Future transit system for Uppsala

This is an abbreviation and translation of a study that was made by Beamways, Arken arkitekter and TriVector Traffic for the city of Uppsala. The report was finalized on September 11, 2009. This translation was made by Bengt Gustafsson of Beamways AB shortly thereafter. The entire report is 124 pages including the appendices, so this translation is just a brief account of the main findings, with focus on the hard figures. Other parts of the report detail the impact of the choice of system on the future development of the city, environmental aspects, risks etc.

Beamways' conclusions

Note that this section is not a translation from the report, but an independent analysis based on the results.

From the results of the report's economic calculation a small advantage for PRT can be seen in the form of a marginally lower yearly cost. There are however several factors which modify these figures in a real case, where ridership is not a given and tram lines are more accurately priced.

The risk of building a city wide PRT network at this stage is of course high, which makes the initial pilot stage the more important. Given a successful pilot track in Boländerna (or elsewhere in Sweden) it ought to be possible to start a controlled build out of a PRT system in the entire city.

The most important additional factors to consider are:

- More realistic tram investment figures: Instead of 60 million kronor per km (including the busway part) most studies use numbers on the order of 200-600 million per km.
- Considering travel time differences in a CBA would show an advantage of 400 million kronor per year for the faster PRT mode.
- More realistic tram mean speed. Other tram lines run at about 21 km/h instead of 24 km/h used in this study (given the stop intervals). This further increases travel time cost.
- Calculating the ridership of the different modes using for instance Logit models would show a significant advantage for the faster PRT based system.

Beamways AB
Westmansgatan 29
SE-582 16 Linköping
Sweden

BEAMWAYS

info@beamways.com
www.beamways.com
T. +46 (0)13-465 10 85

Prerequisites

Uppsala is a city with a steady population growth. The city proper will grow from the current 145 000 to 196 000 during the study period, according to the city's estimates. The report is based on this assumption. A goal of the City is to increase public transit share to be able to reach environmental goals. These two facts taken together mean that the number of transit trips is expected to grow by a factor of 3.2 compared to today's figures.

The study is to contrasts bus/tram and PRT based systems with target years of 2014, 2020 and 2030. Initially it was the idea to have three systems compared, but it was soon evident that a bus based system would not by itself be able to cope with the passenger flows, so this alternative was merged with tram into a combined system.

Back casting from environmental targets creates target figures to reach:

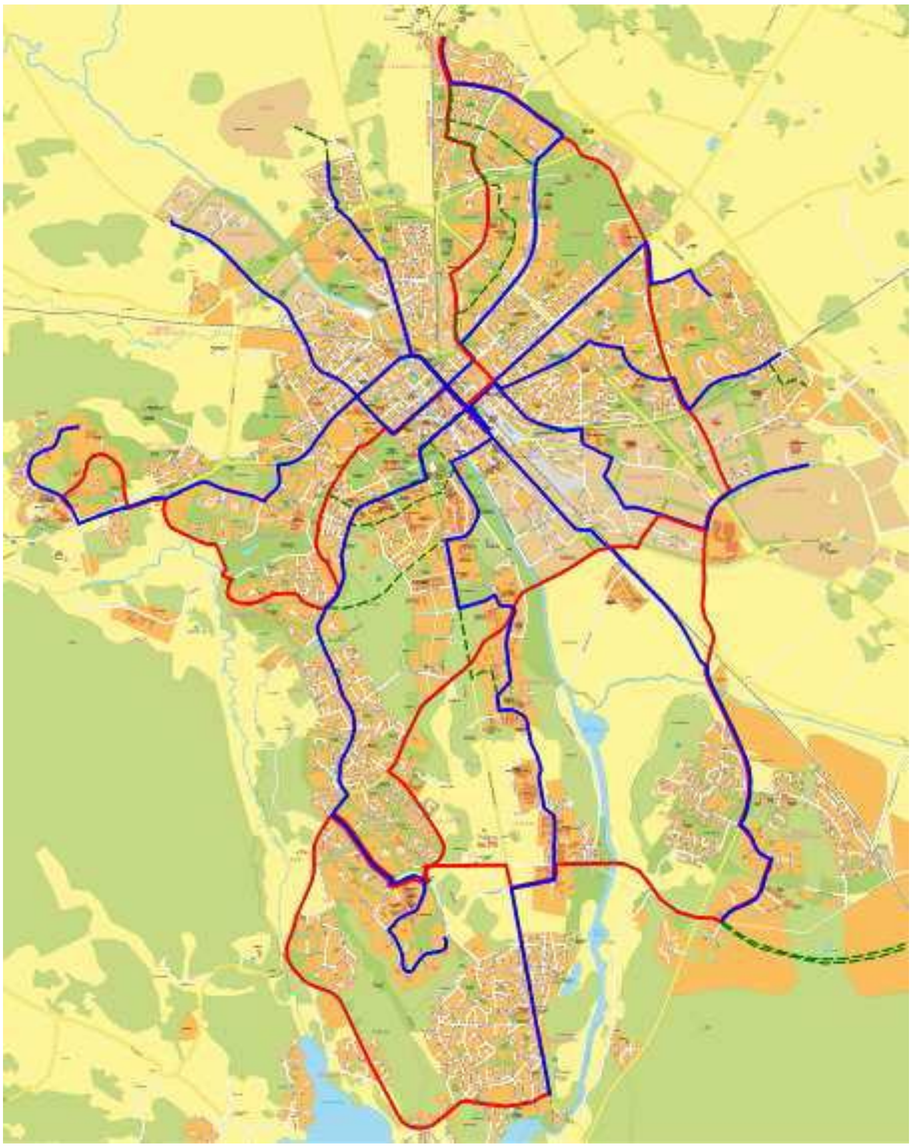
Year	Market share	Trips/day
2008	13 %	44640
2014	18 %	69 000
2020	26 %	110 000
2030	30 %	141 000

Note that the means of reaching the market shares as listed above was not included in the study, it was to be taken as a prerequisite.

Bus/tram system

The investigated bus/tram system has five main lines (blue) and five complementing lines (red). For 2030 four of the main lines are tram lines, while the remaining main line and the complementing lines are bus. The length of the main lines is 63 km, while the length of the complementing lines is not reported.

By 2030 all main lines have 5 min vehicle intervals, while complementing lines have 10-20 minute intervals.

