# PERSONAL RAPID TRANSIT: LIVE APPLICATIONS CHALLENGES

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## ABSTRACT

Personal Rapid Transit is an energy-efficient, electric transit system with four to six-person vehicles which offers outstanding passenger service. In many applications PRT offers a higher average speed than a car, while also being more sustainable. PRT is complementary to conventional transport, making bus, rail or carpooling more effective by solving the "last mile problem." Practical operations have demonstrated both exceptional passenger response and excellent reliability.

The three established PRT manufacturers are 2getthere, ULTra PRT, and Vectus. 2getthere's system at Masdar City (Abu Dhabi) features 1.1 miles of guideway, five stations, and 13 vehicles. ULTra PRT's system at London Heathrow Airport has 2.4 miles of guideway, three stations, and 21 vehicles. 2getthere and ULTra PRT began passenger operation in late 2010. Vectus is implementing a six-mile, 40 vehicle system at Suncheon Bay, South Korea.

The vendors co-operated to provide joint experiences, with emphasis on planning, designing, constructing, operating, and maintaining the infrastructure and systems.

## INTRODUCTION

Personal Rapid Transit (PRT), an automated taxi-like service concept, has the qualities to provide the mobility desired in a modern city, while also meeting sustainability requirements of the sustainable city, without having to compromise on any other aspect of the development of the dwelling. PRT offers on demand transport, direct and non-stop to the desired destination. PRT is a new form of public transport offering different capabilities to conventional types such as rail or bus. PRT offers a combination of the characteristics of the personal automobile, the advantages of public transportation (reduced congestion, parking) and clean technologies to ensure a sustainable transit system.

The PRT system functions as a local area network, connecting the locations within its network, and can be particularly attractive as a feeder system to conventional public transit, as well as to parking locations where access to more traditional private transit systems is provided. It can also operate as a local circulator for job centers, airports, and Universities.

There are three established PRT manufacturers: 2getthere, ULTra PRT, and Vectus. Each have an application in operation or realization (Table 1).

| **Company** | **Application** | **Length** | **Stations** | **Vehicles** | **Opening** |
|---|---|---|---|---|---|
| 2getthere | Masdar City (UAE) | 1.1 | 5 | 13 | November 28, 2010 |
| ULTra PRT | Heathrow Airport (UK) | 2.4 | 3 | 21 | April 2011 |
| Vectus | Suncheon Bay (SK) | 6 | 2 | 40 | Expected to open mid 2013 |

Table 1 Established PRT Manufacturers

The specific characteristics of each PRT system differ in detail. A detailed specification of current PRT systems to a common standard is maintained on-line at: http://www.advancedtransit.org/advanced-transit/comparison/prt-characteristics/. It will be noted the three systems have many features in common. All of the systems offer major new opportunities for consideration to meet requirements for transport applications. Personal Rapid Transit is attractive in comparison to other options such as cars, taxis and public transport.

## 2. BASIC ISSUES

Based on the research conducted over the past years, with various papers and studies being available through the Advanced Transit Association's website (http://www.advancedtransit.org/library/papers/), the advantages of PRT are:

1. Shared usage: one PRT car can perform the task of 30 to 40 private cars.
2. Congestion on the network is avoided through dynamic rerouting.
3. Automation leads to predictability, creating safety by avoiding human error.
4. PRT provides direct travel and on-demand service, ensuring trips are quicker, seamless and energy consumption is less.
5. Off-line stations warrant the level of service is not reduced if the number of stations is increased. The station density is limited only by the space available and the cost.
6. PRT guarantees the privacy of the passengers; users can allow other passengers with the same destination to board the PRT vehicle with them, but only at their choice.
7. At off peak times the level of service increases as typically a car will be waiting at the station already.

Although PRT has significant advantages, there are several aspects that need to be addressed to be able to properly configure the system for the city of the future.

