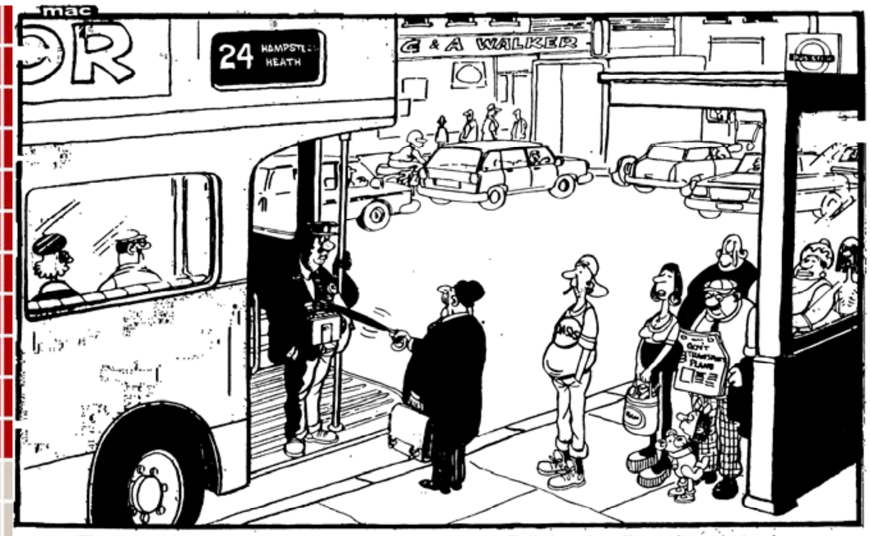

'Thought I'd give this public transport thing a try. Tell the chauffeur chappie to drop me off at my club, hang about then pick me up again about six

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Severe shortfalls in current public transport – and why podcars may make the difference

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Abstract

This paper starts with trying to answer the question why the existing public transportation systems seem unable to attract new travelers and why the public transportation market share does no expand, but drops in most countries in spite of large sums being spent on increasing the supply and modernizing the networks. Arguing that Personal Rapid Transit (PRT), or podcars, could be the trick that breaks the trend, capacity, consumer benefits, and costs are then explored for both traditional transit modes and PRT. Finally, recent case studies are cited, in which socio-economic benefits and costs of PRT networks have been calculated.

Summary

There is a fundamental drawback inherent in the line-haul scheduled technology for the bus, LRT and other "stop-go" modes. The perceived user travel speed for these existing modes can never be competitive to the private car, except for in the very dense urban areas where road congestion is severe. In both the County of Uppsala, the Mälaren Valley, and all of Sweden, as well as for many OECD countries, there is a strong need for a new and better public transit mode instead of more of the old kinds.

Therefore, before decisions about expanding the current line-haul systems are made, decision-makers ought to consider more innovative options, such as the podcar – or PRT – system, as a potential for improving the attractiveness of public transportation.

In spite of their modest size, podcar vehicles can offer large capacity! The podcar does not provide the same capacity as metro or commuter rail, but has a line capacity comparable with LRT or higher, and a much higher capacity than bus. The station capacity is dependent on the number of berths per station, and varies between a hundred and 1,400 passengers per hour. However, the structure of a podcar network, akin to a spider's web, facilitates the adding of links or stations should the capacity need to be increased.

When it comes to travel times, podcars offer about half that of traditional transit, thanks to much less "stop-go" time and much less time spent waiting. The podcars wait for you, instead of you having to wait for the bus, LRT, metro or train.

In addition, the podcar passenger comfort level is higher than that of the traditional modes, affecting the users' willingness-to-pay for the transit. We claim that the higher comfort level offered through podcars is around 20 % higher compared to modernized but standard public transit, and 75-80 % higher compared to non-modernized public transit. Furthermore, podcars may offer a higher level-of-service through the size of the network. When the podcar track length increases from 9 to 28 kilometers, the demand grows by 50 % per track kilometer. Apparently but not surprisingly, the PRT mode exhibits economies of scale through its network properties.

The costs of podcars are low; lower than with Light Rail Transit, and of the same (low) magnitude as the urban bus. To sum up: podcar systems offer twice as high level-of-service at about half the total cost per trip for producers and users taken together, compared to the current public transportation modes.

In socio-economic terms, the largest benefits of podcars seem to be time gains, followed by benefits from decreased external effects from auto traffic, and gains in comfort. Podcar projects in general show very good prospects of proving socio-economically profitable. As with other infrastructure investments, however, each case must be put to trial on its own accounts.

There is no easy-fix solution to the major transport challenges that face us today. However, if wisely planned and implemented, podcars could contribute as a more attractive, cost-efficient and environmentally-friendly mode for individual trips on a common network, available for all, in the striving towards a sustainable urban and inter-urban transport system.

1 Severe shortfalls in current public transport

This paper will draw attention to the performance of podcars compared to the current public transportation systems: bus, LRT, metro, and commuter rail. Comparisons will be made of capacity, consumer benefits (including benefits also to the society as a whole) and of costs; i.e. the three essential 'C's of providing a certain type of transport service.

This chapter deals with the competition of the public transportation modes compared to the private car mode, with examples from

- the City of Uppsala,
- the County of Uppsala,
- the Mälar Valley,
- all Sweden, and
- many OECD Countries.

1.1 Transit loses market shares in Uppsala and the Mälar Valley

In the **City of Uppsala,** public transportation ridership has dropped significantly during the last 27 years, see **Figure 1** below.

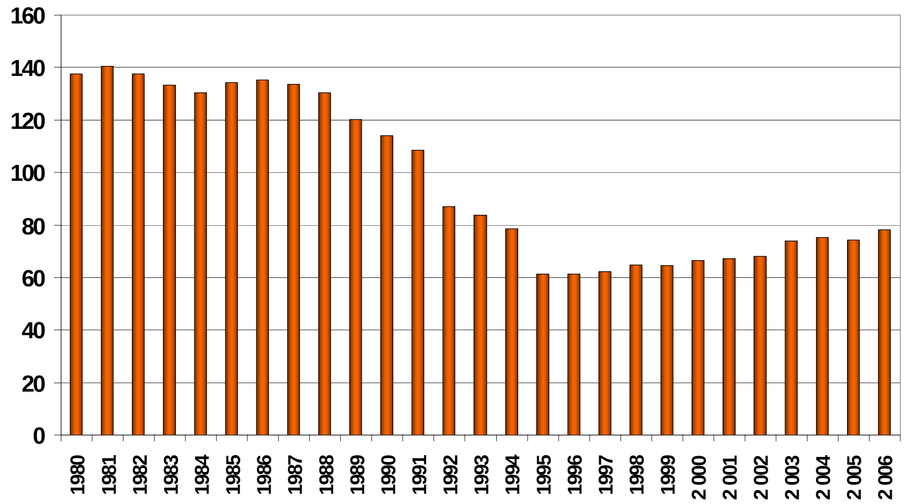

Figure 1. Public transportation demand and supply in the city of Uppsala 1980-2006. Source: Own calculations based on the data from AB Uppsalabuss.

The public transportation ridership dropped sharply in Uppsala from 140 to 64 trips per inhabitant and year in Uppsala between 1980 and 1995. Since 1995, a recovery has been achieved with an increase from 64 to 78 trips per inhabitant and year. However, the amount of transit trips per capita is still only a little more than half of its early 1980-level. Something went terribly wrong with the attractiveness of the bus system in Uppsala in the early 1990's. However, the 28 % increase in ridership since 1995 is a positive break in the trend.

In the **County of Uppsala**, the public transportation supply (in vehicle kilometers) has since 1985 been reduced by 5 % per capita, although it has increased over the last 10 years by 3 % per capita. At the same time, ridership (boardings) went down by 44 % per capita between 1985 and 2005, while car ownership went up by 22 %. During 1995-2005, ridership fell by 4 % per capita:

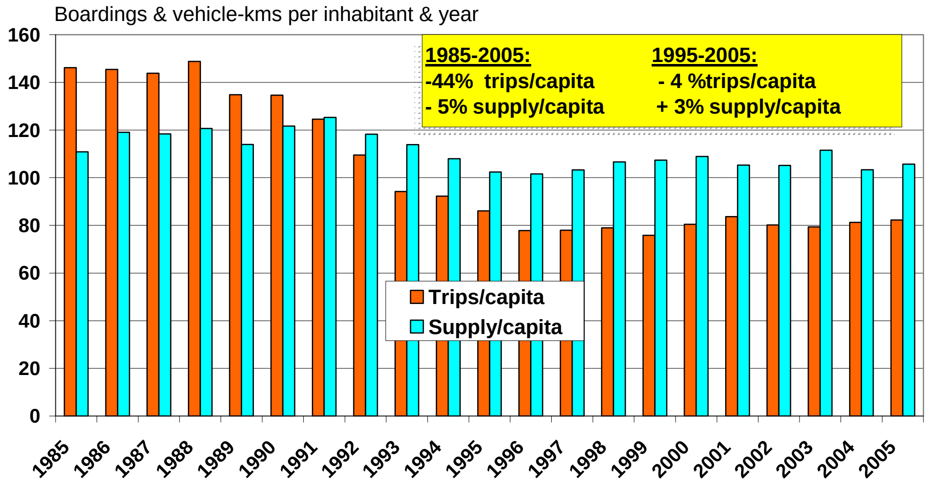

Figure 2. Public transportation demand and supply in Uppsala county 1985-2005. Source: Own calculations based upon statistics from the Swedish Association of Public transportation Authorities (SLTF).

