Preliminary Investigation (PI-0293)

Caltrans Division of Research, Innovation and System Information

Micro-Rail Exploration Study

Requested by
Jamaica Gentry, Office of Freight Planning

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Executive Summary

Background

To further its goals to improve safety, modality, efficiency and innovation, and to reduce vehicle miles traveled, California Department of Transportation (Caltrans) is investigating micro-rail technology to determine its ability to complement California's transportation network and support healthy, livable communities.

Although it can be found in several forms, the micro-rail application of interest to Caltrans is one in which podcars carrying four to six passengers travel suspended from an above-ground rail track. Similar in form to a ski gondola yet capable of speeds up to 100 mph, this style of micro-rail system addresses two issues:

- It takes advantage of the airspace above existing right of way (ROW) to avoid conflicts at ground level and requires no new—or much less—ROW acquisition.
- By running podcars instead of railcars, micro-rail can provide on-demand personal rapid transit (PRT) service, which addresses the issues of privacy and convenience, and can support ridership.

Aware of the theoretical potential in micro-rail technology, Caltrans is seeking information that will help determine how to move forward: Proceed with an independent effort to design a system specific to Caltrans' needs, or partner with a private company to adapt a commercial system.

To assist with this information-gathering effort, CTC & Associates conducted a literature search of domestic and international research and related resources.

Summary of Findings

Related Research and Resources

The literature search of recent publicly available domestic and international resources identified a representative sampling of publications that are organized into the following topic areas:

- Background.
- Practical applications.
- Feasibility studies.
- Comparing transit alternatives.
- Station design.
- Implementation guidance.
- Technology and design.
- Vendors and consultants.

Background

A sampling of publications that offers general descriptions of PRT and the technology supporting it includes an undated online article on the railsystem.net web site. The article notes the similarities of PRT with automobiles, trams, buses and monorails, and highlights its distinct features:

- Vehicle movements may be coordinated, unlike the autonomous human control of automobiles and bikes.
- Small vehicle size allows infrastructure to be smaller than other transit modes.
- Automated vehicles can travel close together. Possibilities include dynamically combined

"trains" of vehicles, separated by a few inches, to reduce drag and increase speed, energy efficiency and passenger density.

The Advanced Transit Association (ATRA) describes PRT and provides links to a wealth of papers on PRT and related topics. Among them is a January 2019 ATRA paper written by the co-founder of the San Rafael, California-based Transit Control Solutions, Inc. The paper examines the benefit/cost, networkability and sustainability of automated transit networks (ATNs) and PRT systems, and includes a description of what is needed to achieve higher line capacities at higher line speeds. Supplementing these domestic descriptions of PRT is a presentation from the president of the India Metro Association that summarizes the technical aspects of PRT systems.

Practical Applications

Online resources describe two real-world PRT applications:

- *West Virginia University PRT.* Described as the "first large-scale Automated Guideway Transit system in the United States," this system was designed in the early 1970s and began passenger service in 1975 as the primary mass transit system for students, employees and visitors. Today, approximately 15,000 people ride the PRT daily during the school year. The system has 69 cars that are built on a Dodge truck chassis. Each car can accommodate eight seated passengers, comfortably carry a total of about 15 passengers, and travel up to 30 mph. Each car is powered by environmentally friendly electric motors.

  The university's PRT Modernization Plan includes three phases to ensure the PRT system "remain[s] a viable part of the community's mobility network":
  - *Phase I* targets the replacement of the on-board vehicle computer system and vehicle propulsion system.
  - *Phase II* includes the redesign and replacement of the automatic train control system, replacement of substation and electrical gear, and hospital tunnel repair.
  - *Phase III*, scheduled to begin in late 2020, includes vehicle replacement. Other efforts will be directed to inspect the infrastructure and perform the required repairs to maintain the system's structural integrity.
- *Heathrow Terminal 5 pod*. This PRT system links London's Heathrow Terminal 5 with a business car park. The 21 battery-powered, driverless pods carry four passengers and their luggage along a guideway with speeds of up to 25 mph.

Feasibility Studies

A sampling of feasibility studies illustrates how domestic and international publications have made the case for PRT systems.

Domestic: California

A 2014 study funded by Caltrans and U.S. Department of Transportation addresses the opportunities and challenges in planning and funding an ATN, which is described as "fully automated vehicles on exclusive, grade-separated guideways provid[ing] on-demand, primarily nonstop, origin-to-destination service over an area network." Design guidance, including physical dimensions, station placement, sizing and capacity, and guideway placement; network capacity; control systems; scalability; costs; and other factors are discussed.

A March 2007 report commissioned by the city of Santa Cruz considered PRT and its applicability in Santa Cruz by examining technologies, route selection, funding options and implementation options. Web sites developed by PRT advocates after publication of the 2007 report highlight the continued interest in implementing PRT within the community. A November 2018 conceptual evaluation prepared by a private consulting firm evaluates a PRT alternative to the bus and train options examined in the Santa Cruz Draft Unified Corridor Investment Study; an appendix provides a project description and cost estimates.

Domestic: Georgia

In 2020, the ATL Airport Community Improvement Districts (previously Aerotropolis Atlanta) proposed a six- to 12-month comprehensive study and 12- to 36-month demonstration center and system in 2021 to improve mobility for property owners in and around the world's busiest airport, Hartsfield–Jackson Atlanta International Airport. A July 2020 article indicated that the group expected to launch a micro-transit pilot by the end of 2020 that could extend through 2021.

Domestic: South Carolina

An August 2018 study presented an ATN solution comprising 47 stations and 24.5 miles of one-way track as an alternative bus route in Clemson, home to Clemson University. The study estimated costs, annual revenue and traffic impacts.

International

A 2015 Australian case study used a desk exercise to propose a PRT system as a feeder for rail and bus stations in an edge city (an area of suburban density within the city limits). A simulation "showed that the overall performance of the PRT is very effective, even in the busiest hours of the morning and afternoon peak." The case study appearing in a November 2016 conference paper sought to determine the viability of a new PRT network in India. The authors provided technical details of a travel demand assessment and presented the results of a financial analysis.

A series of resources produced by UK Tram Limited, self-described as "the authoritative voice of the light rail sector in the UK [United Kingdom] and Ireland," provides guidance for preparing a business case for PRT and advice on the benefits, costs, procurement and regulatory issues associated with PRT.

Comparing Transit Alternatives

Leaders of a PRT consulting firm and PRT-focused association authored a July 2018 presentation that outlined a case for PRT. The authors concluded that PRT would be an effective alternative to bus service in two communities, paying for its own capital and operating costs and generating a range of positive impacts.

The same authors compared existing light rail transit with the results that could be reasonably expected for group rapid transit or PRT; results that could be expected for high-speed and high-capacity PRT technology were also estimated. The conference paper's conclusions highlight the benefits of PRT, including a significant increase in projected ridership, an improved level of service and a sixfold increase in destinations from any one station.

A paper published by the Centre for Traffic Research at Stockholm's Royal Institute of Technology explored the suitability of PRT as a feeder/distributor to rail stations, identifying the most suitable implementations of these systems and describing station layouts, vehicle scheduling, ride sharing and other operational characteristics of the typical PRT system.

<u>Station Design</u>

Researchers in Italy examined PRT station characteristics in a May 2011 conference paper, noting that they are "a complex function of geometry, vehicle dynamics, boarding strategies and user behavior." Using analytical and microsimulation techniques, the authors compared three types of PRT stations: serial off-line stations, ordinary sawtooth stations and high-capacity sawtooth stations.

