

PRT: A Technology-Push Innovation

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Abstract

Most break-through innovations have been technology-push developments. Market research with regard to customer wants and needs are of no use when customers don't know what they want – or what they need. (Local) authorities, city planners and other decision makers tend to think along the lines of existing systems; to avoid the risk of doing something new (and different), but also because of a human inability to think outside the box.

Automated People Movers (APM) have arrived and are no longer an uncommon sight. Personal Rapid Transit (PRT) is in the position APM were years ago: being pushed to the market, trying to create awareness of the possibilities of the new technology.

2getthere is a subsidiary of Frog Navigation Systems – a company with a long history of bringing innovations to the market. Frog Navigation Systems was one of the pioneers with 'free ranging' automated guided vehicles in industrial applications using the patented FROG-navigation technology. The company also realized supplied the navigation system for the first automated container terminal (Port of Rotterdam) and realized the first electronically guided people mover system (ParkShuttle system). Now 2getthere and Frog are actively developing Personal Rapid Transit.

Personal Rapid Transit (PRT) is 'a transport method that offers personal, on-demand non-stop transportation between any two points on a network of specially built guide-ways'. Personal Rapid Transit is all about (network and vehicle) controls. With the automation technology and network controls available, the market approach is different as it requires the development (and understanding) of the concept and related aspects rather than the technology itself. The focus of the concept development was on the wants and needs of the customer and the passenger, resulting in a system implementable as 'true PRT' – providing direct connections, on-demand operations and personal transportation – but alternatively 'ride sharing' (single origin, multiple destinations) and scheduled operations (to optimize capacity) can also be implemented (a PRT-like application).

The paper addresses the development and the vision with regard to PRT and the various projects actively pursued in recent years.

Introduction

Automated Guided Vehicles (AGVs) are driverless industrial trucks, usually powered by electric motors and batteries. Applications of AGV-systems, with loads ranging from (cardboard) boxes to pallets and (steel) coils, can typically be found in and between production- and storage environments.



Automated Guided Vehicles (or Automatic Guided Vehicles) have been moving material and product over 50 years. The first AGV system, a modified towing tractor with trailer following an overhead wire, was built and introduced in 1953 in a grocery warehouse. By the late 50's and early 60's towing AGVs were in operation in many types of factories and warehouses. This type of AGV, a tugger, is still applied today. In 2003 Frog Navigation Systems supplied four automated 7tons Tuggers for a chassis marriage process within an automotive factory.

Wire guidance was the principal AGV guidance technology in the 1970's. An electronic frequency is induced in a wire that is buried in the floor. A device called a 'floor controller' turned the frequency on the wires on and off and directed the AGV through its intended route. The AGVs were equipped with an antenna that would seek out the frequency and guide the vehicle based on the strength of the signal. For decision points and intersections, multiple (costly) wires need to be installed. The system would energize the wire that would correspond to the intended direction of travel. As the intelligence of the system was in the floor controllers, these systems were typified as 'smart floors, dumb vehicles'.

During the 1980s, non-wire guided AGV systems were introduced. Frog Navigation Systems developed a free ranging system based on grid-reference points. The patented Free Ranging On Grid (FROG) technology was developed and first implemented for an application at Apple Singapore. The system features 'smart vehicles, dumb floors'.

Throughout the years the system was developed further. The 'black-box' is the brain of a vehicle and allows any type of vehicle to be automated, creating new market opportunities. The FROG-technology is now applied in several different markets, including various outdoor operations and people mover applications

From Outdoor to APM applications

There are multiple technologies that allow for free ranging movement in indoor environments, but the FROG concept proved to be applicable outdoors as well. Banking on 25-year Sealand contract, ECT (Europe Combined Terminal) decided in 1988 to automate their Delta Terminal in their quest to reduce costs. Based on simulations and thorough technical and operational evaluations, ECT opted for a combination of Automated Stacking Cranes and Automated Guided Vehicles.



The ECT container terminal has been operational well over 10 years now and features over 240 automated container carriers. Currently a 2nd automated container terminal (Euromax) is being built in the harbor of Rotterdam, also automated based on the FROG-technology. It is the ECT application that leads to the development of the electronically guided APM concept ParkShuttle.

The idea for the ParkShuttle was quite simple: if we can transport goods outdoor with our technology, why wouldn't we be able to transport people? Based on this notion some initial designs were made for what a vehicle should look like. Also the market was approached to see what interest there would be for such a transport system. As the concept generated a lot of interest, the development proceeded steadily.