In the expansive and densely populated Mälar Valley, including cities like Uppsala, Stockholm, Södertälje, Västerås, and Eskilstuna, there are regional commuter trains and a high speed rail service, as well as express and ordinary bus services between the cities and towns. The political ambition is to raise the market share for public transportation, especially by environmentally friendly rail service.

Still, the transit travel times in the area are not very competitive compared to the private car mode. And as a consequence, the public transportation mode shares are rather modest. As an example, the City of Södertälje (with 80,000 inhabitants) contains four rail stations, but has a public transportation mode share of only 8 %.

In a recent study the trip conditions between cities and towns in the Province of Södermanland and the city of Södertälje were examined in detail. The study shows that the reason for the very long door-to-door transit travel times may be found in the long out-of-vehicle times, such as walk, wait and transfer times.

The share of out-of-vehicle travel time in the included OD-relations, in terms of in-vehicle travel time, is very often far more than 100 %:

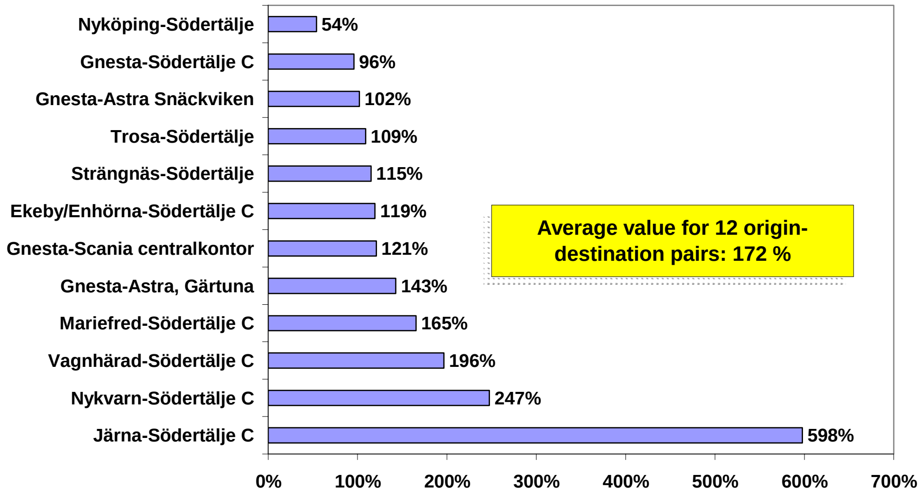

Figure 3. Out-of-vehicle travel time in % of in-vehicle travel time for 12 trips relations between Södermanland towns and the city of Södertälje. Source: Own calculations based upon Resplus.

In Södertälje, the reason behind all this walking, waiting, and transit can be found in the Inter-city rail station's location to the south of the city center, meaning that the traveler has to transfer to a city bus to reach the center. This location was considered a necessity due to the fact that high speed rail lines need long curve radiuses. In Figure 4 below, the generalized travel time by car and transit for trips to/from Södertälje are presented:

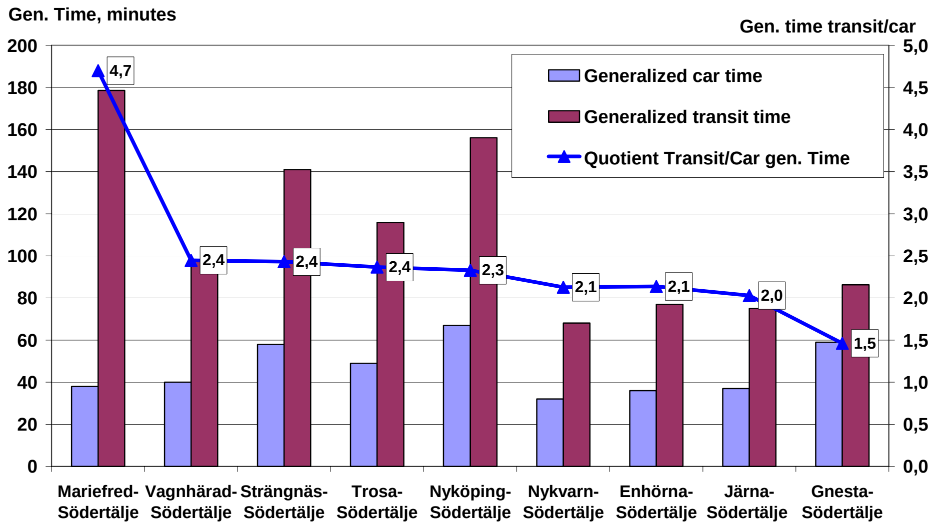

Figure 4. Calendar (un-weighted) travel time door-to-.door by car and by public transportation in nine origin-destination pairs in the Mälar Valley. Source: Own calculations based upon Resplus.

The relationship between transit and car times lies well above two. The absolute difference in generalized travel time is – for these OD-pairs – on average 1 hour and 6 minutes. The examples are abundant: In Stockholm County, an average public transportation travel time of 30 minutes is equal to a door-to-door travel time which is twice as long: 62 minutes. The *perceived* travel time (in terms of "generalized time" becomes three times as long: 90 minutes. In the other counties in the Mälar Valley, the share of time spent outside the vehicle (walking, waiting and transferring) adds up to more than 100 % of the in-vehicle time, in an example for trips from Södermanland to the city of Södertälje (equipped with four railway stations).

Below, the resulting average door-to-door travel speeds are illustrated as averages, measured as calendar time and as generalized (weighted) travel times.

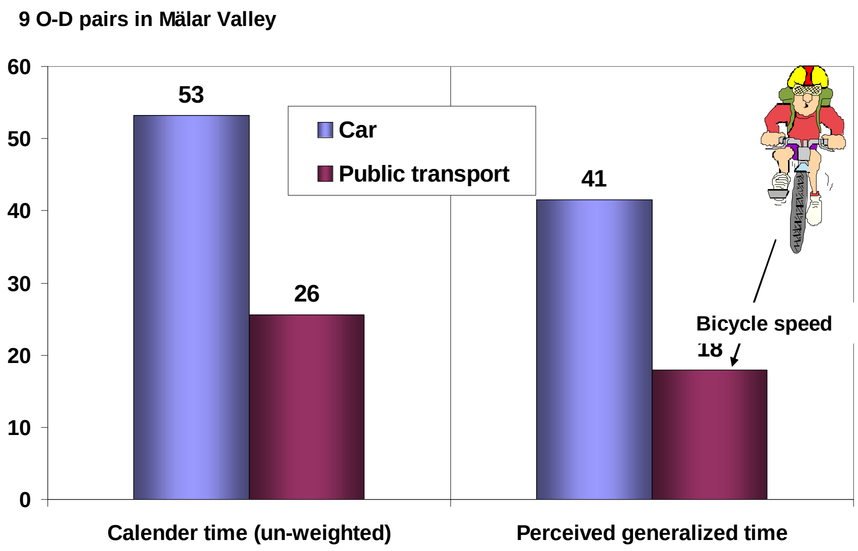

Figure 5. Average door-to-door speed for nine Origin-Destinations pairs between Södermanland towns and Södertälje; Calendar time and Generalized time, respectively. Source: Own calculations based upon Resplus.

Figure 5 shows that the door-to-door car speed drops from 53 to 41 km/hour, when the walking time to and from parking is weighted by a factor of two (due to the fact that people tend to value out-of-vehicle travel time about twice as high as in-vehicle-travel time). In the same way, the public transit travel speed drops from 26 to 18 km/hour.

However, 18 km/hour is roughly bicycle speed. Of course, such perceived speeds are not very competitive. These findings might explain why public transportation market shares are steadily falling in the Mälar Valley, as shown below.

