PRT network economy, an example calculation

When arguing for PRT the most common coutner argument is that it is too expensive. This is entirely wrong. Instead a PRT system can pay for its own costs in many cases. This is in stark contrast with transit, where even the operation is heavily subsidized. In Sweden today the level of this subsidy is 58%, meaning that the ticket revenue only pays for 42% of operational cost.

The example calculations below show that both the investment and operation of a Beamways network can be payed for by ticket fares alone in a typical Swedish city. The home town of Beamways AB, Linköping, is used in the example, but the numbers will hold true to a great extent for similarly sized cities.

To translate these results to American conditions would require significant changes in the numbers. The main difference is in the transit mode share which is around 10 % in Sweden but maybe as low as 1 % in the USA. This reduces the possible gains in travel times a lot. On the other hand congestion on the road network is often much more severe in the US, which would make an even larger mode shift from car to PRT than indicated here plausible, and a lot of travel time gains for former car drivers a great plus. Finally the population density is lower in American cities than in Swedish cities, which makes PRT service more expensive. The population density in Linköping's network area is 2500 people/km^2, which translates to 6500 people/mile^2.

To make it obvious that this document is mainly valid for Swedish conditions the currency has been kept as Swedish crowns. One dollar translates to roughly 6.5 crowns.

At the end of the document a CBA is shown, which results in a net benefit of **+2.16**, i.e. a total return of 3.16 crowns for each crown invested.

The Linköping example

We have simulated a network which covers the entire city of Linköping, including relatively sparsely populated suburbs (by Swedish standards). This network covers an area of 40 km^2 which houses 100 000 persons. The network consists of 100 km of guideway and has about 100 stations.

Note that even if a network which covers an entire city of this size is economically profitable this is not true for small networks or single PRT lines, as you don't achieve the largest advantage to passengers: Direct travel to the destination. Such small networks can seldom compete with the car and thus get much lower ridership. Profitability thus depends both on the absolute size of the network and on the relative size compared to the city size. A similarly sized network is more profitable in a smaller city where it supports all local trips than in a large city where most trips still has at least one end point outside the PRT network.

Despite this fact it is of course reasonable to design and build a PRT network in a step by step fashion, or continually over a period. It is however important to notice that the economy of the network will get good only when the network reaches a high level of coverage. It can however be concluded that PRT is always a more advantageous investment than tram, even for a single line, unless maybe if the city already has a well functioning tram system.

Revenue

The revenue from a PRT system is first and foremost the fares. Other revenue sources like additional on-board services (entertainment, internet access) and some advertisement revenue are also possible, much like in today's transit vehicles. The total revenue is the product of the fare and the ridership. As a system gets fewer passengers as the fare increases there is an optimal price where the revenue is maximized. From a business standpoint the price should of course be set as close as this optimum as possible. But from an environmental perspective a maximum PRT ridership is desired which can motivate a lower price than the commercial optimum.

Ridership

The mode split of travel in Swedish cities is often similar to that of Linköping:

15 %	Walking
15 %	Bike
10 %	Transit
60 %	Car

And as each person makes about 3 trips a day the same table looks like this in number of trips:

0.45	Walking
0.45	Bike
0.30	Transit
1.80	Car

A PRT network will take market shares from all these modes, and in addition create numerous new trips. This is as there are large groups in the society which don't have access to a car and does not find the cause of the trip important enough to bother with the long travel time and low ride quality of transit. This fact is very clear from statistics which show that persons without access to a car make 0.5 trips less per day than those who have.

Taken together this results in the following mode split after a PRT system has been introduced. Some assumptions have been made, which are explained below the table.

