Towards advanced transport for the urban environment

“Report on the Uppsala Boländerna PRT feasibility study”

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Executive summary

Traditional mass transit modes have declined in share of ridership in the last 25 years in Uppsala as well as in Sweden as a whole. Therefore more competitive public transportation systems are needed. This report illustrates the advantages and the impacts of a PRT network in Uppsala Boländerna. The PRT system offers an individual trip with departure on demand and a direct origin to destination trip without any stops, just like the car.

The proposed PRT network for Boländerna includes 9.4 km of single track, 16 stations on the main net and 130 vehicles with room for four people. The average waiting time is short, about a minute, and the maximum distance to a stop is 300 metres. The stops are all placed on separated and elevated tracks and since the PRT vehicle doesn’t stop on route a high and even speed is obtained (average speed 36 km/h). Compared to the existing bus system the PRT system offers half the travel time. For example a trip from the central station to IKEA is made in 15 minutes with the bus but only 6 minutes with the PRT system.

With the existing bus network the public transit share in Boländerna is calculated to almost double from the year 2007 to the year 2020. With a PRT network system this share is instead calculated to rise to 5 times as many trips as today. This means that the public transit share increases from 5 to 20 %. At the same time the car share decreases from 65 to 55 %. Thus, a PRT network for Boländerna would contribute to enhance the public transport mode share from 5 % to 20 % or to fourfold.

The gain in travel time by PRT amounts 0.9 million hours per year. For a daily commuter working 225 days per year, this travel time gain corresponds to 49 hours saved per year, or more than one ordinary working week.

A comparison of capital costs for bus, LRT and PRT on three different cost levels indicates that PRT is less expensive than LRT in all three alternatives. The investment costs for bus is always less expensive than PRT and LRT mainly because the buses use the already existing infrastructure.

The PRT network at Boländerna is found to be highly economic viable. The social benefit-cost ratio amounts an interval between 1.25 and 1.48 and with an average of 1.36. This means that the annual benefits exceed the costs by 25 to 48 %. And the costs also include the capital costs. As we assume the low cost to be the most probable alternative, one might state that a PRT network at Boländerna yields 48 % in return in terms of higher benefits. From a social benefit-cost point-of-view, PRT at Boländerna seems to be very well justified.
1 A brief description of Uppsala and Boländerna

Uppsala is Sweden’s fourth largest city with 119,000 inhabitants. It is situated in the Stockholm-Mälar region, the most prosperous and densely populated part of Sweden, a region with 3.0 million inhabitants. Travel between Uppsala and important international trade centres is fast and easy and the ride from the International Airport into the city centre of Uppsala takes 20 minutes.

The industrial town lost most of its manufacturing industries during the 1970s and 1980s, and the fastest growth since then has taken place in the knowledge-intensive sectors, first and foremost in Life Sciences. One example of this change is the Boländerna district which now is in rapid change from an industrial site into a shopping area and into an area for advance biotech industries. From the perspective of politics, the city has to respond to the growing interdependence of internationalized business life. The response has been to create a vision as a common ground for the development of its future. A comprehensive strategy with five focal action programmes was produced; these were sustainable city development, institutionalizing triple helix (horizontal cooperation), regional networking (vertical cooperation), international cooperation, and city branding.

The comprehensive plan for the city of Uppsala focuses on establishing three equally important structures: the built-up structure – including new development areas for business and science and new housing areas; the green structure – based on green core areas, green links, parks, and other open spaces, which guarantees access to recreational assets and to secure biological diversity; the infrastructure – which promotes accessibility to the city from local, regional, national and international perspectives.

To implement the plan, a management strategy that includes public and private partnerships has been established. Important partnerships include stakeholders in the city centre and in Boländerna to establish a close, active and permanent cooperation. A strategic development programme for the city is now in progress including a regeneration plan to turn the district into one integrated part of the inner city; provide the area with modern public transport, well design parking areas, and a green structure that makes it pleasant to bike and walk through the area. The planning process has been going on since 2007.

The reasons to choose Boländerna as a pilot area for PRT are the following: easy commuting for employees, shopping costumers could park once and use the PRT for travelling in the shopping area, possibility to combine park & ride in the city periphery with PRT to the city centre and to the railway station, a greater scope to design the parking lots in the district, no conflicts with the cultural heritage and conservation perspectives on urban design matters.
2 A short introduction to the PRT system

Traditional mass transit modes have declined in share of ridership in the last 25 years in Sweden. While this study was done in Sweden, these trends were echoed elsewhere. Research shows that delay and transfer times are perceived to be more onerous by travelers than the actual travel time. Relative weights have been found, for example: delay times are weighted by travelers at four times more onerous than travel time. The total weighted trip time for mass transit, including walk, wait, and transfer is compared to that of auto trips, and the results show that weighted transit trips are twice the duration of auto trips. This helps explain the decline in transit ridership share despite mass transit investments.

Personal Rapid Transit, or PRT, in contrast to mass transit, minimizes wait and delay time and eliminates transfer time. A case study of Stockholm, the capital of Sweden, shows a substantial market impact from a high level-of-service transit system such as PRT. Total transit ridership would increase by about 20 to 40 % depending on the travel period.

Personal Rapid Transit (PRT) offers individual trips in public vehicles, a competitive alternative to the most popular mode of urban transport, the private automobile. PRT is developed to offer some of the advantages of the private auto:

- It departs on demand without any timetable
- It runs the quickest path without stops and without any transfer
- It offers a private trip alone or together with passengers of your own choice

At the same time it avoids some of the major disadvantages of the private auto:

- Noise and exhausts
- Congestion and accidents
- Parking demand

PRT is a system of small, driverless vehicles on their own guideway that is demand-responsive and offers a direct trip to the destination without any stop en route.
3 The travel pattern in Uppsala

3.1 The present situation

Every day over 350,000 trips are made in the City of Uppsala (year 2005). This equals to about 3 trips per inhabitant and day. The trips are divided on the transport modes with a pedestrian share of 19 %, a bicycle share of 27 %, a bus share of 11 % and a car share of 40 %. The remaining 3 % for example include the train share. The total market share for public transport in the three statistic areas that are covered by the PRT network at Boländerna is 6 %, a decrease with 2 percentage units from the year 2000.

The public transit share in the County of Uppsala (passenger-kilometres) is 12 % (year 2007).