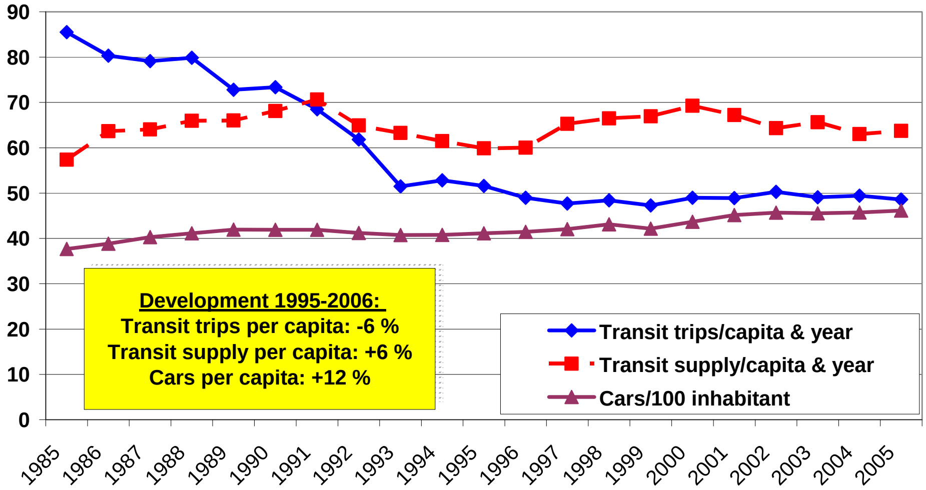

Figure 6. Falling public transportation market shares, indicated by boardings and supply (vehicle-kilometers) per capita compared to car ownership (cars per 100 inhabitants) for Mälaren Valley Counties (Stockholm County excluded), 1985-2005. Source: Own calculations based upon statistics from the Swedish Association of Public Transportation Authorities (SLTF).

In all Mälaren Valley, public transit demand fell sharply during the 1980's. However, the reliability in the statistical series was quite poor in those days. Still, from 1995 and onwards, public transportation ridership has dropped by 6 % per capita in the Mälaren Valley counties. In Stockholm County it fell by 0.2 %, while at the same time, public transportation supply was increased by 6 % per capita between 1995 and 2005.

Between 1995 and 2005, car ownership expanded by 12 %. This indicates that while the public sector has expanded the supply of public transportation services, the customers' demand has not corresponded at all. On the contrary, travelers prefer to go by car, in part surely due to the bad travel time performance indicated above for the current bus and rail modes.

1.2 Transit use drops as supply expands in Sweden

What might be a general characteristic for existing urban public transit systems is the tendency towards an increased supply of vehicle-kilometers, combined with a stagnating or even diminishing demand for this type of transport service. This phenomenon has been quite obvious for the local and regional public transportation sector in Sweden since decades. Since 1970, the market share for all public transportation modes in Sweden has never exceeded 20 %.

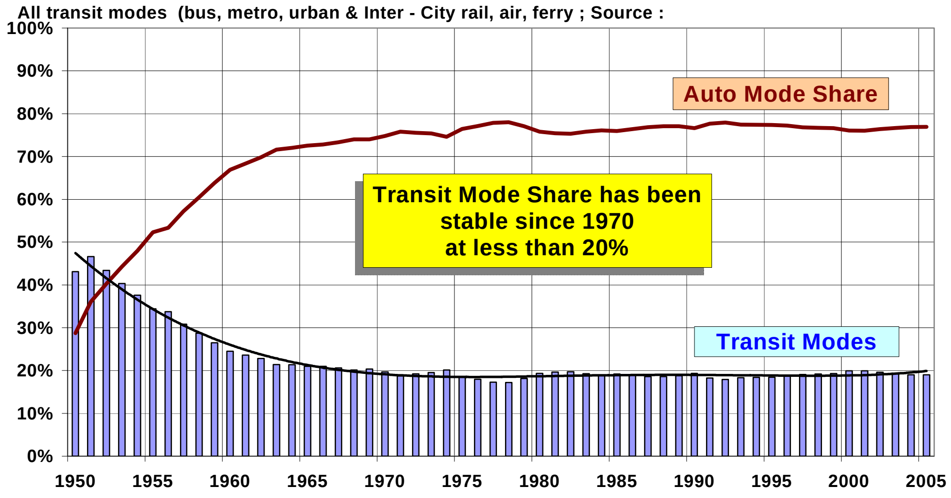

Figure 7. Public transportation mode share in Sweden 1950-2005. Source: "Kollektivtrafikens Marknadsutveckling". Vinnova report in Swedish, presented by G. Tegnér, Transek, 2006.

In absolute terms, the supply of local and regional public transportation services (in vehicle-kilometers) increased by as much as 15 % between the years 1985 and 2004, while demand dropped by 0,5 %. The corresponding figures counting per capita were a 7 % increase in supply, and a 7 % decrease in demand. Generally, one might conclude that public transportation only expands when and where population and occupation expands, i.e. in the larger cities and in the university cities.

Again: For a complete door-to-door journey, current public transit most often offers bicycle speed. Therefore it is not surprising that the walk and bicycle modes together have a three times higher market share (29 %) than public transit (9 %), while the car mode captures a market share of almost 60 % among all daily trips in Sweden (averages for the period 1994-2001).

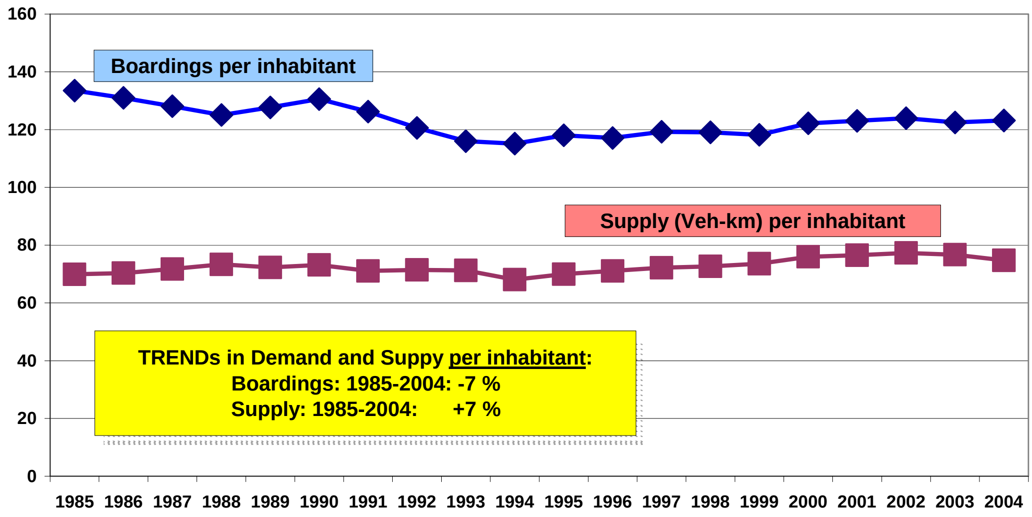

Figure 8. Supply and demand for local and regional public transportation per capita in Sweden 1985-2004. Source: "Kollektivtrafikens Marknadsutveckling". Vinnova report in Swedish, presented by G. Tegnér, Transek, 2006.

The latest National Swedish Travel Survey, RES 2007, indicates that 64 % of all trips are made with cars, that almost 90 % of the Swedes go by car at least once a week, and that 30 % use public transit at least once a week.[1]

An apparent explanation to this is that *walking* and *cycling* are individual modes, with zero wait time and with zero transfer. Walking by foot or taking the bike brings you directly to the destination from every point of origin to every possible point of destination. The only disadvantages with these two individual modes are that they are not weather protected, that they are dangerous from a traffic safety point of view, and that they are time-consuming and physically demanding over longer distances.

Suppose that these three shortcomings could be overcome by an environmental-friendly, swift mode. The podcar concept is such a promising mode.

1.3 Public transportation loses market shares in many countries

However, from an international perspective, the Swedish case might instead be regarded as a success story, as the transit mode shares in most other countries seem to have dropped even more. In spite of substantial investments in urban commuter rail and metro systems, LRT and high-speed rail systems during the

[1] SIKA Statistik 2007: 19. *RES 2005-2006. Den nationella resvaneundersökningen.*

last decades, the car share of inland passenger transport is still increasing, according to recent Eurostat statistics.

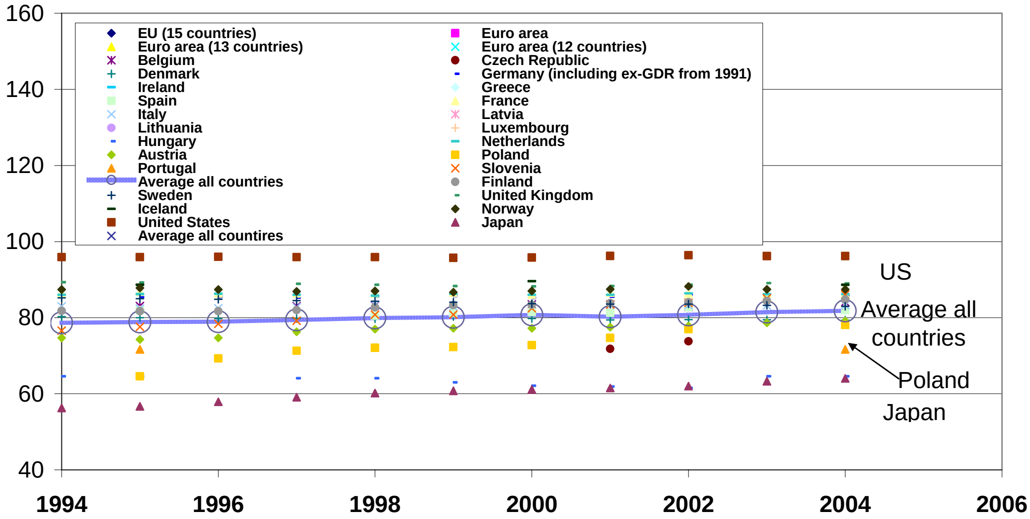

Figure 9. Car Share of Inland Passenger Transport 1994-2004 in Europe, USA and Japan. Source: Eurostat.[2]

The car share increased – on average – from 78.6 % in 1994 to 81.8 % in 2004. This corresponds to an increase in the car mode share by 4 % over the last 10-year period. This also means that urban public transit and inter-city railway are, most likely, still losing market shares to the private car mode.