The city of Capelle aan den IJssel (near Rotterdam) had a business park to be developed that was weakly linked to public transportation. In line with the national regulations, the business park could only be developed if public transportation to the site would be facilitated. The ParkShuttle concept fit the requirements and would allow for the

development of the envisioned business park. Because of the time pressure construction of the first vehicles had already commenced, when the decision to order was postponed.

Fortunately, Amsterdam Airport Schiphol had interest as well. Being a 'private' entity, Schiphol was able to make a decision quicker, resulting in implementation of 4 ParkShuttles, each accomodating 10 passengers, in December 1997. In the mean time, the city of Capelle aan den IJssel had also decided to proceed and 3 ParkShuttles were installed in February 1999.

Amsterdam Airport Schiphol Application

At Schiphol the system operated on long term parking lot P3 (accomodating 10.000 cars). The track consisted of two (single directions) loops of 1km, each with 3 stations. Each loop had several crossings for automobile traffic (equipped with barriers and traffic lights) and pedestrians (audible alarms). To ensure maximum flexibility in the operations the vehicles are able to access both loops. The system operates on demand, carrying passengers from the shuttle stops near their cars to the main passenger lounge. From here buses provide transportation towards the passenger terminals. The service is available 24/7 and free of charge to users of the parking lot.

The main purpose of the pilot project was to acquire knowledge about passenger acceptance, ease of use, traffic management, comfort and safety of the ParkShuttle. In a next phase the track could have been extended to the passengers terminals. Although surveys showed great passenger satisfaction over the 7 years of operations of the pilot system, they were (temporarily) ceased in 2004. Installation of the 2nd generation ParkShuttle was seriously considered, but based on the uncertainty in the airline-industry the decision has been postponed. *2getthere* remains in contact with Schiphol Airport with regard to the operations of automated people mover systems.

Business Park 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. The goal of the pilot was to proof that at the same expense, a better service and higher frequency could be achieved – making (public) transportation a more attractive alternative for car drivers. From February 1999 to November 2001, three ParkShuttle vehicles operated on the 1300-meter



single lane trajectory. Bi-directional travel was enabled by means of three passing locations. The success of the system prompted the decision in December 2001 to upgrade the system from its' pilot status.

In phase II, the trajectory has been extended and the number of stations increased to 5 – significantly reducing walking distances for employees and making the system more attractive to use. 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 forementioned tunnel and bridge). Several at grade crossings with pedestrian and car traffic are realized. In Phase II both the number of vehicles (6) and the capacity of the vehicles (20 passengers) doubled – at the request of operating company ConneXXion. 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.

Making the leap to PRT

The ParkShuttle has been developed based on market demand, with limited knowledge within the company about public transportation and the APM-market. Market intelligence was quickly gathered through research, but the fact remains that Frog is a technology oriented company that pushes new innovations to market. Most break-through innovations are realized through technology push, instead of market demand as customers (almost) always think along the lines of existing systems and technologies.

For Personal Rapid Transit this is also the case. Whether coming from a theoretical or technical perspective, the companies now offering PRT systems are pushing their system (technology) to market. Potential customers are unaware of the existence and/or possibilities of PRT systems and need to be educated. Not only about the possibilities, but also about the management of the risk associated with newly developed transport systems such as these. The perceived risk is often large, while the actual risk in practice is very manageable.

For the last couple of years PRT has mainly been a topic of discussion on the internet and at conferences. Slowly it is starting to develop with the topic being embraced in more discussions and larger conferences. The market education is working and more potential customers are being informed about PRT and its characteristics – either by suppliers or by a growing number of consultants with PRT-expertise. However, this is still just the 'tip' of the iceberg, as the first true PRT application still needs to be realized.

The development of the PRT concept was started in 2000, co-operating with a golf-cart manufacturer to research whether it was possible to automate these vehicles using the FROG-technology. Automation proved possible, but a field trial of the golf-cart system (Floriade 2002) showed that the golf-cart basis is not suited for a public transit system with the requirement for a large yearly mileage. Redevelopment would be required to guarantee a longer technical life-span and enable the system to run 100.000km a year.

The Floriade 2002 was not a true PRT application as it only featured two, on-line stations. However, it was a PRT-like application that introduced 2getthere (the then founded subsidiary of Frog Navigation Systems, specifically concentrating on APM-systems) to the concept. However, at this point in time there had been no strategic decision to develop the complete concept of PRT further, as it remained to be determined first whether the market would be interested in such a concept.



