Benefits and Costs of a Podcar Network in 59 Swedish Cities – The role of City Size for the Net Benefits

By Göran Tegnér, M Sc Econ, Senior Transport Advisor,
WSP Analysis & Strategy, Stockholm, Sweden

Abstract

This paper deals with the question of the economic viability for PRT in terms of city size and population density. The evaluation criterion chosen is the Benefit-Cost Ratio. The analytical comparisons between bus, LRT and Podcar (PRT) are based on a city and town data base, containing data from 59 Swedish cities for the year 2006. For each city or town information about the number of bus trips, their costs and ticket revenues have been collected. A synthetic podcar network is constructed, considering the size and density of the city/town. Also the generalized time and cost is calculated for the bus and the podcar mode. A travel demand model has been adopted to calculate the demand for PRT trips. The costs and benefits associated with the podcar mode are then calculated.

Conclusion will be drawn about the necessary city size so as to achieve a positive social net surplus for the podcar mode.

The results should be interpreted as indicative and the recommendation is that they might serve only as simple "rules-of thumb". In concrete case studies, we will recommend to carry out in-depth studies that might be unique for each city or town.

1 The 59 Swedish cities data base

A Swedish Company, Stadsbuss & Qompany, has collected bench-marking data from some 60 Swedish city transit companies. For the year 2006 the following variables were reported:

1. Line length
2. Vehicle-kilometers
3. Annual trips (boardings)
4. Annual costs
5. Annual ticket revenues
6. Subsidies
7. Population
8. Population density

The data base was completed by us at WSP with the following variables:

9. City area
10. Street length
11. Annual operating costs for the street network

This data base allows us also to calculate:

12. Transit network density (i.e. line length per street length)
13. Population density
14. Frequency of transit service (vehicle-kilometers per line-kilometers, assuming 18 hours transit service)
15. Average walking distance to stops (by combining line length and city area data)

The average bus speed has been assumed to be 24 km/hour (data from the transit industry), which yields the bus travel time, once the average trip length is known. Trip length and market share data was obtained from the national travel survey data for the various cities.

Figure 1. City size distribution for 59 Swedish cities

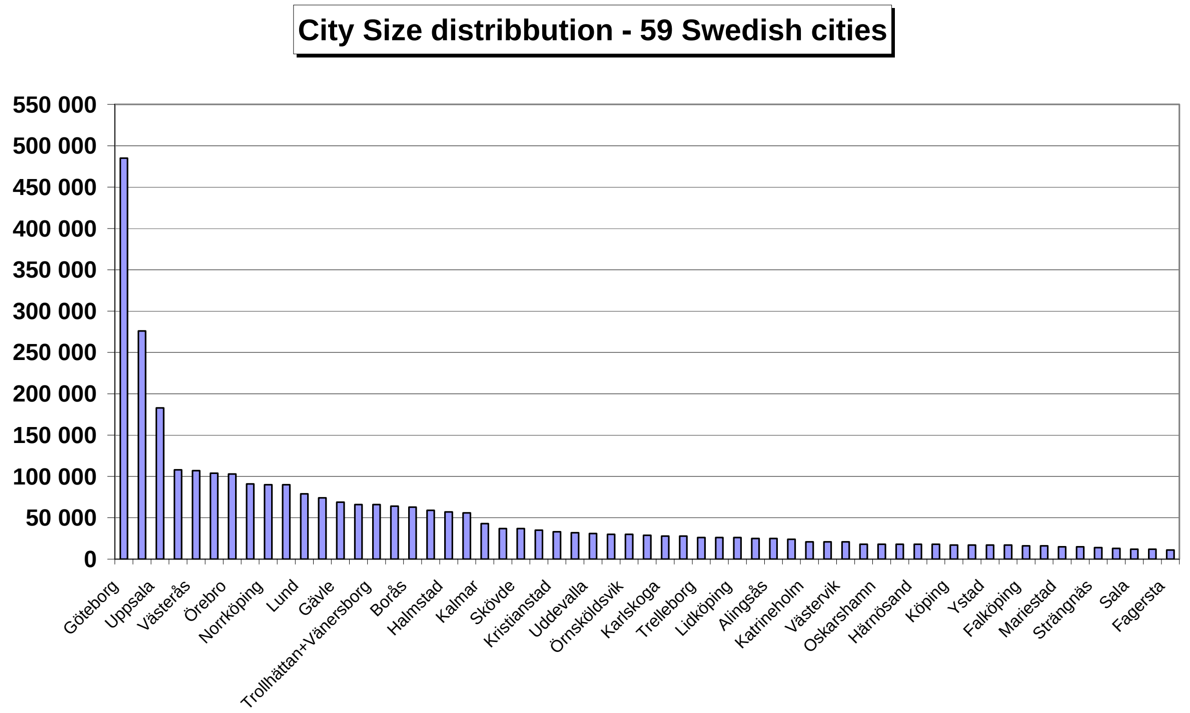
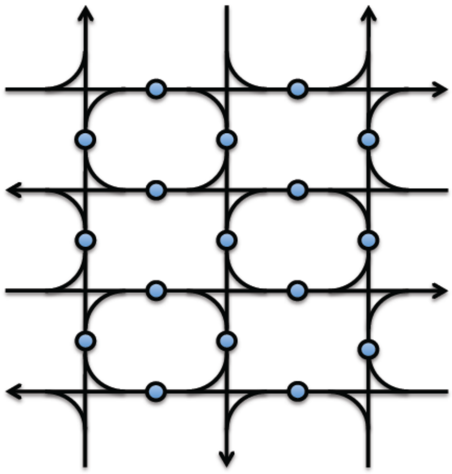