**Planning:** Mobility and accessibility in particular, is an important element for people in the selection of their housing or place of work. Hence a transit system is an integral part of the urban planning. The network needs to be planned to provide the required capacity, while also minimizing its footprint to ensure space can be used for other activities.
To be able to ensure the throughput of any transit system, avoiding the congestion on 'normal' roads and avoiding using the space at grade, leaving it for other activities (such as walking), systems require a dedicated, grade-separated infrastructure (guideway). For Personal Rapid Transit the popular choice is an elevated infrastructure, a result of the costs of underground installation and working within existing spatial planning in build-up areas. The elevated infrastructure ensures that many locations are easily reached. The design of the infrastructure is a vital element to ensure the width and visual intrusion are minimized.

One clear aspect needing to be addressed is the accessibility of the stations. Where cars (and bikes) provide door-to-door transit (if parking is available at both origin and destination), the best effort for PRT requires a network with a high station density. If the walking distances are kept relatively small, accessibility is improved and the network will become more attractive to use for people in the catchment area of a station. This could impact the costs of the network, as stations are not located at grade.

**Design:** The transit system is one of many elements within a city, with each element influencing and being influenced by all of the other elements. The PRT network needs to take into account that:

- Stations need to be featured near main attractors of traffic;
- Stations need to be spaced such that the walking distance is minimized;
- The exact location for a station is based on the space available at each location;
- The routes may be restricted by the current spatial planning;
- PRT tracks should preferably be one way;
- The junctions of the PRT network should preferably allow only merge/diverge maneuvers;
- On- and off ramps are required near stations and at turns

The complexity in the design is matching the architectural needs of the city with the attraction of traffic to the characteristics of the PRT system.

In parallel with the design of the route network, the locations of the PRT stations has to be determined, based on the requirement to ensure the maximum accessibility. The design constraints are basically generated by a compromise between opposite goals: achieving maximum coverage and not having an excessive number of stops, which leads to an uniform land coverage.

The network planning is closely related to the dynamic envelope of the system. This again depends on the technology selected. In the case of rail-guided systems the vehicle is wider than the infrastructure (Vectus), while in the case of system using an elevated road (2getthere, ULTra PRT) the actual road is wider than the vehicle. Local regulations can also factor into this: an evacuation path parallel to the track is a requirement in some countries, adding to the width of the system and the difficulty of integrating it into the urban fabric (and minimizing the visual intrusion at grade).

There are different designs of the infrastructure: steel and concrete being the most traditional (and common) choices.

**Construction:** The construction of the guide way and the stations is a vital phase. Any problems for the public and the existing services taking place in the implementation environment should be minimized. This means flexibility is required: the ability to fit within the demanding space constraints and the ability for reconfiguration after installation.

Flexibility is an important issue in many developments. Cities are constantly changing and are subject to extensive and extended growth – especially in developing countries. Thus the flexibility to easily reconfigure a transport system to meet new needs is vital. The basic design approach and small scale of all PRT systems provide considerable flexibility. This has been demonstrated in the applications to date

Installation of new Automated People Mover (APM) systems has proven to be a difficult task taking extended time. The installation of the Las Vegas Monorail was a comparatively straightforward installation by APM standards. In this case the time taken from ground breaking in Aug 2001 to initial operation of the 3.9 mile track in July 2004 was just under three years. In other contexts, notably airports and historic city centers, the small space available makes installation of heavy structures complex and expensive.

The disturbance to operations caused by major rebuilding programs is a fact of life for most applications, but nevertheless remains a major issue and is a significant negative factor for larger scale APM systems. 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. PRT offers the opportunity to alter column spacing with the same superstructure to overcome local ground features such as services, footways and roadways, and can operate on smaller radius curves so that fitting into existing built environments is more readily achieved. The modular construction also allows elements to be removed and replaced within a short time (such as overnight) as part of route modification or extension.

Stations are perhaps the more complex elements relative to the guide way. A station needs to accommodate the throughput expected, but can also be limited in its footprint and/or shape by the spatial planning in the area of realization. A 'standard-design' for a PRT station (one-size-fits-all) is very unlikely and the stations most of the time will be designed to the surroundings. Although the need for multiple station designs can impact the design and construction costs, this is (partly) offset by being able to integrate the system in the most favorable location.