The various Public transport modal shares can be summarized in the table below:

<table>
<thead>
<tr>
<th>Relevant area &amp; year</th>
<th>Public transport market shares</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boländerna sub-area, in 2007</td>
<td>5 % - 6 %</td>
<td>of all trips</td>
</tr>
<tr>
<td>City of Uppsala, in 2005</td>
<td>11%</td>
<td>of all trips</td>
</tr>
<tr>
<td>County of Uppsala, in 2007</td>
<td>12%</td>
<td>of all passenger-kilometres</td>
</tr>
</tbody>
</table>

3.2 Future transport demand

3.2.1 A Meta-analysis forms the starting point

A common experience from many urban PRT studies, in which travel demand models have been applied, is that bringing PRT to the customers in the cities would affect the modal split in favor of more public transport trips in a substantial way. Figure 1 summarizes 10 cases with the modal split without PRT networks as compared to a forecasted situation with PRT networks.

Figure 1. Public transport modal split without and with PRT. Results from British and Swedish case studies in which travel demand models have been adopted.
As can be seen the augmentation in modal split is substantial. On average it might increase by 15 percentage units, when PRT will be introduced. The improvement in the modals split is higher when the original modal split is lower without PRT networks. This relationship between the transit mode share without and with PRT can also be illustrated by Figure 2 below:

**Figure 2. Relationship between transit mode share without and with PRT networks in 10 case studies, in which travel demand models have been used.**

![Graph showing the relationship between transit mode share without and with PRT networks.](image)

Transit mode share with Podcars - as a function of mode share without Podcars (relationship based on 10 case studies with demand models)

To our knowledge, very few other urban public transport projects yield the same magnitude in increasing the public transport modal split as PRT tends to do.

**3.2.2 Application for Boländerna**

Based on the above mentioned meta-analysis, the modal share for PRT has been calculated to become 20 %. The existing bus network in Uppsala has about 1 200 passengers boarding for Boländerna a day. The transit market share is assumed to rise from about 5 to 20 % if a PRT network is introduced in the area. This assumption is based on formerly made modeling studies from 10 cities in Sweden and England, with the result that the public transit share would rise with about 15 % when introducing a PRT network. For the Boländerna area the number of trips rises from 1 200 trips to 4 600 trips a day. The main part of the increase is assumed to come from car traffic but to some extent also from the bicycle traffic.

With consideration to a future increase in the number of workplaces in the area and to an extension of the shopping area, the number of trips with the PRT network in the year 2020 is assumed to be about 8 000.
4 The land use at Boländerna

4.1 The present situation
The main activities in the Boländerna area are shopping, small industries, warehouses and offices. There are about 9 500 people working in the area but almost no people living there. The adjacent areas Fyrislund and Kungsängen have a similar structure with a number of workplaces but very few inhabitants.

There are a large number of shops within the area, for example IKEA, and these shops are mainly concentrated to the east part of the area. The total shopping area is estimated to 60 000 square metres. This in turn is estimated to attract about 25 000 persons per day.

4.2 Future land use
The planned changes for the Boländerna are devoted to an expansion of the present shopping area. The total shopping area is estimated to total to 100 000 square metres in the year 2020. This in turn is estimated to attract about 40 000 persons per day. The increase is 60%.
5 The PRT network for Boländerna

5.1 The PRT network design

Figure 3 below illustrates a proposed PRT network for Boländerna. The network includes 9.4 km of single track and 16-18 stations.

The proposed PRT network is mainly a single track system with elevated guideways completely separated from other traffic. Where the guideways cross busy roads a free height of 5.1 meters is needed but on other sections 2.7 meters is sufficient. On a few locations it is possible to place the guideways and stations on ground level but then a protective fencing is needed.

The single track system results in some detours but is still acceptable considering the high and even speed (average speed 36 km/h) during the entire trip. Compared to a double track system a larger area can be reached using the same length of total guideways. All the stations are placed on separated tracks and hence passing vehicles do not have to stop.

The proposed PRT network has 16 stations on the main network and another two in the adjacent area Fyrislund. The distance between the stations is 400-600 metres and the walking distance to the stations are 300 metres at the most.

Elevated guideways and stops consume a minimum of space on the ground. Load-bearing posts of about 50 cm in diameter are placed at intervals of 15-20 metres. The detached stations will also need space for a staircase and a lift. For some of the stations it is instead possible to incorporate the stations into existing buildings.

The network has been placed on municipal land but it is possible to locate the stations on private property if the owners so wish. Our judgement is that this should be attractive for the owners of commercial properties in order to offer a high availability.
The entire network is designed to have merge and diverge points on the same level, thereby eliminating the need for level crossings and high constructions.

The PRT network is designed for gradual extensions, primarily to the northeast and southwest. The control system is decentralized so that it does not restrict a later extension of the network.

There is also a possibility to condense the network within the growing shopping area so that each shop can have a PRT station of their own (at their own expense). This does not increase the travel time for those already travelling with the system, since all the new stations are placed on separated tracks. A condensed network within the shopping area makes it easier to move from one shop to another, and this could reduce both the external and internal car use.

A summary of the proposed PRT network design:

- 9.4 km of tracks (11 km including the station tracks)
- 16 stations on the main network (18 in total)
- 130 vehicles for 4 sitting passengers
- 36 km/h in average speed
- 400-600 m between the stations
- 300 m of walking distance to the station (at the most).

The PRT network is aimed at replacing the local bus network within the Boländerna area. However, most existing bus lines also serve areas outside the Boländerna area.

5.1.1 Consultation

During the project period the proposed PRT network design has been presented to and discussed with representatives of the City of Uppsala as well as the private propriety owners and entrepreneurs in the area. With the help of a local consultant the local conditions of the area has also been studied to find the best possible network design.

The outcome of the consultations was overall positive. The entrepreneurs in the area had positive expectations on the PRT network and saw the possibilities of increased accessibility for both visitors and employees.
5.1.2 Stations

The proposed 16 stations are assigned to approximately the same catchment areas as the present day bus-stops. However, PRT will facilitate to locate stations inside newly built-up buildings. Two specific PRT stations are planned to take care of railway passengers emerging from the central railway station in Uppsala.

Figure 4: Two proposed PRT stations at the Uppsala Central Station, Illustration: Magnus Hunhammar

The next couple of figures illustrates possible design of PRT stations in Uppsala, stations above ground level as well as stations at ground level.