<u>Implementation Guidance</u>

Transit X, LLC, a Massachusetts-based vendor that builds and operates privately financed public transit podways, published its August 2020 Podway Handbook to serve as a "companion guide to proposals for a privately financed public transit podway—a fleet of automated electric vehicles (pods) for passengers and freight on a local and intercity micro-guideway providing equitable transportation." Also providing guidance is a European Commission 2010 publication for PRT implementers that includes a checklist for evaluating city size, costs, implementation time, stakeholders involved and undesirable secondary effects.

<u>Technology and Design</u>

The California-based Transit Control Solutions, Inc. develops technology that "will enable ATN systems to achieve significantly increased capacity (3,600 cars per hour per direction at a speed of 60 mph—about 4x higher than other systems in the market)." A general discussion of the use of magnetic levitation (referred to as "maglev") for mass transit applications is addressed in a web site hosted by a company founded in 1992 by a University of California, Santa Barbara professor. Maglev-propelled vehicles are also the focus of a 2016 journal article that considers the specific design and validation of a maglev-powered system that runs on elevated guideways in South Korea.

<u>Vendors and Consultants</u>

Ten domestic and international vendors and consultants offering or proposing the type of PRT system of interest to Caltrans are highlighted:

Domestic

iTran Systems LLC. This Florida-based company markets Mobility on Demand, an aerial PRT with two- to four-passenger or cargo-only vehicles.

PRT Consulting, Inc. In addition to describing the Colorado company's services that help clients implement driverless transit solutions, this web site offers access to a wealth of PRT-related resources.

Transit X, LLC. This Massachusetts company builds and operates privately financed public transit podways.

Virgin Hyperloop. Based in Los Angeles, this company hopes to have a full-scale application of its hyperloop vehicle system operational by 2030.

International

2getthere from ZF Friedrichshafen AG (Utrecht, Netherlands).This vendor has been installing PRT systems since 2010.

Fairwood Group (Noida, India). The PRT system developed by this group employs a four- to six-seat battery-powered driverless vehicle that uses rubber wheels that run on an elevated guideway.

skyTran (Mumbai, India). In February 2021, Reliance Industries Limited acquired a majority equity stake in skyTran, which has corporate offices in California's NASA Research Park, an engineering platform in California and a full-scale production track in Texas.

SkyWay from Rsw-systems.com, Inc. (Tortola, British Virgin Islands). This vendor is developing high-speed vehicles that operate on truss string-rail overpasses. Vehicles to move cargo are also in development.

Ultra Global PRT (Bristol, UK). This vendor developed the PRT system in operation at London's Heathrow Terminal 5.

Vectus Ltd. (offices in the UK, Sweden and South Korea). This legacy web site provides information about a PRT installation in South Korea.

Gaps in Findings

This Preliminary Investigation provides a current snapshot of the publicly available resources in a targeted area of micro-rail technology. Because this technology is a relatively new and burgeoning field, vendors and consultants enter and exit the marketplace with some frequency. Continuing review of the micro-rail landscape will be required as Caltrans pursues its examination of appropriate applications of this technology in California. Finally, PRT installations using an above-ground rail track that achieve the high speeds Caltrans envisions appear to be in development but are not yet publicly available.

Next Steps

Moving forward, Caltrans could consider:

- Contacting representatives overseeing the modernization of West Virginia University's PRT to learn more about the upgrades needed to keep the system viable.
- Reviewing in detail the domestic and international feasibility studies cited in this report that provide details of planning parameters and anticipated system impacts.
- Examining the case made by PRT proponents that compares PRT as an alternative to bus service.
- Reviewing the background information for the domestic and international vendors and consultants provided in this report to identify topics for discussion with company contacts.

Detailed Findings

Background

California Department of Transportation (Caltrans) is investigating micro-rail technology given its potential to meet known challenges while building resiliency and adaptability into the transportation network. Although it can be found in several forms, the micro-rail application of interest to Caltrans is one in which podcars carrying four to six passengers travel suspended from an above-ground rail track that is similar in form to a ski gondola yet capable of speeds up to 100 mph. With a small footprint in urbanized areas, micro-rail could be an attractive alternative to highway driving and shorten trip lengths by forming direct paths between residential and commercial land uses. With proper design, micro-rail can be a first mile/last mile option, which would facilitate increased biking and walking in all settings.

Aware of the theoretical potential in micro-rail technology, Caltrans is seeking information that will help determine how to move forward: Proceed with an independent effort to design a system specific to Caltrans' needs, or partner with a private company to adapt a commercial system.

Related Research and Resources

To assist with this information-gathering effort, CTC & Associates conducted a literature search of domestic and international resources to identify publications and other resources that described:

- The community impact of micro-rail, including station design.
- Costs for installation, operation and maintenance, and whether such a system can be self-sustaining.
- Operational issues, such as scalability, safety, speed and accessibility to people with disabilities.
- Relationship to the overall transportation network, including identifying appropriate locations.
- The technology used to propel micro-rail systems.

Findings from this literature search are presented below in the following topic areas:

- Background.
- Practical applications.
- Feasibility studies.
- Comparing transit alternatives.
- Station design.
- Implementation guidance.
- Technology and design.
- Vendors and consultants.

Resources may be further organized into domestic and international citations.

Background

The publications and other resources cited in this Preliminary Investigation provide varying descriptions of personal rapid transit (PRT). The article excerpt below offers one of the more comprehensive summaries of PRT and its components:

> PRT is a passenger-transit, on-demand system, based on automated small and light electric vehicles ("pods") which run along dedicated guideways. The track lines can be built

underground, at street level or elevated, with various design solutions available. Different materials from simple concrete bases to steel or fibreglass grid floors can be used to construct the guideway. The stations are built off-line, making non-stop travelling possible, between any two stations. The low-demand loops may have on-line stations. Stations could be easily integrated within new buildings or customised to fit into a specific area.

> Passengers arriving at a station can call a vehicle, which is usually waiting at the station; otherwise the quickest available vehicle will be automatically directed from the nearest station. A software programme is designed to find the optimum path for each passenger and to enforce a minimum distance between the vehicles in order to avoid collisions. All vehicles offer high safety and security standards for the passengers through track and vehicle location systems that permanently monitor each vehicle.

> The vehicles are computer-controlled and do not require human drivers. They are equipped with comfortable seats, air-conditioning, and an on-board information system with audio and video communication channels and are designed to accommodate passengers with wheelchairs, bicycles or prams. Most of the vehicle prototypes were designed for two or four passengers (Ultra, 2getthere, Taxi2000), but there are also solutions for up to nine passengers (Austrans). (From *Personal Rapid Transit Application in Retrofitting Edge Cities—Macquarie Park Case Study*, cited on page 14.)

Personal Rapid Transit, railsystem.net, undated.
http://www.railsystem.net/personal-rapid-transit/
This online article provides background information on PRT, noting the similarities of PRT with automobiles, trams, buses and monorails, and highlighting its distinct features:

- Vehicle movements may be coordinated, unlike the autonomous human control of automobiles and bikes.
- Small vehicle size allows infrastructure to be smaller than other transit modes.
- Automated vehicles can travel close together. Possibilities include dynamically combined "trains" of vehicles, separated by a few inches, to reduce drag and increase speed, energy efficiency and passenger density.

The article also examines in some detail a PRT system's:

- Infrastructure design (guideways, stations).
- Operational characteristics (headway distance, capacity (single line and networked), travel speed, ridership attraction and control algorithms).
- Safety.
- Energy efficiency.
- Costs.