Figure 1 shows that Göteborg is the largest city in the data base with its 485,000 inhabitants. Including Göteborg there are seven cities with more than 100,000 inhabitants, and another thirteen cities with more than 50,000 inhabitants. The average city size is 54,000 inhabitants.

2 Podcar networks in 59 cities

To be ale to compare today's bus network (and partly, in Göteborg and Norrköping, tramway network) with a podcar network, a "synthetic" podcar network has been suggested, designed as a grid network with 250 meters walking distance in the origin and in the destination area, respectively. The size of the podcar network depends on the city size and population density**,** see Figure 2.below:

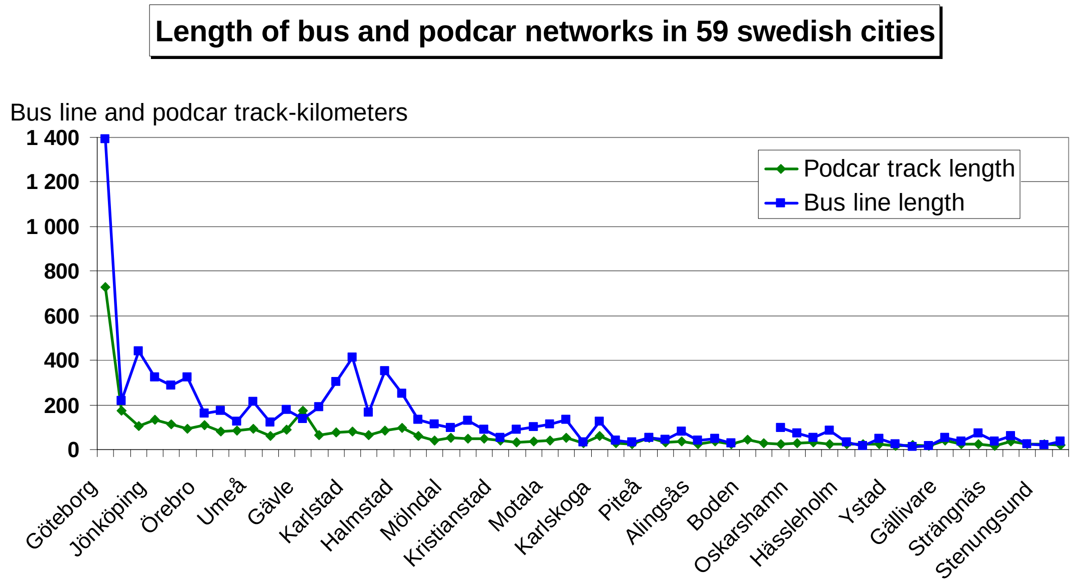
Figure 2. A structure of a podcar track system



The present bus network is very dense, with an average walk time of 4 minutes, but with very low service frequency – over the day with an average waiting time of 18 minutes. The podcar network provides very short waiting times, between 0 and 1 minute for the vast majority of riders, but the average walking time will be 6 minutes (3 minutes at each of the origin and destination station).

3 Generalized time and mode shares by bus and by PRT

Figure 3. Network length of the bus and the podcar networks in 59 Swedish cities



The average network size will be 80 km for the podcar network, compared to 144 km for the bus network in the 59 cities. The total bus network length is 8,162 km and the total podcar network is 2,835 km long.

