Transport by Design – January 2017 - John Cleeland M.Eng.Sc. Transport (Monash)

Podcars: efficient; safe; liveable; profits; jobs.

Abstract

Peak hour speeds can be **doubled** with Personal Rapid Transit (PRT)[1]. Suspended vehicles (podcars) have ***better speed, safety and comfort than normal cars.*** Routes must be grade separated with turning ramps, similar to freeway interchanges. You can conduct your business while travelling. Safety can only be achieved with fully automatic operation, segregation from other traffic, and private, door to door travel. Required SCADA control systems have redundancy and are used throughout industry. Reliability requires FMEA & independent regulation. Commuting and freight can use PRT. It is more accessible. Road space can be converted for walking, cycling and greater liveability. Electric, public use, low weight vehicles (~700kg gross), address pollution. High, light guideways have better appearance and are preferably routed through parkland. PRT stops must be reached via 45^{o} grades. Stop spacing ranges from 100m to 300m and stops are subject to value capture. PRT is ***commercially viable***. Build a demonstration route to the airport first for $400M, starting with small links to the car parks for concept proving. Second, build coarse coverage of city trip ends. Next create radial tourist routes to grow jobs. PRT should be a cheap feeder service to existing modes in low density catchments; with a competing premium service, to relieve excess traffic in congested corridors, and to fund network expansion. The industry must be structured for competitive supply of guideways, pods and extremely reliable maintenance and operations. Fares must be configured to balance the load.

Introduction

Personal Rapid Transit (PRT) is now the best way to improve the transport system. It can displace all other capital improvements to the transport system. This document examples the Metrino system, suspended from guide-rails, outlines benefits and design criteria, justifies PRT and suggests some development stages. FAQ are appended.

Suspended PRT

There are many PRT systems[24], but Metrino[21] has been awarded, so selected as an example. Pod size and weight, guideway design, system geometry, operating speed, route capacity, reliability design, and energy consumption are confirming features.

Metrino cabin design can carry bikes, motorised wheelchairs, 400kg freight or garbage, or seat 5 people. The guide rail is 10m high with 7m clearance: poles are spaced at 30m. Pods can remain level on steep grades and bank on corners, can climb 45 degree grades, turn on 3m radius, run at 70kph with 0.5 second spacing. Its power rail is inside an inverted track and is switchable at junctions. The system is under development. A full scale prototype was developed. Critical functions are duplicated: power, electric motors, movement detectors and communication channels. The Metrino video does not show grade separation and interchanges yet they are intended.

Design Criteria

Speed: Inner Melbourne arterial peak hour speeds[26] for cars average 25kph, reducing by 0.4kph per year. For cars, capacity is related to congestion and speed, but not for PRT: any line of poles can carry the capacity of an 8 lane freeway.

PRT is fully automatic, can run at 70kph, (faster if rural, in platoons), is not impacted by adverse weather or traffic incidents and is reliable by design. With vertical separation, on light guideways, pods fly over intersections and past intermediate stops without delay. For consistent speeds and direct routes, grade separated interchanges with turning ramps, similar to freeways are required. The technology for vehicle routing will need proving, as PRT networks grow from the initial set of individual routes. Close proximity to stops requires many parallel routes, so there is no congestion. Suspended vehicles have better passenger comfort than cars, because they compensate for turns, acceleration and grade (but resist wind), by control of the connection to the guide rail. Coffee will not spill during an emergency stop.

Conclusion: Peak hour speeds can be **doubled** with PRT: congestion and traffic incidents would not occur. Suspended vehicles (podcars) have better speed, safety and comfort than normal cars. PRT routes must be grade separated with turning ramps, similar to freeway interchanges. You can conduct your business while travelling.

Safety: In 2015, there were 6804 road crashes in Victoria[27] involving hospital admission and 253 fatalities. There were also crimes against the person[28]: for 2013/14: 1,895 on public transport, 1,347 on other transport and 11,617 on the street. Our ageing society requires wheelchair access and secure, affordable transport, door to door.

Fully automatic group transit has been demonstrated to be remarkably safe when segregated from other traffic. A pilot site at Morgantown[4], West Virginia has operated for 41 years, and carried 83 million passengers without any fatalities (expected rate 10 fatalities). **Personal** Rapid Transit means not sharing with strangers, so is safer than group transit (as Morgantown).

