

Towards Improvement in Singapore's Transportation Efficiency and Environmental Impact

Ben Edelman – October 29, 2011

I write in response to the NCCS consultation as to emissions from ground transport.

The consultation appropriately flags high and growing emissions from ground transport. More generally, Singapore's ground transportation system is under pressure from a growing population with increasing car ownership and intensive car use. Meanwhile, despite significant upgrades, public transit continues to struggle: Buses are delayed in traffic; MRT remains crowded while offering modest line speed and incomplete service areas. Choosing between the private automobile and public transit, Singaporeans increasingly choose cars – enjoying greater privacy, climate control throughout the journey, door-to-door service without transfers and, for many journeys, faster transit time despite traffic. The growing choice of private automobile is rational in light of current conditions. NCCS and transit planners should seek to tilt this balance back towards sustainable, environmentally-friendly transit systems while adjusting their approach to deploy new technologies offering a higher quality of service that lures drivers from their private automobiles.

I see just one technology that can make the required contribution to ground transportation in Singapore: personal rapid transport (PRT). PRT calls for small, lightweight vehicles that allow cost-effective service to areas that are undeserved by current transit. And with vehicles serving just a single person or preformed group, PRT offers a level of service – including journey time, privacy, and comfort – unmatched by any alternative.

In the remainder of this document, I describe the relevant design changes I envision, identify specific applications in Singapore, and address key concerns. I conclude by proposing specific steps forward.

The PRT concept

The "PRT" concept calls for a set of key design features:

- Unscheduled, on-demand service. Vehicles wait for passengers, not vice versa.
- Transport of individuals or small preformed groups, typically not more than four adults.
- Small, lightweight exclusive guideway. No delays for cross traffic, cars, or pedestrians.
- Small stations close to desired destinations, leveraging existing infrastructure.
- Nonstop service without delays for others to get on or off. Your vehicle proceeds directly to your destination without intermediate stops.

These design features interact to provide a set of services quite different from traditional mass transit. For example, because each vehicle holds relatively few passengers, vehicle weight is reduced, imposing a lower burden on guideways and other support structures. Small guideways in turn reduce construction costs, for example by allowing the use of prefabricated guideway sections rather than large components constructed on site. Meanwhile, small stations, again built at modest cost, make it possible to transport passengers closer to their desired destinations. Crucially, all stations are "offline," such that a vehicle only visits a station if a passenger wants to get on or off. This design lets some vehicles stop at

a given station without delaying others that seek to bypass the station. Exhibit 1 presents images of a recent installation at Heathrow T5 embodying these benefits.

The PRT emphasis on small vehicles stands in sharp contrast to traditional rail-based transit. In most transit systems, a single vehicle must accommodate peak demand along the entire line. To justify the costs of traditional transit, installations are only feasible where demand is substantial, implying a large vehicle, hence large stations and imposing guideway. Beyond the direct costs of building these systems, their linear structure imposes further constraints. For example, every vehicle visits every station on the line, so each additional station on the line delays all passengers proceeding beyond that station – making extra stations undesirable. Given the delay imposed by each additional station, one might hope to separate stations by substantial distances in order to increase average line speed. But large separation between stations is also unworkable, as feeder services are typically limited and lower-quality (bus, walking, etc.), such that each neighborhood requires a station – even at the cost of lower line speed and increased travel time. Meanwhile, if stations deviate from a straight line, all vehicles on the entire line must follow an indirect path, reducing effective line speed even further. And adding or relocating stations along an existing route is so burdensome and costly that it is rarely attempted.

PRT addresses these limitations. PRT calls for a web of guideways with arbitrary layout, not limited to the linear structure of traditional rail-based transit. Expanding a PRT system to serve additional destinations implies adding more guideway and more stations, but no drop in service standards to existing stops. See the proposed installation in Exhibit 2, where colors denote possible stages of construction, though unanticipated additions are possible at a later date.

PRT vendors estimate a cost of SGD\$5 to \$11 million per kilometer of one-way guideway. Compare MRT Circle Line at approximately SGD\$90 million per kilometer of one-way guideway, and Punggol LRT at approximately SGD\$17 million per kilometer of one-way guideway.

PRT Capacity

Can PRT systems offer high capacity despite carrying just a few passengers per vehicle? By all indications, they can.

Traditional transit offers a natural concept of *line capacity*. For example, if a vehicle holds 1,000 people and arrives every six minutes in each direction, then the line has a capacity of 10,000 people per hour in each direction, or 20,000 per hour assuming full vehicles traveling in both directions. This notion of capacity is intuitive and well-established.