To calculate the future demand for podcars in 59 Swedish cities, we need first to calculate the generalized time and cost. This was done for each of the 59 cities with the database described above for the bus/tram mode. For podcars the following assumptions were made:

- Walk speed: 5 km/hour
- Wait time: 0,5 minutes
- In-vehicle speed: 40 km/hour
- Number of transfers: 0 within the city-wide system
- Podcar fare: the same as for bus/tram, i.e. 0,78 € per boarding on average

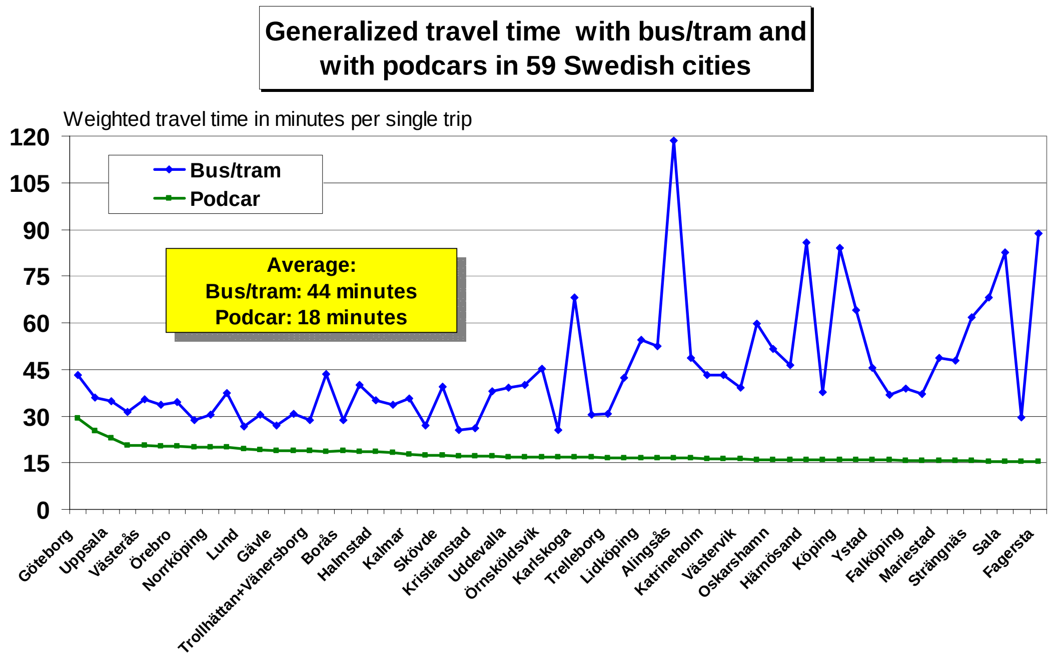
In calendar time the total door-to-door travel time is 32-33 minutes by bus or tram, but would be 11-12 minutes by podcar, which is one third of the bus/tram travel time. The generalized time will be 44 minutes by bus/tram and 18 minutes by podcar, i.e. less than half the travel time. These figures are averages for the 59 Swedish cities, see
Table 1 below:

Table 1. Travel time component comparison between bus/tram and podcar. Averages for 59 Swedish cities

Minutes of travel time components	**Bus/tram**	**Podcar**
Walk time	4	6
Wait time	18	0,5
Transfer time	2,5	-
In-vehicle time	8	5
Total calendar time	**32,5**	**11,5**
Generalized time	**44**	**18**

The generalized time for the bus/tram and the podcar modes is shown in Figure 4 below:

Figure 4. Generalized travel time with bus/tram and podcar in 59 Swedish cities



As can be seen, the variation in (weighted) travel time between cities would drop from a range of 25-120 minutes to a range of 15-29 minutes.

A simplified demand model, called ELMA, has been used to derive the new demand for transit trips by podcars. The model is an elasticity model, with variable elasticities (such as the logit model). The model is based on the generalized cost (thus including not only the above mentioned travel time components, but also the fare), and also the original mode share for transit.

In most demand model applications, the podcar mode is treated as a public transport mode, with "a mode specific constant term" that resembles the negative mode specific perception of the bus mode. As most stated preference studies and the pilot tests in Cardiff Bay with the ULTra system clearly has shown, the podcar travelers regard the comfort and convenience in riding the podcar is much more like going by taxi. Therefore we have tested to treat the podcar journey as something in between going by bus and going by the private car. This has been achieved by inserting "a half car mode specific constant" into the demand model. In Daventry, a similar approach has been carried out, shown in Table 2 below:

Table 2. Car, transit trips and modes shares in Daventry, UK, at varios PRT penalties