Figure 5: Sketch of a PRT station at the Uppsala Central Station, Illustration: Anja Moisander
Figure 6: Examples of stations above ground, Illustration: Anja Moisander

Figure 7: Example of station at ground level, Illustration: ULTra
5.1.3 Who will travel with the PRT system?
Following is a description of possible PRT travelers:

**People working in the area.** For those who work in the area the PRT can be a good alternative to traveling by bus or their own car to work. This means that surfaces previously used by employees for parking can be reduced and used for other purposes.

**Those who attend school in the area.** There are a number of schools in the area and for those who go there the PRT system should be a good alternative to the current bus service network. The demand for school travels can be great at certain times of day and the design of these stations should therefore be made accordingly.

**Those who go shopping in the area.** For those who live in Uppsala and go to Boländerna for shopping the PRT is a suitable option on the occasions when they buy only as much as can conveniently be carried on the PRT vehicle. However, the vehicles can hold quite a lot of cargo. For those not coming from Uppsala but from the surrounding region the PRT can be a way to get around in the area, from one shop to another. For this to work in a satisfactory manner the stops in this part of Boländerna are slightly more frequent than along the rest of the network. It is also appropriate with stops in some key buildings and close to parking spaces, because in this way the passengers gets close to their goal.

**Park-and-ride passengers.** There are a number of large parking spaces close to the Boländerna shopping area. These parking spaces could be used by travelers coming from the surrounding region and going to the central train station or to the city center as a park-and-ride solution. In this way they don’t have to park in the city center where it might be difficult or just expensive. Discussions have been held with IKEA that are interested in making an agreement for such a solution.

**Carpooling travelers.** The eastern part of Boländerna lies close to the road to Stockholm, and one can therefore imagine that carpooling travelers use the east station as a meeting place. The person driving can go there by car and the others arrive by PRT before they continue their journey together in the car.

5.1.4 Accessibility to the PRT network in the area
With the proposed location of PRT stations in Boländerna the accessibility to the PRT network will be good. The red circles in the figure below shows the area covered within a 300 meter walking distance from the stations. As can be seen the whole area is well covered and in most cases the walking distance will be no more than 100-150 metres.
Figure 22. Accessibility to the PRT network assuming a 300 meter walking distance

The accessibility is shown more clearly in the next figure.

Figure 23. Proposed PRT network with catchment area within a radius of 300 meters

A fundamental idea and the strength of the PRT system is to take care of travel demand as soon as it arises in order to minimize the waiting time for the travelers. Travel demand emerges randomly and therefore the podcar stations are designed to take care of the individual travel demand in the best way possible.
5.2 The PRT trip pattern and simulation results

5.2.1 Trip pattern

Today’s trip pattern is presented in terms of modal split between the walk/bike, the bus and the car modes at the Boländerna area.

Figure 8: Modal split at Boländerna today with the bus network

<table>
<thead>
<tr>
<th>Mode</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>65%</td>
</tr>
<tr>
<td>Bus</td>
<td>5%</td>
</tr>
<tr>
<td>Walk/Bike</td>
<td>30%</td>
</tr>
</tbody>
</table>

Source: Travel survey data from Uppsala

Two-thirds of all trips entering the Boländerna area arrive by car, and another 30% arrive on foot or by bike. Only 5% of all such trips use the city buses. With a PRT network the mode shares will be changed due to the introduction of a PRT network for Boländerna:

Figure 9: Modal split at Boländerna in 2020 with the PRT network

<table>
<thead>
<tr>
<th>Mode</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>55%</td>
</tr>
<tr>
<td>PRT</td>
<td>20%</td>
</tr>
<tr>
<td>Walk/Bike</td>
<td>25%</td>
</tr>
</tbody>
</table>

Source: Own calculations based on a meta study on public transport modal shares
The modal shares have been calculated to change in the following way:

- The car share decreases from 65 to 55 %
- The bicycle and walking share decreases from 30 to 25 %
- The public transport share increases from 5 to 20 %

Thus, a PRT network for Boländerna would contribute to enhance the public transport mode share from 5 to 20 % or fourfold.

The Trip pattern is illustrated in Figure 10 below:

**Figure 10. Calculated trip pattern during morning peak hour for the Boländerna PRT network**

The origin-destination demand is in yellow bars. PRT peak hour flows are marked with red links, and boardings and alightings are marked with blue/white circle segments.

During the most congested hour, the afternoon peak hour, approximately 1,600 trips will be made by the PRT mode. This corresponds to 15,225 daily PRT trips. The average trip length is calculated to be 2.9 kilometers and the traffic production to be 13.3 million passenger-kilometers per annum.

### 5.2.2 Simulation results

The assumption is that the PRT can move with the speed of 45 km/h on the straight segments. With due regard to the comfort and convenience for the passengers at curves, and to the stop and start part of the journey, the estimated average resulting speed will be 36 km/hour. The vehicle fleet has been dimensioned to be able to take care of the future (in year 2020) estimated peak hour travel demand with an average waiting time of 1 minute at peak hours. During other periods of the day and night, usually no waiting time is calculated.
The calculated supply of vehicles is simulated to amount 130 vehicles with some car-sharing during peak hours. The average waiting time becomes 1.7 minutes resulted from the micro-simulation model PRTsim\(^1\). Access time is set at 1 minute (including time for vertical movement with the elevator up to the platform including time for ordering the trip. The walk time has been calculated to the PRT station from each centroid of the relevant traffic zone.

Some key figures from the simulation:

- With 130 vehicles the resulting waiting time becomes 1.7 minutes, and 99 % of the waiting times are under 5.8 minutes
- The average journey time is 6.3 minutes, and each loaded vehicle carries 2.4 travelers during the peak hour
- The most congested link is served by 552 PRT vehicles during the peak hour (i.e. by 6.5-second time slot)
- Each PRT vehicle makes between 5 and 6 missions per hour.
- The PRT system carries more than 13 persons per vehicle-hour

\(^1\) PRTsim is an advanced micro simulation model especially designed to handle PRT networks and the demand and supply. As input is a PRT network designed with tracks, stations and merge/diverge point. Another type of input is a demand station-to-station matrix. The model simulates the route choice within the PRT network, the distribution of waiting and in-vehicle travel times, as well as the needed vehicle fleet, in order to fulfil goals of average or maximum waiting times. It also keeps track of vehicle movements and delays, and vehicle queuing at stations, and has algorithms for empty vehicle management. The model has been developed by Professor Ingmar Andréasson at LogistikCentrum, Sweden.
6 The benefits and costs of the PRT network

6.1 Benefits of PRT at Boländerna

A cost-benefit analysis has been carried out for the Boländerna area with a PRT network replacing the existing bus network within the area. On the benefit side the following aspects are considered:

- Travel time gains
- Travel comfort gains
- Ticket revenues
- Traffic safety gains
- Environmental gains

And on the cost side the following aspects are considered:

- Investment costs
- Operating and maintenance costs
- Reduced gasoline tax revenue from less car traffic

6.1.1 Travel time gains

The travel time gains are calculated from trips between the most remote part of Boländerna, i.e. at the shopping mall area in the south-eastern corner of the area, and to the central railway station in Uppsala, a distance of 4.8 kilometres. The travel time components for the bus network is derived from the trip planner at Upplands Lokaltrafik, and the corresponding travel times for the PRT system is derived from the micro simulation of the PRT network (with the PRTsim-programme).

