In Proceedings of the AATS conference, Bologna, Italy, 7-8 Nov.2005

Emerging Personal Rapid Transit Technologies Introduction, State of the Art, Applications

M. Buchanan [1], J.E Anderson [2], G. Tegnér [3], L. Fabian [4], J. Schweizer [5]

Personal Rapid Transit (PRT) is a novel form of fully automated rail-based public transportation which will become commercially available in the near future. With PRT up to 6 persons or light freight travel in small, individually controlled and electrically driven vehicles on a network of narrow guideways. The vehicles are available on demand and 24h a day. Any PRT network destination can be reached directly, in a private atmosphere and without intermediate stops or transfers.

The purpose of the paper is to inform urban development officials, planners and transport authorities about PRT developments and to recommend the comparison of benefits and costs of PRT with conventional solutions. In particular, the paper demonstrates how PRT is meeting all requirements for a future, high-quality public transportation systems in terms of sustainability, safety, accessibility and cost-effectiveness. The paper shows how the currently developed PRT technologies can be applied to solve specific urban traffic problems as well as transport tasks within private development areas. The paper concludes with key-recommendations to transportation experts working in the official and private sector.

This paper has been written by an international, multidisciplinary group of leading experts in the field of advanced transit.

The requirements for a new urban transport system

Many ongoing global changes are challenging the transportation sector to provide sufficient and sustainable mobility at affordable prices. The main drives behind the changes are: (i) an increasing transport demand for persons and freight due to the globalization of markets and the expanding economies most notably in Asia and eastern Europe; (ii) the increase of costs of current transport due to the limited fuel and land resources as well as increasing insurance fees. (iii) the increasing concern about health, well-being and environmental damages such as global warming.

In the past decades, massive investments have helped to improve and expand the present rail and road infrastructures. For this reason any new, additional transport infrastructure must prove to have a high problem solving potential and to be very cost-effective in order to be acceptable as alternative option to current modes of transportation. A future transportation system would need to satisfy all of the following general requirements:

1 Colin Buchanan and Partners, UK
2 PRT international, USA
3 TRANSEK Consultants, Sweden
4 Trans.21., USA
5 University of Bologna, DISTART-Trasporti, Italy

1. It must be sustainable. This means (a) significantly lower energy consumption, (b) independent of fossil fuels, (c) greatly reduced land-use.
2. It must provide high safety standards.
3. It must have zero emission in the vicinity of the user and low noise levels.
4. Infrastructure must fit within the urban fabric and there should be little interference with present traffic during transitional phases.
5. It must offer similar or better service than a car at affordable prices.
6. It must be cost-effective for the operator.
7. It must be accessible and usable for all parts of the society.

Additional requirements are determined by the particular transport task and application for which the new transport system should serve, as for example low capacity, low speed for local distribution systems or high speed, high capacity for sub-urban and extra-urban links. See also PRT applications section.

The characteristics of PRT technology

All requirements for a future transportation system can be addressed by deploying systems of small, light-weight, automatically controlled vehicles operating between off-line stations in a network of interconnected, small, low-cost, exclusive guideways. Use of off-line stations permits the trip to be nonstop, with little or no waiting, day or night, in seated comfort – features that will markedly increase transit ridership. Off-line stations permit sufficiently high throughput with small vehicles, which in turn permit marked reduction in the cost and visual intrusion of guideways [1]. Moreover, such systems can be easily adapted to hauling a wide variety of mail, goods, and waste.

Fig.1: Renderings from active PRT developments. Left: ULTra by Advanced Transport Ltd, UK (http://www.atsltd.co.uk). Center: Skyway Express by Taxi 2000, USA (http://www.skywebexpress.com). Right: Vectus PRT by Vectus, Korea (http://www.vectusprt.com/).

