capital costs of the PRT system are greater than those of the moving sidewalk system, the operating costs are very similar. When the cost of time is accounted for, the PRT system costs 64% the existing system.

It is noteworthy that the capital cost of the Minneapolis-St. Paul Concourse C tram system is reported to be more than double the PRT capital cost in Table 5. This despite the fact that the length of concourse served by the PRT system is 20% greater.

Inter Concourse/Terminal Transportation

The trip from the terminal to the gate typically originates at the ticket counter and is sometimes interrupted by a visit to a restroom or restaurant. It is always interrupted by security screening. Assuming the portion of the trip from the ticket counter to the security checkpoint is unsuitable for any mode other than walking, the origin is the security checkpoint and the destination is the gate.

A PRT system combining the APM replacement and the intra concourse systems described in the previous two sections is an application made possible by the small guideway radii that are feasible. The two systems are combined by guideways spiraling up the station cores of the concourses. These guideways would replace the escalators and elevators currently used to transport passengers between the concourse level and the underground APM station.

The existing station cores are large enough to accommodate a radius of more than one hundred feet. One trip around such a spiral would take about 20 seconds and result in a grade change of more than 60 feet – sufficient to reach the in-concourse guideway from the tunnel level. The PRT system would thus allow a non-stop, seated trip from security screening to the gate.

An analysis of the costs of such a system has not been undertaken. Suffice it to say that the cost of the spiral guideways would probably be offset by the elimination of the underground station and its associated escalators and elevators. The ridership of the in-concourse portion of the system would no doubt increase since outbound travelers could select their gate as their destination and get there without stopping. Inbound travelers would have a similar non-stop trip.

NOVEL APPLICATIONS

While the following novel applications make not occur for many years, airport master plans typically have a twenty-year horizon. Airport planners therefore need to be cognizant of these opportunities.

Novel applications (unconstrained by conventional airport facility layout) would allow significant improvements in the way airports are planned, designed and operated. They are applicable to all airports so comparisons with DIA are not made in this section. These applications arise because of PRT’s unique characteristics as well as the capabilities presented by other emerging technologies. Rather than developing novel application scenarios, the following examples illustrate opportunities enabled by PRT and other compatible technology.

PRT is a public transit system that mimics the characteristics of automobile (mostly private) transportation; small groups of people traveling to the same ultimate destination share vehicles. Because a PRT station operates like a taxi stand (continuously whisking people away), crowds should not form at stations or in vehicles. Small guideways are lightweight, quick and easy to construct. Additional guideways can be built in a network to add capacity and system redundancy. These features result in PRT being more resistant than other transit systems to gridlock caused by unforeseen problems on any one guideway and inherently less attractive to terrorist attack.

Airports such as Los Angeles International have considered enhancing terminal security by conducting prescreening of passengers at APM stations in remote parking lots. This solution has been criticized (*5*) as merely relocating the terminal security problems to the stations in the parking lots. In addition, the APM systems transporting passengers from the parking lots to the terminal themselves become potential targets. PRT technology enhances security by having numerous small stations in the parking lot. T-Pods could carry people to a centralized screening facility and deliver screened passengers to the terminal building. A previous paper (*6*) discusses how this can be accomplished without ever allowing a crowd of unscreened passengers to develop.

Automated check-in kiosks have recently become popular. Airports such as Las Vegas have common-use kiosks which are not airline specific. The technology already exists to make such kiosks wireless and incorporate them inside T-Pods. The airport design paradigm changes enabled by this combination of technologies are limited only by the imagination. Since ticketing, check-in, boarding pass and bag tag transactions could be accomplished while traveling in a T-Pod, the need for a terminal building to accomplish these tasks goes away. If security screening is accomplished in a specialized facility as discussed above, then no real reason for a terminal building remains beyond a place to wait for departure.

Waiting for departure could be accomplished at the gate. However this requires duplication of restrooms, concessions and other facilities. Consolidating waiting, restrooms and concessions into one facility makes sense for numerous reasons. Consolidated concessions can be larger and offer more variety. Consolidating waiting and concessions potentially generates more airport revenue. In this way the terminal remains but its function is primarily for waiting and concessions.

If the PRT system could notify the passenger (say by cell phone or pager) when they are needed at the gate by the airline, waiting at the gate could be reduced or eliminated. This just-in-time passenger delivery would reduce the need for facilities and eliminate the need for concessions at the gate.