Within stations there are different types of configurations, also dependent on the technology of the PRT system that also influences shape and size. 2getthere and ULTra recommend berths which allow arrival and departure independently from each berth. Vectus use am in-line berth arrangement. The berth layout selected will be a function of the specific application.

An important aspect to take into account is station access. With the guideway typically constructed on an elevated level, there is a requirement for either the track to come down or the stations to be constructed elevated as well. Because of the space constraints the spatial planning in existing cities pose, bringing the track to grade level is typically not a option – the length of the guideway to reach ground level becomes restrictive of achieving this. Hence stations are constructed elevated, which means stairs, escalators and elevators need to be integrated – increasing the costs of the system.

There are however opportunities to integrate the stations directly into buildings. With the small cross section of the vehicles combined with low weight, the structural load can be easily accommodated on first or second floors in most buildings. A prime example of this is the station at Heathrow Terminal 5, which has retrospectively been integrated in the existing parking garage. Which means the existing stairs, escalators and elevators can also be used. For commercial buildings, this can generate similar store- front value to these upper floors as is often attributed today to the ground floor.

**Operations and Maintenance:** Once the system is implemented the operations and maintenance phase commences. This does not only concern the vehicles, but also the infrastructure. It is a system and should be approached as such with proper care being paid to all aspects.

The maintenance of the stations is the most visual aspect. It is the first contact point of the passengers with the system and hence the first point of evaluation of the experience. There is only one chance for a first impression and an unclean, untidy or otherwise negative impression will leave a mark for the system as a whole. For the operations at Rivium, Masdar and Heathrow cleanliness has been taken into account as a key requirement, resulting in positive experiences and feedback. Where cleanliness is perhaps the most important aspect, good way-finding and good functionality of the controls at the stations is vital also. Regular checks on the functionality will need to be performed.

Where the maintenance of the guideway may be less visually impacting, it will have a distinct and clear effect on passengers when not performed properly: the ride quality will suffer. The infrastructure surface of the guideway is an important factor often neglected; it impacts comfort (noise, vibration) and the passenger experience very directly! Although the weight of PRT vehicles is limited, the consistency in driving (maximum normal lateral deviation of 1cm) means that rutting is a potential issue for systems not operating on a rail. A concrete infrastructure would solve this issue, but the longitudinal evenness (or roughness) could be a point of concern, especially as it directly impacts the ride comfort. In addition concrete provides less comfort and more noise hindrance, as well as it is more difficult and expensive to maintain

## 3. PRACTICAL EXPERIENCE WITH PRT

**2getthere: Masdar & Rivium:** 2getthere realized her first APM application, a Group Rapid Transit (GRT) system, at the Rivium business park (Fig 1). At this application the track is created at grade and allows for at grade crossings with other traffic. This is only possible as the intensity of both intersecting transit flows is low, allowing for the crossings at grade.


Figure 1 Rivium Application

The initial decision to implement the ParkShuttle transportation system between subway station Kralingse Zoom and business park Rivium (city of Capelle aan den IJssel) was taken in 1995. In phase II, the trajectory has been extended and the number of stations increased to 5. The 1800-meter track has three stops within business park Rivium. A new stop has been created to service business park Brainpark III and the residential suburb Fascinatio. The dedicated infrastructure, installed at grade, is now dual lane (with exception of the fore mentioned tunnel and bridge). Several at grade crossings with pedestrian and car traffic are realized.

During peak-hours all vehicles are operational, on-schedule, based on a 2.5 minute interval. The scheduled service ensures the capacity is optimally used, while the on-demand operations in off-peak hours ensure the passenger service is maximized. The business park Rivium case is a good example of the success of Group Rapid Transit applications. The passenger acceptance of the system is great and the experience with the operations of the system recently having been awarded to Connexxion (operating company) for the next 5 years.