Such systems became known in the 1970s as Personal Rapid Transit. The idea of PRT emerged over 50 years ago, and various technological approaches have been explored. Some common characteristics and intrinsic properties of PRT make it particularly suitable to achieve the above mentioned requirements:

1. *PRT is sustainable*. It has (a) a significantly lower energy consumption: Energy for accelerations is minimized as the vehicle's speed profile is almost constant from origin to destination. Energy efficient electric motors allow partial brake energy recovery; (b) the electric propulsion makes PRT independent of fossil fuels, (c) land-use is greatly reduced. There is no need for parking space. The narrow guideways can be cost-efficiently installed on columns or in underground tunnels.
2. *PRT is safe*. Fully automation removes the most frequent cause of accidents: the human driver. Safety standards are similar of those applied for modern trains and Automated People Movers.
3. PRT is electrically driven and produces *zero local emission*.
4. *Infrastructure does fit within most urban fabric*. PRT guideways are narrow (cross-section of approximately 1m^2) with tight curve radii. Guideways can be elevated (with columns at 15m to 30m separations), at grade (protected by fences or gates) or underground in small tunnels. They are thus flexible to be installed within most urban settings without the interference of present traffic. The small emission-free vehicles even allow the integration of PRT stations in existing buildings.
5. *PRT offers a 24h, on-demand, direct origin to destination service*, without the need for transfers. The trips are made by individuals or small groups, traveling together by choice [1]. The flexible, low-cost guideways allow the design of a dense grid with station placed close to the users. Automation and on-demand service are a major factor in reducing the operating costs per passenger-km to a value under that required for bus systems. This means PRT service could be offered at prices of current public transport.

   In such a situation, road pricing can be easier justified as it would not penalize users with low income.
6. *PRT has relatively low capital costs*. The use of minimum-size, minimum-weight vehicles (which can be mass-produced) and light-weight guideways (which can be prefabricated in-doors and rapidly assembled on-site) reduce the capital cost to a small fraction of that required for conventional rail systems, even on a per-seat basis. From 3 independently developed PRT systems based on elevated guideways, the average capital costs have been estimated to 6-8$ Mil per km (5-6.5 MilEuro/km) [2]. The relatively low capital- and operating costs as well as the high expected ridership may even allow operation on profitable bases without the need for governmental subsidies.
7. *PRT is accessible for all.* Before boarding, it is sufficient to select the name or number of the destination and to purchase the ticket at a vending machine. This ticket allows entry to any available vehicle at the station. Vehicle floors are level with the station platform. Strollers and wheelchairs can be easily rolled into the vehicle. The system will automatically route the vehicle to the

desired destination within the shortest possible time and without further user-system interaction – a particular knowledge about the PRT network layout or geographical location of the destination is not required.

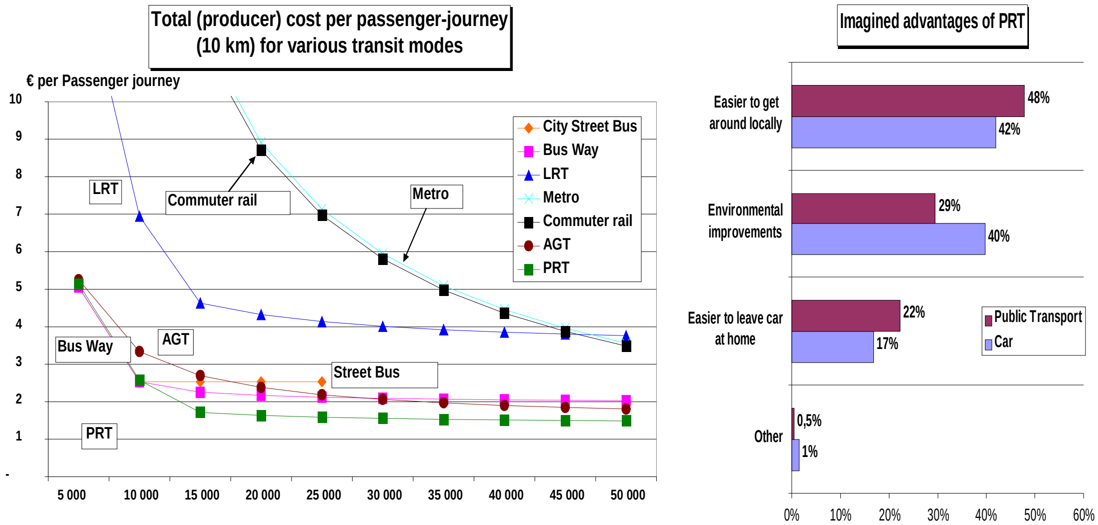

Fig.2: Costs per passenger journey for various transport modes and an average of 3 PRT systems under current development (Left). Why car drivers and public transport users would like PRT, a Swedish PRT application study (Right). As a total, 41% of the correspondents and 83 % of the public transport respondents believe that introducing a PRT system would have positive effects [2].