Table 2. Travel time components for bus and PRT at Boländerna

<table>
<thead>
<tr>
<th>Travel time components in minutes</th>
<th>With bus</th>
<th>With PRT</th>
<th>Travel time gain</th>
<th>Travel time gain in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking time</td>
<td>5.0</td>
<td>5.0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Waiting time</td>
<td>7.5</td>
<td>1.7</td>
<td>5.8</td>
<td>77%</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>15.5</td>
<td>6.3</td>
<td>9.2</td>
<td>59%</td>
</tr>
<tr>
<td>Generalized time</td>
<td>38.3</td>
<td>19.2</td>
<td>19.1</td>
<td>50%</td>
</tr>
</tbody>
</table>

Today’s bus service operates with 15 minutes of headway in peak hours and the in-vehicle travel time varies between 12 and 19 minutes from Boländerna to the railway station. With the PRT network the waiting time will be reduced from an average of 7.5 minutes to 1.7 minutes, or by 77%. The in-vehicle travel time will be reduced from an average of 15.5 minutes to 9.2 minutes, or by 59%. With a behavioural weight of 2 for walking time and with a weight of 1.7 for waiting time, the generalized travel time can be calculated to 38 minutes by bus and to 19 minutes by PRT (assuming a 2.5 minute of walk at the origin and destination end of the journey for both systems). This will result in a travel time gain of 19 minutes (or almost one-third of an hour) or by 50%. Thus, PRT will yield half as long travel time as by bus.
The gain in travel time components is shown in the figure below:

**Figure 11: Travel time components by bus and by PRT at Boländerna**

In Table 3 below, the travel time values\(^2\) to be used for the benefit-cost calculations are presented:

<table>
<thead>
<tr>
<th>Travel time value, €/hour</th>
<th>Private trips</th>
<th>Business trips</th>
<th>All trips</th>
<th>Share of all trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local trips</td>
<td>5.1</td>
<td>27.5</td>
<td>5.8</td>
<td>97%</td>
</tr>
<tr>
<td>Long distance trips</td>
<td>10.2</td>
<td>27.5</td>
<td>10.7</td>
<td>3%</td>
</tr>
<tr>
<td>All trips</td>
<td>5.3</td>
<td>27.5</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Share of trips</td>
<td>97%</td>
<td>3%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The travel time value has been calculated to amount 5.9 € per hour, according to the composition of trips in Uppsala. The total travel gain from switching from bus to PRT at Boländerna would therefore be 5.5 m€ per annum with 15 225 PRT trips per day.

Table 4. Travel time gain in m€ per year with PRT

| Travel time gain per day, hour per person | 0.32 |
| Old bus riders | 1 334 |
| New PRT riders | 1 751 |
| Total travel time gain/day, hours | 3 085 |
| Travel time gain per year, hours | 925 601 |
| Travel time gain per year, m€ | 5.5 |

Thus the gain in travel time by PRT amounts 0.9 million hours per year, which corresponds to a monetary value of 5.5 m€ per year. For a daily commuter working 225 days per year and making one single and one return trip per day, the travel time gain corresponds to 91 hours per year, or more than two ordinary working weeks (of 40 hours).

6.1.2 Comfort gains

As PRT offers a better level-of-service to the passengers than ordinary public transport modes usually do, there is a good reason to calculate also the gains in level-of-service (comfort and convenience).

In the table below, we present comfort values at stations and in vehicles that have been obtained from various Stated Preference-studies in Sweden:

Table 5. Comfort values per trip

<table>
<thead>
<tr>
<th>For PRT relevant Level-of-service factor</th>
<th>Willingness-to-pay per trip in % of fare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air condition</td>
<td>7%</td>
</tr>
<tr>
<td>Less noise &amp; smoother ride</td>
<td>6%</td>
</tr>
<tr>
<td>Info-display in vehicle</td>
<td>10%</td>
</tr>
<tr>
<td>Seating all journey</td>
<td>11%</td>
</tr>
<tr>
<td>Travel alone</td>
<td>39%</td>
</tr>
<tr>
<td>Multiplicative sum</td>
<td>72%</td>
</tr>
</tbody>
</table>

As the ticket price per boarding at Boländerna amounts 0.66 €, the comfort value per trip becomes 0.48 €. The total annual comfort value becomes 2.4 m€ per year.

6.1.3 Ticket revenues

The forecasted number of public transport trips in the year 2020 is estimated to be 4 200 trips per day by bus. By PRT the forecasted number of trips is 15 225 per day. The ticket price at Boländerna is 0.66 per boarding. The annual ticket revenues will be 0.84 m€ by bus and 3.0 m€ by PRT. The gain in ticket revenue will be 2.2 m€ annually.

6.1.4 Traffic safety gains

An introduction of a PRT System at Boländerna in Uppsala will result in a predicted reduction in the number of car trips. The forecasted number of car trips to and from Boländerna is 52 000 per day in 2020 with the bus network, and 44 000 car trips with the PRT network. This is a reduction of 8 000 cars per day, or by -15 %. As car trips will be reduced, so will also the number of street accidents. The estimated effect on the number of road accidents will be a
reduction from 10.3 to 8.7 annual accidents, or by 2 accidents from the car traffic. The annual cost saving from the reduction in accidents is estimated to amount 0.3 m€ per annum, as the monetary value per road accident is 0.18 m€/accident. Also the replacement of bus kilometres by the new PRT system will lead to a reduction of the number of accidents. According to a Danish study the accident risk for bus trips (for passengers and for pedestrians) is 0.19 accidents per million passenger-kilometre. The fatality risk for the PRT system has been verified by Vectus in Uppsala to be lower than 0.15 fatalities per billion passenger-kilometre.