2getthere was selected as the supplier for the first phase of Masdar City, providing the link to the Masdar Institute of Science and Technology (MIST) by means of 8 PRT, 2

VIP (leather interior) and 3 FRT vehicles. In this phase the network is approximately 1.5 kilometers long and features 5 stations (2 for passengers, 3 for freight). (Fig 2)

Figure 2  Masdar  PRT Application

The system was the world's first PRT system to open to the public on November 28th, 2010. The short lead time to realization was possible only due to the previous experiences with automated systems – including the installation at Rivium business park.

The system has been getting very good feedback, familiarizing VIP's with these types of systems: royalty and (prime) ministers of various countries, as well as leaders of international organizations (such as the UN) and multi-nationals. During the first year of operations the system availability has been consistently high (>99,4%), leading to a reduction of staff for the next years of operations and further reducing the costs of operations.

**ULTra: Heathrow & Amritsar:** The Heathrow pod system is in operation at Heathrow airport, London travelling between the Terminal 5 Business Car Park and the main terminal. This system, which started life as a Bristol University project in 1995– was developed by ULTra PRT, now Ultra Global. The pods carry 30,000 passengers every month, and are expected to eliminate 50,000 bus journeys on the roads around Heathrow each year. (Fig 3)

The introduction of the first ever Heathrow pod system is in addition to Heathrow's existing £4.8bn investment into improving passenger experience, while reducing the overall environmental impact of the airport's operation.

Operational data show high availability, >99%. This figure is greater than the availability delivered by any transport system currently operating in London. Of even more significance, passenger response has been exceptionally positive.


Figure 3 "Heathrow pod" PRT system

John Holland-Kaye, BAA Commercial Director at Heathrow, said: "We've been listening carefully to our passengers as part of our plan to make every journey better at Heathrow. Passenger feedback has been amazing and positive Twitter comments abound. We love watching people's reactions when they see the pods for the first time and then again when they step off just five minutes later at their destination.

The Heathrow pods offer a personal, comfortable and reliable ride that is free of emissions. That's why our excitement for this pioneering technology is being shared by town planners, architects, other airports, business parks, campuses, retail and residential destinations from the US, Europe, India, Mexico and the UK, who believe that this system could revolutionize transport in urban environments."

**Amritsar: World's first and largest urban PRT system announced**

The Punjab Government has awarded a contract for the world's first urban Passenger Rapid Transport (PRT) system in Amritsar, India to Ultra Fairwood. The foundation stone for the system was laid by the Punjab Deputy Chief Minister Sukhbir Singh Badal on December 12th 2011. At peak capacity the PRT system will carry up to 100,000 passengers a day on a 8km elevated guideway in over 200 specialist vehicles between seven stations, making it the world's largest PRT system to date. (Fig 4)

Financed entirely by private funding on a build, own, operate transfer (BOOT) basis, the passenger services will go live in 2014. This demonstrates that a large scale urban PRT system can be delivered on a financially viable, fare-based model and offer real returns for financial backers. Amritsar is home to the holiest shrine of Sikhs, the Golden Temple, and is rich in historical, religious and heritage sites. It attracts large numbers of visitors, especially during festivals and religious events, as pilgrims flock to the area. The route takes passengers from the railway and bus stations to the Golden Temple and will take 35% of daily visitors to the Golden Temple and save up to 30 minutes on the current journey times against competitive fares to alternative modes such as taxis and auto rickshaws.

Ultra Fairwood's CFO and Deputy CEO Alan Moore said "The Punjab Government and city of Amritsar are leading the world in the application of a PRT system to provide volume transport in a major city environment. In one city by installing a PRT system we could potentially reduce a current journey of up to one hour in peak hours to around seven minutes, in another country we may be able to reduce the number of cars on a major city's streets by up to 20%. People are at last starting to understand how this innovative technology can play a role in city transport solutions"