In the subsequent year (2003) research was conducted to establish the market demand for PRT. As there were various indications that PRT was drawing attention from potential customers, the development of the PRT-concept itself and the understanding thereof within the company, was commenced in 2003. To date the concept has been largely completed, but continuous refinements to detailed areas, incorporating new developments, are still being made.

PRT by 2getthere

Personal Rapid Transit (PRT) is ‘a transport method that offers personal, on-demand non-stop transportation between any two points on a network of specially built guide-ways’. A PRT system consists of a number of small automated vehicles (seating 2 to 6 passengers) combining the desirable aspects of the private car (private travel at any desired time) with the social advantages of public transport (no congestion and parking issues).

2getthere's Personal Rapid Transit system features of a number of automated taxi's (CyberCabs) and a supervisory control system. The guide way can be constructed at grade, but also elevated, embedded in buildings or underground. The system is configurable as ‘true’ PRT – providing direct connections, on-demand operations and

personal transportation – but alternatively ‘ride sharing’ (single origin, multiple destinations) and scheduled operations (to optimize capacity) can also be implemented.

PRT-like systems have been installed (e.g. at the Floriade 2002), but to date no ‘true’ PRT system has been realized. The first applications are imminent, however, as increased market interest indicates. A PRT system can be installed as feeder system to a public transportation node or (central) parking facility and as a local transit system. Possible applications range from airports to business and industrial parks, theme parks and resorts, city centers and residential areas.

PRT Applications

For any application it is important that the PRT system fits within the environment. Based on its’ characteristics Personal Rapid Transit is most suited for high-density areas, each featuring its own requirements and faces with tis own (unique) transit challenges. An airport environment will differ considerably from a residential area (e.g. with regard to visual intrusion) and a resort. The (local) environment and the direct surroundings of the system should be the basis of the design of the PRT routes, network and all other related aspects.



In an existing environment, the system will be optimized in light of the restrictions its surroundings pose, optimizing the value to both passengers and local residents. Where and how (at grade or elevated) the system is constructed should be carefully evaluated with regard to visual intrusion, noise and other effects on the surroundings. In a Greenfield development system optimization within the site development requires an integrated approach.

A flexible approach in the system configuration allows the system to be designed as true-PRT or as a PRT-like system. A PRT-like system will feature a single or multiple aspects that contradict the definition of PRT. A PRT-like system might feature scheduled

operations (for specific periods) and/or 'ride sharing' functionality. Scheduled operations can be considered to reduce the empty vehicle movement, while ride sharing functionality is intended to increase the average occupancy of the vehicles – both resulting in a higher hourly capacity or a lower required fleet size to achieve the same hourly capacity.

2getthere's system operates according to operational scenarios. The scenarios can become active automatically based on time-settings or can be activated by the operator (allowing him to act immediately on changing transport patterns). This allows scheduled and on-demand operations to be combined in the same application – using the scheduled service in rush hours to reduce the required fleet size (and the capital cost of the project). Or it allows to combine ride-sharing and personal, non-stop transportation in a single application. Scenarios provide the flexibility to customize the system to the required operations for every (occasionally repeating) transport pattern.

In the end each application is designed uniquely based on the requirements and characteristics of the application, the spatial planning and the customer preferences. A transportation system should be customized for each application, taking into account all specifics to ensure the passenger service is optimized and the capital and operating costs are minimized.

Controls

Personal Rapid Transit is all about network (and vehicle) controls. *2getthere's* controls and experience are a significant competitive edge and the basis of several key advantages: proven reliability and availability, flexibility in configuration and operations, speed of implementation and minimum capital and operational costs.

The system allows for synchronous control of operations on the basis of Frog's time synchronization patent. Merging and docking procedures at stations (with independent berths) are accurately timed to allow for smooth operations. The system operates according to the parameters set in a scenario. The scenarios contain parameters with regard to work scheduling, traffic control, communication and job generation and assignment. The number of scenarios that can be programmed is virtually unlimited, allowing the operations to be optimized for each hour of each day.