Since the PRT system would deliver passengers to a station in close proximity to their gate, the need for gates to be joined together in long concourses would go away just as the need to join concourse fingers to the terminal went away with the advent of APMs. This means that gates could be clustered in small groups served by small buildings surrounded by aircraft parking aprons. There would be no need for such small concourses to be near each other or the terminal building. In effect the PRT system would take passengers to the aircraft as opposed to current airport layout which brings the aircraft to the passengers. The system thus facilitates the construction of remote runways. It also potentially facilitates the operation of two airports as one since secure passengers could be transferred from gates at one airport to gates at the other.

Most PRT systems are designed to carry luggage, pushchairs, wheelchairs, etc. in addition to regularly seated passengers. With a little adaptation they could exclusively carry luggage and do so very efficiently. Thus PRT systems have the potential to also replace baggage systems. While security requirements dictate that outbound passengers and their bags must travel separately (in separate T-Pods) to the gate, this does not apply to inbound passengers. Inbound passengers could collect their bags at the gate, board a T-Pod and travel directly to their parked vehicle or other on-airport destination without stopping.

BARRIERS TO ENTRY

Of all the potential barriers to entry faced by PRT systems, the lack of existing systems operating in the real world is surely the greatest. Simply put, most airports are reluctant to be the first to try something new. The new high-speed baggage handling system that delayed opening by more than a year at DIA has not been forgotten. Even APMs which are supposedly a mature industry, continue to suffer problems with new installations. However, APMs no longer suffer from this barrier and, now that London's Heathrow Airport has committed to have a PRT system running in 2006, PRT systems should soon also overcome it.

Capacity concerns are another potential barrier. Many people find it difficult to understand how sufficient capacity can be obtained with small vehicles. This barrier can be superficially addressed by pointing out that highways operate with considerable capacity utilizing similar-sized vehicles. In order to truly overcome this barrier, PRT systems will have to put theory into practice and demonstrate that they really can operate safely at small headways thus providing high capacities.

System reliability will also have to be proven by full-scale operations. While the typical network of guideways provides redundancy, can the control systems seamlessly reroute the T-Pods? Can the systems become overloaded with resultant gridlock?

Public fear of travel in automatically controlled vehicles is probably no longer a barrier to entry. DIA has been operating with an automatically controlled APM as the only means of accessing most gates for ten years. While the system has not operated flawlessly, public fear of traveling on it has not been an issue. The smaller size of PRT vehicles may result in increased apprehension but public trials (*7*) have not indicated this to be significant.

The not-in-my-backyard (NIMBY) syndrome is certainly a potential barrier to entry for PRT in general. However this is not expected to be an issue on airport property. In fact, airports may welcome the futuristic look and feel of overhead guideways carrying modern-looking self-guided vehicles.

CONCLUSIONS AND RECOMMENDATIONS

Personal rapid transit may indeed be an airport panacea for dealing with surface transportation issues. While probably not economically viable in isolated applications with low traffic volumes, it appears able to provide superior high-volume service at lower cost than conventional systems. It could have the ability to dramatically alter the way airports are designed and operated – even the potential to put the joy back into flying by reducing waiting in line, losing one's way and the continual barrage of public address announcements – all this while improving security too. However, more rigorous research is needed to substantiate the findings presented here.

A persistent effort to implement PRT systems will be needed to overcome the barriers to entry. Once PRT is accepted in airports and its benefits fully understood, urban implementation is likely to follow. However, failures of initial systems could unduly delay acceptance. Federal funding of research and pilot projects is therefore important in order to ensure that this system becomes robust as soon as possible to the benefit of the traveling public.

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LIST OF TABLES AND FIGURES

TABLE 1 PRT System Parameters

Parameter	Vendor Response Range[1]	Study Value[2]
Seating capacity	3-6	4
Operating Speed	15 – 100 mph	25 mph
Minimum Headway	0.5 – 4 seconds	2 seconds
Maximum Gradient Down	6 – 10%	10%
Maximum Gradient Up	10%	10%
Absolute Minimum Curve Radius	17’ – 60’	17’
T-Pod Height, Width, Length	5’x5’x9’ – 6’x5’x12’	5.6’x4.9’x12.1’
Guideway Width	3.3’ – 6.9’	6.9’
T-Pod Life Span	10 Years	10 Years

1. Responding PRT vendors were:
    - 2getthere, Utrecht, Netherlands
    - Taxi2000 Corporation (SkyWeb Express), Fridley, Minnesota, USA
    - Advanced Transit Systems Limited, Bristol, United Kingdom
    - Mitchell Transit Systems, Inc, Marshall, Virginia, USA

2. It should be noted that not all respondents could meet all study values. Thus some of the applications described here may be achievable by only one or two vendors. In particular, most systems could not meet the 17’ minimum curve radius. This would impact their ability to operate within the constraints of existing buildings as described but may not limit their ability to provide similar service in specially designed facilities.