Cheaper stops for PRT means stops closer to “door to door”, reducing the risk of assault. Video surveillance inside and outside of pods is another layer of security.

Required Supervisory Control and Data Acquisition (SCADA) systems are similar to those used throughout industry, including for control of traffic signals. Multiple redundant inputs such as lidar, track sensors, accelerometers …, multiple redundant communication channels, and control devices for vehicles, interchanges and stops, use distributed processing to ensure a higher level of control, comfort, reliability, safety, security and enforcement. Split-second headways[15, video] are not dangerous for PRT vehicles. Reliability requires Failure Modes and Effects Analysis & independent regulation.

Conclusion: Safety can best be achieved with fully automatic operation, segregation from other traffic, and private, door to door travel. Required SCADA control systems have redundancy and are similar to those used throughout industry. Reliability requires FMEA & independent regulation.

Liveability: Road traffic is essential but it causes noise and emits pollutants. Remedial measures are simply not practical, so limits for noise[18] and pollution[17] have been restricted to exceptional cases. But replacing most cars and trucks[19] with PRT is now feasible, and roads can be converted to more friendly environments for walking and cycling[2], with reduced number of lanes for cars and reduced speed limits.

Multiple choices will be available for transport and the single person commute can be more efficient with PRT: cars will become an inferior option. Urban freight can also use PRT. One PRT pod, re-used for multiple trips during the peak and shoulder periods can do the same number of trips as eight cars, modelled as 4.5 in the peak direction and 3.5 counter peak. So PRT requires to park only one eighth the number of (smaller) vehicles, saving on parking space.

PRT pods can load powered wheelchairs at all stops, to expand accessibility, and load bikes, to

facilitate cycling at trip ends. No licence, nor user capital requirement further expands accessibility. Conclusion: Commuting and freight can use PRT, that is more accessible. Road space can be converted for walking, cycling and greater liveability.

Pollution: The greenhouse effect is well documented[3, see the movie]. Collectively, cars and trucks account for nearly 20% of all emissions. This can be reduced to zero for electric vehicles[9] when the power comes from renewable sources. Electric motors are 80% efficient compared to 15% efficiency[10, at 2 minutes] for petrol engines. The elimination of intersections, reduction in trips when empty, and reduction in weight of vehicles also has a major impact on emissions.

PRT requires fewer cars and energy is saved in vehicle manufacture. Trains consume 8 times the energy per pax-km[30, slide 31 & private communication] used by Metrino (buses 12 times; cars 10 times).

Conclusion: Electric, public use, low weight vehicles (~700kg gross), address pollution.

Urban Design: The appearance of suspended vehicles is better than of supported (PRT) vehicles because of the relative size and location of the guideway. 45° climbs will minimise the severence[16], caused to pedestrians and cyclists, by the stop size at ground level (25m x 5m), and will avoid expensive lifts and elevated stop infrastructure. Light guideways and steep ramp grades also minimize the visual intrusion of guideway interchanges. Vehicles are quiet and unobtrusive so can be routed through parkland and linked with bicycle paths.

PRT stops are expensive, but each end of the trip must approximate **door to door**, within the limits of economics. Stops can be as close as 100m spacing where trip ends are dense, yet in sparsely populated areas, 300m spacing may be affordable. Business will fund stops to attract custom, providing value capture. Trips to stops for both directions may be required. Stops are loaded with waiting vehicles 24/7. Off peak storage of vehicles at selected stops is required. Separate stops can consign freight to unobtrusive locations and improve freight delivery.

Conclusion: High, light guideways have better appearance, and are preferably routed through parkland. PRT stops must be reached via 45° PRT grades. Stop spacing ranges from 100m to 300m, and stops are subject to value capture.

Viability: Consider $400M costs for building a link from Melbourne City to Airport, via Highpoint with 60 stops and 2,300 pods.

After 2.5 years, the annual profit is $191M/year. In comparison, Melbourne Airport heavy rail link

requires additional tracks, is estimated to cost $5,000M, requires an operating subsidy, but would have a longer wait times and slower trips with less comfort and security.

