EXTENDING PRT CAPABILITIES

Prof. Ingmar J. Andreasson*

* Director, KTH Centre for Traffic Research and LogistikCentrum AB.

Teknikringen 72, SE-100 44 Stockholm Sweden, Ph +46 705 877724; ingmar@logistikcentrum.se

Abstract

Personal Rapid Transit (PRT) offers direct, on-demand travel in automated vehicles seating 3-6 passengers on exclusive right-of-way. Commercially available systems now offer speeds up to 45 kph at headways from 3 seconds.

With 3-second headways, a typical load of 1.5 passengers and 30 % empty vehicles, the link capacity will be 1200 passengers per hour (one direction).

This paper explores ways to extend the capabilities of PRT with respect to capacity and speed. Strategies have been developed and verified with the generic simulation software PRTsim.

Conventional PRT may not provide the required capacity

One sceptic (Vuchic 2007) claims that Personal Rapid Transit (PRT) ”in suburban areas … is economically infeasible, and on major arterials … cannot provide the required capacity”. The present paper addresses the second part of his claim by extending the traditional PRT concept.

Safety approved and commercially available PRT systems now offer speeds of 40-45 kph at headways of 3-4 seconds. With 3 seconds headway, a typical load of 1.5 passengers and 30 % empty vehicles, the link capacity would be 1200 passengers per hour in one direction. This is sometimes insufficient.

We have explored ways to extend PRT capacity with respect to both capacity and speed. Operational strategies have been developed and verified with our generic simulation software PRTsim.

Network vs corridor systems

As opposed to line-haul transit, PRT offers network-wide transport without stops or transfers. Vehicles take the fastest route to each passenger's destination. If one link should be overloaded then vehicles will avoid that link when there is an alternative route. The concept of capacity applied to PRT should refer to the total capacity of alternative routes for each relation. Therefore corridor or link capacity is not the dimensioning factor for PRT. We shall still discuss ways to increase link capacity of PRT while remembering that the network capacity will be the sum of one or more link capacities.

Ride-sharing

The most efficient way to improve passenger capacity is to increase the load of each vehicle. In contrast to scheduled services PRT vehicles operate only when there is a demand. Since operation is on demand, PRT vehicles are made small, seating 3-6 passengers. In pure on-demand service the average load will be 1.1-1,5 passengers.

Passenger trials performed by BAA indicated that passengers with the same destination spontaneously share vehicles without being told to do so. Ridesharing can be encouraged if destinations are displayed over standing vehicles.

Fig 1. Destinations signs over vehicles in stations encourage ridesharing.

Simulations have shown that ridesharing is efficient and worthwhile only in stations where many trips start and where passengers show up in bunches as is the case in transfer stations from scheduled services, especially from trains or subways during peak hours. In such situations it is possible to fill vehicles with passengers sharing the same destinations without anyone waiting. Instead, average waiting can be reduced by shorter queuing for vehicles.

The Fornebu area in Oslo is a newly developed area served from a nearby commuter train station. In our study Andréasson (2005) we demonstrated that the application of ridesharing would increase the average vehicle load from 1.5 to 3.1 passengers with the same short waiting (0.9 min). As a consequence the required fleet was reduced from 610 to 285 vehicles. On the critical link leading out from the train station there were no empty vehicles and most vehicles could be filled to capacity. The resulting link flow was 4500 passengers per hour with 4-passenger vehicles and 3-second headways.

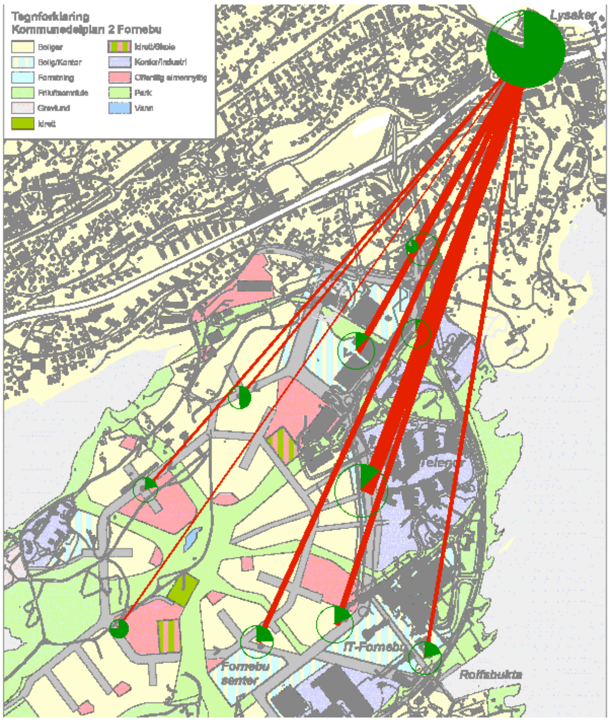

Fig. 2. PRT demand pattern during the morning peak in Fornebu.

More elaborate ridesharing strategies with more than one destination for each vehicle did not bring any further improvement.