In terms of total mobility, the number of passenger kilometers by car increased by 16 % in the EU25-countries between 1995 and 2003. In the same time, the number of bus passenger kilometers increased by only 4 % and rail passenger kilometers by 12 %.

In the year 2006, 92 % of land passenger transport was carried out on the roads (83 % by private cars and 9 % by bus), and 8 % by rail (railway by 7 % and metro and light rail/tramway by 1 %)[3].

Even in such a dense country as the Netherlands, where the pre-requisities for an efficient public transportation would be at their best, the public transportation mode shares are very low; only about 11 %:

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2 http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_transport&root=Yearlies_new_transport/G/en034

3 Source: EU Directorate General for Energy and Transport; http://ec.europa.eu/dgs/energy_transport/matthias_ruete/mission_en.html

Table 1. Modal split in the Netherlands in 2006. Source: Eurostat, Passenger Mobility in Europe Survey.[4]

Mode of transport	Million pass. kilometers	Market share in 2006
Walk and bicycle	17.8	9.1 %
Public transportation (bus, coach, rail)	21.1	11.4 %
Private car	146.1	78.9%
All land transport modes	**185.0**	**100.0**

4 http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-087/EN/KS-SF-07-087-EN.PDF

2 Europeans demand better public transportation

The European Commission recently launched a survey about the “Attitudes on issues related to EU Transport Policy”[5]. In this study the main views of the European citizens’ are expressed in terms of car usage and attitudes towards public transportation and the urban environment. When considering potential changes to the public transportation system that might encourage more people using it, respondents who primarily use a car claimed that better schedules and better connections would be the most likely factors to encourage them to use public transportation and to drive less frequently. “Only” 22 % of the primary car users said that they would not change their attitudes regardless of any changes to the public transportation system. The vast majority of the EU citizens (78 %) share the opinion that the type of the car and the way people use them have an important impact on the environment in the respondent's area. The least popular mode is using public (or community) transport (21 %).

Our conclusion is that there is a fundamental drawback inherent in the line-haul scheduled technology for the bus, LRT and other “stop-go” modes. The perceived user travel speed for these existing modes can never be competitive to the private car, except for in the very dense urban areas where road congestion is severe. Clear evidences have been demonstrated both for the County of Uppsala, the Mälaren Valley, and all of Sweden, as well as for many OECD countries, that there is a strong need for a new and better public transportation mode; not more of the old kinds.

Before decisions about expanding the current line-haul systems are made, decision-makers ought to consider more innovative options, such as the podcar system, as a potential for improving the attractiveness of public transportation.

[5] Analytical Report, Flash Euro Barometer 206b, in collaboration with the Gallup Institute; July 2007. European Commission

3 Podcars offer enough capacity

3.1 Line capacity as LRT or higher

When discussing the pros and cons of various transit modes, capacity is a central issue. The highest practical capacity among manual-driven line-haul transit systems is often said to be 3 minutes headway. For AGT – Automated Guided Transit systems – the headway could be 1 minute or slightly less, which is the case for Vancouver's SkyTrain.

When the demand for public transportation trips exceeds 10,000 trips per hour for one corridor, metro or commuter rail are the most commonly used means of transport. Urban LRT and AGT[7]-systems usually provide an hourly capacity of some 7,500 – 8,500 passengers per hour per direction (pphpd). In the figure below, seating capacity is presented for typical transit vehicles from Stockholm, except for AGT (which refers to SkyTrain in Vancouver) and PRT (4 seated persons per podcar), and includes all seated passengers. Podcars – only – allows 100 % seated passengers.

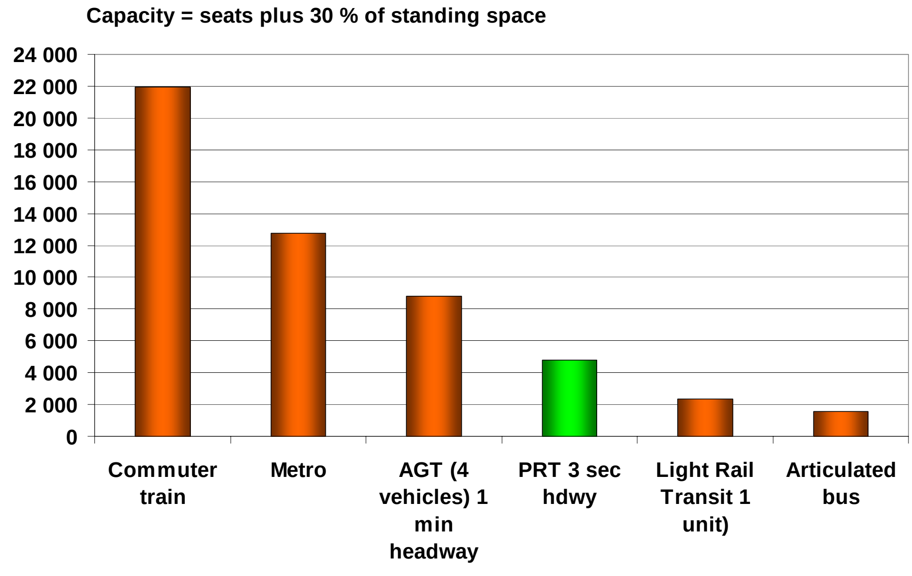


Figure 10. Passenger capacity at 3 minutes headway for various transit modes. Source: Own calculations, partly based on data from Greater Stockholm Transit Co (SL). Capacity defined according to SL's comfort criteria: seat+30% of standing space

[7] AGT = Automated Guided Transit, driverless but line-haul systems, often with much larger vehicles than PRT.

As can be seen above, the articulated bus has a fairly low capacity at about 1,560 passengers per hour and direction (of which 700 seated). A podcar single track – at a 3-second headway – has a higher seating capacity (4,800 passengers) than the traditional LRT (with 1 unit) operating at a 3-minute headway (2,460 passengers). Many PRT advocates talk about an even higher frequency for podcars than 3 seconds. The commuter train and the metro have higher passenger capacities than the podcar, as long as 30 % of the standing places are counted, with 21,960 places for commuter train and 12,740 places for metro. But when in competition with the car in the forthcoming decades, can public transportation afford to offer its passengers transit standing up?

As indicated in the figure below, even heavy rail modes show a low capacity when headways are longer than 10 minutes of intervals between departures. An LRT system with 3 minutes headway has a slightly higher seating capacity (4,680 pphpd) than a full commuter train every 10 minutes (4,488 pphpd).

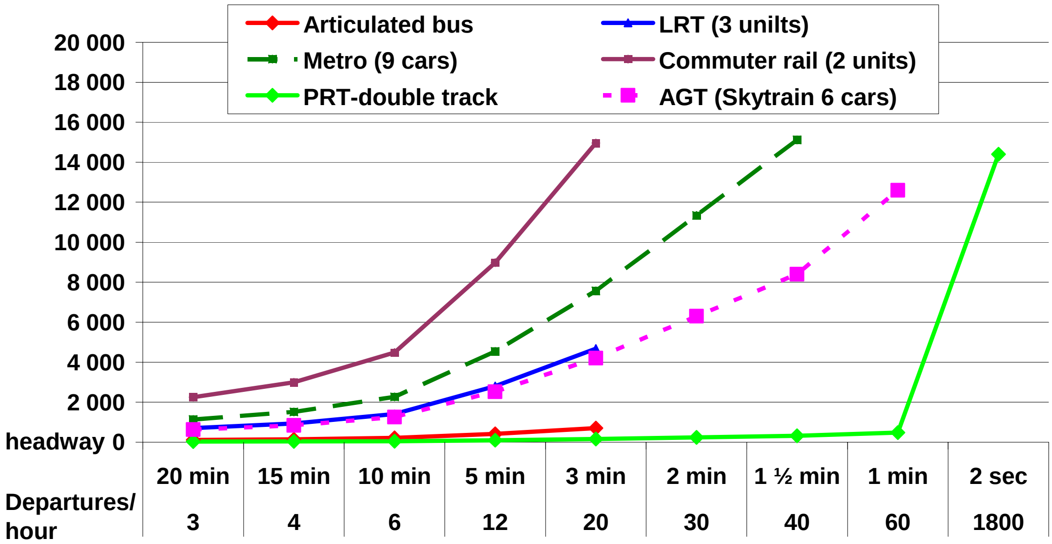


Figure 11. Hourly seating capacity at various headways. Source: Own calculations, partly based on data from Greater Stockholm Transit Co.