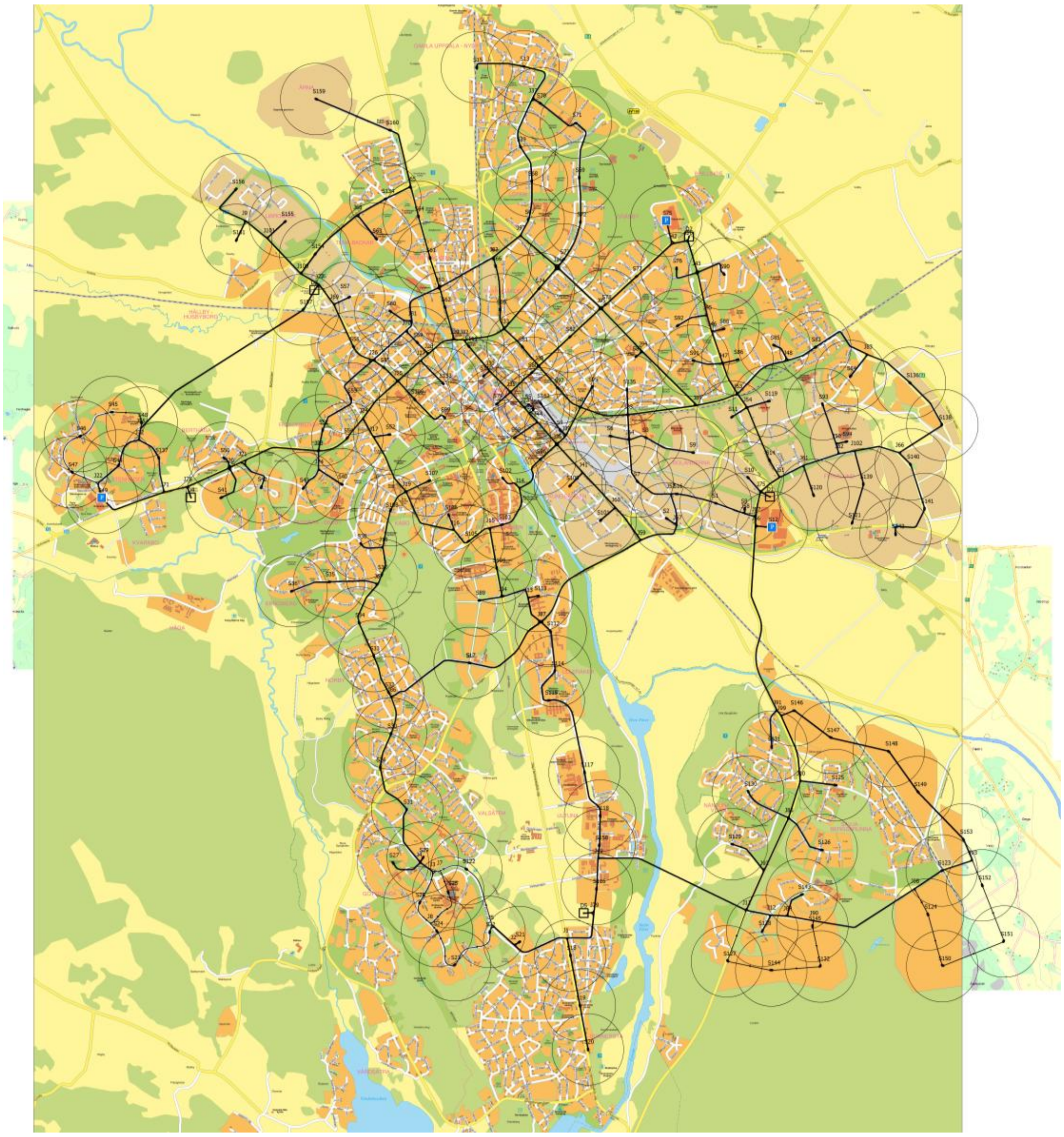


Tram/bus network

PRT system

The PRT network was designed using Beamways' design principles which include mostly dual direction lines with rather large loops, complemented by spurs extending inwards into loops and outwards at system edges. No spur has more than three stations, to minimize the impact of a breakdown of a guideway section.

The PRT system has 125 km of track, 162 stations and 101 crossings.



PRT network. 400 m circles around stations.

Comparison between networks

A number of measures were compared between the networks. This section contains the results for 2030 in a condensed form.

Coverage

The coverage of a network is defined here as the percentage of all inhabitants and workplaces (including schools, universities) having a walk-in distance of 400 m or less. For comparison the numbers where generated also using a 600 m distance.

Coverage	Tram/bus	PRT
Inhabitants, 400 m	80 %	85 %
Inhabitants, 600 m	92 %	93 %
Work places, 400 m	80 %	86 %
Work places, 600 m	92 %	94 %

Note that while these differences seem quite small, each trip has two ends, and trips where one end is not covered by the network are unlikely to happen. The following table lists the percentage of eligible trips:

Eligible trips	Tram/bus	PRT
400 m walk in	64 %	73 %
600 m walk in	85 %	87 %

Note: The coverage numbers for bus/tram counts all bus stops equally, if you have a complementary line stop nearby you are covered, albeit not as effectively as by a main line or PRT stop.

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SE-582 16 Linköping
Sweden

info@beamways.com
www.beamways.com
T. +46 (0)13-465 10 85

Capacity

The capacity of the networks has been evaluated using rules of thumb for bus/tram network and using the BeamEd simulator for the PRT network. In both cases the commuter trains to/from Stockholm present the hardest capacity problem. It is estimated that 50 000 persons will commute to/from Stockholm daily by 2030. This would mean that during a rush hour including 12 % of the daily trips 3000 people would leave and another 3000 would enter the local transit system at the railway station.