Vehicle capacity

Without ridesharing it makes little sense to build larger PRT vehicles than 3 or 4 passengers. With the introduction of ridesharing at peak load from transfer stations, there is prospect of higher passenger loads. A vehicle seating 4 in comfort may be modified to seat 6 children or even 6 adults in less comfort when needed.

Train transfer stations

The normal PRT station is designed for randomly arriving passengers. The station can be made small since most passengers depart immediately so that only few people are waiting and then only for a short time. Small stations can be placed in city streets.

Transfers from scheduled services with large units such as commuter trains create a challenge for systems based on small vehicles. People do not prefer to travel in large bunches but they are forced to do so by transit planners in order that money can be saved on driver wages. Now that the large train units are here, we need to find ways to cope with surges of sudden demand for transfers from trains to PRT.

Train stations have passenger platforms as long as the longest train. A PRT station at a train station can take advantage of long platforms to find space for a long PRT station. A PRT station platform as long as a typical train platform may accommodate around 65 PRT vehicles holding up to 250 passengers.

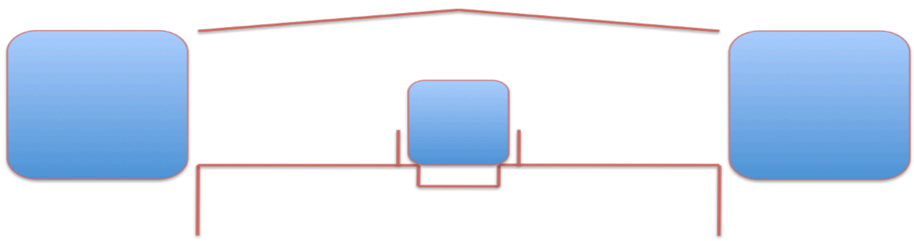

Fig. 3. Cross platform transfers between train and PRT.

We assume that train tickets are valid on PRT as well. Then no handling of PRT tickets is needed at the train platform. The system will collect statistics on demand to each destination and show destination signs over each PRT vehicle to encourage ridesharing. If someone enters the wrong vehicle then some passengers may have to suffer an extra stop on the way to their destination.

The station can be filled up with PRT vehicles (empty or with passengers taking the train) when a train is anticipated. Clearing all vehicles from the PRT station when the train has departed may take 3-4 minutes. If more than say 250 passengers transfer from the train then another platoon of waiting PRT vehicles is moved to the platform.

Platooning of empties

Moving vehicles are separated by a minimum safe distance, depending on speed. This is a requirement to safeguard passenger safety. The spacing between two empty vehicles can be shorter without jeopardising passenger safety. It may be up to the operator to balance risks of hardware against increased system capacity.

If empty vehicles can be spaced closer together, it makes sense to try to group several empty vehicles together in platoons. Platoons of empty vehicles can be created from stations and/or by choice of routes, by appropriate priorities in merges and by allowing empty vehicles to catch up on each other.

Typically about 30 % of all running vehicles are empty. If they can be grouped together and closely spaced then link capacity can be increased by 15-25 %.

High-speed links

Initial PRT networks will probably be planned for local circulation within limited distances. If PRT networks are expanded to long distances then 40-45 kph will be too slow to be accepted. So how about high-speed PRT?

Two undesirable consequences come together with high speed. One is air resistance, which grows with speed squared. The other - worse - is reduced capacity following from increased safe time headway between vehicles, proportional to speed.

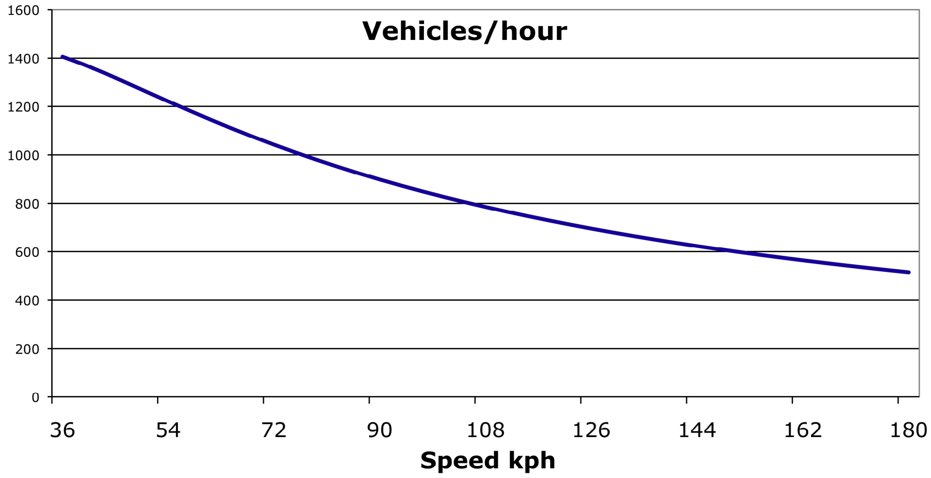

Fig. 4. Line capacity is reduced at high speeds due to increased safe headway.

Train formation

The natural way to increase capacity and at the same time reduce air resistance is to couple vehicles to form trains. Safe distance is only required between trains.