Domestic

Advanced Transit Association, undated.
http://www.advancedtransit.org/
From the web site:

> The Advanced Transit Association (ATRA) is a nonprofit organization aimed at increasing the knowledge and understanding of innovative transit concepts. ATRA envisions a future

when transportation will all be orchestrated for the convenience of people and their businesses—as well as for the benefit of our planet.

Papers on PRT and related topics are available at http://www.advancedtransit.org/library/papers/. Some of these papers are cited in this Preliminary Investigation.

"Is There a Case for High Speed, High Capacity ATN/PRT Systems?," Eugene Nishinaga, Transit Control Solutions, Inc., January 2019.
http://www.advancedtransit.org/wp-content/uploads/2019/02/Nishinaga-20190131-TCS-ATRA-Article-on-HSHC-PRT-Final.pdf
This paper, written by the co-founder of the San Rafael, California-based Transit Control Solutions, Inc., examines the benefit/cost, networkability and sustainability of automated transit networks (ATNs) and PRT systems. Below are excerpts from the paper:

> **Benefit/Cost**. While the use of off-line stations allows smaller cars to be used, the benefit/cost ratio is not improved unless the control technology achieves a headway of 4.5 seconds or less at a speed in the range of 60 mph. This is not achievable using Moving Block control systems* and more innovative approaches must be used. If a headway of one second at 60 mph could be achieved, metro rail-like service can be achieved at about a quarter of the cost. This would result in four-fold improvement in benefit/cost.
>
> **Networkability**. If higher line capacities at higher line speeds can be achieved, regional networks of PRT service lines would become possible and could, in concept, scale up indefinitely.
>
> **Sustainability**. The use of small cars instead of long trains makes it possible to use sustainable forms of energy generation. Also, energy used per passenger-mile is approximately one third of that for other transit modes. This is probably due, in large measure, to the efficiencies resulting from the reduction in unoccupied seat miles noted earlier.

* The author describes the Moving Block control system as "the current state of the art." In these systems, "the positions of all controlled cars are tracked with a relatively high degree of accuracy, and the actual detected locations of the cars are used as inputs to the control logic which continuously calculates the Worst Case Stopping Distance (WCSD) of each car and fail-safely commands cars to brake if the distance to other cars becomes less than the WCSD."

See page 21 for more information about the technology developed by Transit Control Solutions, Inc.

International

Personal Rapid Transit System (PRT): 21st Century Urban Transport System, Sukhbir Singh, India Metro Association, undated.
https://www.india-metro.org/Personal-Rapid-Transit-System.html
This presentation from the president of the India Metro Association summarizes the technical aspects of PRT systems.

Practical Applications

Domestic: West Virginia

Personal Rapid Transit, West Virginia University, 2021.
https://prt.wvu.edu/
This web site describes the "first large-scale Automated Guideway Transit system in the United States." Designed and developed by Boeing in the early 1970s, the PRT system is the primary mass transit system for the movement of students, employees and visitors (about 15,000 riders per day). Technical specifications for the Boeing-designed PRT system are available at http://www.boeing.com/history/products/personal-rapid-transit-system.page.

From the "fun facts" offered on the site:

- The PRT first began passenger service in 1975.
- The PRT is a public transportation service that receives capital funding assistance from the Federal Transit Administration.
- The system has 69 cars that are built on a Dodge truck chassis.
- Each car can accommodate eight seated passengers and comfortably carry a total of about 15 passengers.
- The PRT can travel up to 30 mph.
- The vehicle's position on the tracks is monitored constantly through computers.
- The car is powered by environmentally friendly electric motors.

The site notes that "[d]ue to its age, the PRT system now lacks technical and vendor support, and a dwindling market for replacement components has resulted in a steep increase in operational costs. Additionally, the current PRT system reliability rate of 93[%] to 98[%] is not satisfactory. In order for the PRT system to remain a viable part of the community's mobility network, the system's reliability must be addressed."

The university's PRT Modernization Plan, available at https://prt.wvu.edu/about-the-prt/modernization, includes the following phases:

- *Phase I* targets the replacement of the on-board vehicle computer system and vehicle propulsion system.
- *Phase II* includes the redesign and replacement of the automatic train control system, replacement of substation and electrical gear, and hospital tunnel repair.
- *Phase III*, scheduled to begin in late 2020, includes vehicle replacement. Other efforts will be directed to inspect the infrastructure and perform the required repairs to maintain the structural integrity of the system.

International: United Kingdom

Heathrow Terminal 5, UK Tram Limited, 2021.
https://uktram.com/systems/heathrow-terminal-5/
From the web site: The world-first Heathrow pod is the personal rapid transit (PRT) system linking Terminal 5 with the T5 business car park. The pods are battery-powered, driverless vehicles.

The 21 pods carry four passengers and their luggage, along a guideway with speeds of up to 25 mph.

Heathrow T5, Ultra Global PRT, undated.
https://www.ultraglobalprt.com/wheres-it-used/heathrow-t5/
From the web site: Here, Ultra's first commercially operational pod system provides 800 passengers per day with a vital link between the T5 Business Car Park and the terminal itself.

A powerful example of the system's benefits, the small footprint of the Heathrow pods system enables it to fit within the tight constraints imposed by the airport infrastructure.

Commissioned by Heathrow Airport operator BAA, the system consists of 21 vehicles, a total of 3.8 kilometers of one-way guideway, and three stations—two in the T5 Business Car Park and one at Terminal 5.

To date the system has carried over 700,000 passengers and in May 2013 celebrated reaching its 1 millionth autonomously driven mile.

Feasibility Studies

Domestic: California

Automated Transit Networks (ATN): A Review of the State of the Industry and Prospects for the Future, Burford Furman, Lawrence Fabian, Sam Ellis, Peter Muller and Ron Swenson, California Department of Transportation, Research and Innovative Technology Administration, September 2014.
http://www.advancedtransit.org/wp-content/uploads/2013/05/1227-automated-transit-networks.pdf
This study explains ATN technology—described as "fully automated vehicles on exclusive, grade-separated guideways provid[ing] on-demand, primarily nonstop, origin-to-destination service over an area network"—and places it in the larger context of automated guideway transit. Included in the report is a discussion of the opportunities and challenges in planning and funding ATN systems, and approaches for procuring a system.

A discussion of planning parameters begins on page 33 of the report (page 51 of the PDF). Among the topic areas addressed:

- Design parameters affecting guideway configuration (see Table 5 on page 34 of the report (page 52 of the PDF)).
- Physical dimensions of the various components of an ATN project. Guideways and stations "are the two prominent and highly visible parts of an ATN system."
- Four ATN configuration characteristics that differ significantly from other forms of guideway transit:
    - It is a network, not a line or even a set of lines.
    - Placement of stations is extremely flexible.
    - Capacity of a station is a variable and often quite small.
    - Guideways can be flexibly conceived and designed in three dimensions.
- Station placement and sizing. The authors note that "ATN stations operate off the main line and are sized to the volume of passengers and vehicles that planning studies have

determined. Compared with conventional rail, ATN stations are small, and many of them may be very small—similar to bus shelters rather than to a rail station."

- Station capacity. Capacity of an ATN station depends on factors that include:
  - Average vehicle occupancy for arriving vehicles.
  - Average vehicle occupancy for departing vehicles.
  - Number of bays.
  - Bay configuration (in-line or off-line).
  - Vehicle dwell time in station (maneuvering time, plus door opening time, plus unloading time, plus loading time, plus door closing time, plus maneuvering time).
  - Delays due to other vehicles, including waiting for a bay to open up.
  - Delays waiting to enter the main guideway.
- Guideway placement. The authors note that guideways "can be placed at grade, elevated slightly or fully, below grade and protected, or fully underground. … However, capital costs for elevated systems tend to be about three times those for at-grade systems, and below-grade systems tend to cost about three times that of an elevated system or nine times that of an at-grade placement."
- Other topic areas:
  - Station ramps.
  - Guideway capacity and speed.
  - Capacity and load factors.
  - Network capacity.
  - Control system.
  - Scalability.
  - Aesthetics.
  - Capital costs.