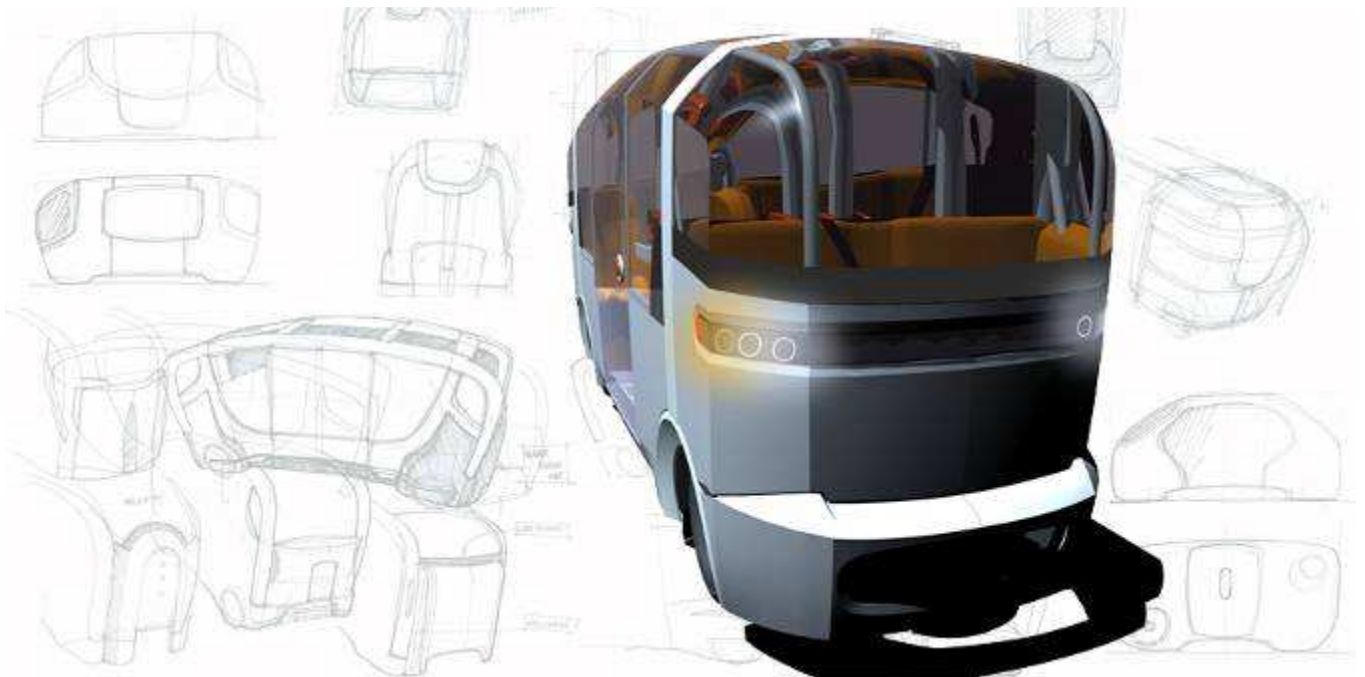
Work scheduling, the assignment of transport requests to vehicles, is based on a customized set of rules (framework of conditions). The rules incorporate elements such as vehicle availability, distances, lay-out and transport requirements. Generation of transport requests is typically done by push-buttons at the stations of the system or generated automatically based on logged patterns of transportation requests and/or synchronization with the arrival/departure of other modes of transportation. The supervisory system is also in control of fleet management. This entails a.o. ensuring timely recharging of the batteries and keeping log files of all system events, alerts and transportation requests. The log files can be retrieved for statistical processing at any time.

The necessary communication to and from vehicles is done via a Radio Frequency (RF) wireless link. The system is easily expandible in terms of the fleet size and has standardized interfaces for communication with other systems (traffic lights, beams, etc.). The system was developed and tested in-house and operates on a Linux-platform.

PRT Vehicle

Often the PRT vehicle draws the most attention as it is the most visible aspect of a PRT system (along with the elevated infrastructure). However, with all the automotive technology available in a competitive market, the development and fabrication of the vehicle is no longer the most difficult aspect. It requires the proper attention, but the expertise and technology is readily available.

The CyberCab PRT vehicle can be compared to an automated taxi. It offers direct connections between origin and destination (via the shortest route in the network) and offers personal transportation (charging passengers per vehicle, while allowing for group travel). The CyberCab vehicle is developed in close co-operation with expert 3rd parties with automotive experience. The CyberCab accommodates a 6-person family (4 adults, 2 children) and additionally has space available for either a wheelchair or luggage. The vehicle features an automated sliding door, optionally a second door can be installed allowing (dis)embarking on both sides of the vehicle.