Costing, City to Airport		
Guide way, 23.2km @ $6.7M/km	= $220M	(includes 40% contingency)
Stops, 60 No. @ $300k	= $ 26M	(includes 40% contingency)
Pods, 2,300 No. @ $25k	= $ 80M	(includes 40% contingency)
Other, Item	= $ 80M	(includes 40% contingency)
Capital Cost	**$ 406M**	
Interest/year @ 6%	= $ 25M	
Op. Cost, 60,000 trips/day @ 20c/km	= $ 74M	
Fares, airport to City, 25,000/day @ $19	= $173M	
Fares, commute, 35,000/day @ $3.9	= $ 41M	
Freight, A/P to city, 1,000/day @ $50	= $ 14M	
Advert, pods/stops, 2060 @ $50/day	= $ 37M	
Annual profit	**$166M**	(repay in 2.5 years)

Compare SPRT $406M; $19 fares; Fares $214M; OpCost $74M; Interest $25M; Time 25Min.
to Monorail $1,200M; $25 fares; Fares $228M; OpCost $41M; Interest $72M; Time 26Min.
to Rail $5,000M; $19 fares; Fares $173M; OpCost $20M; Interest $300M ; Time 59Min .
Note Monorail & Rail do not service the corridor, nor freight, nor each stop in the airport car park ! Locks out point to point (to Werribee...). Load sharing may dictate premium commute fare is $19!

Conclusion: PRT is preferable and commercially viable.

Implementation

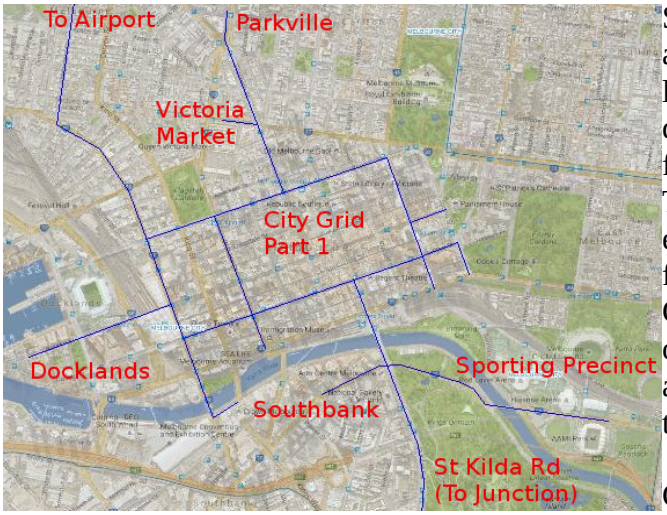
Create an industry: Suspended PRT is a proven and most desirable concept that needs to be brought into production. Attracting mode change from cars requires as close to **door to door** service as is practical. Trips can be broken up into the **last mile,** at trip ends, and the intervening **linear route**.

Build a demonstration route to the airport first, starting with small links to the car parks for concept proving. Second, build coarse coverage of city trip ends. Next, create radial tourist routes, to grow jobs. PRT should be a cheap feeder service, to existing modes, in low density catchments; with a competing premium service, to relieve excess traffic in congested corridors, and to fund network expansion. Premium fares may need to be ~$19 to balance loads, (save 30 min) halving the payback period. The project needs: a pro-podcar champion; open systems; technical excellence; competitive supply; 2 years for approval & development. Mindless implementation has proven to fail. Podcars are innovation and care must be taken to avoid unnecessary costs[12, page number 129] and restrictions[13].

The industry must be regulated for competitive supply of guideways, pods and extremely reliable maintenance and operations. Fares must be structured to match Myki when feeding another mode, but at a premium to balance the load when competing with other modes: cars; buses; trams; or trains. This can fund annual doubling of the network.

Step 1. New Tourist Attraction: Create a spectacular aerial gateway to Melbourne, from the airport, designed to attract more tourists. A suggested route is shown. Personal, fully automatic, air conditioned pods travel safely and independently, on an overhead network of light guideways, suspended 10m above the ground, carrying an individual or up to five passengers, from each airline concourse, directly to any Melbourne City hotel lobby or Southern Cross station, with no stops en route, in 25 minutes, 24/7.

Comment: Melbourne Airport to City has a simple “last mile” at the airport, can use the public transport network for the “last mile” at the City end, so a linear route can be profitable as a first stage. The route should be scenic, via Highpoint, the Olympic Village, and stops can service cycle paths. Commuters, students and shoppers can use the route and cyclists can extend the catchments. Businesses would sponsor stops on their premises. Stops for freight would be few, separate, but included. Airline concourses to car parks with an extra 10 stops should be used to bring the concept into production.