Altogether this means that the number of accidents will be reduced from 11.1 to 8.7, i.e. a reduction by 2.3 accidents per year (-21 %), and the total cost saving from less accidents is calculated to be 0.43 m€ per annum.

6.1.5 Environmental gains

Through the replacing of car and bus trips by PRT trips, environmental gains are made up from reduced exhaust of CO\(_2\), HC and NO\(_x\). The monetary value of the reduction of CO\(_2\) is 0.17 € per gram. Even when taking into account the exhausts from electricity production for the PRT system the overall result is positive.

6.1.6 Capital costs for PRT

In this section the capital costs are calculated. A natural starting point is to refer to ATRA’s Status Report from 2002. In a summary table they summarized the unit costs as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Unit Cost</th>
<th>Number</th>
<th>Total (k$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideway – straight</td>
<td>2,300 k$/km</td>
<td>8</td>
<td>18,400</td>
</tr>
<tr>
<td>Guideway – curved</td>
<td>3,400 k$/km</td>
<td>2</td>
<td>6,800</td>
</tr>
<tr>
<td>Vehicle</td>
<td>38 k$ each</td>
<td>100</td>
<td>3,800</td>
</tr>
<tr>
<td>Stations @ 2/km</td>
<td>250 k$ each</td>
<td>20</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>34,000</strong></td>
</tr>
</tbody>
</table>

In US 2002 $, the costs were estimated to amount 34 m$ for a 10 kilometer long podcar system (single track).

We have collected information from 19 various sources regarding investment cost estimates for PRT systems. They do by no means reflect all possible PRT system costs that might be available after a much deeper research, but only what has been known to the author. The cost estimates have been adjusted to the 2007 year price level, with the following results:

---

3 This result is based on an average car trip length of 3.1 kilometers, a load factor of 1.7 persons per car, and 0.36 road accidents per one-million car vehicle-kilometers

As can be seen, there is a substantial variation in the PRT costs. The costs vary between 2.1 and 10.6 m€ per track-kilometer. The average is 6.1 m€, and the standard deviation is 2.4 €/km. As the observations are arranged along a time scale, one can calculate if there is a time trend in costs. There is such a tendency, with an annual increase of 0.24 m€/km and year. The ULTra Heathrow podcar system, with 4 km, 5 stations and 18 vehicles, is estimated to cost 25 m€, or 8.5 m€ per track-kilometer. In a recent study: “The Viability of Personal Rapid Transit in Virginia: Update” Virginia, 18th Dec. 2008, the ULTra cost is lowered to 20 m€, or to 6 m€ per track-kilometer.
Vectus, with its PRT test track in Uppsala, Sweden, has recently confirmed that it is a tricky task to give accurate and general costs estimates. But, for 10-20 kilometer long PRT network an estimate between 7.5 m€ to 10 m€ might be realistic. This cost level corresponds well with the ULTra cost for the Heathrow installation.

As costs vary substantially we have decided to present three cost estimates, one low, one high and one average cost estimate for bus and for PRT. The high cost estimate for PRT reflects the ULTra Heathrow cost level, which also is the average Vectus’ cost estimate. The low PRT cost estimate corresponds to ULTRA’s cost estimate at a lower utilization rate (i.e. 100 000 annual trips per track-km) from 2002, adjusted to the 2007 price level.

**Figure 13. Investment cost for Bus, Podcar and LRT in m€ per track-km at three cost alternatives**

<table>
<thead>
<tr>
<th>Investment Cost for Bus &amp; Podcar in m€/track-kilometer at three cost estimate levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Cost estimate</td>
</tr>
<tr>
<td>Bus (m€/track-km)</td>
</tr>
<tr>
<td>PRT (m€/track-km)</td>
</tr>
</tbody>
</table>

Nota bene: Exchange rate has been = 1 Euro (€) = 10 SEK
For the high cost estimate, the annual transit share of the street replacement cost (including also the transit share of the street operating cost) has been accrued as the bus infrastructure cost. For the average and for the low cost estimate, these street infrastructure costs are not included, but only the infrastructure costs for bus stops, bus terminals and bus depots.

In a recent engineering study for the city of Södertälje\(^5\), WSP Sweden and LogistikCentrum has calculated the capital cost into more detail for a PRT network of 43 track-kilometres:

**Table 7. Investment cost for a 43 km PRT network in Södertälje according to an engineering study**

<table>
<thead>
<tr>
<th>Cost component</th>
<th>M€ per km</th>
<th>Number of items</th>
<th>Investment costs, m€</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideway</td>
<td>4.5</td>
<td>43</td>
<td>193.5</td>
</tr>
<tr>
<td>Installations in Guideway &amp; stations</td>
<td>1</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>2 bascule bridges</td>
<td>1.3</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Vehicles</td>
<td>0.075</td>
<td>650</td>
<td>48.8</td>
</tr>
<tr>
<td>Small stations</td>
<td>0.3</td>
<td>51</td>
<td>15.3</td>
</tr>
<tr>
<td>Big stations</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>station at railway</td>
<td>1.3</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Guidance system</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Trimming</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Depot in existing building</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total investment cost, m€</strong></td>
<td></td>
<td></td>
<td><strong>311</strong></td>
</tr>
<tr>
<td><strong>Average investment cost per track-km</strong></td>
<td></td>
<td></td>
<td><strong>7.2</strong></td>
</tr>
</tbody>
</table>

The costs in Table 7 above include stations, vehicles, guidance system and depot costs and two bascule bridges. In these costs extra charges on the fixed equipment of 34 % has been added for engineering, civil works, and contingency. The average cost per single-track kilometer amounts 7.2 m€, which perfectly corresponds to the low cost estimate of Figure 13 above. Therefore we will use this low value as our major cost estimate for Uppsala.

The first PRT phase in the City of Uppsala, for the Boländerna area, has a 9.4 km long guideway (11 km including station tracks). The investment cost might range between 68 and 85 m€, with an average of 76 m€. The most probable cost estimate is thus the low value of 68 m€. We assume the economic life span for the guideway and the depot to be 60 years, 25 years for stations and 15 years for the vehicles. This gives us an average annuity factor of 6.31 %. Thus, the annual capital costs might vary between 4.3 and 5.3 m€ and with an average of 4.8 m€.