TABLE 2 APM System Parameters

Parameter	**Vendor Response Range[1]**	**Study (DIA actual operating) Value**
Seating/standing capacity	(35 – 130) x (1-10) vehicles	62 x 4 vehicles
Speed	22 – 50 mph	31 mph
Minimum Headway including stops	120 – 150 seconds	160 seconds
Maximum Gradient Down	10%	Not reported
Maximum Gradient Up	10%	Not reported
Absolute Minimum Curve Radius	70’ – 98’	85’
Vehicle Height, Width, Length	10’x8’x16’ – 12’x9’x37’	11’x9’x39’
Guideway Width	3’ – 5’	Not reported
Vehicle Life Span	25 – 30 years	20 years or 1 million miles

1. Responding APM vendors were:
    - Doppelmayr Cable Car GmbH, Wolfurt, Austria
    - Mitsubishi Heavy Industries, Sinagawa, Japan
    - Intamin Transportation Ltd., Lichtenstein, Switzerland.

TABLE 3 Shuttle Bus/PRT Comparison

Parameter	**Shuttle Bus**[1]	**PRT**[2]
No. of vehicles	7	10
No. of stations	One base station with roaming stops	10
Total route length	Varies	10,600’
Ave. walk times	30 seconds	57 seconds
Ave. wait times	60 seconds	29 seconds
Ave. travel times	150 seconds	76 seconds
Total trip times	240 seconds	162 seconds
Passengers per year	463,740	463,740
Cost of time @ $28.60/hour	$884,197	$596,833 (67%)
Capital costs	$1,420,000	$19,358,000 (1,363%)
Annual operating & maintenance costs	$1,625,100	$1,587,000 (98%)
Vehicle life	5 years	10 years
Net present value	$24,062,000	$41,687,000 (173%)
Net present value incl. cost of time	$35,769,000	$49,690,000 (139%)

1. Costs provided by DIA. Times measured by limited on-site observation.
2. Based on the average of costs provided by Taxi2000, 2getthere and Advanced transit Systems Limited using the Study Values in Table 1. Mitchell Transit Systems responded with some costs used on other projects which were generally similar to those provided by the other vendors.

TABLE 4 APM/PRT Comparison

Parameter	**APM[1]**	**PRT[2]**
No. of vehicles	27	124
No. of stations	4	4 with a total of 21 bays
Total guideway length	12,100 feet	23,500 feet
Ave. walk times	Not measured	Not measured
Ave. wait times	80 seconds	20 seconds
Ave. travel times	218 seconds	115 seconds
Total trip times	298 seconds	135 seconds
Passengers per year	18,000,000	18,000,000
Cost of time @$28.60/hour	$42,614,000	$19,305,000 (45%)
Tunnel Costs	$75,305,000	$37,652,500 (50%)
System Costs	$126,204,200	$32,616,500 (26%)
Total Capital costs	$201,509,200	$70,269,000 (35%)
Annual operating & maintenance costs	$10,950,000	$4,200,000 (38%)
Vehicle life	20 years	10 years
Net present value	$356,769,000	$139,086,000 (39%)
Net present value incl. cost of time	$928,182,000	$397,947,000 (43%)

1. Costs provided by DIA. Times measured by limited on-site observation.
2. Based on the average of costs provided by Taxi2000, 2getthere and Advanced transit Systems Limited using the Study Values in Table 1. Mitchell Transit Systems responded with some costs used on other projects which were generally similar to those provided by the other vendors.

TABLE 5 Moving Sidewalk/PRT Concourse B Comparison

Parameter	**Moving Sidewalk**[1]	**PRT**[2]
No. of T-Pods	0	30
No. of moving sidewalks/stations	4 sets of 4, 2 sets of 2	5, 3-bay and 2, 2-baystations
No. of electric carts	5	0
No. of wheelchairs	35	7
Total guideway length	0	9,550 feet
Cost of time @ $26 /person/hour	$26,455,000	$15,246,000 (57%)
Capital costs	$8,585,000	$16,082,000 (187%)
Annual operating & maintenance costs	$2,510,136	$2,369,000 (94%)
Moving sidewalk, cart/ T-Pod life	15	10
Net Present Value (NPV)	$44,462,000	$50,976,000 (115%)
NPV including cost of time	$399,198,000	$255,406,500 (64%)

1. Costs provided by DIA and obtained through interviews with United Airlines staff. Times measured by limited on-site observation.
2. Based on the average of costs provided by Taxi2000, 2getthere and Advanced transit Systems Limited using the Study Values in Table 1. Mitchell Transit Systems responded with some costs used on other projects which were generally similar to those provided by the other vendors.