Because PRT calls for many small stations on a web of guideway, PRT does not naturally lend itself to a notion of line capacity. But consider instead the concept of *system capacity*. Suppose a PRT system includes 20 stations, each with four berths, each berth capable of dispatching one vehicle per minute¹, each vehicle with a capacity of four persons. If each vehicle leaves full, analogous to the full vehicles contemplated in the preceding paragraph, then hourly system capacity is $20 * 4 * 60 * 4 = 19,200$.

Of course some might question the realism of filling each vehicle completely and of fully utilizing berth capacity at each station. But stations can be built in multiple sizes: A PRT station expected to have high demand (perhaps above a heavy rail station or inside a skyscraper) can include more berths, while a station expected to have lesser demand (perhaps a quiet neighborhood or low-density office park) can include fewer berths. If demand grows later, a station can be expanded to add more berths, constrained primarily by available space. (In contrast, consider the difficulty of building another station on an existing heavy rail line.) Furthermore, in an area newly found to have high demand (perhaps due to construction of a new office park or housing development), more stations can be added as needed, since the PRT web of guideways allows expansion in any direction.

Application of PRT in Singapore, Short-Term: MRT Feeder

In the short run, I believe PRT is best suited to installation as a MRT feeder, supplementing or replacing existing feeder buses. One PRT station would be installed as close as possible to a MRT platform (ideally, across from a MRT platform to allow same-platform transfers, or directly above or below a MRT platform to allow transfers via a single short escalator). In residential areas, PRT stations would be built within clusters of HDB residences or in shared community spaces. In office parks, PRT stations would be built within a cluster of office buildings or, potentially, inside large buildings.

PRT stations could easily be linked directly to existing structures or even placed within existing structures. The low weight of PRT vehicles means that PRT stations can be built inside most buildings without enlarging foundations.² Building a PRT station inside an existing building reduces construction costs (foundations, escalators, elevators, HVAC) and reduces total journey time for those seeking to reach that building.

In this type of installation, PRT would serve a function much like LRT. For one, PRT is more than an order of magnitude smaller:

	<u>PRT</u>	<u>LRT</u>
vehicle	Ultra Global as installed at Heathrow T5	Bombardier Innovia APM100 / Crystal Mover
capacity	4 passengers (all seated)	105 passengers (18-22 seated)
weight (empty)	820 kg	approximately 15,000 kg
size (LxWxH)	3.7 m x 1.47 m x 1.8 m	12.8m x 2.8m x 3.4 m

With smaller vehicles, PRT calls for correspondingly smaller guideways and stations, reducing cost while allowing less intrusive installations, quieter operation, and stations closer to users’ desired destinations. Furthermore, PRT would take each passenger directly to the requested destination, whereas LRT makes all stops on a loop. PRT service would be ready to come as soon as a user requests it, whereas LRT requires passengers to wait for the next LRT service, extending the journey and adding uncertainty to total travel time.

Initial “feeder” installations would sharply increase the value of the areas they serve. At present, the real estate market places a large premium on locations exceptionally close to MRT stations. Yet it still takes three to five minutes to exit a MRT platform, take ride two to four congested escalators, and walk

multiple passageways to reach a building purportedly “adjacent to” a MRT station. Within that same time period, a PRT could transport a passenger from a MRT station to a PRT station on the second floor of a commercial building two kilometers away, mere meters from that building’s elevators. If buildings served by PRT enjoyed an increase in property values to levels nearing properties directly adjacent to MRT, the increase in property values could pay much of the cost of PRT. To the extent that such properties are owned by the government of Singapore (e.g. HDB or government administration buildings), the benefits would accrue directly to the government and, through appropriate accounting, defray PRT costs. Otherwise, property tax would capture a portion of the benefit granted.

In some respects, this PRT “feeder” approach is similar to the approach explored in initial LRT installations. Certainly PRT feeders would address the same need that prompted LRT, including facilitating transit-oriented development, providing a more reliable and more comfortable journey than buses, and encouraging alternatives to the private automobile. But PRT would offer improvements over LRT in every relevant respect: PRT stations and guideway would be smaller, taking passengers closer to their desired destinations. PRT would be quieter thanks to lighter vehicles. PRT could be installed at lower cost, thanks to lower materials requirements as well as efficiencies from prefabricated parts. Most of all, PRT would provide passengers with faster service and lower total travel times thanks to vehicles that to depart as soon as users are ready.