**Table 8. Investment and annual capital costs for the 9.4 km PRT Boländerna network**

<table>
<thead>
<tr>
<th>Investment cost alternatives</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost, M€</td>
<td>68</td>
<td>76</td>
<td>85</td>
</tr>
<tr>
<td>average annuity, 4%</td>
<td>0.0631</td>
<td>0.0631</td>
<td>0.0631</td>
</tr>
<tr>
<td><strong>Annual capital cost, m€</strong></td>
<td><strong>4.3</strong></td>
<td><strong>4.8</strong></td>
<td><strong>5.3</strong></td>
</tr>
</tbody>
</table>

---

\(^5\) Source: Spårbilar i Södertälje:- en vision för hållbar stadstrafik – teknik, gestaltning, kostnad (in Swedish), i.e. in translation: “PRT in Söderüälje - a vision for sustainable city transport – technique, design and costs. City of Söderüälje, LogistikCentrum and WSP Civils, Sweden: 2009-03-25
6.2 Operating costs for PRT

The O & M costs (Operating & Maintenance costs) refer to costs for personnel, administration, operations, maintenance of vehicles, stations and guidance systems, cleaning, spare parts and electric power supply.

There is a real lack of real life experiences from PRT operations. Available cost estimates are just estimates. However, the operations of the Morgantown PRT system (i.e. in reality a GRT, a Group Rapid Transit System) since the mid-1970’s gives a good hint of the magnitude. The Morgantown PRT system – although an old-fashioned and rather clumsy driverless system – show about one-third O & M cost per trip, compared to both bus and other APM’s.

A summary of several international comparisons of O & M costs show an average O & M cost for PRT of 0.19 € per passenger-kilometer. In the figure 14 below the PRT operating and maintenance costs are also compared to the corresponding Swedish and US bus and metro O & M costs:

Figure 14. Operating and maintenance costs (O&M costs) per passenger-kilometer for various transportation systems


There is a substantial variation in operating & maintenance costs across various public transport modes. Among PRT modes the estimates vary between 11 cents and 39 cents per passenger-kilometre. PRT has an average of 19 cents per passenger-kilometer for the O & M cost. This is lower than for the Stockholm and US Bus and also lower compared to the Stockholm Light Rail Transit (LRT). However, the PRT O & M costs per passenger-kilometer...
are somewhat higher than for the metro and commuter rail systems in Sweden and in the US.

For the Boländerna PRT network, the operating & maintenance costs have been calculated to amount 1.7 m€ per annum. This corresponds to 0.12 € per passenger-kilometer. This latter figure is, however, slightly lower than the lower figure in Figure 14 above. The explanation for this discrepancy is that the operating cost per passenger-km for the podcar system in Uppsala is based on a rather detailed PPP-calculation for Uppsala, while figure 14 is based on area-aide averages from several other studies.

### 6.3 Total annual cost for PRT

The total annual costs will then sum up to the following ones:

<table>
<thead>
<tr>
<th>Table 9. Annual capital and operation &amp; maintenance costs for the Boländerna, Uppsala 9.4 km PRT network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boländerna costs</td>
</tr>
<tr>
<td>Annual capital cost</td>
</tr>
<tr>
<td>Annual oper. &amp; maint. Cost</td>
</tr>
<tr>
<td>Total annual PRT cost</td>
</tr>
</tbody>
</table>

The total annual costs (excluding any public funding) for capital and O & M costs amounts an interval between 5.9 to 7.0 m€, and with an average of 6.5 m€. We assume the low capital cost alternative to be the most probable estimate (see Table 78 above). Therefore a point estimate for the annual costs for the Boländerna network would be 6.5 m€.

### 6.4 A Benefit-Cost analysis for Boländerna

Combining the various benefit components derived from section 6.1 above with the cost components derived from sections 6.1.5 and 6.2 above, brings the input to the benefit-cost analysis below:

<table>
<thead>
<tr>
<th>Table 10. Benefit-cost analysis for the PRT network at Boländerna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit Cost Analysis</td>
</tr>
<tr>
<td>Travel time gain</td>
</tr>
<tr>
<td>Comfort gain</td>
</tr>
<tr>
<td>Ticket revenue</td>
</tr>
<tr>
<td>Traffic safety gain</td>
</tr>
<tr>
<td>Environmental gain</td>
</tr>
<tr>
<td>Total annual benefits</td>
</tr>
<tr>
<td>Annualized capital cost</td>
</tr>
<tr>
<td>Tax on capital cost, 23 %</td>
</tr>
<tr>
<td>Annual Oper. &amp; maint. Cost</td>
</tr>
<tr>
<td>Reduc. gas. tax revenue from less car traffic</td>
</tr>
<tr>
<td>Total annual costs</td>
</tr>
<tr>
<td>Net surplus</td>
</tr>
<tr>
<td>Benefit/Cost Ratio</td>
</tr>
</tbody>
</table>
The PRT network at Boländerna is found to be economically viable. The benefit-cost ratio amounts to an interval between 1.25 and 1.48 and with an average of 1.36. This means that the annual benefits exceed the costs by 25% to 48%. As we assume the low cost to be the most probable alternative, one might state that a PRT network at Boländerna yields 48% in return in terms of higher benefits. From a social benefit-cost point of view, PRT at Boländerna seems to be very well justified. The net social surplus amounts between 2.2 to 3.5 million € annually.

The composition of benefits and cost are shown in Figure 155 below:

**Figure 15. Composition of benefits for the PRT network at Boländerna, Uppsala**

<table>
<thead>
<tr>
<th>Benefit Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time gain</td>
<td>51%</td>
</tr>
<tr>
<td>Comfort gain</td>
<td>22%</td>
</tr>
<tr>
<td>Ticket revenue</td>
<td>20%</td>
</tr>
<tr>
<td>Traffic safety gain</td>
<td>5%</td>
</tr>
<tr>
<td>Environmental gain</td>
<td>2%</td>
</tr>
</tbody>
</table>

Approximately half of the total benefits are made up by travel time gains (51%). Another fifth part comes from comfort gains (22%). Ticket revenues contribute with another fifth part (20%). Traffic safety gains make up 5% and environmental gains 2%.

In the City Mobil Business Case Analysis Tool, a net present Benefit-Cost Analysis is carried out also for Uppsala. The main result in that analysis is a total Benefit/Cost Ratio of 3.33. This result is deducted from a total net present value of Benefits of 772.5 million € and a total net present value of costs of 178.3 million €. The BCR value is calculated as (benefits - Costs)/Costs.

