Ride-Sharing on PRT

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Abstract

The name Personal Rapid Transit (PRT) indicates that passengers are served on an individual basis. It is an important quality of PRT that passengers do not have to wait for vehicles to be filled up. They travel alone or in company of their own choice. PRT vehicles like taxis are designed for small parties, typically for 3-5 passengers.

In this paper we will discuss pros and cons with non-puristic PRT where some passengers are matched to share the same vehicle. Simulation results are given for a proposed PRT network for Fornebu Oslo.

Why bother with ride-sharing

Even if PRT vehicles are small in size it is tempting to try to increase their load factor at least during peak demand. More passengers in each vehicle would reduce the required fleet size and increase the capacity of both guideway links and stations. In this paper we will look at ways to increase vehicle load without giving up the short waiting-time for PRT passengers.

The required fleet size is determined by the passenger demand during the peak hour, the average passenger load and the average time for a vehicle mission (travel with passengers plus empty travel). We can save on the fleet size by utilizing shorter distances, higher speeds, shorter empty trips or higher passenger load. In this paper we will focus on increasing the passenger load.

The capacity of a guideway link depends on the minimum safe headway between vehicles and the average passenger load of vehicles. With higher load we need fewer vehicles and the headways may be longer for the same guideway capacity.

The capacity of a PRT station depends on the number of loading berths and the cycle time for door operation, unloading and loading a vehicle. The loading cycle per passenger is shorter for a large group than for a single passenger.

We have seen that ride-sharing would bring the following advantages:
+ reduced fleet size
+ increased system capacity
+ lessen the requirement for short headways.

The common objections towards ride-sharing are:
- longer waiting-times
- loss of privacy
- risk of assaults or harassment by other passengers

We will discuss ways to mitigate the objections in order to benefit from the advantages.

Ride-sharing strategies

One feature of PRT is departure on demand with no or very little waiting. Then ideally there is never a queue of waiting passengers in a station. Matching passengers may imply that a passenger has to wait for others. Ride-sharing strategies should be designed to avoid waiting.

Another feature of PRT is non-stop travel from origin to destination. Detours or stopping on the way would be a deterioration of service.

Stopping to pick up passengers would imply a risk that a hostile person enters a vehicle later during the trip.

We can consider three types of ride-sharing depending on origins and destinations of passengers:

SS: Single origin – single destination
SM: Single origin – multiple destinations
MM: Multiple origins and destinations

Type MM is the most general and maybe the most efficient from initial loading point of view while type SS is the least efficient. However type MM is also the least acceptable for the reasons just stated.

In this paper we will only consider types SS and SM which means that all sharing passengers board together and the matching can take place at the origin station. A passenger may decide to not enter when he or she sees the other passengers.

Incentives to ride-share

We have identified some clear incentives for the operator of PRT to promote ride-sharing. In order for the passengers to accept sharing it may be necessary to offer them some incentives too.

The fare can be per vehicle rather than per ride. This would be an incentive for passengers arranging themselves to share with others. However sharing needs to be organized before paying and passengers have no overview of who else is going to the same destination.

A more practical arrangement would be for a passenger to indicate before paying whether he or she would be willing to share with other passengers. The price would be lower for passengers willing to share. It is then up to the system to organize the sharing and it may happen that a passenger gets to travel alone even if he or she paid the lower fare for sharing passengers.

We recommend to introduce a time limit so that passengers willing to share get to ride alone if the system has not found a match within a specified time (e.g. 1 minute).

In situations with many passengers waiting there will be a social pressure from queuing passengers to fill up vehicles. This happens today in ski-lifts where people are encouraged to fill up chairs.

Commuting passengers will soon get to know or at least recognize colleagues going to the same company or to the same station. If there is a queue they will probably volunteer to share.

Security

The most common objection to ride-sharing is fear of other passengers. A number of measures can be taken to lessen such fear.

- Since all sharing passengers board at one time it is possible to opt out and not board. The system should allow this. By counting boarding passengers it is possible to keep track of how many passengers are left waiting for each destination.

- All seats should have a call button to be used in emergencies. This will open a voice and video connection to central control. Central control can redirect a vehicle to a station with a guard or police.

- PRT tickets or passes can only be bought by credit card or identification card. Each ticket carries a number which is registered when a passenger boards a vehicle. In case of a crime a ticket can be traced back to a person via sales registers which may only be accessed after a court decision.

With these measures it would be extremely unwise to assault anyone in a PRT vehicle. It would be the worst place of all for someone planning an offense.

Station design

We believe that PRT rides should be booked outside of the station. The earlier we get to know the demand the more time we have to call an empty vehicle and to plan for ride-sharing. On the other hand advance bookings by telephone do not seem practical since passengers cannot predict exactly when they want to go.