Unified Corridor Investment Study: Automated Transit Network Alternative; Conceptual Evaluation, PRT Consulting, Inc., November 2018.
http://www.advancedtransit.org/wp-content/uploads/2018/11/20181102-UCS-Conceptual-ATN-Evaluation-Final.pdf
This paper was developed in response to the Santa Cruz Draft Unified Corridor Investment Study that examined bus and train options but, as the paper's author noted, "ignored PRT." This paper evaluates the PRT alternative by addressing 13 key criteria. Appendix A, Project Description and Cost Estimates, begins on page 16.

In the *Related Resources* below, web sites developed by PRT advocates and a 2007 report considering the feasibility of PRT within Santa Cruz provide additional context.

Related Resources:

Santa Cruz County for PRT, Watsonville Personal Rapid Transit, 2017.
http://watsonvilleprt.org
From the web site: We hold a vision for the future of public transportation in Santa Cruz County, maximizing the use of Measure D funds to enhance convenience and sustainability. We hope to unite transit advocates and trail advocates in support of Personal Rapid Transit.

Santa Cruz PRT Inc., 2016.
https://www.santacruzprt.com/
From the web site: Santa Cruz PRT Inc. advocates cutting-edge, solar-powered people movers that will be a sustainable approach toward maintaining our mobility. In looking to be on the cutting edge in Santa Cruz, we hope to provide leadership for other communities and attract global interest that will enhance the Santa Cruz economy with expanded and eco-friendly tourism.

Report on the Feasibility of Personal Rapid Transit in Santa Cruz, California, City of Santa Cruz, California, March 2007.
http://www.smartskyways.com/Market/prtrpt.pdf
This report considered PRT and its applicability in Santa Cruz by examining technologies, route selection, funding and implementation options. The authors addressed a range of concerns (beginning on page 46 of the report, page 49 of the PDF), concluding that "[i]nterviews with Santa Cruz residents, city officials, politicians and business leaders revealed a widespread curiosity about personal rapid transit. While there was some skepticism about whether the technology would live up to its promises, there was no hostility or opposition. Participants were in agreement that more information was needed."

Domestic: Georgia

Innovative Transit Technology, ATL Airport Community Improvement Districts, 2020.
https://aerocids.com/innovative-transit-technology/
From the web site: We have a vision for technological innovation that will improve the quality of life and mobility for property owners in and around the world's busiest airport, Hartsfield–Jackson Atlanta International Airport. One cutting-edge solution for mobility is the use of Personal Rapid Transit (PRT). This is a safe, cost-effective mode of transportation using small modes called podcars that are used to transport passengers between designated locations. When compared to other modes of transportation PRT is [the] most affordable and adaptable.
….

Our Plan
We will begin a 6-12 month PRT Comprehensive Study and a 12-36 month Demonstration Center and System in 2021. In order for this plan to be impactful we will consider the following opportunities:

- Identify funding partners from public and private sectors.
- RFP [request for proposal] to select consultant.
- Include public and private stakeholders and academia.
- A potential route to be implemented within South Fulton County and Clayton County.
- Investigate PRT vendors and system.
- Document potential ridership, demand, construction, operations and maintenance costs.
- Show comparisons between HRT [high-speed rapid transit], LRT [light-speed rapid transit] and BRT [bus rapid transit].
- P3 [public/private partnership] initiative.
- RFP process to select PRT vendor.
- Connections between HJAIA [Hartsfield–Jackson Atlanta International Airport] terminals and local destinations.

Related Resource:

"Aerotropolis Atlanta CIDs Study System of 'Podcars' for Better Airport Area Mobility," Randy Southerland, *Atlanta Business Chronicle*, July 17, 2020.
https://aerocids.com/wp-content/uploads/2020/07/ABC-Article-PRT-July-2020.pdf
From the online article: "We saw that (PRT) provided two major features that we thought could be a solution, not only for the airport area, but the region as well," said Aerotropolis Atlanta Community Improvement Districts [CIDs] Executive Director Gerald McDowell. "It costs significantly less than heavy rail and light rail, and even costs less than bus rapid transit to build and construct."

> PRT routes can be built for about $10 million to $20 million a mile compared to $300 million or more a mile for high[-]speed rail. It's also flexible. The system only deploys the number of podcars needed to meet immediate demand. There's no empty cars traveling between routes, according to McDowell.
>
> The push for PRT came after a year-long transit feasibility study commissioned by the CIDs.
>
> "One of the first recommendations was that we conduct a micro transit pilot, which we are in the final phases of launching," McDowell said. "We're hoping to have that pilot launched by the end of this year where there will be a micro transit service that will be available to those who have worked in the mobility district. We're evaluating two companies and we will be selecting one of those companies to run that pilot for us over 12 months, throughout 2021."

Domestic: South Carolina

Automated Transit Network Feasibility Study for Clemson, Greenville and Mauldin, PRT Consulting, Inc., Dan Boyle and Associates, and Engineering Services Group, August 2018.
http://www.advancedtransit.org/wp-content/uploads/2018/10/20180904-GPATS-ATN-Feasibility-Study.pdf
From the executive summary: The maximum speed assumed in this study is 35 mph while the maximum capacity needed is within the capabilities of existing systems and can readily be increased based on pending changes to the standards.

This feasibility study was initiated for the Greenville Urbanized Area in response to recent studies in both Clemson and Greenville that suggested significant potential for ATN ridership. It utilized results from a public survey along with a [l]ogit model to determine ridership. The model was tested in Clemson by using it to determine the expected ridership of the [CATbus Red Route] system. The projection came within [1%] of the actual ridership.

A Clemson ATN solution comprising 47 stations and 24.5 miles of one-way track was developed as an alternative to the CATbus Red Route. It was found [that] the ATN solution would attract 8,423 daily riders, which is 130% more than the 3,662 that currently use the CATbus Red Route. The capital cost of the ATN solution was estimated at $253 [million] (about $10.3 [million] per mile) and the annual O&M [operating and maintenance] costs at $2.7 [million]. The annual revenue, based on an average fare of $3.50 per trip, is $7.9 [million]. Thus, the fare-box recovery ratio is 2.92, far higher than for conventional transit but not sufficient to cover capital cost amortization. The benefits of the ATN solution include:

- A 23% decrease in SC-93 traffic.
- Reduced need for road widening and maintenance, congestion mitigation and parking facilities.

International: Australia

Personal Rapid Transit Application in Retrofitting Edge Cities—Macquarie Park Case Study, Monica Zarafu, Heather MacDonald and Garry Glazebrook, 2015.
http://www.advancedtransit.org/wp-content/uploads/2011/08/PRT-Application-in-Retrofitting-Edge-Cities.pdf
This case study used a desk exercise to propose a PRT system as a feeder for the rail and bus stations in an edge city (an area of suburban density within the city limits). The simulation "showed that the overall performance of the PRT is very effective, even in the busiest hours of

the morning and afternoon peak. In Macquarie Park, a 17.8 kilometre-long, one-way single loop network with [20] off-line stations and two simple depots can handle as many as 3,800 passengers per hour."

Noting that the major constraints on the growth of edge cities are size and road infrastructure, the authors found that the PRT network "may address these constraints and allow for future growth, while providing alternatives to the construction of new major roads and consequently having a positive impact on a variety of social goods—health, environmental quality and urban space."