0.30	Walking
0.30	Bike
0.00	Transit
1.35	Car
1.35	PRT (out of which 0.3 new trips)

The PRT ridership listed above is taken in part from walking and biking, taking 1/3 of those trips. This results in a public health loss but also in a travel time gain for those who select to go by PRT which (apparent from the behavior) outweighs the ticket cost. The number 1/3 emanates from the reasoning that those who walk often have such a short stretch to cover that waiting for the bus is not motivated, but that there is still a substantial fraction of these who would choose PRT thanks to the easiness of use. For transit the wait for the bus or tram often is longer than the actual walking time for short trips, while for PRT this is almost never the case. Bike trips have a longer mean length, 2-4 km, but as the bike's speed is correspondingly higher we have set the ratio of PRT adoption to 1/3 here too.

That transit share is down to zero is of course as the PRT network replaces legacy transit. There is simply no way that a bus or tram network can keep any significant part of its ridership with PRT as a competitor.

When it comes to car ridership the Beamways simulations show that the Beamways network gives a door-to-door speed comparable to that of a personal car. It is thus a reasonable assumption that half of the current car trips could be transferred to PRT (provided that both endpoints are within the PRT network). The mode split is of course affected by other factors than the travel times, notably cost and ride quality. When it comes to cost the calculations assume about the same vehicle cost for PRT and car, or 3 crowns per km (50 cents / km). The ride quality is different between car and PRT of course, but it is hard to say which is better. The PRT trip relies on a short walk to the nearest stop, but on the other hand you don't have to drive and you don't have to park the vehicle.

The BeamEd simulation also shows that the mean trip length in a city of this size is about 5 km. Statistics for Sweden says that about half of the car trips are shorter than 5 km. While these numbers are not directly comparable this at least indicates that for this size city about half of all car trips have both endpoints within the network area. These two numbers together indicate that 25% of all car trips could be taken over by PRT.

With 100 000 inhabitants each doing 1.35 trips per day and an average of 1.35 people in each vehicle we get 100 000 vehicle trips per day. With 3 crowns in revenue per km and 5 km as the mean trip length we get a daily revenue of 1.5 million crowns, or 550 million per year.

Cost

The cost of a PRT system consists of amortization of the investment and operation & maintenance cost. At an investment level of 40 million crowns per km and 5 million per station the example network costs 4500 million. With an amortization period of 40 years and an interest rate of 6.5 % the annual cost is 290 million crowns per year.

The operation cost has been calculated to 1 crown per km but as there are also an additional 20 % of empty trips according to the simulation the real cost is 1.2 crowns / km. This includes amortization of vehicles.

With the above mentioned ridership and mean trip length the example system gets a total trip length of 182.5 million km, at a cost of 219 million crowns per year. Total cost is thus 509 million crowns per year.

Results

The annual profit of the example system is 41 million crowns per year, which corresponds to a profit margin of 7,5 %. This is rather normal for a commercial enterprise. Many of the figures above are however uncertain and there will be differences between different cities and depending on the quality and extent of the networks. If the commercial result is disappointing there are quite a few ways to improve the situation. If an improvement of the profit margin by 10 % is required any of the below measures, which according to our opinion are all quite viable, could provide this.

- An increase of the fares of med 10-15 %
- An operational subsidy by half of what the buses get today. That is 50 million crowns per year for our example network.
- An investment subsidy of 20 % (transit today: 100 %)
- Other types of fees, for instance a connection fee for housing developers when developing new areas.
- Other types of revenue from advertizing, on board internet connection etc.

Socio-economic analysis

The study presented above views the PRT system only from an operator standpoint, i.e. it is a commercial analysis for the operator. This is of course an important perspective but the socio-economic perspective where costs and benefits for all concerned parties are calculated is also important. While such socio-economic studies are not perfect they are the best objective tools we have to see whether a project is beneficial. Socio-economic studies are especially apt at comparing different solutions to the same problem and provide a valuable basis for an informed decision.

Typically transportation infrastructure projects don’t have splendid socio-economic results but for PRT the numbers are generally much better than for other types of projects. Below a few examples of Swedish projects are shown. The key figure used is the net cost benefit ratio, defined as the net of benefits and costs divided by the investment. This is thus a net profit ratio per invested amount. A value of -1 means that there are no benefits at all, while a value of 0 if the project is pointless in the sense that the costs and the benefits are the same, while a positive number indicates that the benefits are larger than the costs.