There are currently different PRT technologies under development which have specific characteristics and address different segments of urban transport markets. Such systems are presented below in more detail.

Short distance PRT

This PRT type offers comfortable rides for short trips within city centres or smaller private areas. An important characteristic is the flexible installation of guideways and stations. Short waiting times and high punctuality are achieved at modest maximum speeds and low capacities. There are different development activities in the UK and Korea.
The most advanced example is ULTra , developed by the Advanced Transport Systems Ltd (ATS), UK (http://www.atsltd.co.uk). It is in test operation since 2003 on a 1km test track near Cardiff, Wales. ULTra has recently received a 7Mio Pound Sterling funding by the British Airport Authority (BAA) with the aim to operate in public as shuttle at the London Heathrow airport by 2008.

Fig.3: ULTra vehicle by the Advanced Transit Systems Ltd, UK. Left: Vehicle running on ground-level. Center: On-level boarding with stroller. Right: Two vehicles on elevated guideway.

The vehicles of ULTra have 4 seats (500kg payload) and run at a maximum speed of 40km/h (25 miles/h). A typical one mile (1.6 km) journey would take around 3 minutes. ULTra vehicles have an extraordinary small turning radius (3.8 m) and cope with grades of 20%. Guideways can be elevated and at grade with protecting fences. An exceptional characteristic of ULTra is its low noise levels with respect to cars. ATS claimes that ULTra saves at least 70% of automotive energy requirements and even 90% when compared with a car in congested traffic [3].

High speed, high capacity PRT

This type of PRT is suitable for longer distances as it meets speed targets of greater than 60km/h. This technically more challenging systems are currently under active development by several groups in the USA. However, dates for their commercialization have not been announced.

Current achievable minimum time headways are approximately 2-seconds which means a capacity of 1800 vehicles per hour. This headway still satisfies brick-wall stop criteria corresponding to current rail safety regulations. Assuming an average occupancy of 1.2 passengers per vehicle, this means an effectve transport capacity of 2160 passengers per hour per direction.

The technically most advanced system is developed by the Taxi2000 Corp, USA (http://www.skywebexpress.com). The aim is to build a so called High Capacity PRT (HCPRT) with time headways even below 1 second. Taxi2000 has announced a capacity of 7200 vehicles per hour running at speeds from 30 to 100km/h (20 to 60 mph). The energy consumption has been indicated with ¼ of what is required by an average car

Fig.4: Prototype of Skyweb Express by the Taxi2000 Inc, USA. Left: Vehicle on short test track. Center: Open vehicle with wheelchair passenger at station. Right: Vehicle chassis inside guideway which has a cross section of approximately 1m by 1m.

PRT applications

The emerging PRT technologies have many distinguishing features and provide adequate solutions for different application fields.

Special applications

The earliest PRT systems are expected to be of the short-distance type with low speed and low capacity. Initially there will be small scale applications where the characteristics of such systems have a particular advantage:

- *Airport shuttles*: A PRT connection between car-park and airport terminal(s) give customers a convenient ride with their luggage from the car directly to the flight-terminal where they wish to depart. Such a system is currently planned for the London Heathrow Airport, using the ULTra PRT.
- *Private property developments*: PRT connections between car parks or bus stops with internal office buildings or other activity centers would make a private development area more attractive, because it is quieter and without fumes. An elevated PRT network would additionally save space, avoiding the need for internal access-roads

Fig.5: Photo manipulations with ULTra PRT at London Heathrow Airport, UK.

Fig.6: Network layout at Microsoft's campus in Redmond, USA. Pictures provided by bettercampus (http://bettercampus.org).