FIGURE 1 The 2getthere system. Note how the wheel tracks of numerous T-Pods verify the accuracy with which the guideway (defined by magnets under the surface) is followed.

FIGURE 2 ULTra elevated guideway and T-Pods.

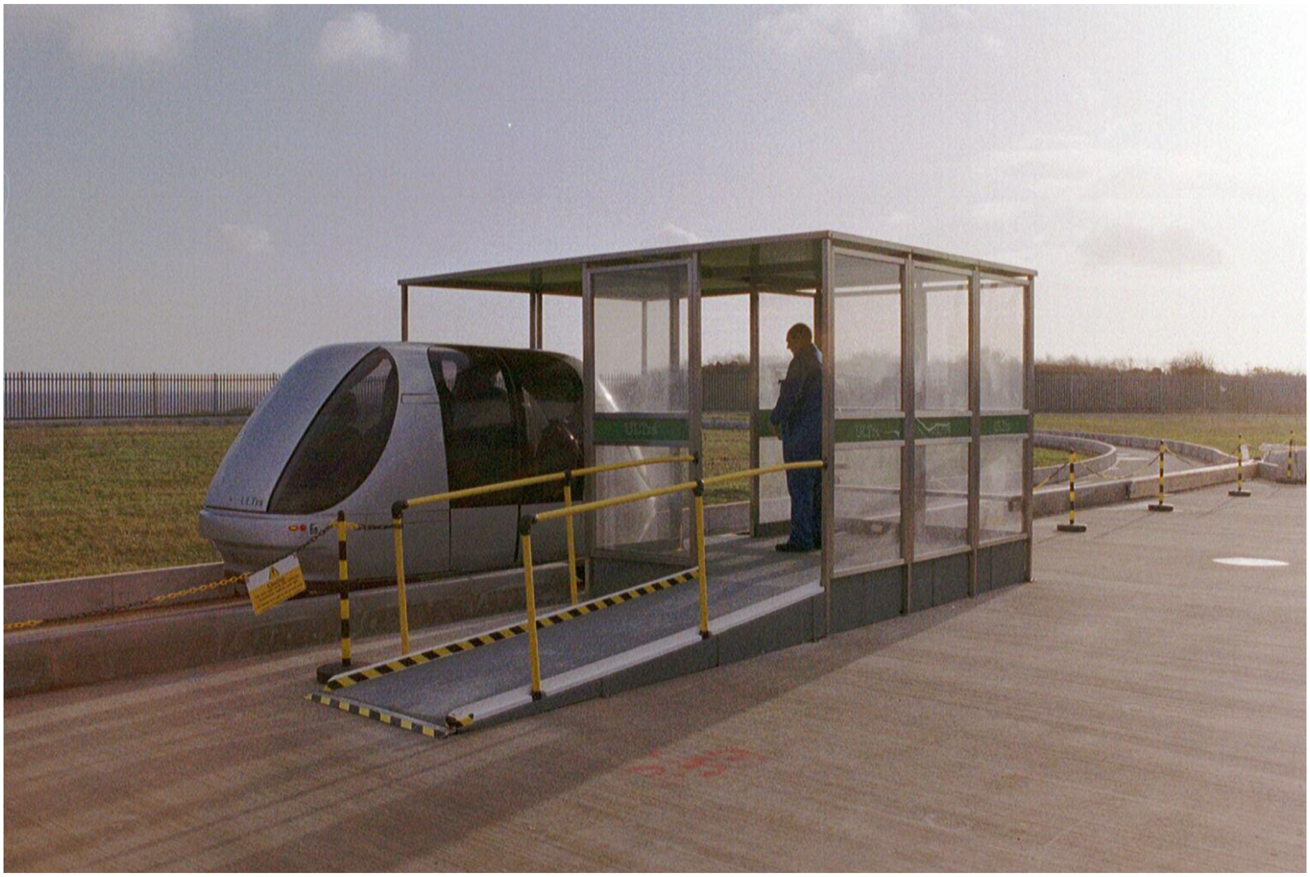

FIGURE 3 ULTra ADA-compliant station.

FIGURE 4 SkyWeb Express T-Pod.