The cabin is spacious and well illuminated at night. Large windows provide excellent all round vision and add to the personal safety (feeling) of the passengers. Seating is comfortable with all measurements exceeding normal (public) transportation standards

(standing passengers are not facilitated). Information is conveyed to the passengers by means of the user console, display and voice module. The camera system allows the operator to display images of each vehicle interior real-time.

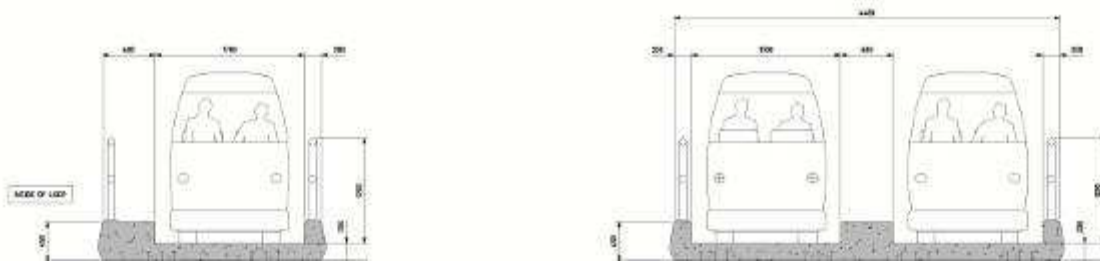
Each vehicle is equipped with advanced safety systems, a.o. for short- and long range obstacle detection. The sensors create a sensory shield, serving as a virtual bumper enabling the vehicle to make a controlled stop prior to contact with obstacles. In the control logic this is an integrated aspect of the normal operations and not an exception handling procedure – ensuring a more comfortable ride experience.

The vehicle is a mere 1450mm wide, resulting in a narrow track. The maximum speed of the CyberCab is 40 km/h (25 mph).

Infrastructure

2getthere's CyberCab system operates on its' own dedicated guide way, enabling it to provide direct connections unhindered by the congestion of other traffic. No physical guidance (rail) or guiding infrastructure elements (kerbs and/or walls) are required for the operations, making the system less vulnerable (more reliable) and ensuring reduced capital and maintenance costs.

The integration of the infrastructure within the (existing) environment is key. In (historic) city centers, build-up and residential areas, applications are faced with a dilemma: installation at grade would require reconfiguration of the spatial planning, but an elevated guide way is usually not acceptable because of the visual intrusion (even when minimized). The system will need to be optimized in light of the restrictions its surroundings pose, optimizing the value to both passengers and local residents.



All stations are typically created off-line. Each individual station would be designed to the requirements, its' surroundings (spatial planning and space available), user friendliness and capital and maintenance costs. When required a station can feature multiple (independent) berths – allowing for multiple vehicles being boarded at the same time, ensuring a higher throughput, eliminating single-point-of-failure vulnerability and thus increasing system availability.

As the system uses a simple, completely flat infrastructure, it is possible to create at-grade crossings with other traffic. An at-grade crossing will only be possible if the intensity of both traffic flows is low enough to allow for it. In case of (multiple) intensive traffic flows, either grade separated crossings are required or the entire track should be constructed elevated.

The communication network is an important element of the infrastructure. Base-stations, connected to the glass fiber backbone, are used for the wireless LAN communications with the vehicles. Additionally the intercom and CCTV modules at stations (and crossings) are also connected to the backbone. All connect to the control room, preferably located near the maintenance depot.

Conclusion

Personal Rapid Transit is an interesting concept that is increasingly drawing attention. True PRT, adhering the definition¹ to the letter, is envisioned and being developed, but has not been implemented to date. PRT-like systems, which feature many of the qualities mentioned in the definition (but not the combination of all), have been installed and have proven successful (Morgantown, ParkShuttle at Rivium and Schiphol, CyberCab at the Floriade).

New projects are being developed, with potential PRT customers such as DestiNY USA and Dubai International Financial District receiving a lot of attention. In 2008 a PRT-like system is scheduled to become operational at Heathrow. The number of potential suppliers is continuously increasing, generating an even larger push of the concept to the market.

In the end the success of PRT will be its ability to fit in the surrounding environment – especially within existing build-up areas. The systems that are not flexible and can not deal with local requirements or desires (e.g. no visual intrusion in residential areas), will only be suited for a restricted number of applications. The first applications are thus being realized in applications where the ‘negative’ aspects of PRT do not weigh that heavily – look for the first applications to be realized at airports, business and industrial parks and theme parks in the coming 5 to 10 years.

¹ ‘a transport method that offers personal, on-demand non-stop transportation between any two points on a network of specially built guide-ways’