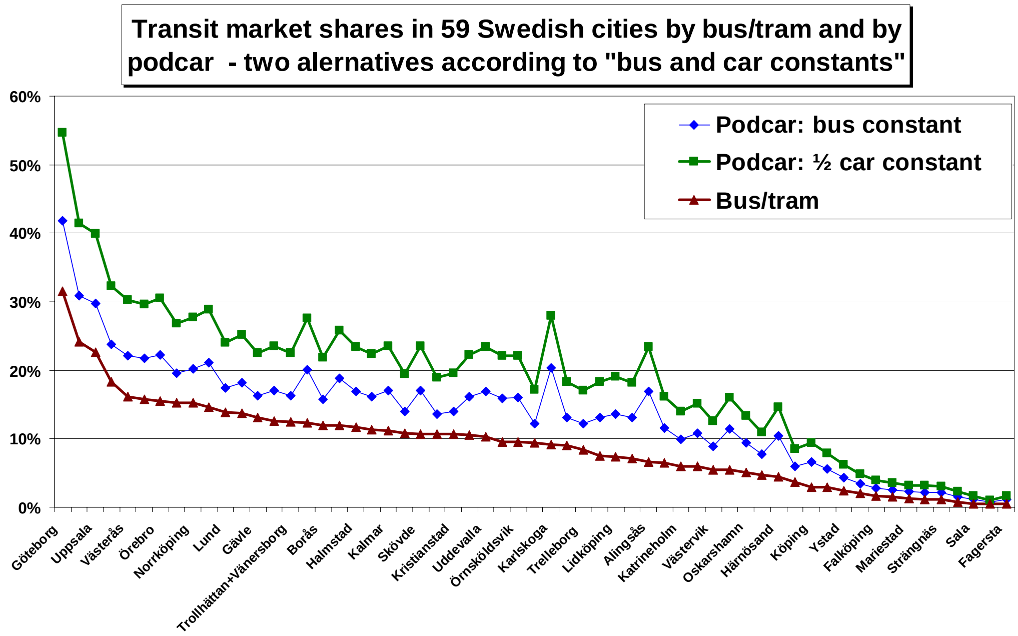
Option	Highway trips	PT Trips	Highway mode share (%)	PT Modes share (%)
Base 2004	3 617	157	96%	4%
DDC Preferred Bus option 2021	8 023	911	90%	10%
PRT – modal penalty as car	6 354	3 110	67%	33%
PRT – modal penalty as bus	7 214	1 978	78%	22%
PRT – modal penalty as car £1.60 fare	7 186	2 014	78%	22%

Source: Daventry Development Transport Study. Draft Stage 1B and 2 Report. Daventry District Council; November 2006, By Malcolm Buchanan, Colin Buchanan.

The Daventry study shows that using the "car constant" instead of the "bus constant" increases the share of PRT trips from 22 % to 33 % or by 50 percent. Our similar tests refer to the City of Linköping, where bus traffic has a market share of 12 %. The walk and bike modes make up 40 % and car traffic 48 %. With a podcar network for the city of Linköping, the transit market share would double to 23 %, assuming a bus constant. With a "half car constant" it would augment up to 28 % and up to 41 % if we apply "a full car constant".

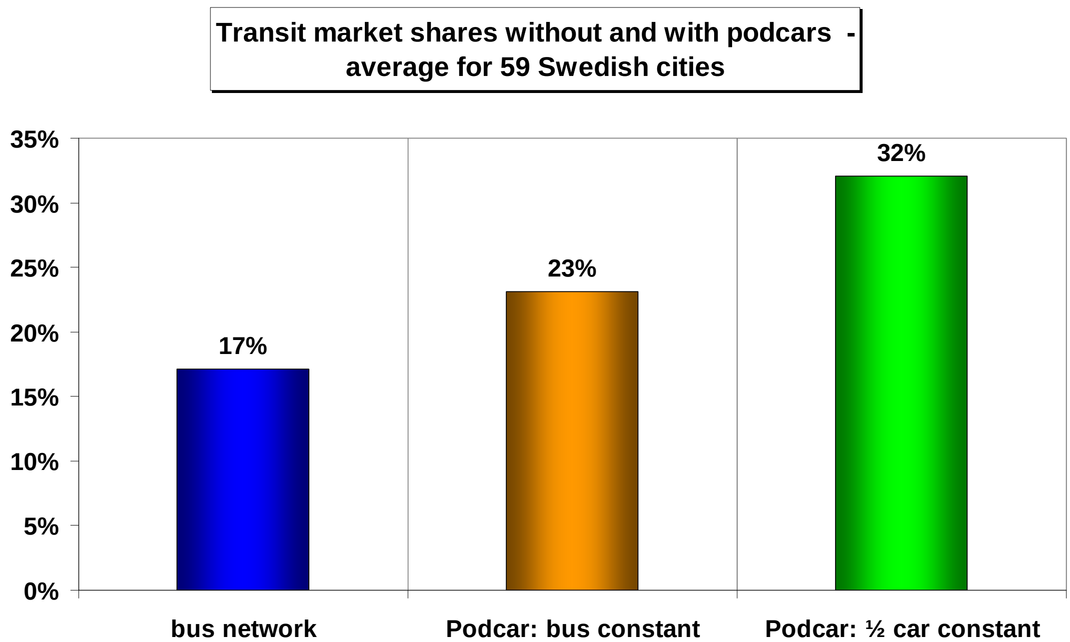
According to the Kungens Kurva site assessment study of the EDICT project, a podcar system would generate some 17 % new transit trips, besides from the diversion from previous trips made by car and walk/bike. Both options as regards the choice of constant terms are presented below in terms of transit market shares for the bus/tram mode, and the podcar mode:

Figure 5. Transit market shares in 59 Swedish cities with bus/tram and with podcars



On average over the 59 cities the market share might double from 17 %, with the present day bus/tram networks up to 32 % transit trips by podcar (high estimate), or to 23 % (low estimate):

Figure 6. Average transit market shares in 59 Swedish cities with bus/tram and with podcars at two alternative assumptions about the constant



3 Benefits are 27 % higher than costs by PRT in 59 cities

A cost –benefit analysis as seen carried out for the 59 cities and towns, with podcar networks replacing the existing bus/tram networks. On the benefit side the following aspects are considered:

- Travel time gains
- Ticket revenues
- Traffic safety gains
- Environmental gains (reduced CO_2 exhausts from private cars and from buses

The extra comfort and convenience by podcars is not considered

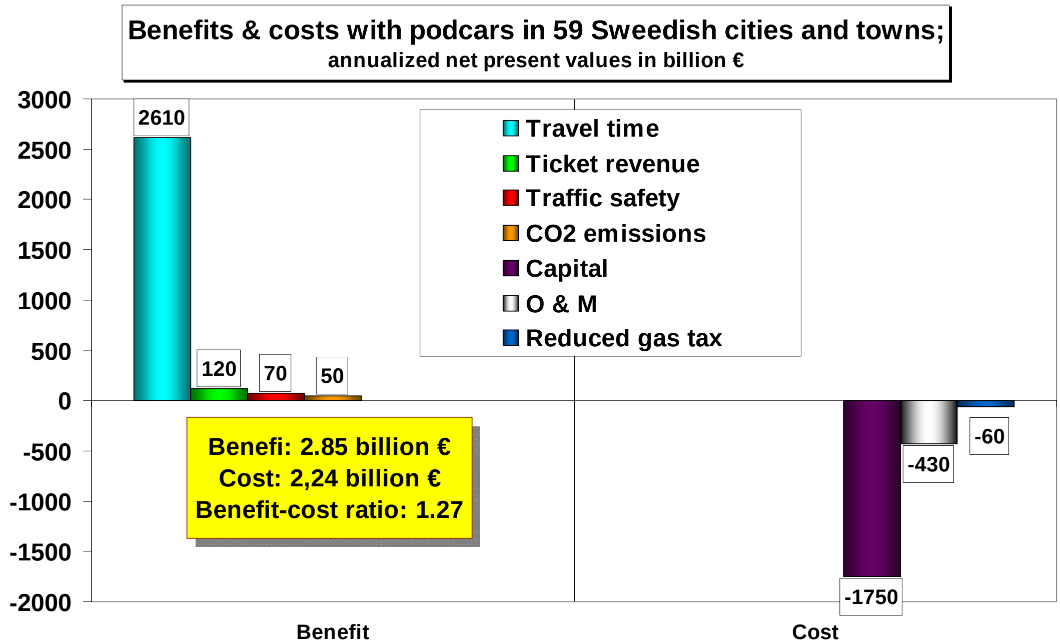
And on the cost side the following aspects are considered:

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

Investment costs are estimated to amount 8.1 M€ per single-track-kilometer. This is about 12.5 % higher than the most recent engineering cost study, carried out for the Södertälje PRT engineering study (dated 25 March, 2009). Operating cost has been estimated to amount 0.174 € per passenger-kilometer (derived from the New Jersey Study made by Booz Allen Hamilton).