This is also true even for podcars. A podcar system has, naturally, a very low capacity at a low frequency of service. But with a 2 second headway, which seems to be technically quite possible, the passenger capacity of a podcar system is 7,200 pphpd for a single track (i.e. 14,400 for a double track), and lies in the same range as a metro line that runs every 3rd minute (7,560 pphpd) or with a commuter train every 6th minute (7,480 pphpd).

The tangential new *Tvärbanan LRT-line* that opened in Stockholm in the year 2000 has been a success story. At present it operates at 7,5 minutes headway, but the intention is to run this popular LRT line at 5 minutes headway.

The Tvärbanan LRT-line in Stockholm carries 78 seats and takes 134 standing passengers per unit. This makes a total capacity of 212 per LRT-train, and at 5 minutes headway, the total capacity is 2,544 per hour per direction (seated and standing!). Of these, only 936 seats are available. With three multiple units, the *total seating capacity is 2,808 pphpd*, and the *total capacity 7,602 pphpd* (seated and standing).

With a *podcar system* with each vehicle equipped with 4 seats, the total hourly capacity is *2,880 seats per hour per direction*, if operated at 5 seconds headway. This is more than with the present day LRT-line with three units! It is also more than the total capacity of one unit, including standing passengers (2,544 pphpd).

With 3 seconds headway for podcars, 5 minutes for a bus line, and 10 minutes for a Light Rail system, the capacity will in comparison be as follows:

Table 2. Comparison of seating capacity for three modes. Source: Advanced Transit Systems Ltd.

Mode	Seats	Frequency	Capacity, seats/hour
Bus	50	5 mins	600
Light Rail	200	10 mins	1 200
Podcar	4	3 secs	4 800

3.2 Podcar station capacity is crucial

Based on micro-simulation technique, one can count with a cycle time of 14 seconds for the door opening, departure, boarding and door-closing of a podcar vehicle. The *theoretical station capacity* for a one-berth Podcar station might then be between 386 (with 1.5 passenger per podcar vehicle with 4 seats) and 1,029 (with 4 passengers per vehicle) passengers per hour and berth. For a three-berth station the corresponding capacity would be between 770 and 3,090 passengers per hour.

However, the *practical station capacity* will be much less, due to waiting and vehicle queuing for the podcars entering and leaving the stations. Also, the lengths of the boarding and debarking time among different travelers show a substantial variation. Dr. Ingmar Andréasson at LogistikCentrum has simulated this, with an assumption that the boarding time is normal distribution N (5.3), truncated between 2 and 15 seconds, and based on Professor Edward J. Anderson’s measurements. These simulations result in a rule-of-thumb of 60 passengers per hour debarking, or boarding, or 30 passengers boarding and 30 passengers debarking. Therefore, the practical station capacity will be approximately 60 podcar vehicle loads per hour.

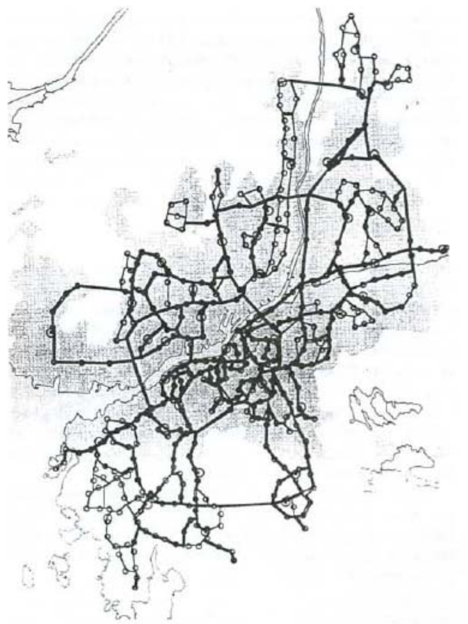
As shown in the table below, the passenger capacity for a podcar station might vary between 90 and 1,440 passengers per hour. If more capacity is needed, then more loops can be added, with more off-line stations. Computer simulations for a podcar network at Flemingsberg in the Municipality of Huddinge in Metropolitan Stockholm show that there would be a need for two podcar stations to take care of the passenger loads from a commuter rail station.

Table 3. Podcar station passenger capacity. Source: Own calculations, partly based on data from Greater Stockholm Transit Co.

Station capacity	Number of berths per station					
Passenger/vehicle	1	2	3	4	5	6
1.5	90	180	270	360	450	540
2	120	240	360	480	600	720
2.5	150	300	450	600	750	900
3	180	360	540	720	900	1 080
3.5	210	420	630	840	1 050	1 260
4	240	480	720	960	1 200	1 440

Can podcars be a sufficient solution even for a large scale network? Yes. Dr. Ingmar Andréasson has shown in a study on Gothenburg, Sweden, that podcars can replace all buses and trams, and up to 60 % of all car trips for the entire City of Gothenburg, with:

- 728 km guideway
- 391 stations
- 17,000 vehicles



Such a large-scale podcar network would reduce travel times by half compared to the current public transportation situation.[8]

Our conclusion is that these small podcar vehicles can offer large capacity! The podcar does not provide the same capacity as metro or commuter rail, but has a line capacity comparable with LRT or higher, and a much higher capacity than bus. The station capacity is dependent on the number of berths per station, and varies between a hundred and 1,400 passengers per hour.

However, the structure of a podcar network, comparable to a spider's web, facilitates the adding of links or stations should the capacity need to be increased.

[8] Source: "PRT in Sweden From Feasibility Studies to Public Awareness", by Göran Tegnér, et.al.; Paper presented at 11th International Conference on Automated People Movers, Vienna, 22-25 April 2007; And: Andréasson, I., m.fl., 1996, Research and development in advanced transit systems - Survey of academic and industry efforts, Rapport Chalmers Industriteknik

4 Consumer benefit speaks for pod-cars

There is obviously a need for better urban public transportation systems. Why? Firstly, people do not travel in corridors! Instead, they travel all around the urban scene in all directions. Secondly, as we have already discussed, busses and trams only offer bicycle speed when counting door-to-door. The trip pattern is to visit "many-to many" points. In sections 4.1 and 4.2 below, these reasons will be explained further from a consumer benefit perspective.

4.1 Trip patterns seldom follow corridors

Most public transportation networks are built up as corridor systems along bus or LRT routes, not to mention the heavy rail modes, such as metro and rail. But very few travelers live within walking distance of the rail stations or bus stops along such corridors. Instead, the trip pattern is more like the example below, derived from a Bristol study.

With such a dispersed trip pattern, it becomes quite obvious that a single corridor line can only serve a minority of actual and potential travelers.

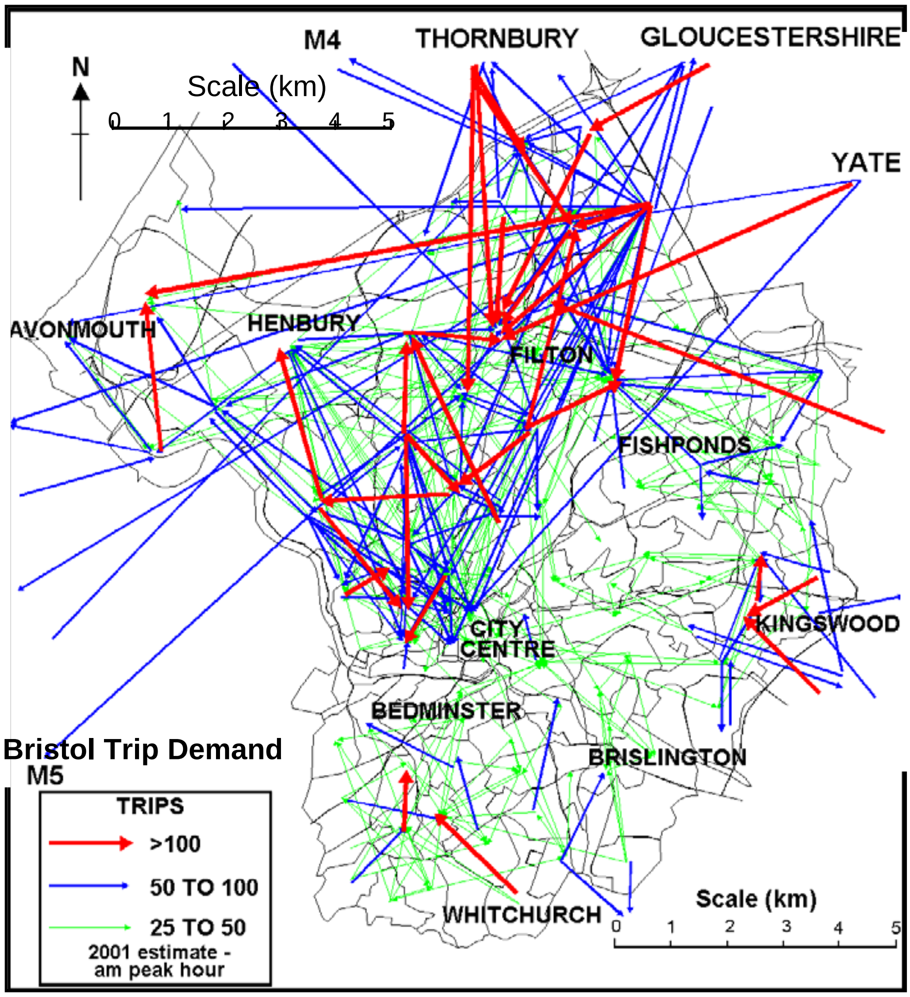


Figure 12. A typical urban trip pattern (Bristol, UK). Source: Courtesy of Professor Martin Lowson; ATS Ltd.