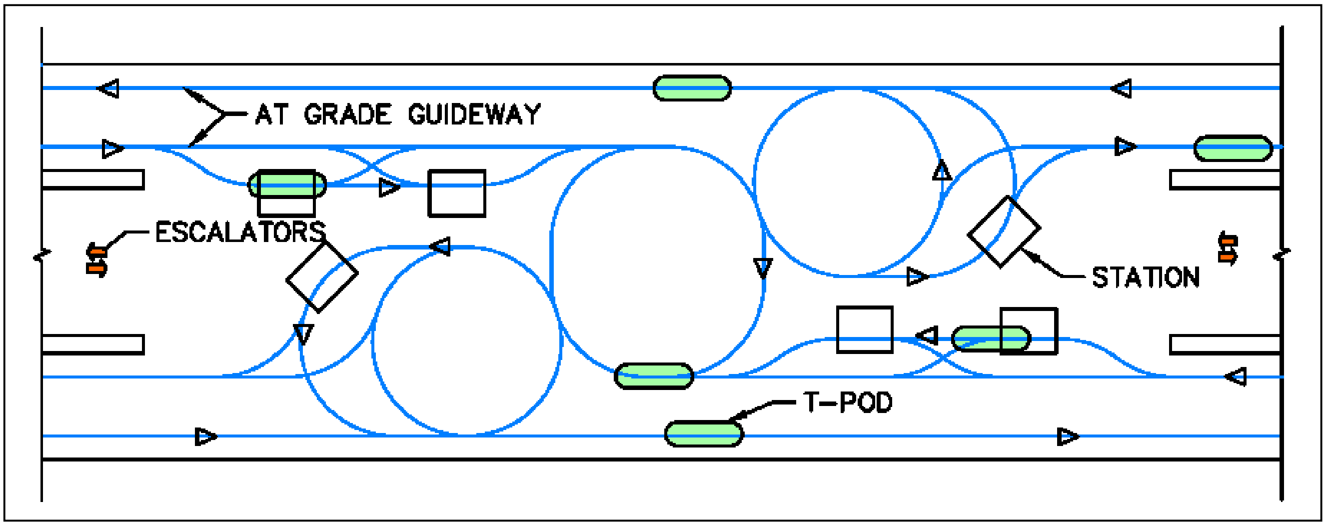

FIGURE 5 PRT station layout. This layout demonstrates how four guideways and a 6-bay station could be accommodated in two tunnels and one station of the existing APM at Denver International Airport. The somewhat complex layout allows any T-Pod to depart any bay and access any guideway while also providing guideway/tunnel redundancy by having bi-directional flow in each tunnel. Uni-directional flow results in a much simpler layout at the expense of redundancy.

Note that off-line stations (even the individual bays are off-line) are intended to reduce origin to destination travel times and prevent variations in boarding time from impacting system capacity.

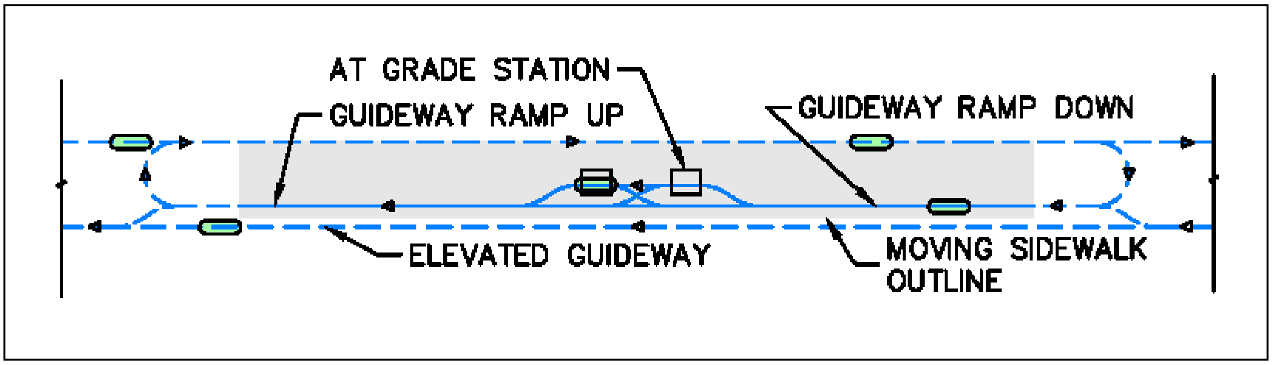

FIGURE 6 PRT station layout. This layout demonstrates how a two-bay station and its associated up- and down-ramps occupies less space than a typical double moving sidewalk (24 feet by 200feet).