Short distance urban connections

When the early PRT systems have proved to work reliably, an operation in public service will become feasible. Initial applications are likely to start with a small network and where PRT has particular advantages, such as:

- Connection of different activity centers with Park&Ride, bus or rail-station (feeders). PRT would offer excellent service for passengers with shopping baskets or luggage – an application where most public transport solution fail.
- Flexible distribution within city centers or larger towns. In this case even a slower PRT would provide significantly shorter trip times compared with bus or tram because no waiting times are needed at stops, or for transfers.

In either case, previsions should be made for future network expansion.

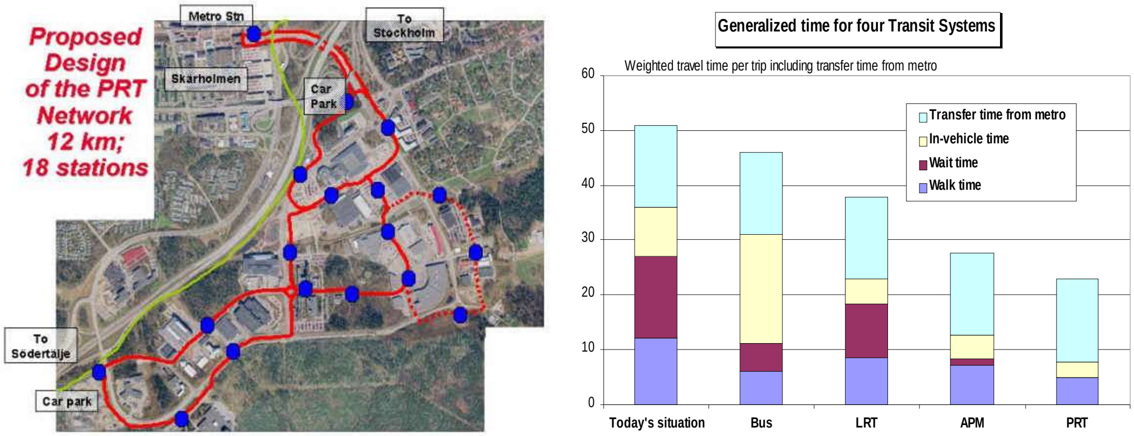

Fig.7: Detailed PRT simulation studies with realistic travel demand scenarios have been carried out for the Kungsen Kurva shopping area near Stockholm, Sweden. The results have been compared with simulations for conventional public transport solutions. Left: the 12km network, connecting the metro-station to the areal. Right: Total time savings for those visitors using the metro and transfer to other public transport modes (or PRT) to reach their final destination [1].

Faster outer suburban connections

The future generation of high speed, high capacity PRT allows to design networks which serve larger target areas. However, initial deployments need to focus on specific application where current public transport offers unsatisfactory solution and where high demands can assure early profits. Examples are:

- High quality service to suburban areas where current buses and trams cannot deliver adequate service.
- Connection between emerging outer urban activity centers (shopping center, industrial area, residences) and the city center, railway station or other destinations of interest.

High capacity PRT would have the performance to provide an area-covering network for entire cities, including suburban and extraurban destinations. Such a PRT network would be particularly suitable for policentric cities, where line-oriented conventional transport has problems to offer an acceptable service. The PRT network would reduce air-pollution and noise-levels. The expected reduction in road-use and parking space will fee up space which may be used for pedestrian ways and bicycle tracks, see Fig.5. All positive effects together will increase quality of life and the attractiveness of a city.