International: India

"Design and Feasibility Analysis of Personal Rapid Transit Network for an Indian Heritage City," Jayvant Choudhary and Anshuman Sharma, *Australasian Transport Research Forum 2016 Proceedings*, November 2016.
https://www.australasiantransportresearchforum.org.au/sites/default/files/ATRF2016_Full_papers_resubmission_168.pdf
The authors identify the four PRT systems operational as of July 2013:

- Morgantown PRT, which has been operating on the West Virginia University campus since 1975. See page 10 for more information.
- Ten-vehicle 2getthere system, which has been operating since 2010 in Masdar City, United Arab Emirates.
- Twenty-one-vehicle Ultra PRT system, which has been operating at London Heathrow Airport since 2011. See page 10 for more information.
- Forty-vehicle Vectus system, which opened in Suncheon, South Korea, in April 2014 after a year of testing. See page 28 for more information.

This paper's case study seeks to determine the viability of a new PRT network in India and addresses the following topics:

- Travel demand assessment. Primary and secondary data are needed to plan the PRT network and estimate travel demand and modal shift.
- Calculation of base year trips.
- Calculation of trip shifting to PRT.
- Modal split.
- Supply capacity of PRT.
- Proposed PRT route. A two-way PRT route network of 8.0 km length with nine stations was proposed in the case study area to meet the estimated travel demand.
- Financial analysis. Financial viability of a project is assessed on the basis of its net present value and internal rate of return (IRR). If the IRR value is greater than 16%, then investment is recommended.

International: United Kingdom

UK Tram Limited, 2021.
https://uktram.com/
From the web site: UK Tram is the authoritative voice of the light rail sector in the UK [United Kingdom] and Ireland. We represent operators, promoters, manufacturers, contractors and

consultants involved not only in tramways and metros but also the expanding ultra and very light rail and personal rapid transit sectors.

Previous [g]overnments have acknowledged the important role that light rail can play in transforming our towns and cities and UK Tram has stepped up to the challenge of helping the sector to grow and become more relevant and vibrant across the country as a whole.

Related Resources:

Guidance Note for Light Rail, Ultra Light Rail and Personal Rapid Transit: Guidance on Preparation of a Business Case, UK Tram Limited, April 2012.
https://uktram.com/wp-content/uploads/2018/07/Guidance_Note_for_LR_ULR_PRT2.pdf
The authors describe PRT, also called podcar, as "a public transport mode featuring small automated vehicles operating on a network of specially built [guideways]. PRT is a type of automated guided transit (AGT), a class of system which also includes larger vehicles all the way to small subway systems.

"In PRT designs, vehicles are sized for individual or small group travel, typically carrying no more than 3 to 6 passengers per vehicle. [Guideways] are arranged in a network topology, with all stations located on sidings, and with frequent merge/diverge points. This approach allows for nonstop, point-to-point travel, bypassing all intermediate stations. The point-to-point service has been compared to a taxi or a horizontal lift (elevator)."

Report chapters address:

- *Making a strategic case*. Chapter 2 presents an overview of the "wider strategic issues that a promoter should consider prior to submitting a business case."
- *Option appraisal and value for money*. Chapter 3 summarizes "existing guidance on the appraisal of rapid transit schemes and highlight[s] some of the major considerations in the appraisal of alternatives."
- *Commercial issues*. Chapter 4 provides guidance for relating commercial issues to specific aspects of PRT development.
- *Financial considerations*. Chapter 5 addresses the funding sources available and identifies a range of costs.
- *Project delivery*. Chapter 6 sets out the "key factors which promoters should consider in order to ensure effective delivery of schemes."
- *Approval processes*. Chapter 7 provides an "overview of the various stages of the approvals process for major rapid transit schemes."

Advice Note for Promoters Considering Personal Rapid Transit (PRT), Version 1, UK Tram Limited, July 2012.
https://uktram.com/wp-content/uploads/2018/07/Advice_PRT_Final_V1.pdf
This publication is a companion to the report cited above. Readers are advised to refer to the previously cited report for "general guidance on the preparation and evaluation of major scheme business cases. This is the first important step to be taken in seeking funding for any scheme."

The authors highlight three "established PRT manufacturers":

- Ultra Global PRT, which supplied the Heathrow pod system operating at London Heathrow Airport between Terminal 5 and its business car park.

- 2getthere, which has a system operating in Masdar City in Abu Dhabi.
- Vectus, which opened a system at Suncheon Bay, South Korea, in 2014.

Report chapters include:

- *Chapter 2, Characteristics of PRT*. Summarizes the general attributes of PRT.
- *Chapter 3, Comparative Description of Current Systems*. Includes detailed comparative specifications and contact details for vendors.
- *Chapter 4, Exploiting the Benefits of PRT*. Describes how the benefits of PRT "are revealed through existing applications and studies."
- *Chapter 5, PRT Costs*. Provides general guidance on costs.
- *Chapter 6, Procurement*. Comments on special issues in PRT procurement.
- *Chapter 7, Regulatory Issues*. Examines the special regulation associated with this form of transport.

Comparing Transit Alternatives

Domestic

"Personal Rapid Transit as an Alternative to Bus Service in Two Communities," Peter Muller and Ingmar Andreasson, *International Conference on Transportation and Development*, July 2018.
http://www.advancedtransit.org/wp-content/uploads/2018/08/Muller-PRT-Alternative-to-Bus-ASCE-ICTD-2018.pdf
This presentation that outlined a case for PRT begins with a description of ATNs:

- Small driverless vehicles operating on dedicated guideways (usually elevated).
- Stations are off-line (on sidings).
- Most trips are nonstop.

The authors note that ATN is also referred to as PRT and group rapid transit.

Previous research indicated that a citywide system could pay for itself if it could attract enough riders. The authors sought to assess whether enough riders could be attracted to the proposed system. To make this determination, they:

- Conducted a public survey to determine modal disutility (also referred to as zonal attractiveness).
- Laid out suitable ATN stations and guideways.
- Applied a logit choice model to determine mode split car/ATN and car/bus based on weighted times.
- Confirmed the model works by comparing modeled bus mode split with known bus mode split.
- Determined costs and revenues.

After concluding that ATN could pay for its own capital and operating costs in a community with a population density of about 2,500 per square mile (3.9 per acre), the authors concluded that ATN will also:

- Reduce congestion by removing 72,000 daily car trips.

- Reduce road transportation facility requirements.
- Improve mobility and accessibility.
- Increase real estate values.
- Improve the economy.
- Increase safety.
- Improve resiliency and sustainability.

"A Light Rail, Group Rapid Transit, Personal Rapid Transit Comparison," Peter J. Muller and Ingmar J. Andreasson, *16th International Conference on Automated People Movers and Automated Transit Systems*, April 2018.
https://prtconsulting.com/docs/LRT-GRT-PRT-Comparison.pdf
From the introduction:

> The primary purpose of this paper is to compare an existing light rail transit (LRT) deployment with the results that could reasonably have been expected had the deployment been accomplished using group rapid transit (GRT) or personal rapid transit (PRT) technology that is currently commercially available. In addition, results based on high-speed and -capacity PRT technology (HSCPRT), expected to be available soon, have also been estimated.