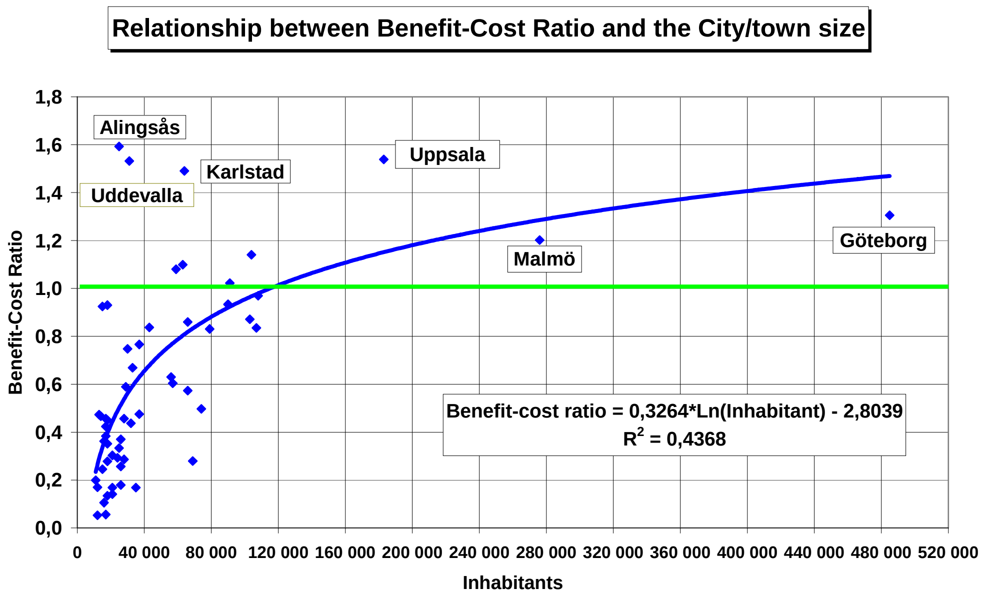
The main result is that the overall benefits amount 2.85 billion €, while the total costs amount 2.24 billon € in present value. The net benefits amount 0.61 billion € and the benefit-cost ratio is 1.27. This means that one € spent on podcars yield 1.27 € in return in terms of benefits to the society.

Figure 7. Benefit and cost components for Podcar networks compared to bus networks. Annualized present values over a 40 year period (at 4 % discount rate) in billion €



Travel time gains make up more than 90 percent of the total benefits. Increased ticket revenues, traffic safety and environmental gain add up to the rest. Podcar networks are clearly worth any cent. But in how many cities and towns will a podcar network be economically justified from the social surplus point-of-view? To answer this question, I have calculated costs and benefits for each of the 59 cities and towns, with the following result:

Figure 8. Relationship between benefit-cost ratio and city size. Statistics for 59 Swedish cities, at podcar capital cost of 8 m$ per track-km



On average smaller towns are less suited for introducing podcar networks compared to the larger towns and cities. Even if there is certain variation from the regression line, on average, one might conclude, that podcar networks seem to be suitable to introduce in cities and towns down to a size of approximately 100,000 inhabitants. From the Figure 8 above it can be seen that at least seven smaller cities than 100,000 inhabitants still show a positive benefit-cost ratio for podcars.

4 Sensitivity analysis – when is PRT economically viable?

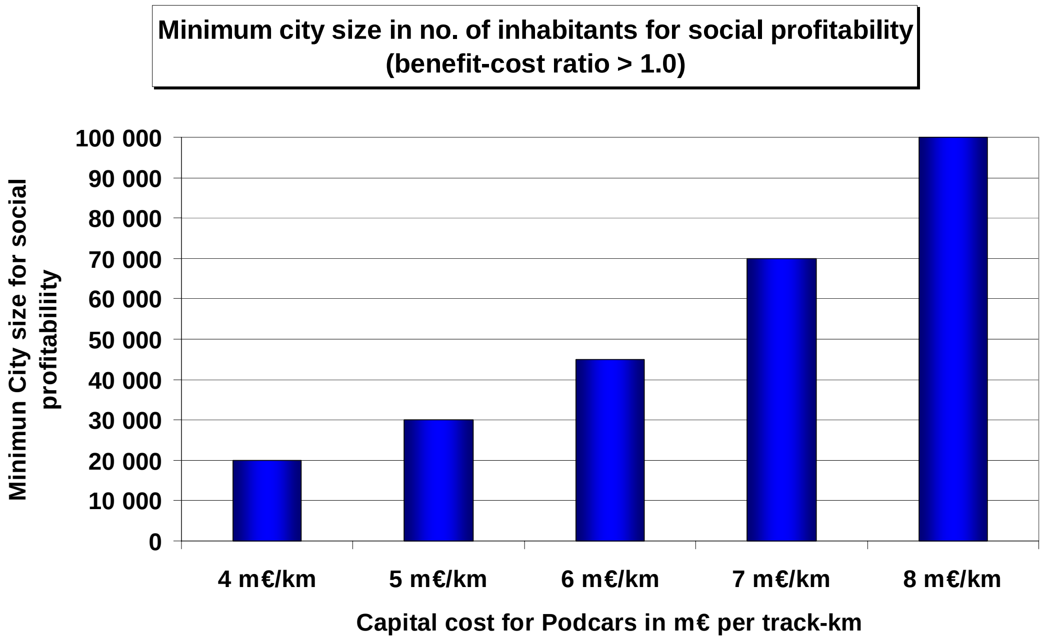
The social profitability (i.e. when the social benefit-cost ratio is greater than 1.0) is highly sensitive to the capital cost per track-km for the podcar system. A sensitivity analysis has been carried out, for the capital cost per track-kilometer in the range between 4 – 8 m€ per km, with the following results fro the 59 cities Swedish data base:

Table 3. Benefit cost ratio, city size, share of profitable cities, total benefits and cost in m€: Results from 59 Swedish at capital costs of 4 – 8 m€ per track-km

Podcar capital cost/track-km, in m€/km	B/C ratio, all 59 cities/towns	City size limit in no. of inhabitants for profitability	No of profitable cities	Share of profitable cities	Total annual benefits in m€	Total annual costs in m€	Share of total population in profitable cities
4 m€/km	2,15	20 000	31	53%	2 036	946	82%
5 m€/km	1,67	30 000	27	46%	2 036	1 218	76%
6 m€/km	1,32	45 000	22	37%	2 036	1 547	68%
7 m€/km	1,03	70 000	15	25%	2 036	1 972	59%
8 m€/km	0,9	100 000	10	17%	2 036	2 220	43%

At 8 m€ per track-km the city size limit for profitability is around 100,000 inhabitants. At this cost level only 10 out of the 59 cities are profitable, but they carry 43 % of all citizens in the 59 cities group of Swedish cities.

Figure 9. Relationship between City size and Social profitability (B/C ratio > 1.0)



At 6 m€ per track-km, the overall benefit/cost ration becomes 1.32, i.e. benefits are 32 percent higher than the costs. The minimum city size for a podcar network, that covers the whole city drops to 45,000 inhabitants. Approximately one third of all 59 cities fulfill this criterion, and these 22 profitable cities carry two-thirds of all citizens (3.2 million) in all the 59 cities.
If the podcar capital cost could be reduced to 4m€ per kilometer, then the benefits would be more than twice as high as the costs, and podcars would be profitable down to a town size of only 20,000 inhabitants. Of all 59 Swedish cities and town, 31 cities and towns fulfill this criterion, and they make up more than 80 % of all inhabitants.

Thus, the conclusion is that costs matters and that the profitability of podcars in cities is highly dependent on the unit costs.

In reality, I recommend to carry out detailed cost-benefit analysis for each town and podcar case in order to draw the correct conclusion if the podcar project will be economically justified in terms of benefits and costs.

5 Conclusions

This paper deals with the question of the economic viability for PRT in terms of city size and population density. The evaluation criterion chosen is the Benefit-Cost Ratio. The analytical comparisons between bus, LRT and Podcar (PRT) are based on a city and town data base, containing data from 59 Swedish cities for the year 2006. For ach city a synthetic PRT network has been constructed with the track length as a function of city size and population density

The main findings and conclusions that can be drawn are the following ones:

1) Compared to the urban bus network, an urban podcar network would reduce the generalized time (weighted travel time) from 44 to 18 minutes on average, which is a 59 % door-to-door time reduction.

2) Using a logit type variable elasticity demand model, the potential demand for PRT trips can be estimated to increase by 35 %, assuming the same attractiveness for

podcars as today's bus system. If, on the other hand, podcars are regarded as attractive as a system in between the bus and the private car, then the demand for podcars is likely to increase by 88 %. This means that the average public transport modal share then might augment from 17 % to 32 %.

3) The main result is that the overall benefits amount 2.85 billion €, while the total costs amount 2.24 billon € in present value for the podcar networks in all 59 cities. The net benefits amount 0.61 billion € and the benefit-cost ratio is 1.27. This means that one € spent on podcars yield 1.27 € in return in terms of benefits to the society.

4) At a cost of 8 m€ per podcar track-km some ten out of the 59 cities show a positive benefit-cost ratio. These ten cities have more than 100,000 inhabitants. If the podcar cost per track-km could be reduced to 6m€, then there are 22 socially profitable cities, with a B/C ratio of 1.32 and the minimum city size will be reduced to 45,000 inhabitants. Thus, the economic viability in terms of both the number of cities and of city size, is quite sensitive to the podcar system costs.

References

1 Andréasson, I. (1996), et al., Research and development in advanced transit systems - Survey of academic and industry efforts, Report, Chalmers Industriteknik.