In our own calculations of the corresponding net present values we obtain a lower cost estimate, for the total costs, 129 million €. Also, on the benefit side, we obtain a lower value for the total benefits, 295 million €: the result will therefore be a Net social surplus (a BCR-value) of 1.28. The explanation to these differences seems to be due to different traffic growth figures over

---

6 In our own calculations we assume a 60 year economic life time for fixed investments and an average annual traffic growth rate of 1%, which yields a factor of 27.68 to reach a net present value from the corresponding annual figure. The discount rate is 4% in real terms.
In a Financial Benefit-Cost Calculation, the Ticket Revenues should be compared to the Operating Costs. This comparison is made in Table 11 below:

### Table 11. Financial revenue-cost analysis for the PRT network at Boländerna

<table>
<thead>
<tr>
<th>Average investment cost scenario</th>
<th>m€ per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual capital cost</td>
<td>4,8</td>
</tr>
<tr>
<td>50 % subsidy</td>
<td>2,4</td>
</tr>
<tr>
<td>Annual operating cost</td>
<td>1,7</td>
</tr>
<tr>
<td>County Council 50% subsidy on oper. cost</td>
<td>0,8</td>
</tr>
<tr>
<td>Net Capital cost (after subsidy)</td>
<td>2,4</td>
</tr>
<tr>
<td>Net Oper. Cost (after SCC subsidy)</td>
<td>0,8</td>
</tr>
<tr>
<td>Total net annual cost (after subsidy)</td>
<td>3,2</td>
</tr>
<tr>
<td>Ticket Revenue</td>
<td>2,2</td>
</tr>
<tr>
<td>Financial surplus</td>
<td>-1,0</td>
</tr>
<tr>
<td>Financial surplus in % of tot net annual cost</td>
<td>-32%</td>
</tr>
<tr>
<td>Financial operating surplus</td>
<td>1,4</td>
</tr>
<tr>
<td>Fin. Oper. Surplus in % of net oper. Cost</td>
<td>165%</td>
</tr>
</tbody>
</table>

Table 11 shows that the result of the financial analysis is dependent on whether only the operating costs are included, or if also the capital costs should be included. If both the capital and the operating costs are included, then the financial surplus becomes negative, amounting -1.0 m€ per annum, or by -32 % in terms of the total net annual costs. In this exercise we have assumed the average public subsidy both for capital costs (50 % for urban rail investments) as well as for the urban public subsidy for operating costs (financed by the local governments, i.e. municipalities and county councils).

If, on the other hand, only the operating annual costs are considered, then the financial surplus becomes positive, amounting +1.4 m€ per annum, or +165 % % in terms of the total net operating costs.

An explanation to this financial outcome (when considering both the capital and the operating costs) is that PRT projects usually yields a much higher user benefit than traditional line-haul public transport systems. This performance will not be reflected at all in this financial calculation, while - on the other hand - the costs, especially the capital costs, that are related to this higher performance and service level of the Podcar system, is fully represented in this financial analysis.
7 Financing of the PRT network at Boländerna

PRT should be considered as part of the general public transportation system. The regular rates should be applied for the PRT system and the same ticket should be valid for the PRT as well as for the buses and commuter trains.

Most Swedish municipalities have limited possibilities of financing the public transportation systems on their own. Therefore in this section we discuss various options for funding new systems such as the PRT system, and how these options can be used for Boländerna.

7.1 Subsidies
The possibility of obtaining subsidies from either the Swedish state or the EU has been discussed. The Swedish state can grant subsidies for investments in local rail facilities if this reduces the environmental impact or increases the security. Considering that these investments first have to be part of long term plans this is not an option for a quick implementation of a PRT system.

The EU offers a number of possibilities for subsidies. The Seventh Framework programme supports the research and development of more safe, environmentally friendly and smart transport systems with about 4.1 billion €. The program does not support the installation and operation of a PRT system, but might be an option for planning, implementation strategies and evaluation.

The EU structural funds for regional policy making offer subsidies for eight Swedish regions. All of these regions, including the region that Uppsala is part of, have specified the public transportation system as a prioritized area. For this region at stake and the period 2007-2013 there are 73 million € to apply for. The subsidies are limited to 40 % of the total project cost.

The third alternative is the EU environmental fund LIFE+. The subsidies are limited to 50 % of the total project cost. A requirement for the subsidy is that there is another 40 % subsidy from a national public organisation. Private co-financing is also encouraged, but should not replace the public part of the financing. Typical projects are supported by LIFE+ with 0.5-3 million €.

It might be possible to combine these different kinds of subsidies so that for example regional funds provide support for a feasibility study, LIFE+ for a pilot PRT network and regional funds for the operation of the system. One should be aware of that the applications consume both time and money, and that the administration of EU subsidies is also time-consuming.

7.2 Land exploitation
At the exploitation of private property the municipality has the right, by the Planning and Building Act, to regulate the implementation. The law allows exploitation fees for public facilities if the benefits and the importance of the facilities can be motivated.

In those cases where the municipality owns the land it should be possible to finance a PRT network by selling or developing the land, or by making an agreement on the exploitation of the land.
7.3 Public-Private-Partnership

The Public-Private-Partnership (PPP) is frequently discussed as a means of achieving different types of investments, primarily within the infrastructural area. The PPP could be a faster and more efficient alternative than the financing through public funds. If capital and operating costs are not covered by user fees, the public transport authority (PTA) will in this case pay an annual fee to the contractor. The fee should cover the costs for depreciation, interest and operation for the first 30 years. Then the system will be taken over by the PTA. Another advantage is that the PTA easily can compare the fee for the new system with the costs for other traffic, such as bus. The benefits for the buyer is that:

- There will be an operational cost during the contract period instead of a direct investment cost
- The policy making process will be simplified
- The risks decreases as the supplier is responsible during the whole period
- The solution will be cost-effective since the supplier has to offer operation-effective solutions

The PPP financing is particularly suitable for the PRT network system because of the relatively high investment costs and low operational costs.

7.4 A BOT cost estimation

Following is an example of financing of the PRT network through Public-Private-Partnership. We assume that the contractor covers the part of the investment that is not covered by subsidies by a loan. The interest rate is assumed to be 5 %. After 30 years the ownership is taken over by the PTA. We assume that the fleet needs to be renewed after 15 years. For the investment we assume the following unit costs:

- Guideway single track – 4 million € per km
- Station – 0.3 million €
- Vehicle – 0.075 million €
- Control system – 1 million €
- Depot – 3 million €

The calculus includes an extra 30 % on design, studies, contacts, unpredicted costs and profit.