Highlights from the conference paper's conclusions:

- The PRT mode approximately matches, or improves upon, weighted trip times by car for all of its passengers except for those trips accessed by bus.
- The very significant increase in projected ridership results from these reduced times and the improved level of service provide by the increase from 14 LRT stations to 82 PRT stations.
- A significant aspect of this level of service improvement is that over 50% of riders are within ¼ mile of a station as opposed to less than 12% for the LRT system.
- Researchers identified a sixfold increase in destinations from any one station (from 13 to 81). Even with an accessibility factor of 1 (no increased ridership due to improved accessibility), the PRT and HSCPRT solutions have costs per passenger of less than $4.
- While the PRT ridership is estimated to be 12.5 times higher than the LRT ridership, the PRT capital cost is only expected to be 2.1 times, and the operating and maintenance cost 3.2 times, higher than that of the LRT system. This results in a much more favorable business case wherein fare-box revenues cover both operating and capital costs, and there is a positive return on the equity investment.
- The high increase in transit ridership resulting from a fairly widespread PRT deployment has also been found by other researchers.

International: Sweden

Personal Rapid Transit as Feeder/Distributor to Rail, Ingmar J. Andreasson, Centre for Traffic Research, Royal Institute of Technology, October 2011.
http://www.advancedtransit.org/wp-content/uploads/2011/08/Rail-PRT.pdf
This paper explores the suitability of PRT as a feeder/distributor to rail stations, beginning with a concise description of PRT:

> Personal Rapid Transit (PRT) is individual public transport on demand. Driverless vehicles run on guideways separated from other traffic. Stations are off-line so that passing traffic can be nonstop. While the concept is not new, only recently have commercial suppliers entered the market, such as ULTra, 2getthere and Vectus. Vehicle capacity ranges from 4 to 6 seated passengers.
>
> PRT offers zero or short waiting and typically travel speed twice that of bus. Although the investment is relatively high, it is only a fraction of the investment for light rail and the operations cost is lower than any other public transport. The main hurdles for PRT implementation are believed to be the visual intrusion of guideways and the lack of operating experience.

The authors note that “early implementations of PRT systems” are most suitable for:

- Landside transportation around airports.
- Circulation to and within shopping areas.
- University and hospital campus areas.
- Feeding/distribution around rail stations.
- Local transport in new cities.

The authors consider a range of PRT-related issues:

- Station layouts.
- Vehicle scheduling.
- Catchment area.
- Ticket handling.
- Ride sharing.
- Signage.
- Time to depart.
- Coupled PRT vehicles.

From the paper’s conclusions on page 14 of the PDF:

- Ridership on the rail system may benefit from attractive feeder/distribution systems.
- Feeding rail stations is a feasible application of PRT.
- Transfer stations between rail and PRT can be designed to handle peak loads.
- Rail fares should include feeding/distribution to speed up transfers.
- Destination signs may facilitate ride-sharing, thereby increasing capacity.
- Coupled PRT vehicles may reduce station clearing time to about half.
- With 28 destinations, PRT vehicles from one rail station were loaded to 78%.
- Effects have been verified by simulations in PRTsim software.

Station Design

International: Italy

“Analytical Capacity Limits of Personal Rapid Transit Stations,” Joerg Schweizer, Luca Mantecchini and J. Greenwood, *APM (Automated People Movers) Conference*, May 2011.
Publication available at
https://www.researchgate.net/publication/266265857_Analytical_Capacity_Limits_of_Personal_Rapid_Transit_Stations
This article examines PRT station characteristics, noting that they are “a complex function of geometry, vehicle dynamics, boarding strategies and user behavior.” Using analytical and

microsimulation techniques, the authors compared three types of PRT stations to aid in the selection of “the most suitable station for a given space constraint and demand scenario.”

The authors focused on three types of PRT stations:

- *Serial off-line stations* where vehicles line up at a platform to get loaded. Issues with this type of station:
    - A loaded vehicle waiting at the platform can only depart if all vehicles in front are also loaded and ready to depart. This means the capacity depends on the passenger boarding times.
    - These stations have a high sensitivity to a small proportion of slow boarding passengers. For serial stations with a small number of berths (up to approximately four), the capacity is mostly limited by boarding times. As the number of berths increases, the forwarding time, which depends on the length of the station and vehicles and the maximum speed in stations, becomes the dominant factor. Increasing speed in stations raises issues with the control systems that guarantee safe headways.
- *Ordinary sawtooth stations* are where each loading berth can be accessed individually by the vehicles. The advantage of this station configuration is that it depends less on the boarding behavior of passengers. The capacity of the sawtooth type of station is less dependent on boarding times but is dependent on the organization of vehicle movements in the station.
- *High-capacity sawtooth stations*, which offer additional parking spaces for each berth, have a better capacity than the serial station for slower boarders but, because the berths are more spread out, the space efficiency is lower relative to serial stations.

With both types of sawtooth stations, “vehicles can leave independently unlike the serial configuration. The main reason is that a loaded vehicle can back out (or move forward out) and depart without having to wait for the other vehicles in front to complete boarding.” The authors suggest investigating a mixed-type station such as one with serial-type berths for the majority of passengers combined with some sawtooth-type berths for slow boarders.

The article offers details on how to estimate station capacity. While microsimulators can identify capacity bottlenecks for specific networks and for a given travel demand, the authors noted that, “to design a network, it is useful to estimate the capacity limits of single network elements, particularly stations, before switching to the microsimulation of the entire system.” The article summarizes recent findings on the determination of station capacities that consider different station layouts and operation modes, and offers a method to calculate the empty and full vehicle flows on a PRT network to verify capacity bottlenecks.

Implementation Guidance

Domestic

Podway Handbook, Transit X, LLC, August 2020.
https://www.transitx.com/transitxhandbook.pdf
This publication is billed as a “companion guide to proposals for a privately financed public transit podway—a fleet of automated electric vehicles (pods) for passengers and freight on a local and intercity micro-guideway providing equitable transportation.” More information about this Massachusetts-based vendor is provided on page 23.

International

Guidelines for Implementers of Personal Rapid Transit (PRT), NICHES+, European Commission, June 2010.
http://www.rupprecht-consult.eu/uploads/tx_rupprecht/NICHES_WG4.2_PRT.pdf
This publication, while somewhat dated, provides background information on implementing a PRT system and includes this checklist:

City Size	Initially for widening catchment areas (e.g., for stations etc.) and serving dispersed sites, but city-sized networks are possible.
Costs	Less than for an equivalent bus scheme using drivers and less than for a tram. Capital costs are needed to procure the podcars; provide the control system and a depot for vehicle maintenance/charging; and provide and equip the guideway, stations and security measures.
Implementation Time	Medium term; five years or more may be needed to plan and implement a scheme in a city environment.
Stakeholders Involved	Operating company, local authority as the infrastructure owner, national government for safety certification, local community and users.
Undesirable Secondary Effects	Possible visual intrusion caused by elevated sections of guideway and of severance caused by sections at-grade, although these can be mitigated by using “cut and cover” or tunnels.

Technology and Design

Domestic

Transit Control Solutions, Inc., undated.
http://transitcontrolsolutions.com/
From the web site:

> Transit Control Solutions, Inc. (TCS) develops world-class technologies and delivers overwhelmingly superior control solutions for Automated Transit Network (ATN) and Personal Rapid Transit (PRT) systems. Our product also applies to automated people mover (APM) and driverless train systems.
>
> Our highly scalable and globally applicable technology advancements will enable ATN systems to achieve significantly increased capacity (3,600 cars per hour per direction at a speed of 60 mph—about 4x higher than other systems in the market), passenger convenience, economic value and operational control while achieving a very high degree of safety (calculated Mean Time Between Unsafe Failures greater than 10^9 hours).
>
> Our key, enabling technologies fundamentally improve people’s lives, communities, public services and businesses.