Therefore, when designing an efficient public transit network, the actual trip patterns should be taken into consideration, and a cobweb-like network as shown in the figure below ought to be preferred if the ambition is to attract new riders.

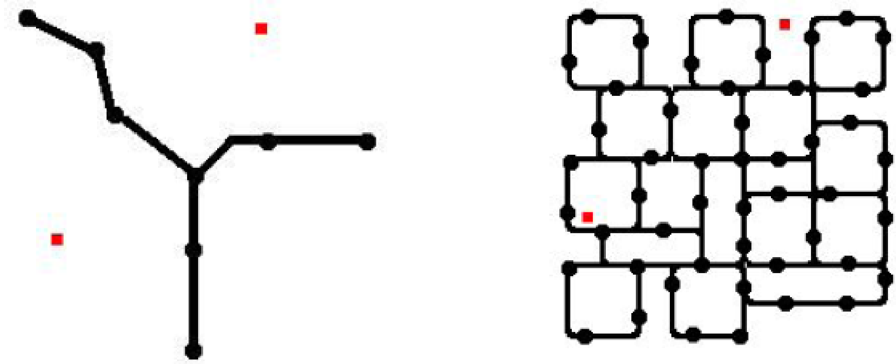


Figure 13. A typical LRT network versus a typical podcar network.

A public transportation system with fixed corridors and scheduled service is a system that takes you from a point where you are not located to a point to where you do not want to go, and often at time that does not suit you very well. A dense podcar network with many small vehicles and with many distributed stations allows shorter walking distances, almost zero waiting time due to an extremely high frequency of service at the time you wish to depart, and at a cruising speed that is not hindered by intermediate stops under way. The desired origin and destination of the individual trip is more closely related to better and more densely distributed station-pairs.

4.2 Podcars offer twice the speed

The door-to-door speed of an urban bus or an urban Light Rail transit (LRT) is restricted by all the intermediate stops underway. Let us calculate the door-to-door speed for a typical urban city trip of 8 kilometers. Assume a bus stop at every 500 meters, or an LRT Stop at every 750 meter of spacing. The bus speed does not exceed 30 km/h in the city area, while the LRT to speed could be 80 km/h. Assume 5 minutes of average waiting time (10 minutes headway). For a PRT system, assume off-line stations at every 250 meters and a cruising speed of 40 km/h. Waiting time for the PRT-system is assumed to be 1 minute in average. As can be seen below, the podcar door-to-door speed is more than twice as fast as the existing modes, bus and LRT.

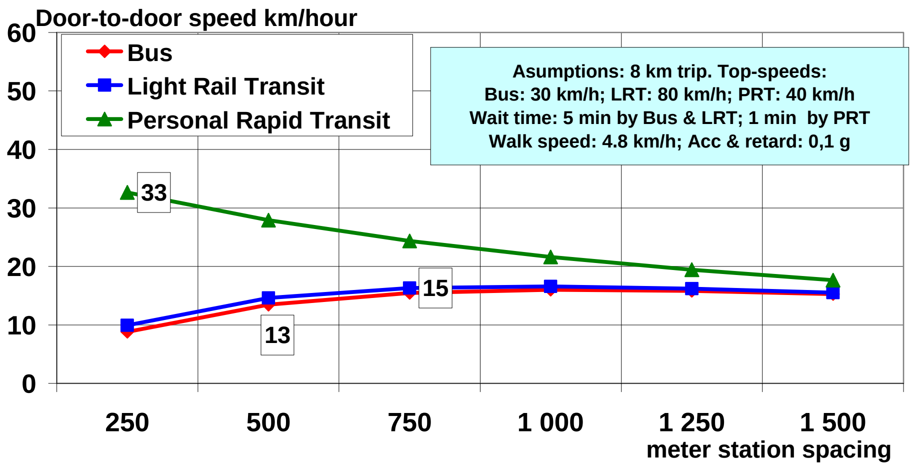


Figure 14. Door-to-door travel speed for three modes as a function of station spacing. Source: Own calculations.[9]

The figure above shows that an urban bus never exceeds an average speed of 13 km/h from door-to-door. And this is calculated without any car competition in terms of road or street congestion, caused by too dense car traffic in the city centers.

An Urban LRT door-to-door speed is about 15 km/h at best, irrespective of its maximum speed. This is due to intermediate stops underway. The podcar (PRT) mode, on the other hand, offers a door-to-door speed which is twice as fast as the existing public transportation modes, and rather close to its cruising speed: around 33 km/h.

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[9] See also: "Service Effectiveness of PRT vs Collective – Corridor Transport", in Journal of Advanced Transportation - Vol. 37. No 3 Sep 2003; By Prof. Martin Lowson, Advanced Transport Systems Ltd and The University of Bristol.

4.3 Podcars offer half the door-to-door travel time

The explanation to this higher speed, or lower travel time, by podcars is shown below:

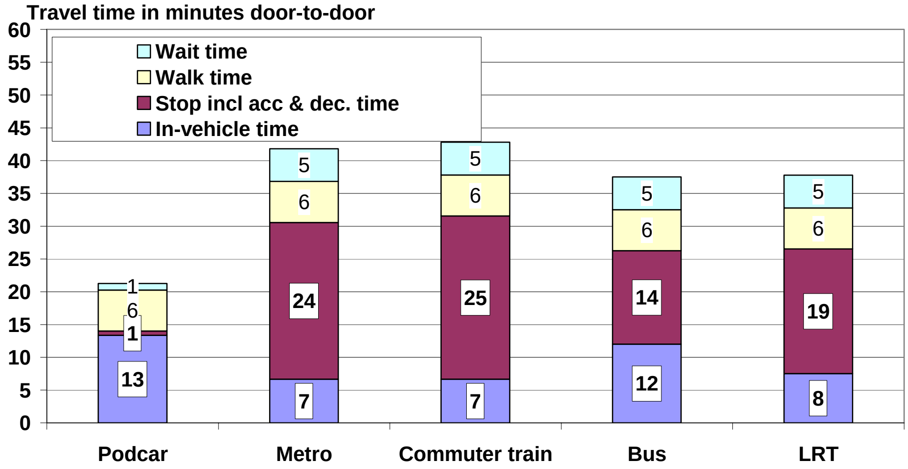

Figure 15. Travel time components for a 10 km trip[10] by podcars, metro, rail, bus and LRT. Source: Current modes: data based on Stockholm Greater Transit Company, podcar data from Swedish computer simulations.

Walking and waiting times are all assumed to be the same, 5 minutes. As can be seen, the in-vehicle time is longer for the podcars, as the speed for podcars has been assumed to be 45 km/hour, while the cruising speed between stops for metro and commuter is set to 90 km/hour (80 km/hour for LRT).

However, the time used for stations stops, including acceleration and deceleration, more than offsets this top speed advantage for the heavy rail modes. While the podcar needs 15 minutes from the origin to the destination stop including 1 minute of waiting time, it takes more than twice as long time, between 35 and 39 minutes, for LRT and bus respectively, of which the “stop-go” time makes up for 22 (LRT) to 27 minutes (bus), including 5 minutes spent waiting for this 10 km transit trip.

Thus, podcars offer about half the travel time, due to much less “stop-go” time and much less time spent waiting. The podcars wait for you, instead of you waiting for the bus, LRT, metro or train.

[10] Nota Bene: all modes are compared for a 10 km journey. Most line-haul systems implies longer distances due to the corridor type of line itineraries, while the more spider-like podcar network would yield less excess distance. Thus, the comparison in Figure 15 favors the traditional line-haul systems.

Another aspect of the level-of-service is the size of the network. When the track length increases from 9 to 28 kilometers, or threefold, then the demand *per track-kilometer* grows by 50 % (elasticity: 0,23). Apparently but not surprisingly, the PRT mode exhibits economies of scale through its network properties.

Our conclusion is that the willingness-to-pay for the higher level-of-service offered through podcars is around 20 % higher compared to modernized but standard public transportation, and 75-80 % higher compared to non-modernized public transportation. An important aspect of the level-of-service is also the size of the network.