Another advantage with ticketing outside is that we only allow passengers who intend to ride to get into the station. A PRT station should not be a place for muggers.

The ticketing computer at the station knows how many passengers have booked for each destination, when they booked and whether they have departed. It would be easy for the system to group passengers into vehicles but it may be impractical to direct them individually.

We suggest that the station system allocates a vehicle to a destination based on number of queuing passengers for that destination and the waiting-time of the first booking passenger for that destination. The destination can be indicated by a sign over the vehicle and maybe a voice call. It is up to passengers for that destination to get on board and the system gets to know who (ticket number) did and who are left. The signs over vehicle loading positions are the only additional physical arrangements needed for ride-sharing.

If the station is so big that it needs multiple platforms (two tracks can be loaded from the same platform) then each platform would be designated for a set of destinations so that passengers going to the same destination will be waiting at the same platform.

Empty vehicle management

Multiple destinations would be a complication for vehicle management. A dropping vehicle wants to continue out of the station without waiting. This may require pushing out empty vehicles which are blocking the way through the off-line track. That may cause a delay to the continuing vehicle and additional empty vehicle trips to some other station. There is no undisturbed place to keep a buffer of empty vehicles unless the station has two entries or two exits.

Our simulations have confirmed that empty vehicles can be managed without dedicated buffers albeit with more empty movements and some delays.

The Fornebu case

Fornebu is the former airport of Oslo which is now being developed for offices, housing, service and a sports arena. The only public transport to the area is by buses and a political decision has been taken to serve the area by some kind of Automated People-Mover system - monorail or PRT. The new system would feed to the nearby train station at Lysaker. A possible layout of a PRT system is shown in figure 1.