SPM Maglev: Reinventing Maglev Transportation, LaunchPoint Technologies Inc., 2017.
https://www.launchpnt.com/portfolio/transportation/spm-maglev
This web page describes the use of magnetic levitation (referred to as "maglev") for mass transit applications. Among the topics discussed is Applied Levitation's stabilized permanent magnet (SPM) suspension technology, which "provides capabilities that were not previously possible and at a lower cost than any other high-capacity approach."

International

"Design and Validation of a Slender Guideway for Maglev Vehicle by Simulation and Experiment," Jong-Boo Han, Hyung-Suk Han, Sung-Soo Kim, Seok-Jo Yang and Ki-Jung Kim, *Vehicle System Dynamics: International Journal of Vehicle Mechanics and Mobility*, Volume 54, Issue 3, pages 370-385, 2016.
https://doi.org/10.1080/00423114.2015.1137957
From the abstract: Normally, [m]aglev (magnetic levitation) vehicles run on elevated guideways. The elevated guideway must satisfy various load conditions of the vehicle, and has to be designed to ensure ride quality, while ensuring that the levitation stability of the vehicle is not affected by the deflection of the guideway. However, because the elevated guideways of [m]aglev vehicles in South Korea and other countries fabricated so far have been based on over-conservative design criteria, the size of the structures has increased. Further, from the cost perspective, they are unfavourable when compared with other light rail transits such as monorail, rubber wheel and steel wheel automatic guided transit. Therefore, a slender guideway that does have an adverse effect on the levitation stability of the vehicle is required through optimisation of design criteria. In this study, to predict the effect of various design parameters of the guideway on the dynamic behaviour of the vehicle, simulations were carried out using a dynamics model similar to the actual vehicle and guideway, and a limiting value of deflection ratio of the slender guideway to ensure levitation control is proposed. A guideway that meets the requirement as per the proposed limit for deflection ratio was designed and fabricated, and through a driving test of the vehicle, the validity of the slender guideway was verified. From the results, it was confirmed that although some increase in airgap and cabin acceleration was observed with the proposed slender guideway when compared with the conventional guideway, there was no notable adverse effect on the levitation stability and ride quality of the vehicle. Therefore, it can be inferred that the results of this study will become the basis for establishing design criteria for slender guideways of [m]aglev vehicles in [the] future.

Vendors and Consultants

Information is presented below for vendors and consultants in two categories: domestic and international.

Domestic

Four domestic vendors offering or proposing PRT solutions are highlighted below:

- iTran Systems LLC.
- PRT Consulting, Inc.
- Transit X, LLC.
- Virgin Hyperloop.

iTran Systems LLC, 2019.
https://itran.us/
From the web site:

> **About Aerial Personal Rapid Transit**
> APRT [aerial personal rapid transit] is smart, fast, safe, cost-effective, flexible and sustainable. It's the first 21st century transit solution. It glides quietly, autonomously, within its aerial guideway 20 feet above the traffic.
>
> **Mobility on Demand**
> Unlike current (outdated) mass transit solutions, APRT operates only on demand—whenever a paying customer reserves a 2 or 4 passenger (or a "cargo only") vehicle to be transported swiftly, nonstop from an ADA [Americans With Disabilities Act] compliant station to their desired station destination. Mobility on Demand is powerful because it's the key to profitability. It's why we say: iTS—the future of transit.
> ….
>
> Due to its small footprint and use of unoccupied airspace for its network of guideways APRT is faster to erect, less disruptive to traffic during its construction and can be put in place at a fraction of the cost of adding lanes to existing, congested roadways. When combined with first mile and last mile options like Uber and Lyft[,] APRT will reduce the need for many to own a motor vehicle. This has great appeal to large segments of Florida's population—including millennials and baby boomers. Once APRT connects airports, hotels and popular tourist destinations[,] the need for tourists to rent cars will be less of a necessity—thus reducing their burden on Florida's crowded roads and highways.

PRT Consulting, Inc., undated.
https://prtconsulting.com/
From the web site:

> PRT Consulting provides professional planning and engineering consulting services related to driverless transit systems. We can help you improve mobility, safety and economic development while reducing congestion and emission.

The site offers access to a wide range of PRT resources:

- Company brochure: https://prtconsulting.com/brochures/PRT-Consulting-Overview.pdf.
- How PRT works: https://prtconsulting.com/how-prt-works.html.
- PRT papers: https://prtconsulting.com/personal-rapid-transit-papers.html.
- PRT reports: https://prtconsulting.com/personal-rapid-transit-reports.html.

Transit X, LLC, 2020.
https://www.transitx.com/
From the web site: Transit X builds and operates privately financed public transit podways that can transform cities and metropolitan areas to be green and walkable. A podway is an automated micro-guideway with the convenience, capacity, and cost to replace cars, buses, trains, trucks, ferries, and short flights. Transit X is the silver bullet for transportation.

Powered by 100% renewable energy... Carbon-free and zero pollution… Over 10 times more efficient than electric vehicles. Podways can rapidly decarbonize transportation and achieve Vision Zero Pollution… Nonstop door-to-door travel at 72 km/h (45 mph) along main roads and 242 km/h (150 mph) along highways or railways. It's why we say that our pods fly.

….

Our first project will break ground in 2020 and begin operations in 2021. Installation is fast and not disruptive to neighborhoods. Our first public demonstration was on October 29, 2018, in Leominster, Massachusetts, USA.

….

Featherweight four-passenger pods quietly cruise above traffic suspended under a thin rail. Stops are typically a block or two away, and destinations are entered via smartphone or kiosk prior to boarding. A pod lifts up and travels nonstop until landing at the destination. Fares are similar to existing public transportation.

Podways are fully automated microtransit with high-capacity micro-guideways that provide fast and wait-free travel. A podway has the equivalent capacity of a 12+ lane highway. Installation is fast and minimally disruptive. Podways have less visual impact than roadways. The system provides door-to-door service for both passengers and freight.

Related Resource:

> **Transit X Process: Sample Letters and Agreements**, Transit X, LLC, undated.
> https://www.transitx.com/process/
> *From the web site*: Transit X operates on easements along public or private rights of way. Before a project is started we need a commitment to build and operate on those easements. This document is an overview of our process along with examples of initial documents.

Virgin Hyperloop, 2021.
https://virginhyperloop.com/
From the web site: We're building for fast, effortless journeys that expand possibilities. Our system can propel passenger or cargo pods at speeds of over 1000 km/h. That is 3x faster than high-speed rail and more than 10x faster than traditional rail. Sustainability is not a nice thing to have; it's a requirement for transportation that moves us forward. Over its lifetime, the Virgin Hyperloop will have a lower environmental impact than other modes of mass transportation. The Virgin Hyperloop delivers airline speeds, the same G-forces as rail, and the ease of riding a metro. A central command [and] control ensures safe and reliable passage throughout the network. The passenger of the future will expect direct and on-demand transportation. With Virgin Hyperloop, there are no timetables. Several pods can depart per minute, and the system does not require stops at every station.

Related Resources:

> **"Virgin Hyperloop Outlines How It Thinks Journeys Will Actually Work in 2030: A New Concept Video Shows Its Vision of the Future,"** Daniel Cooper, *Engadget*, Verizon Media Inc., January 27, 2021.
> https://www.engadget.com/virgin-hyperloop-2021-concept-video-140000961.html
> This article includes a concept video of how the Virgin hyperloop will work in practice.