2 Andréasson, I. (2001) " Innovative Transit Systems – Survey of Current Developments". Vinnova Report VR 2001:3.

3 Badger, Charles, M.: "The Viability of Personal Rapid Transit in Virginia: Update": Commonwealth of Virginia; 18 Dec. 2008

4 Buchanan, M: "Daventry Development Transport Study – Draft Stage 1B & 2 Report". Daventry District Council, Nov. 2006. By Malcolm Buchanan, Colin Buchanan consultants.

5 Dahlström, K, et al, 2005, A General Transport System – A Case Study within the project: The Value of Alternative Transport systems. SIKA Report 2006:1 (including two reports in Swedish)

6 Daventry District Council: "Daventry PRT Scoping Study". Febr. 2008

7 EDICT, European Commission, 2004, DG Research, 5th Framework Programme, Key Action: "City of Tomorrow and Cultural Heritage", EDICT Final Report, Deliverable 10, December 2004.

8 Hoffman, P.: "Personal Rapid Transit - Innovative Transportation Technology; Overview and State-of-the Industry: Boos Allen & Hamilton, Febr, 2006.

9 Hoffman, P.: "Personal Rapid Transit - Strategies for advancing the state of the industry. Transportation Research Board; and Boos Allen & Hamilton, January 23rd, 2007.

10 Hoffman, P. and Carnegie, Jon A: "Viability of Personal Rapid Transit Study in New Jersey - Final Report". By Jon A Carnegie, Alan Vorhees Transportation Center, Rutgers, The State University of New Jersey and Paul.S.Hoffman, Booz Allen Hamilton, Inc., Febr 2007

11 Johansson, O. "Are PRT systems socially profitable?" Gothenburg University; 1997

12 Lowson, Martin, Advanced Transport Systems Ltd and University of Bristol: "Service Effectiveness of PRT vs Collective – Corridor Transport", in Journal of Advanced Transportation - Vol. 37. No 3 Sep 2003.

13 Poskey, J: "Report on the Feasibility of Personal Rapid Transit in Santa Cruz, California", Draft Report prepared for the City of Santa Cruz, by Jeral Poskey, Da Vinci Global Services.

14 Raney, S. & Young, S.: "Morgantown People Mover - an updated Description". http://www.cities21.org/morgantown_TRB_111504.pdf

15 SIKA: ”Evaluation of a PRT System”. Report 2008:5 (in Swedish)
16 SIKA: ”Infrastructure planering towards an enhanced goal fulfilment in major cities” Report 2008:6 (in Swedish)
17 Tegnér, G., “Market Demand and Social Benefits of a PRT System: A Model Evaluation for the City of Umeå, Sweden”. Infrastructure, Vol. 2, No. 3, pp. 27-32, 1997, John Wiley & Sons, Inc.
18 Tegnér, G.: “Benefits and Costs of a PRT system for Stockholm”. 7th APM Conference. Copenhagen, May 1999.
19 Tegnér, G and Fabian, L.: “Comparison of Transit Modes for Kungens Kurva, Huddinge, Sweden”; 8th APM Conference in San Francisco, July 2001.
20 Tegnér, G. and Andréasson, I: “Personal Automated Transit for Kungens Kurva, Sweden - a PRT system evaluation within the EDICT project”. 9th APM 2003 Conference, Singapore, Sept. 2003
21 Tegnér, G.: “EDICT – Comparison of costs between bus, PRT, LRT and metro/rail”. Transek, February 2003
22 Tegnér, G.: “PRT Ridership Analysis; in: Personal Automated Transportation- Status and Potential of Personal Rapid Transit”. The Advanced Transit Association, January 2003. (ATRA).
http://www.advancedtransit.org/doc.aspx?i=1015
23 European Commission, 2004, DG Research, 5th Framework Programme, Key Action: City of Tomorrow and Cultural Heritage: “EDICT Final Report, Deliverable 10”, December 2004
24 European Commission, 2004, DG Research, 5th Framework Programme, Key Action: City of Tomorrow and Cultural Heritage, “EDICT Huddinge Site Assessment Report”, June 2004 (Ed: G Tegnér, I. Andréasson, N.E. Selin)
25 Tegnér, G., 2005, “PRT Costs compared to Bus, LRT and Heavy Rail, Some Recent Findings”. Paper presented at: AATS European Conference in Bologna 7-8 Nov, 2005”Advanced automated transit systems designed to out-perform the car”
26 Tegnér, G, et.al. “PRT in Sweden - From Feasibility Studies to Public Aware-ness”; Paper presented at 11th International Conference on Automated People Movers, Vienna, 22-25 April 2007.
27 UITP: ”Ridership and Market Share”. : www.uitp.org