Application of PRT in Singapore, Long-Term: MRT Supplement

In the long run, successful PRT in Singapore could offer a flexible alternative to MRT. Suppose several MRT stations were served by PRT feeders – perhaps PRT feeding Bishan, Ang Mo Kio, and Yio Chu Kang. Interconnecting these PRT feeders could allow a PRT journey from the northern edge of the Yio Chu Kang neighborhood all the way to the southern end of the Bishan neighborhood, without a transfer to MRT. Using PRT as an alternative to short MRT journeys would relieve burden on the already-crowded MRT, including reducing the number of passengers boarding and exiting MRT, thereby reducing MRT dwell times at busy stations and reducing congestion on this key section of the MRT line.

As the PRT network grows, these benefits would increase further. In principle, unattended PRT stations could operate around-the-clock, offering an alternative to money-losing late-night MRT operations. In the long run, extensive PRT feeder routes could allow a reduction in the number of MRT stations – allowing the closing of selected MRT stations, increasing line speed, reducing MRT operating costs, and letting the MRT better serve longer journeys.

Limiting the Downside Risk

Prior evaluations of PRT have often rejected PRT on the view that the technology is untested.³ But recent installations are bringing an end to that concern. A Heathrow Airport PRT began public operation in May 2011, providing non-stop on-demand service from Heathrow T5 to the T5 Business Car Park, bypassing shuttle bus wait and traffic delays. Other PRT systems are being installed in Suncheon City, Korea and Amritsar, India, and numerous installations are under consideration elsewhere.

Furthermore, an initial installation of PRT has limited risk. A “feeder” PRT could be installed as a one-off trial without long-term commitment to the PRT concept – limiting costs if PRT falls short of expectations.

PRT vendors are sensitive to the perceived risks of early PRT installations. Vectus (a subsidiary of POSCO) is building a PRT at the Suncheon City Center and International Garden Expo, and I understand that Vectus is developing that installation at or below cost. In cooperation with Ultra Global, Fairwoods Consultants is installing PRT in Amritsar, India at no direct to Amritsar taxpayers. (Ultra will cover capital costs and recoup its investment through operating proceeds.) If capital outlays are a key concern, a suitable contract with a motivated vendor may further reduce Singapore’s risk.

The Distinctive Fit of PRT in Singapore

Singapore leaders may find it tempting to delay fully considering of PRT until another city has demonstrated the suitability of PRT to urban transit needs. Such a demonstration may be coming in the recent contract for an urban PRT in the congested historic city of Amritsar, India⁴ with other installations under consideration in Delhi⁵ and Gurgaon.⁶ I’m told installations are under consideration in China, including in Caofeidian New Area and Tangshan Bay Eco-city.

Whether or not others’ installations quickly demonstrate the benefits of PRT, it is unclear whether any city could host PRT as readily as Singapore or could enjoy benefits from PRT as large as those that would accrue to Singapore. Consider the factors that make Singapore uniquely well-suited to PRT:

- Singapore’s residential and commercial areas are dense, a necessary condition for public transit systems with dedicated guideways.
- Singapore’s urban planners have a genuine, longstanding commitment to public transit, and have long recognized the country’s inability to accommodate transport needs by private automobile due to the infeasibility of providing sufficient roads and parking.
- Singapore has demonstrated its willingness to invest in innovative technologies that solve an immediate public need. (Consider ERP.)
- Singapore’s citizens highly value their time, and they enjoy incomes sufficient to justify transportation improvements to let them spend more time with their families.
- Singaporean engineering talent provides extra basis for confidence in the feasibility of PRT design and operation.
- Singapore’s government is able to internalize many public benefits, including through increased value of government-owned property and, unusually, government-coordinated housing.

While Singapore might prefer for another city to demonstrate PRT first, these factors naturally lead others to look to Singapore as the most promising first urban installation.

Meanwhile, PRT provides a notable opportunity for Singapore to demonstrate leadership in engineering, construction, and design. If PRT takes off, a several-year headstart would let Singapore firms take a leading position in designing and installing systems for use elsewhere in Asia and worldwide. The resulting high-skill jobs would be a natural fit for Singapore’s workforce.