4.4 Podcars – environmentally friendly, safe and secure

Environmentally friendly podcars use less energy

By attracting higher ridership, podcars replace car trips with trips with much higher efficiency. The efficiency gains come from running vehicles with electric power in a non-stop manner, eliminating the gasoline engine and the power wasted with starts and stops. The result is decreased emission of unburned hydrocarbons, nitrogene oxides (NO_x), carbon monoxide (CO) and carbon dioxide (CO_2)[11]

The exhaust of greenhouse gases, such as CO_2 is to a great extent proportional to the energy required for propulsion, which in turn is a matter of weight and speed and acceleration.

In Figure 16 the vehicle weight per seat is compared between six various transit systems.

A podcar - like the ULTra –system – has a weight per seat that is only half of a normal bus. Compared to the so called “light rail”, the podcar weight per seat is less than one third. An LRT vehicle has a weight which is 90 % of that of a commuter rail car. Who called Light Rail Transit (LRT) “Light”?

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[11] See also: ”Report on the Feasibility of Person Rapid Transit in Santa Cruz, California”, Draft Report prepared for the City of Santa Cruz, By Jeral Poskey, Da Vince Global Services

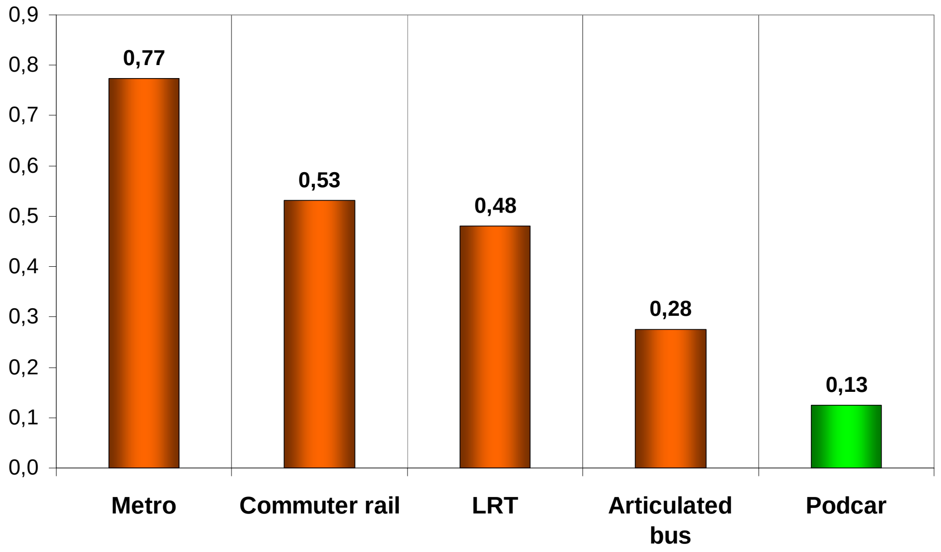

Figure 16. Vehicle weight in tones per seat for five transit systems. Source: Current modes: Stockholm Data from Greater Stockholm Transit Co; Podcar: ULTra-data from ATS Ltd.

The ULTra and other similar podcar systems are extremely energy saving. The energy usage of various modes are as follows, according to a Swedish research report. “Energy use and exhaust emission for various transport modes”[12]:

Table 4. Equivalent energy use in MJ/pkm for various modes. Averages. Source: NTMCALC 2005 (www.ntm.a.se), and ”Huddinge Site Assessment Report” EDICT, European Commission; June 2004.

Transport mode	Load Factor (pass/ Vehicle)	Energy use (MJ/pkm)
Car (gasoline) 2003	1.8	1.49
Car (diesel) 2003	1.8	1.2
Bus (diesel)	19 (32%)	1.1
Bus (ethanol)	19 (32%)	1.1
Bus (bio gas)	19 (32%)	1.6
Commuter train	61 (35%)	0.86
PRT (ULTra)	1.7 (42 %)	0,55

As a comparison the energy use for the ULTra podcar is inserted in the table. PRT is more energy saving than all other modes of transport. The reader should

[12] Source: Swedish Road and Transport Research Institute, Report: 718:1993

also remember that for train, only 1/3 of its total energy use is related to propulsion[14].

Safe and secure elevated podcars

Among podcar benefits, safety is first. The current road transport system kills over 40,000 persons per year, only in Europe. This is a compelling reason why a safe system such as podcars ought to be introduced.

Personal Rapid Transit (PRT) is generally regarded as a safe mode of transportation mainly because it is mostly elevated and therefore does not conflict with road traffic and/or pedestrians. The ULTra system is also accepted as feasible and reasonable by Her Majesty's Rail Inspectorate. However, a key issue of concern emerging from the stated preference surveys and the ULTra user trials related to the system's safety and the personal security of passengers. Because the system does not exist and the public have nothing with which to compare it, respondents had reservations about its technical reliability and efficiency, and about how it would cope in severe weather conditions. Also, because the system is driverless, respondents raised an element of concern about their personal safety especially when using the system alone. To enhance the feeling of safety so that people would use the system, it must be well-lit and be under continuous CCTV coverage, with direct links to the controller from stations and vehicles[15].

In October 2003 three focus group interviews were carried out at Kungens kurva, Sweden, in order to study the users' acceptance and willingness to pay for a PRT system there. In all, 28 persons participated in these in-depth interviews. The attendants were chosen among those who are frequent visitors to the area and who travel by various means of transport to Kungens kurva. On *safety and security* the respondents were much concerned about the podcar system's technichal reliability, but less so about personal safety:

"The podcar system (PRT) must always work properly and be fresh-looking, to have a future." "If it fails and gets into trouble, it gets a bad reputation and nobody will use it." "Security is no problem, because many people are moving around during shopping hours at Kungens Kurva." "Fine with cameras and possibilities to choose companions for the ride." "The short travel time and short distance between stops-brings a sense of security to you." "A break-down of the PRT-system would be most unpleasant."[16]

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[14] Indirekt energi för svenska väg- och jörnvägstransporter. Daniel K. Jonsson, FOI & KTH (Royal Institute of Technology)

[15]. "Site Assessment Report". European Commission EDICT: Deliverable 6, June 2004

[16] "PRT- a high-quality, cost-efficient and sustainable public transportation system for Skärholmen - Kungens Kurva: Summary of the Site Assessment Report". Transek AB, 2004-06-01

4.5 Higher modal split with podcars

A summary from five various feasibility studies about podcars, show that the share of public transportation (the so called "modal split") can be substantially augmented with podcars, replacing bus or other current transit modes.

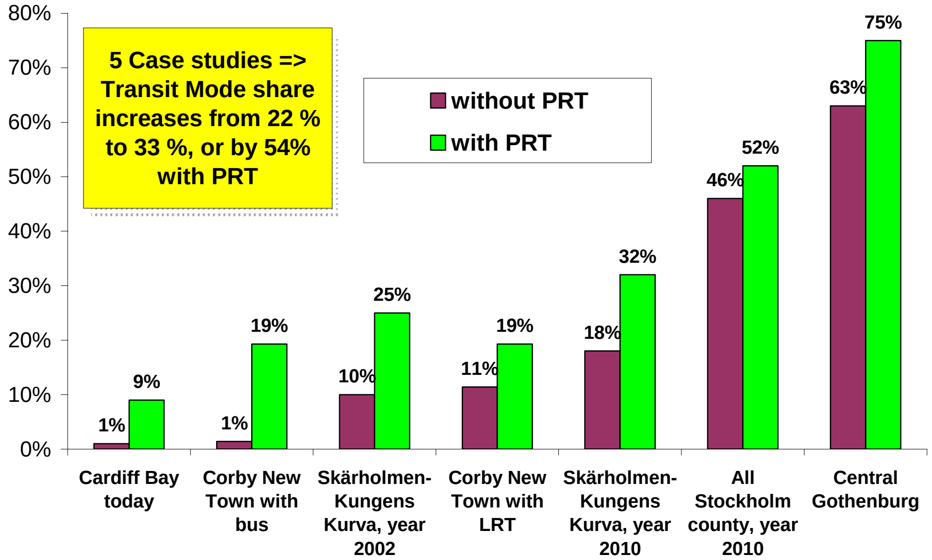

Figure 17. Share of public transportation ("modal split") in terms of car plus public transportation in seven cases (five case studies) without and with podcars. Source: Own calculations from various sources

In all of Stockholm County and in Gothenburg, both with high shares of trips made by public transportation, a podcar system would increase the modal split by 13 % and 19 % respectively.

In a typical Swedish suburb, such as Skärholmen - Kungens Kurva, the modal split might augment by 25 to 32 %, as the original level is lower in such an area. In Corby New Town the expansion of the public transit market share is estimated to increase even further with a podcar network, while with bus and even an LRT system the market share would be rather limited (1 % to 11 %).

As an average, the modal split might expand from 22 % to 33 %, with podcars replacing the current modes of public transportation.

5 Podcars cost less

In the earlier chapters of this paper, the issues of *capacity* and *consumer benefits* of podcar systems have been elaborated. The third "c" is the *cost* aspect of providing such a system. Usually, providing higher comfort and higher speeds are equivalent also to higher costs. But as we shall see in this chapter, the costs of podcars are low; lower than with Light Rail Transit, and of the same (low) magnitude as the urban bus.