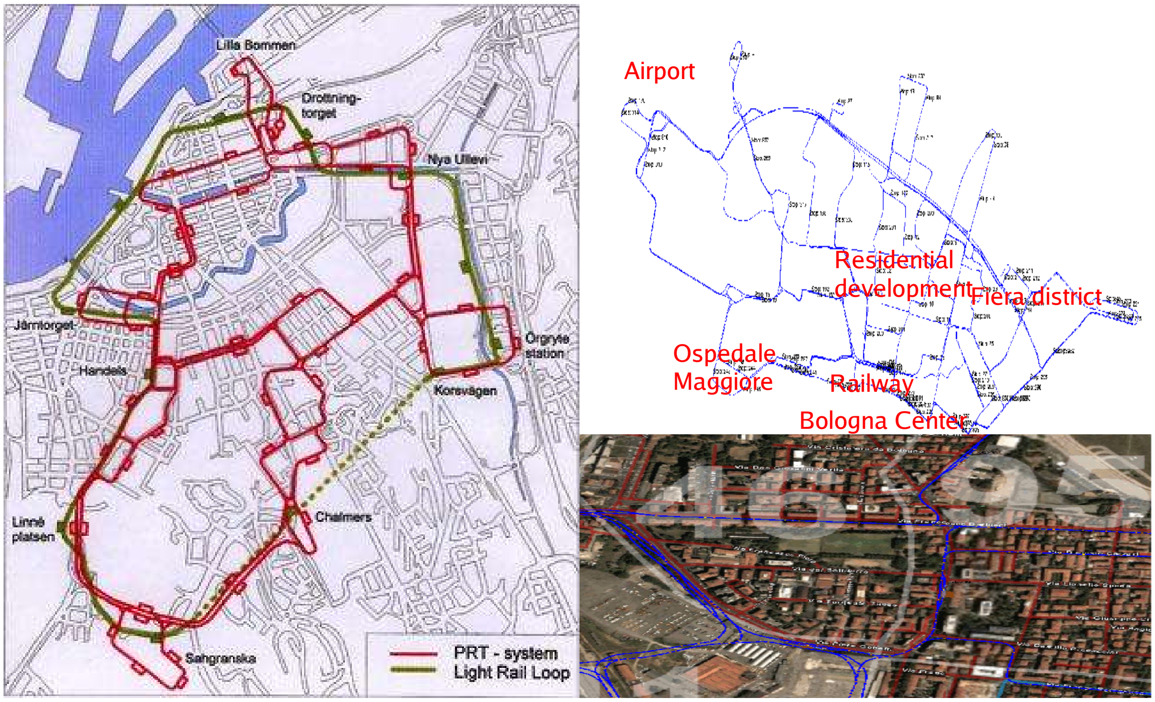

Fig.8: Left: PRT network of Gothenburg center (simulation study by the Logistic Zentrum in Stockholm, Sweden). Right: PRT network north of Bologna (simulations by the transport-institute of the University of Bologna, Italy).

(a) (b) (c) (d)

Fig.9: Visual impact of the narrow elevated PRT guideways. Renderings (a) and (b) by Taxi2000. Photo-manipulations (c) and (d) by Advanced Transport Systems (ATS).

Key recommendations

Infrastructure investments have far-reaching consequences that last many decades. The commercialization of the first PRT systems is due in a few years. Characteristics, performance data and the costs are already known to a degree that PRT can and should already be an option for medium and long term mobility plans.

To governments and local transport authorities

- Ensure PRT is treated as a possible form of future public transport.
- Funds for research and fellowships to explore these potential environmental and economic benefits should be made available.
- Funds to implement demonstrations of PRT in real urban settings should be made available.
- Literature describing the advantages of PRT should be created to communicate them to architects, city and regional planners, and urban transportation officials.
- Conferences, workshops and seminars should be organized to convey this body of knowledge to interested officials and professionals.

To urban planning authorities

- Specify the urban forms and densities you would like to see and require the transport authorities to consider PRT as an option for serving them. When possible, the transport requirements of planning studies should be specified prior to the decisions for a particular transport technology. PRT should then be evaluated as thoroughly as conventional modes.
- Demand sustainable solutions.

To private sector developers, entrepreneurs, etc.

- Demand PRT rather than yesterday's forms of public transport and refuse to fund the latter, unless it has been demonstrated to be the best option.
- Contribute to PRT investment from enhanced land and property values.
- Get in on the act and invest NOW in the technology or the applications.

Referferences

[1] J.E. Anderson, *Transit system theory*, Lexington Books, 1978, Lexington, MA
[2] G. Tegnér, and G. Andréasson: P*ersonal Automated Transit for Kungens Kurva, Sweden - a PRT system evaluation within the EDICT project*. 9th APM 2003 Conference, Singapore, September 2003.
[3] M. Lowson, *A New Approach to Sustainable Transport Systems*, 13th World Clean Air and Environmental Protection Congress, London, August, 2004.