The French Aramis system in the 1970:ies was designed to form trains dynamically en route. Although this can be done, it is not clear if it will be considered safe by the regulating authorities. Before a connecting vehicle has reached the one in front, it has to pass an unsafe area (closer than the safe distance). In any case it is safe to form trains during standstill in stations.

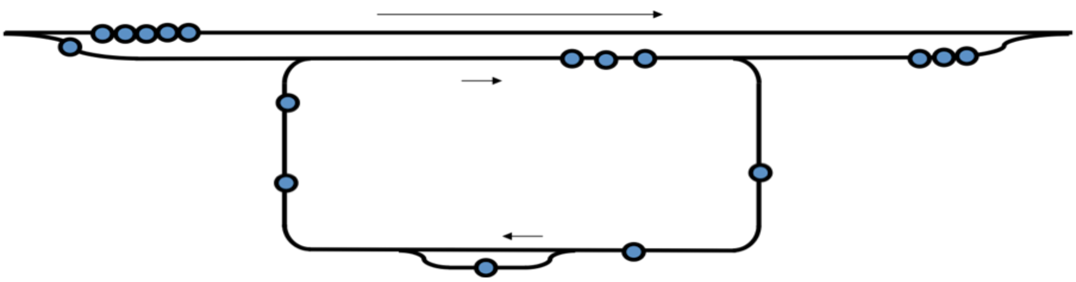

Fig. 5. Formation of PRT trains before entering a high-speed link.

A local PRT network can be connected to a high-speed link via a transfer terminal. Passengers remain in their vehicle while vehicles get connected into trains, before entering the passing track.

Splitting up trains

One particular feature of PRT is vehicle switching on passive guide-ways. Vehicle switching makes it possible to switch out a vehicle from a train at the passage of a track diverge. In this way trains can be divided as necessary en route, at least as long as one or more vehicles brake out from the front or from the rear of the train.

Breaking out from the middle of a train would create a gap, which is smaller than the safe distance. It would be desirable to arrange vehicles in the train so that separations can be made from the front and rear of the train. However rearranging vehicles is a difficult operation requiring both space and time.

Until break-outs from the middle of a train has been safety approved, the length of trains is limited by the order in which vehicles are connected and the destinations of individual vehicles.

We have so far limited the implementation of train formation to pairs of vehicles.

Pair-coupling

Trains of two vehicles can always be separated, by switching apart at speed. Pairs are easy to form in stations as long as destinations do not matter. Running vehicles in pairs will almost double the line capacity as long as the pairs are kept together, as they typically may be during about half of the trip. The effect is almost a factor of two near departure stations. In some networks, such as connecting a suburb to a city centre there may be a long stretch where the pairs can be kept together increasing the line capacity on that stretch. This is often the part where higher speeds are desirable and where the capacity would otherwise be a bottleneck.

We have applied pair-coupling in stations, at merge points when queues are formed and at points of speed increases where queues may form due to a drop of capacity.

Implementation and effects

We have implemented the features discussed in this paper in our generic simulation system PRTsim. The same features can, with limited amendments, be incorporated into the control systems of commercially available PRT systems.

The effects on link capacity of the various improvements depend on network and demand patterns but are in typical cases estimated to be:

Feature	**Capacity improvement factor**
Ride-sharing	1.5 – 2.1
Platooning of empties	1.15 - 1.25
Pair-coupling	1.5 - 1.9

Combinations

Obviously ride-sharing can be combined with the other features. Platooning of empties will have less additional effect if vehicles are already pair-coupled. However empty vehicles can be dynamically platooned whereas pair-coupling is only applied in stations and pairs are broken up successively along the route. Combining all features it is reasonable to expect a capacity increase by a factor of 3.

On the main link leading out from a large transfer station there will be no empty vehicles during the peak. With pairs of 6-seater vehicles departing every 3 seconds the theoretic capacity would be 14 400 passengers per hour. During the peak, waiting passengers can be expected to fill up most vehicles if destinations are displayed over each vehicle. Provided that passengers board the right vehicles they still get to their destination without timetables and without stopping en route.

Comparison with LRT

The new LRTs for Stockholm accommodate 213 passengers (most of them standing). They run at 10 minutes headway but plans are to introduce 7.5 min headway. It is possible to operate LRT down to 3 minutes headway and LRT vehicles can be coupled in pairs provided that all stations have been made large enough. That gives a theoretic LRT capacity of 8 520 passengers per hour per direction.

Conclusions

We have discussed several ways to increase the capacity of “conventional” PRT meaning individual trips in individual vehicles. Without giving up the traditional PRT qualities of direct non-stop travel on demand it is possible to offer capacities similar to capacities of LRT systems.

At least where LRT is an option we claim that PRT can provide the required capacity. It may not be “conventional” PRT during peak demand but it very much looks like it. Further the available commercial PRT systems can with small software amendments incorporate the required features.

In comparison with LRT these PRT systems offer practically no waiting and about half the travel times. And they cost less to install and a lot less to operate.

References

Vukan Vuchic, Urban Transit Systems and Technology, Wiley 2007

Ingmar Andréasson, Ride-sharing on PRT. Proceedings of the ASCE Automated People Mover Conference, Orlando 2005.