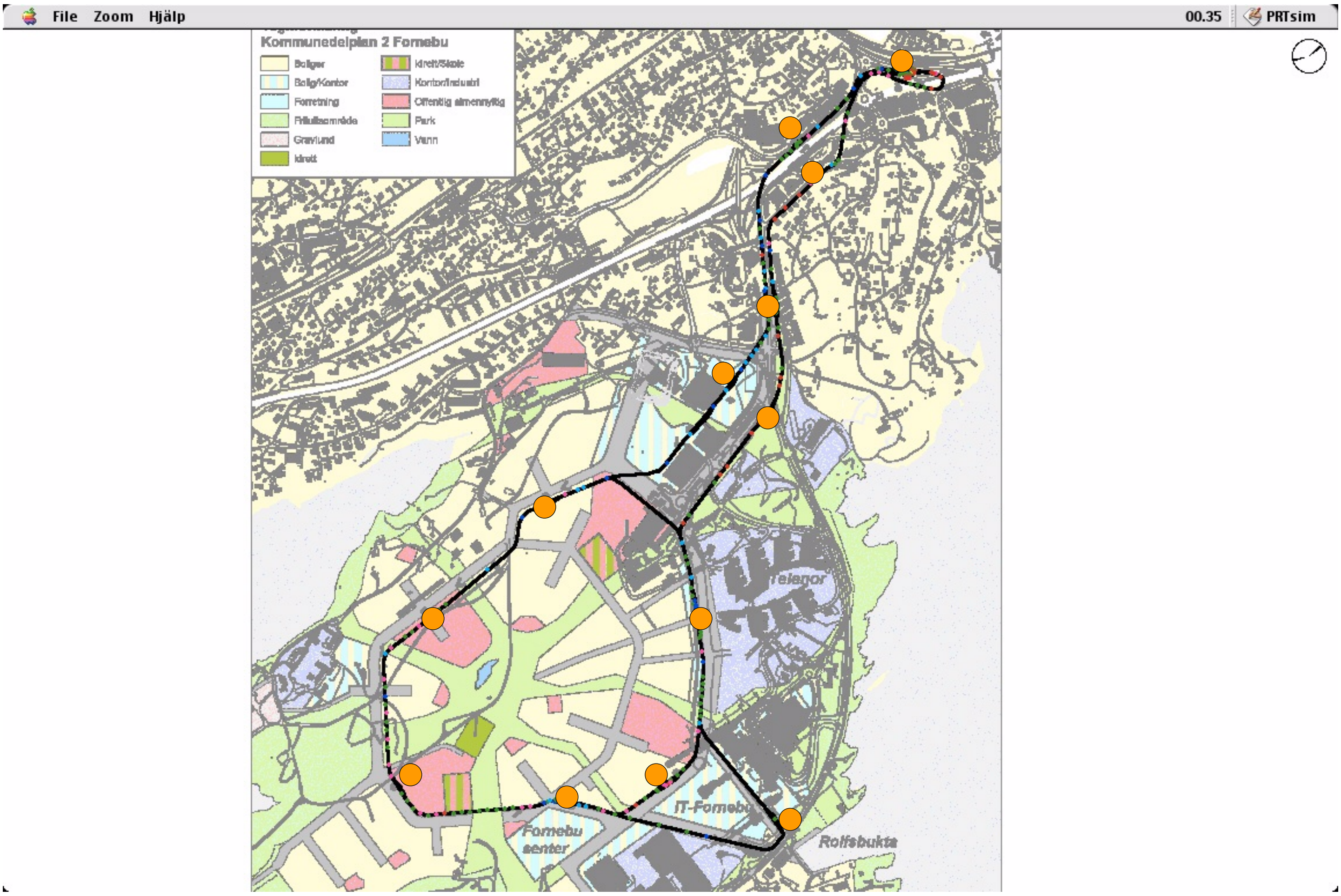

Figure. 1. Tentative PRT network for Fornebu with Lysaker station at the top.

The peak hour demand may be as high as 4500 passengers out of Lysaker station. In a PRT solution that would probably require four parallel station tracks loaded from two platforms.

The illustrated PRT system would have 7.8 kms of guideway, 13 stations and 285-610 vehicles depending on loading strategy. We have used our simulation software PRTsim to dimension vehicle fleet and station sizes in such a way that the average waiting-time of passengers is below 1 minute. The results are given in Table 1 for three different loading strategies:

1. Individual rides
2. Ride-sharing from single origin to single destination
3. Ride-sharing from single origin to multiple destinations

Vehicle capacity is 4 passengers. The average party is 1.5 passengers. Ride-sharing is only applied at the Lysaker station and we have only studied the morning peak. In the two ride-sharing strategies a vehicle departs as soon as it has three passengers or as soon as one of the passengers has been waiting 30 seconds. The algorithm was set to allow a detour to drop off passengers but in practice there were no detours other than station tracks (drop-offs along the way).

Simulation results

Table 1. Simulation results for three different loading strategies at Fornebu.

	Individual rides	Single to Single	Single to Many
Average load (pass/vehicle)	1.5	3.1	2.7
Required fleet (vehicles)	610	285	300
Required headway (secs)	1.0	2.5	2.0
Waiting avg – 99% (mins)	0.9 – 2.2	0.9 – 2.0	0.9 – 4.2
Platform length (vehicles)	10	5	5
Average queue (passengers)	30	19	15

The average party is 1.5 passengers which is also the average load without ride-sharing. With ridesharing SS we can more than double (3.1 passengers) the average load. With multiple destinations the average load out of Lysaker station is increased from 3.8 to 4.0 passengers (not shown in Table 1) but passengers are dropped off along the way so that the average load is lower (2.7 passengers).

The vehicle fleet required to achieve the desired level of service is a reflection of the average vehicle load. With both sharing strategies we can save more than half of the vehicles required for individual rides.

The more vehicles in the system the shorter headways are required to accommodate the vehicles. With individual rides we need to run vehicles at 1.0 second headways. This is too tight to meet the brick-wall safety requirement (if one vehicle comes to sudden stop the next vehicle must be able to avoid a collision). With acceptable braking rates the minimum safe headway at 45 kph is about 2 seconds depending on detection and reaction times. With ride-sharing this requirement can be met.

In all cases the system has been dimensioned to offer average waiting-times below 1 minute. 99 % of all passengers would wait less than about 2 minutes. With multiple destination the 99-percentile waiting-time is raised to 4.2 minutes. Stopping to drop off passengers is less efficient, at least in the Fornebu case.

The required number of platform berths (unloading/loading positions) depends on demand volumes and station cycle time (open+unload+load+close). We have assumed average cycles of16 seconds (3+5+5+3) with a normal distribution for loading/unloading, each with standard deviation 3 seconds and limited between 2 and

15 seconds. With this assumption each platform position can handle about 80 parties per hour unloading plus loading.

For the Lysaker station with 4500 departing passengers during the peak hour we need two platforms each with 10 berths on each side. With ride-sharing we can do with 5 berths on each side making station smaller, less costly and easier to integrate in cityscape.

Passenger queues are also reduced to half with ride-sharing so that in average there are 3-4 passengers queuing for each berth.

Overall, in the Fornebu case with one dominating origin station the SM strategy turned out to be less efficient than the SS strategy. This is attributable to the lower load factor and the extra delays caused by intermediate stopping. Each vehicle mission takes longer and more vehicles are needed.

Conclusions

- We recommend to apply ride-sharing during peak demand from busy PRT stations
- Sharing to the same destination is often enough and the most efficient
- Voluntary ride-sharing should be encouraged by fare structure
- Half of the vehicle fleet can be saved without any sacrifice in service level
- System capacity can be doubled
- Longer headways make safe control less of a challenge
- Stations can be made smaller
- Vehicles can still be kept small
- PRT service is still on demand and non-stop to destination