Tvärbanan in Stockholm, a tram line: -0,46
Ostlänken, a high speed railroad: 0
Bottniabanan, a medium speed railroad with lots of heavy goods: 0,54

For PRT systems normal values are between 1 and 3, i.e. each invested crown (or dollar) provides benefits in the range of 2 to four times the investment over the expected system life.

In our Linköping example we have a monetary profit of 100 million crowns per year, coming from the current transit subsidy not having to be spent anymore. From this the increased cost for bike riders and walkers who select PRT and half of the cost for all added trips must be deduced.

In a socio-economic study other types of costs and benefits shall also be taken into account. These include environmental costs, accident costs and gains from reduced travel times. In our example the travel time gains for previous transit users dominate, but in an American scenario it is more likely that travel time gains for reduced road congestion is larger. Note that such gains for those still using their cars are to be taken into account as the gain they see from reduced congestion is really thanks to other people selecting to be PRT passengers rather than drivers. The environmental gains are also important. In Sweden there is a substantial taxation on petrol which must be deduced but in the American case the environmental gains would be substantial. Another improvement with the introduction of a PRT system is a significant reduction of road accidents, which leads to a reduction of health care costs.

According to the Swedish standard model for socio-economic analysis these are the effects that should be included, but it is also possible to include other effects which are harder to calculate, like the increased walking's effect on public health and the difference in noise and other nuisance. In the PRT case you get a negative effect from lost bike and walking trips, but an improvement in exercise for former car drivers walking to their PRT stops. There is also a positive effect from the reduced traffic noise in the city and a negative effect from the visual intrusion, i.e. that people living and working close to the PRT guideways are disturbed by the tracks and vehicles. Out of these additional effects we have included the health effects but noise and visual impact are excluded as there are no formal ways of quantify these effects.

The table on the next page shows the complete socio-economic study. All numbers are discounted to a *present value* based on an interest of 4% and a study period of 60 years. This is the standardized method practiced in Sweden for infrastructure projects. The present value of a cost or benefit which happens in the future is reduced by the interest and with an interest of 4% and a study time of 60 years an *annual* cost or benefit gets a present value of about 25 times the annual sum. Travel time value is set to 42 crowns / hour according to Swedish standard, even if many studies for other projects have used higher values. From 2009 a new value of 51 crowns / hour is to be used.

In the number “external effects” all environmental, accident and health effects are hidden. For cars this number is surprisingly low, which is due to the fact that a large fraction of these costs are paid for by the high taxes on fuel in Sweden. Thus they are not external. When it comes to walking and biking being replaced by PRT the external effects are a negative health effect and a positive accident effect (PRT being much safer than biking or walking).

Initial investment, Guideway and stations	4457.01	MSEK	Incl tax effects
Investment and reinvestment of vehicles	-2232.29	MSEK	
Operations and maintenance	-11161.45	MSEK	
Ticket revenue	19966.21	MSEK	
Removed bus operations subsidies	2104.02	MSEK	
Net external effects of removed bus traffic	321.49	MSEK	
Travel time gains for former bus passengers	3507.41	MSEK	
Reduced fare costs for former bus passengers	256.99	MSEK	
Net external effects of replaced car traffic	1283.05	MSEK	
Cost reduction for former car drivers	1165.91	MSEK	
Travel time gains for former car drivers	963.76	MSEK	
Net external effects of former bikers/walkers	-2109.95	MSEK	
Cost increase for former bikers/walkers	-2899.22	MSEK	
Travel time gains for former bikers/walkers	2515.67	MSEK	
Travel time gains, new trips	404.50	MSEK	
Net present value	9629.10	MSEK	
Net present value ratio:	**2.16**	Crowns of gain per invested crown	