Step 2. ***More Vibrant Melbourne:*** Install a coarse aerial pod network, covering the inner city, to link tourists and Melbournians, to local shopping, dining, natural, sporting, business and cultural facilities. A suggested first part is shown. Transporting the bulk of traffic in the air will free existing road space for more attractive settings for pedestrians, cyclists and commerce. Convenient pods will give door to door service at one minute per km, creating more trips, business and better living. “To Myers with a friend, then to the Botanics, all within lunch hour.”

Comment: Many car trips end in Melbourne City, so creating a network that covers inner Melbourne would serve 3 purposes: extend the Airport link to inner destinations; provide quicker links within inner Melbourne to increase its' vibrance; and provide inner destinations for future radial links. It also enables the PRT control functions to be refined to include route selection, diversions during maintenance closures, and load balancing. Stops for freight would be added. Businesses would sponsor stops on their premises.

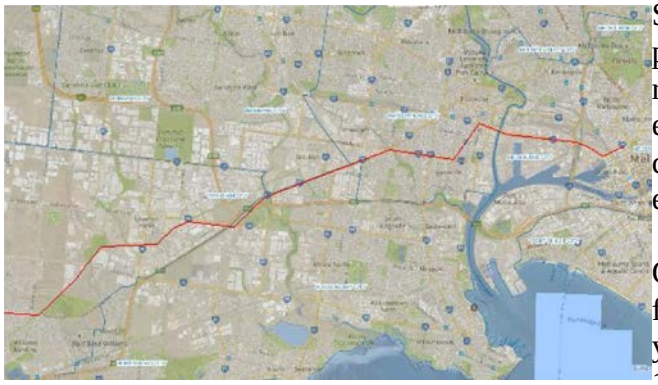
Step 3. ***More Regional Tourism:*** Connect to regional tourist sites and regional cities from the inner city network. A suggested five routes are shown. Familiarity with the pod and its ease of use will help tourists expand their visit to the region. Pods are reliable, immediately available, 24/7, and can take up to 5 people directly anywhere in the network at 70kph (faster in rural areas). New scenic route components can be created along these routes, as the pods can climb steep slopes and can be suspended with cable stayed structures. New platoon technology is needed to increase rural speeds.

Comment: Adding radial routes from the City will introduce the technology to a wider range of

suburbs (with 3 stops/km) and the regions, and be financially supported by premium commuter use. They will also provide backup to existing services. Premium commuter use to the City on radial routes will fund network expansion. Extension of these routes beyond commuter areas would only be marginally profitable at current public transport pricing and should be funded by Government to promote tourism. Add stops for freight.

Step 4. ***Feeders To Public Transport:*** In developing suburbs, provide low cost, profitable pod networks as feeders to existing trains, trams or buses. Pods can be self funding, offer direct trips door to door, function as a second car, 24/7, offer privacy and ever present security.

Comment: Feeders will have a network in developing areas, providing access to local commercial centers and schools, provide access to existing transport services, and provide an alternative premium access to the City via regional routes. An example network in Wyndham is shown. Add stops for freight. PRT is cheaper than buses and 24/7 at no extra cost. Initial skeletal routes (with bike feeders) will serve new development. Modal interchange ***to*** pods has no delay as there will be a pod waiting.



Step 5. ***Relieve Congested Transport:*** Where public transport or roads are currently overloaded, relieve the congestion with a PRT route. An example route to Wyndham is shown. PRT routes can be installed in existing right of way, add to existing capacity, and remedy excess demand.

Comment: Premium commuter PRT fares can fund network doubling each year to 1,000km in year 5. Expanding the commuter network to 1,000km of guideway, with 100,000 pods and 3,000 stops, (the size of the Metropolitan route numbering system,) would cost $10B, can be funded from revenue, and could perform the transport task of the entire existing urban public transport network, without subsidy! Expanding to double that size and cost, can provide stops at 300m proximity throughout the suburbs (year 6) and provide a better service than cars. Premium routes need to connect feeder networks to the City network.

Appendix – FAQ - Why reject other suspended PRT?

A: Beamways is competitive but heavier and so more expensive. It has large gaps between vehicles and so has less capacity/hour. (Metrino reduces these gaps with proven technology.)

A: SkyTran is more high-tech, being maglev, potentially faster, but has only 2 seats and is not accessible. Wind resistance is much more significant than friction and the small size of SkyTran limits its use.

What if vendor business models preclude a competitive industry?