Exhibit 1: PRT as Installed at Heathrow Airport Terminal 5



PRT station at Heathrow T5



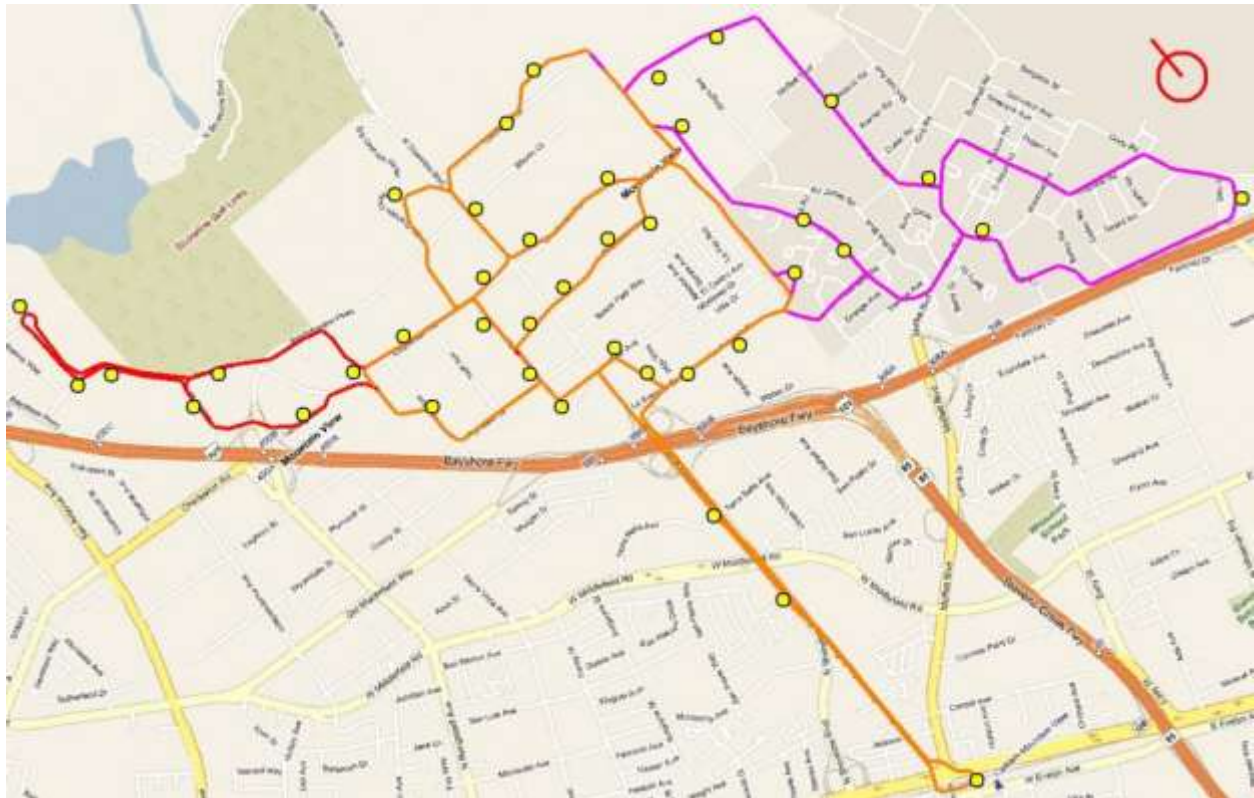
Compare lightweight PRT guideway (top-left to bottom-right) with large elevated roadway (top)



Vehicles can easily bypass any stations where a stop is not required. These 'offline stations' allow nonstop service from origin to destination, without intermediate stops.

All images courtesy of Ultra Global

Exhibit 2: Proposed Alignment of PRT in Mountain View, California



Map courtesy of Steve Raney / Ultra Global

Notes

¹ PRT vendor Ultra Global reports that each of its pod can dispatch 100 to 120 vehicles per hour. See <http://www.ultraglobalprt.com/how-it-works/stations-guideways/>. Ultra offers a video confirming this capacity. See <http://www.ultraglobalprt.com/photos-videos/videos/>, "164 vehicle movements in one hour".

² Ultra Global loading is 2.2kN/m^2 , whereas a standard pedestrian footpath must be designed for 5kN/m^2 .

³ See e.g. the SeaTac People Mover Study, February 1992, finding that PRT would best serve most customers, but ultimately rejecting PRT due to lack of proven installations elsewhere.

⁴ See e.g. "Rapid Transit System To Be a Reality Soon." Tribune of India. October 5, 2011. <http://www.tribuneindia.com/2011/20111006/asrtrib.htm#1>.

⁵ "Now, Zoom in Pod Cars." Times of India. October 10, 2011. http://articles.timesofindia.indiatimes.com/2011-10-10/mumbai/30262586_1_pod-cars-feasibility-study-transport-minister.

⁶ "Pod Taxis a Step Closer." Hindustan Times. October 9, 2011. <http://www.hindustantimes.com/Pod-taxis-a-step-closer/Article1-755384.aspx>.