The rush hour capacity of the tram/bus system is guaranteed by using longer trams, coupled in pairs. The bottleneck will most probably be the traffic around the railway station, where all main lines of the transit system meet to facilitate changeovers, both between tram/bus lines and to/from the trains. No further simulation or calculation regarding this traffic situation has been performed within the project.

For PRT a complete rush hour constituting 17 000 PRT trips (12 % of daily total) was simulated in BeamEd. Out of these trips 6000 were the commutes via the railway station and the balance local trips. The commutes were simulated using the pulse load facility of BeamEd where four trains at 15 minute intervals was specified, each train carrying 750 passengers (for each direction). As the PRT network has three stations close to the railway station and several lines going through this area we could show that the PRT system can cope with this influx of passengers without excessive waiting. The headway required was 2 seconds and a ride sharing scheme was in place which generated a mean of 2.2 passengers per vehicle departing from the PRT stops surrounding the railway station. The ride sharing scheme is similar to the ones suggested by Ingmar Andréasson: If passengers bound for the same destination are waiting at the same PRT station they are grouped together to fill vehicles better. The ticketing system would have to assist in making this ride sharing happen, for instance by showing destination of each vehicle on electronic signs at the gates. A discount on the ticket fare for ride sharing would also encourage this.

Travel times

Travel times have been estimated using 25 *typical trips*. This is a rather rough method, but as there was too much work involved with coding the entire bus/tram network into a traffic simulation software this is what was deemed possible within the project budget. The idea is to take five representative origins (homes) and five representative destinations (work places) and manually calculate the travel times for bus/tram. This is then compared to times collected by BeamEd during the PRT simulation.

The result was that travel time was 23 minutes for bus/tram and 17 minutes for PRT, including walk-in, waiting, riding, transfer time and walk-out. The tram/bus times are based on a mean speed of 24 km/h, and 2 minutes of waiting at the departure station. To achieve the 24 km/h mean speed with a 400 m stop interval the trams (and buses) would have to have full priority over car traffic, and separated right of way for as large percentage of the lines as possible.

As the total number of trips of the systems was a prerequisite for the study the differences in travel times do not cause different ridership in the systems. Instead it must be implicitly understood that for a slower transit network to attract the same ridership other measures must be taken. One such measure would be to decrease ticket fares, others include increasing the cost of driving in various ways and decreasing the speed of driving. Part of this reduced driving speed can be achieved as a side effect of the prioritization required to make the tram/bus system fast enough. If a CBA was performed it would include the effects on the individual inhabitants of the different ride speeds, but no CBA was included in the study conditions.

Cost

As can be expected the investment cost in tram or PRT infrastructure is quite high.

The staging of the bus and tram system envisioned involves first building busways for the main lines and then gradually converting these to tram lines. The cost was estimated to 30 million kronor/km to build the busway, and another 30 million kronor/km to convert to tram. This corresponds to $6.4M per mile for each step. In addition the rolling stock and depot facility are separately costed.

For the PRT network we have used a figure of 40 million SEK/km for the guideway system, 3 million per station and 350 k for vehicles. This translates to a system cost of 56 million kronor/km which corresponds to $12 million per mile.

Operating costs have also been estimated for both systems, using models based on several factors.

In the table below the investment costs in infrastructure and rolling stock have been recalculated into yearly amortization and interest payments. All figures are in million kronor. (A US dollar is about 7.5 kronor).

The ticket revenue has been estimated at 338 million kronor per year at a modest ticket price of 8 kronor per trip. As the ticket price and the number of trips is assumed to be independent of the system type it becomes irrelevant in the comparison.

	Tram/bus	PRT
Investment, infrastructure	3500	5980
Investment, rolling stock	2200	1050
Yearly cost, infrastructure	239	374
Yearly cost, rolling stock	158	105
Operating cost	265	147
Total yearly cost	**662**	**626**