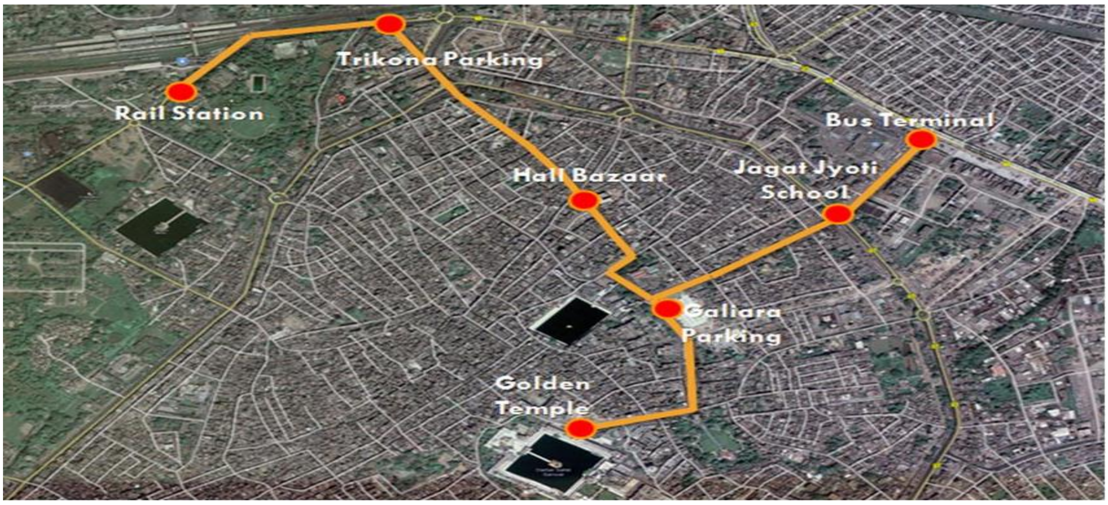


**Figure 4 Route Plan for Amritsar Application**

**Experience Vectus: Uppsala & Suncheon**

The construction of the Vectus Uppsala system was completed mid 2007 (Fig 5). It is a test track created for the purpose of verifying and validating all technical parameters, creating a safety case and obtaining relevant authority approvals. It also continues to be a show case. It has been a fully operating system with 3 vehicles, 2-berth station, ticketing and a fully deployed operational and maintenance regime for a 2 year period to obtain first hand passenger experience and operational reliability feedback. Vectus uses a steel rail guide way. At the test track the girders and columns are also steel. After undertaking the initial alignment, there has been no maintenance required at all, except for regular inspections. Wheel wear on vehicles has been minimal. The propulsion system has successfully used Linear Induction Motors (LIMs) to prove operational performance in adverse weather conditions such as snow and ice.

In Suncheon Bay, Vectus is currently installing a 6 mile, 40 vehicle system. Construction is well underway. For reasons of seismic activity, very high wind loads (due to typhoons), combined with poor ground conditions, extensive piling has been required. This involves substantial concrete columns and 30 meter span girders to accommodate a double track with gangway down the centre. Girders are series produced at a temporary site close by the installations; with up to 8 columns currently being completed per week. Steel tracks will be mounted on the concrete girders, providing the interface to the vehicles. Vehicles are electrically powered, via a DC current collection system, for high performance and continuous operation. To make the vehicles as energy efficient as possible, low rolling resistance wheels running on steel tracks are being used, powered by permanent magnet rotary motors.

Figure 5 Vectus Test Track

The stations have 4 in-line berths. The maintenance shop has a minimal footprint, and overnight vehicle storage is carried out in two underground levels accessed via independent lifts.

## 4. CONCLUSIONS

Personal Rapid Transit (PRT) is a concept which has a considerable history (see: http://www.advancedtransit.org/advanced-transit/history/). It has now reached operational reality. This has demonstrated that PRT does meet its claim of providing on demand, non –stop travel from origin to chosen destination.

Passenger response to the operations at both Masdar and Heathrow has been exceptionally positive. PRT provides a transit experience which delights its users. PRT offers a new mode which can now be considered seriously as part of the transport mix. The network capability offered by PRT complements conventional corridor types of transit, it is designed to take passengers from the major transit hubs to their final destination – making public transit a more attractive alternative and increasing the catchment areas of those stations.

New applications have been announced and more are being considered worldwide. Three companies are offering designed, tested and proven systems. The evidence is that PRT can make a major contribution to solving transport problems in the present Century