> **"West Virginia Goes Back to the Future With Transit Technology,"** David Kidd, *Governing: The Future of States and Localities*, October 16, 2020.
> https://www.governing.com/next/West-Virginia-Goes-Back-to-the-Future-With-Transit-Technology.html
> *From the article*: Last week, Virgin Hyperloop One announced plans to build a $500 million certification facility and 6-mile test track in the Mountain State. Construction is scheduled to begin in two years, with a completion date of 2025. Virgin will use the facility to test and

develop hyperloop technology, working with the U.S. Department of Transportation to establish regulatory and safety standards. If all goes according to plan, Virgin hopes to have a full-scale system operational somewhere in the U.S. by 2030.

International

Six international vendors offering or proposing PRT solutions are highlighted below:

- 2getthere from ZF Friedrichshafen AG (Utrecht, Netherlands).
- Fairwood Group (Noida, India).
- skyTran (Mumbai, India).
- SkyWay from Rsw-systems.com, Inc. (Tortola, British Virgin Islands).
- Ultra Global PRT (Bristol, UK).
- Vectus Ltd. (offices in the UK, Sweden and South Korea).

2getthere, ZF Friedrichshafen AG, undated.
https://www.2getthere.eu/systems/automated-people-movers/
From the web site:

> **Automated People Mover Systems**
> Automated People Mover Systems (APM) use dedicated (elevated) guideways to facilitate direct, high[-]capacity connections along a corridor. Where traditional APM systems use large vehicles at low frequencies, 2getthere employs 24-passenger GRT [group rapid transit] vehicles at high frequencies. The system accommodates capacities in excess of 5,000 passengers per hour per direction. With a maximum speed of 60km/hr, the system is suited to serve both short connections (up to 1.5 kilometer) as well as long corridors (e.g., 12 kilometers).

Related Resources:

PRT Vehicle, 2getthere, ZF Friedrichshafen AG, undated.
https://www.2getthere.eu/technology/vehicle-types/prt-vehicle-automated-taxi/
From the web site:

> 2getthere's PRT vehicles are automated taxis accommodating up to 6 seated passengers (4 adults and 2 children). The vehicles have been developed specifically for the environmental climate of the Middle East and are capable of a maximum speed of 40km/h.
>
> The 2nd generation PRT vehicle has been operational at Masdar City since November 28th, 2010. The vehicle uses a scaled[-]down version of the 2nd generation GRT chassis, with significant improvements in the electronics and sensory systems of the vehicle. In addition the algorithms for control of the vehicle were further improved, ensuring an even better driving behavior and improved passenger comfort.

The web site provides a detailed list of vehicle specifications.

GRT Vehicle, 2getthere, ZF Friedrichshafen AG, undated.
https://www.2getthere.eu/technology/vehicle-types/grt-vehicle-automated-minibus/
From the web site:

> 2getthere's GRT vehicles are automated minibuses accommodating 22 passengers (8 seated, 14 standing). The maximum speed is 60km/hr and [they] are unique as they are the only autonomous vehicles that are bi-directional and feature doors on both sides. The GRT vehicle allows for easy access through accurate docking at the stations, enabled by the "crabbing" capability of the front and rear wheel steering.

The web site provides a detailed list of vehicle specifications.

Personal Rapid Transit (PRT), Fairwood Group, 2017.
http://www.fairwoodgroup.com/technology/prt/
From the web site: The Personal Rapid Transit System (PRT) is a 4-6 seater battery powered driverless vehicle which uses rubber wheels running on an elevated [guideway]. The PRT is, in fact, a personal taxi which is demand responsive to any user. The PRT transports the users anywhere within the track network directly and without any stops. Stations are off-line allowing the PRT pods to bypass all stations en route to the destination thereby reducing travel time. It is an energy efficient and sustainable system.

The PRT System has been designed and developed by ULTra of UK[,] and Fairwood has an exclusive understanding to implement this system in India.

skyTran, undated.
https://www.skytran.com/technology
Note: In February 2021, Reliance Industries Limited, headquartered in Mumbai, India, acquired a majority equity stake in skyTran. skyTran has maintained a corporate office in California's NASA Research Park. *From the web site*:

> Public transport as we know it requires stops. skyTran is different. A skyTran vehicle only stops at your chosen destination. Bypassing stations along the way, you travel at high-speed for the duration of your trip. This is the very definition of seamless point-to-point travel.
>
> Our proprietary maglev technology allows our vehicles to move along the track on a cushion of air. This means that your ride is always fast, smooth, and quiet. The vehicles are electric, producing zero emissions and allowing for high energy efficiency.

This site notes the company has a subscale engineering platform in California and a full-scale preproduction track in Texas.

Related Resource:

> **"These Futuristic Flying Pods Could Make Driving History,"** Leanna Garfield, *Business Insider*, May 4, 2016.
> https://www.businessinsider.com/skytran-flying-pods-will-launch-in-nigeria-2015
> This article discusses a proposed skyTran project in Lagos, Nigeria.

SkyWay, Rsw-systems.com, Inc., 2021.
http://rsw-systems.com/technology
From the web site:

> **Components of Technology**
> [The] [i]nnovative nature of SkyWay technology is due to an original and effective combination of widely known engineering and technological solutions. Each separate

component of SkyWay transport system is not something unique—it is the mode of component connection into the system that ensures its unprecedented design and operational features.

- Types of rails (flexible, semirigid, rigid).
- Rail structure beam overpass (comparison with conventional bridge).
- Passenger unibus configuration.
- Wheels (comparison with conventional ones).

Related Resources:

High-Speed Unibus, SkyWay, Rsw-systems.com, Inc., 2021.
http://rsw-systems.com/technology/high-speed
From the web site:

> High-speed vehicle that [serves] passengers at speeds up to 500 km/h on truss string-rail overpasses. It is driven with a traction electric motor powered from a contact circuit or from an onboard power storage device. It is used as part of transport and infrastructure complexes to provide transportation links on intercity and international routes. Its cabin has six seats equipped with an entertainment system for passengers. The body has a separate compartment for luggage.

Vehicles under development are also described.

Unitruck, SkyWay, Rsw-systems.com, Inc., 2021.
http://rsw-systems.com/technology/cargo
From the web site:

> A vehicle for the haulage of bulk, liquid, hazardous, perishable and piece goods. It is driven with a traction motor powered from a contact circuit or onboard power storage device. Loading and unloading of [a] unitruck can be carried out in automatic mode. It is used as part of transport and infrastructure complexes for operation at industrial facilities, as part of the infrastructure of ports and mining sites, as well as on urban and suburban routes.

The web site provides links to other cargo systems, including Unitrans, Unicont and vehicles under development.

An Effective Solution for Localised Areas With High-Frequency Transport Needs, Ultra Global PRT, undated.
http://www.ultraglobalprt.com/how-it-works/
From the web site:

> The Ultra personal rapid transit (PRT) is a new and innovative on-demand system for developed or urban environments.
>
> Using small, driverless electric vehicles that run on guideways, the lightweight and flexible nature of the system enables it to be retrofitted into a broad range of environments and provide transportation that is environmentally friendly and operationally efficient. Conventional forms of public transit require passengers to collect in groups, wait until a large vehicle with a fixed schedule arrives, and travel on a predetermined route stopping for additional passengers on the way. In contrast, ULTra offers personal transport with no waiting, taking passengers nonstop to their chosen destination.

This web site provides details about vehicle features and customization, stations and guideways, technical operations, reliability, safety and testing, and costs.

Vectus Ltd., 2012.
http://www.vectusprt.com/EN/
Note: This appears to be a legacy site, with the most recent information posted on the site dated 2013.

This web site provides information about a PRT installation in Suncheon Bay, South Korea. A detailed description of the company's technology is available at http://www.vectusprt.com/EN/technology/.