A: Run a competition to design a suspended personal rapid transit that meets requirements.

Why reject supported PRT?
A: A number of supported PRT systems have been implemented and are successful but they do not meet the liveability criteria of minimal visual target (for both guideway and interchanges) and small stop footprint (or stops are elevated): suspended is better and more comfortable.

Cybercab[(23)] opened in Masdar City, Abu Dhabi in 2010. The network is 1.4km with 5 stations (2 for passengers, 3 for freight), served by 10 PRT (Personal Rapid Transit) and 3 FRT (Freight Rapid Transit) vehicles. Vehicles are battery powered, with 1.5hr charge and 60km range. Grades are flat. Track is segregated.

Ultra PRT[(24)] opened at Heathrow Airport, United Kingdom in June 2011. The system consists of 21 vehicles, a total of 3.8 kilometers of one-way guideway, and three stations. Vehicles are battery powered. Grades are flat. Track is segregated.

Skycube[(25)] opened at Suncheon, South Korea in September 2013. The system has 40 vehicles, 5km of elevated double track, is electrified, and has two stations.

Why reject cars for commuting?
A: In cities, normal cars do not provide the level of user service we deserve: they get caught in congestion, stop far too long at intersections, parking is a problem and there are crash issues with speeding, drinking and texting. Better to have a 300kg vehicle with twice the speed, more comfort and safety, accessible to all, no need for focus on driving but ability to conduct business and drink coffee on the trip.

Why reject assisted driving or fully automated cars?
A: PRT objectives are better and attainable: vertical separation removes congestion and permits unrestricted speed. PRT removes polluting cars and reduces traffic on streets. Both assisted driving and fully automated cars are much safer than existing cars, but at the expense of local speed and congestion! Assisted driving will always have safety problems from the driver, but also problems with the change-over[(5)]. Both will always have conflict with pedestrians and cyclists, who will play games with the vehicles, causing them to freeze. Fully automated is accessible. Fully automated driving has limits from its sensors, perceptions[(7, at 37 minutes)] and road rules[(6)], some philosophical issues[(8)] need resolution and even if all issues are resolved, the trip would have pinch-points, at intersections, near pedestrians and cyclists, and be uncomfortable.

Why are fully automated cars a scam?
A: Fully automated cars are super safe because they slow in the vicinity of pedestrians and bikes, even stopping until uncertain risks are resolved. In urban areas, capacity of critical arterial intersections controls congestion, they have bicycles and pedestrians, and fully automated cars will slow and reduce capacity. Evidence of that is hard to find because proponents remove evidence of

slow movement and avoid measuring capacity. It would be easy to model capacity with fully automated cars, buses and trams at Victoria St/Hoddle St intersection, including pedestrians and a few cyclists, using Vissim, but this will never be done because increased capacity claimed is a scam.

Is vertical separation too expensive?
A: Vertical separation of pods from pedestrians and cyclists is beneficial to both parties. Two alternatives are: keep the existing road toll; or upgrade all cars to fully automatic. Removing the road toll with PRT can be self funding. For one route, upgrading 16,000 cars at $22,875 each is the same cost as installing comparable length of PRT. So capital costs are the same but operation of fully automatic cars would be slower and more expensive.

Why has PRT not been previously developed?
A: Successful PRT systems exist, have a good business model[11], have found niche markets and have worked with competitors.

Why not replace existing transport systems?
A: Extensive experience with PRT is required, to develop a body of knowledge, sufficient to enable judgements about the relative merits of PRT, before changes to existing systems are contemplated. This includes skill in design and operation of PRT, and understanding of user requirements.

Are guideway standards required?
A: Standards for guideways[29] have been proposed. Vendors are aware of these but there is too little experience available to justify delay of a project in order to determine standards. Selection of a vendor will set the initial standard.

Why adopt interchanges and one-direction stops?
A: Better to spend $400M and build the airport connection than to spend $5,000M on it. If the concept can be improved, then it is cheaper to rebuild than miss the project opportunity. Quality reviews (a) after trialling the car park links and (b) after building the airport route can improve the standard of the concept but should not delay implementation. Numerous issues will arise, including guideway standards; platoons; grade separation or roundabouts; interchange configuration; ramp grades; network configuration; one or two direction stops; service cables and lighting; control redundancy; extreme reliability; enforcement protocols… Allow two years to negotiate approvals but get the job done, yet plan for obsolescence with modularity.

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