The operational costs include salaries for the operation manager/planner, operators, service engineers and cleaners, spare parts, software maintenance and electricity. The energy consumption is assumed to be 7 kW per vehicle including heat/air conditioning and lightning during 9 hours per day, 300 days a year. The energy cost is assumed to be 0.10 € per kWh. Land and intrusion costs are not included.

The calculus below is made for two scenarios, one with no subsidies and one with a 40 % EU subsidy.
Figure 16: A PPP-calculus for the PRT network at Boländerna

<table>
<thead>
<tr>
<th>Investment</th>
<th>Unit cost</th>
<th>m€</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideways single track</td>
<td>9.4 km</td>
<td>37.6</td>
</tr>
<tr>
<td>Stations</td>
<td>18</td>
<td>5.4</td>
</tr>
<tr>
<td>Vehicles</td>
<td>130</td>
<td>9.75</td>
</tr>
<tr>
<td>Control system</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Depot</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Design, unpredicted costs and profit</td>
<td>30%</td>
<td>17</td>
</tr>
<tr>
<td><strong>Sum Investment</strong></td>
<td></td>
<td>73.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operation</th>
<th>Shift</th>
<th>Salary €/month</th>
<th>Cost per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manager/Planner</td>
<td>1</td>
<td>3000</td>
<td>0.05</td>
</tr>
<tr>
<td>Operator</td>
<td>2</td>
<td>2500</td>
<td>0.36</td>
</tr>
<tr>
<td>Service engineer</td>
<td>5</td>
<td>2000</td>
<td>0.36</td>
</tr>
<tr>
<td>Cleaner</td>
<td>5</td>
<td>1500</td>
<td>0.14</td>
</tr>
<tr>
<td>Spare parts 2.5% of vehicle cost</td>
<td></td>
<td></td>
<td>0.24</td>
</tr>
<tr>
<td>Spare parts 0.5% of guideways+stations</td>
<td></td>
<td></td>
<td>0.22</td>
</tr>
<tr>
<td>Software maintenance 10% of control system</td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Sum Operation</strong></td>
<td></td>
<td></td>
<td>1.47 m€</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electricity</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption per vehicle</td>
<td>7 kW</td>
<td>910 kW</td>
</tr>
<tr>
<td>Operation hours per weekday</td>
<td>9 h/vehicle</td>
<td>8,190 kWh/day</td>
</tr>
<tr>
<td>Weedays per year</td>
<td>300 days</td>
<td>2,457 MWh/year</td>
</tr>
<tr>
<td>Energy price 0.10 €/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sum Electricity</strong></td>
<td></td>
<td>0.25 m€</td>
</tr>
</tbody>
</table>

| Sum Operation + Electricity        |       | 1.71 m€        |

<table>
<thead>
<tr>
<th>Financing</th>
<th>m€</th>
<th>Subsidy</th>
<th>No subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total investment</td>
<td>73.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU subsidy 40%</td>
<td>-29.5</td>
<td></td>
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</tr>
<tr>
<td>State subsidy 0%</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploitation fees 0%</td>
<td>0.0</td>
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<td></td>
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<tr>
<td>Remains for PPP-financing</td>
<td>44.3</td>
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<tr>
<td>Interest 5%</td>
<td></td>
<td>1.11</td>
<td>1.84</td>
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<tr>
<td>Amortization vehicles 15 years</td>
<td></td>
<td>0.39</td>
<td>0.65</td>
</tr>
<tr>
<td>Amortization construction 30 years</td>
<td></td>
<td>1.28</td>
<td>2.13</td>
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<tr>
<td><strong>Sum Financing</strong></td>
<td></td>
<td>2.78 m€</td>
<td>4.63 m€</td>
</tr>
</tbody>
</table>

| Total cost per year                | 4.49 m€ | 6.34 m€ |

| Trips year 2020                    | 15200 per day | 4.6 million per year |
| PPP-cost per trip                  | 0.98 €        | 1.39 €               |

With 15 200 trips per weekday in 2020 the cost will be:
- 0.98 € per trip, with a 40% subsidy on capital costs
- 1.39 € per trip, without subsidies

Even without subsidies, the trip cost will be lower than for the existing bus network in Uppsala, which costs 1.80 € per trip.
8 Conclusions

The proposed PRT network for Boländerna includes 9.4 km of single track, 16 stations on the main net and 130 vehicles with room for four people. The average waiting time is short, about a minute, and the maximum distance to a stop is 300 metres. The stops are all placed on separated and elevated tracks and since the PRT vehicle doesn’t stop on route a high and even speed is obtained (average speed 36 km/h). Compared to the existing bus system the PRT system offers half the travel time. For example a trip from the central station to IKEA is made in 15 minutes with the bus but only 6 minutes with the PRT system.

With the existing bus network the public transit share in Boländerna is calculated to almost double from the year 2007 to the year 2020. With a PRT network system this share is instead calculated to rise to 5 times as many trips as today. This means that the public transit share increases from 5 to 20 % with the podcar network. At the same time the car share decreases from 65 to 55 %. Thus, a PRT network for Boländerna would contribute to enhance the public transport mode share from 5 % to 20 % or fourfold.

The gain in travel time by PRT amounts 0.9 million hours per year. For a daily commuter working 225 days per year, this travel time gain corresponds to 49 hours saved per year, or more than one ordinary working week.

A comparison of capital costs for bus, LRT and PRT on three different cost levels indicates that PRT is less expensive than LRT in all three alternatives. The investment costs for bus is always less expensive than PRT and LRT mainly because the buses use the already existing infrastructure.

The PRT network at Boländerna is found to be highly economic viable. The benefit-cost ratio amounts an interval between 1.25 and 1.48 and with an average of 1.36. This means that the annual benefits exceed the costs by 25 % to 48 %. As we assume the low cost to be the most probable alternative, one might state that a PRT network at Boländerna yields 48 % in return in terms of higher benefits. From a social benefit-cost point-of-view, PRT at Boländerna seems to be very well justified.

To sum up, a PRT network – compared to a bus system - for the Boländerna area would contribute to:

- Reduce travel time by almost a half
- Double the public transport modal share, from 10 to 20 % in 2020 (and compared to 5 % today)
- Reduce the number of private cars by 15 % and reduce road congestion even more
- Reduce road accidents by 21 %
- Improve the accessibility to this area
- Increase ticket revenues by a factor of two
- Increase the social benefits by a factor of ten
- Increase the annual costs by 54 %
- A benefit-cost ratio of 1.48
9 Sources

9.1 Reference list


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9.2 Data base

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