How can one be sure of costs of a system not yet in operation? The question is valid. However, Personal Rapid Transit has been analyzed since the middle of the 1960's, and several prototype systems have already been tested and "cost calculated", such as:

- Cabinentaxi
- PRT2000
- Taxi2000
- SkyWeb Express
- ULTra
- SkyTrain
- MicroRail
- Frog CyberCab
- MIST-Er
- FlyWay
- SkyCab
- Vectus

What to say about cost calculations of non-proven systems? Usually costs go up the closer a system comes to market readiness. This is due to the fact that more technical sub-systems normally have to be added to the original and often more simplistic design of the system in question. On the other hand, the very first prototype of a new system is more or less hand-made, which is expensive. When mass production follows, the unit price goes down due to economics of scale.

Part of the philosophy with PRT is lean production, small scale, and the use of pre-fabricated components. Here one can notice another tendency. Every new researcher of podcars is very anxious not to underestimate the true costs of podcars. Therefore, he, or she, adds a 10 % - 20 % margin of contingency.

The aim of doing cost calculations is to reduce uncertainty, besides from using them in cost-benefit analyses. The only true way to gain more certainty is to test the system in real life, as is the case with the ULTra and the Vectus podcar systems.

5.1 Podcar capital costs are lower

A recent overview of capital costs of podcar systems is given by Jeral Poskey in his Santa Cruz Study[17]. In the table below, capital costs for four such systems are presented.

Table 5. Capital Costs of four podcar systems in million US$/mile and million €/km. The costs include costs for tracks, vehicles, stations, power supply and depots, but not development costs. Source: see footnote [18]

Podcar system	Capital cost in m US $ per track-mile	Average capital cost in m € per track-km
Taxi 2000	16-24	9.7
Vectus	18	8.7
ULTra	9-15	5.8
SkyTrain	< 10	< 4.9
Average	**< 15**	**< 7.3**

The average cost per track-kilometer corresponds to approximately 65 million SEK.

However, for a low capacity installation, the costs can be substantially lower. The CEO of Advanced Transit Systems, responsible for the development of the ULTra-system presently under construction at London Heathrow airport, recently announced a cost reduction to 8 million US $ per one-way track-mile (corresponding to 3.9 m € or 35 m SEK per track-km)[19].

For the Recent PRT study att Daventry in United Kingdom, Ove Arup Consultancy ended up with 20 m SEK per track-km, the same cost per km as Taxi 2000 has shown in a detailed cost study.[20] How is this level of capital cost compared to the current modes of public transport? A comparison of capital costs is presented below.

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17 ”Report on the Feasibility of Person Rapid Transit in Santa Cruz, California”, Draft Report prepared for the City of Santa Cruz, By Jeral Poskey, Da Vinci Global Services

18 As above.

19 Cited from: ”PRT News & Views”, PRT Consulting Inc. Spring 2006.

20 Reported by Mr Bengt Gustavsson, Linköping.

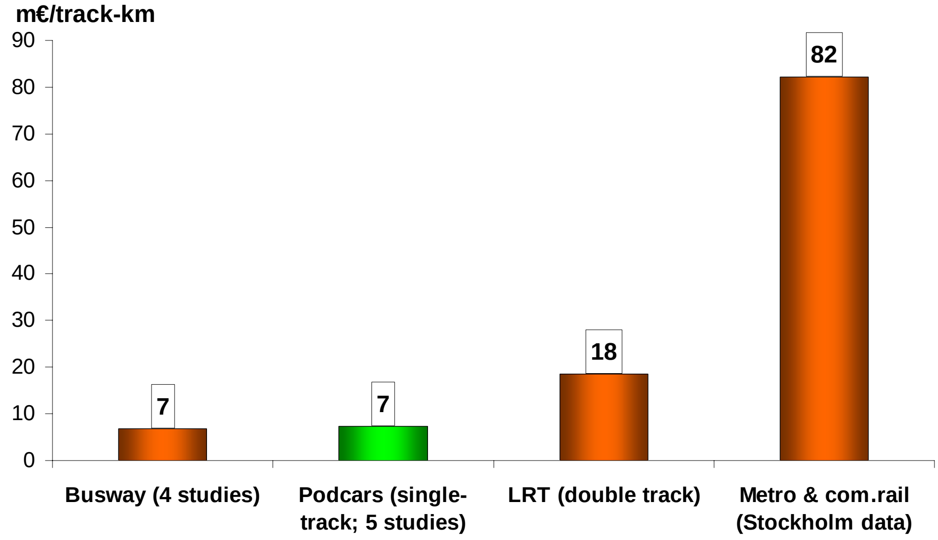

Figure 18. Comparison of capital cost between transit modes. Source: Own calculations based on several studies and on data from the Greater Stockholm Transit Co (SL AB).

The capital costs of the podcar system are similar to those of a surface busway line; around 7 m€ per track-km. The average capital cost of an LRT system is around 18 m€/double-track-km, while metro and rail systems cost more than ten times more, or 82 m€/double track-km.

According to a PRT study made by Paul Hoffman at Booz Allen Hamilton, the podcar cost for a double track is about 1.5 times higher than for a single track podcar system. A 'true' comparison with all systems as double-track, would thus give the following outcome:

Table 6. Capital cost per double-track in m € per km. Source: Own calculations.

Transit mode	Capital cost in m € per double-track-km
Busway	14
Podcar	10.5
LRT	18
Metro or rail	82

Both busways and podcar systems are cheaper (-22 %) per track-kilometer than the Light Rail Transit (LRT) system, and much cheaper (-78 %) than the two heavy rail systems.

Now, one might argue that the capacity is not the same among the four transit modes. This has been elaborated above. Below, a comparison is presented in terms of *the number of seats per hour provided per million Euros in capital cost (per track-km).* The comparison is based on the following typical (best) headways for each system:

- Podcar: 3 seconds
- Busway & AGT: 1 minute
- LRT, Metro & Commuter rail: 3 minutes

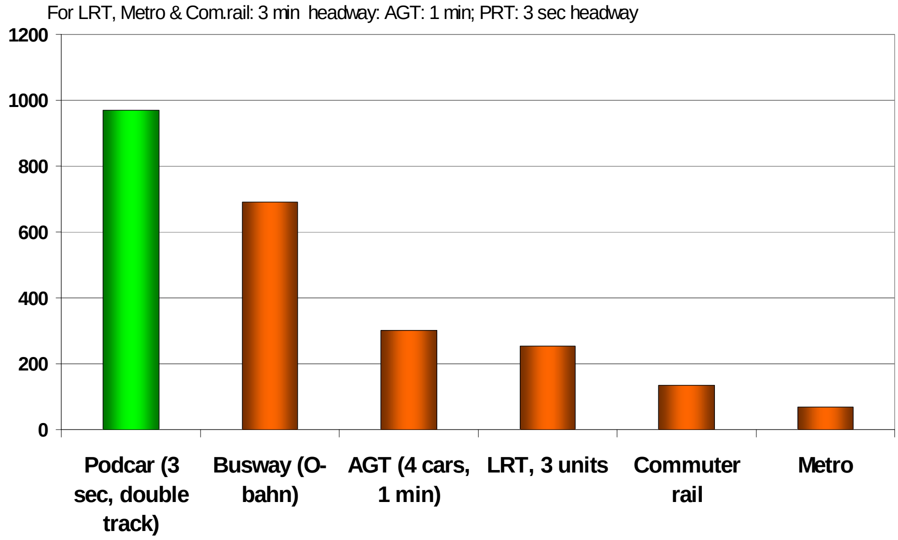

Figure 19. Comparison of seats per hour per m € in capital cost. Source: Own calculations, partly based on data from Greater Stockholm Transit Co.

The metro system offers high capacity, but mostly standing places and not so many seats. It is also a very expensive system. Therefore, the number of seats provided per hour and per capital cost unit is very low (less than 70 seats). LRT is in this respect an intermediate system (with 250 seats/h and m€) and better than metro. However, *the podcar system offers 970 hourly seats per million € in capital cost, that is, nearly four times as many seats per invested Euro as compared to the LRT system, and fourteen times as many seats compared to the metro system.*

5.2 Podcar operating costs are low, too

If the capital cost is lower than all other public transportation rail modes, and equally low as the busway, what about the operating and maintenance costs? Here, it is even more important to gain practical experiences from real life operations. Until such practical evidence can be collected, we will have to rely on feasibility studies from various podcar vendors and from research reports. Therefore, the results below should be judged with caution.

SkyWeb Express[21] has suggested an operating and maintenance cost of 0.22 $ per passenger-mile, corresponding to 0.11 € per passenger-kilometer.

A recent PRT study has been made for New Jersey by Paul Hoffman at Booz Allen Hamilton[22]. As can be seen below, podcars show lower operating and maintenance costs than both bus and LRT.

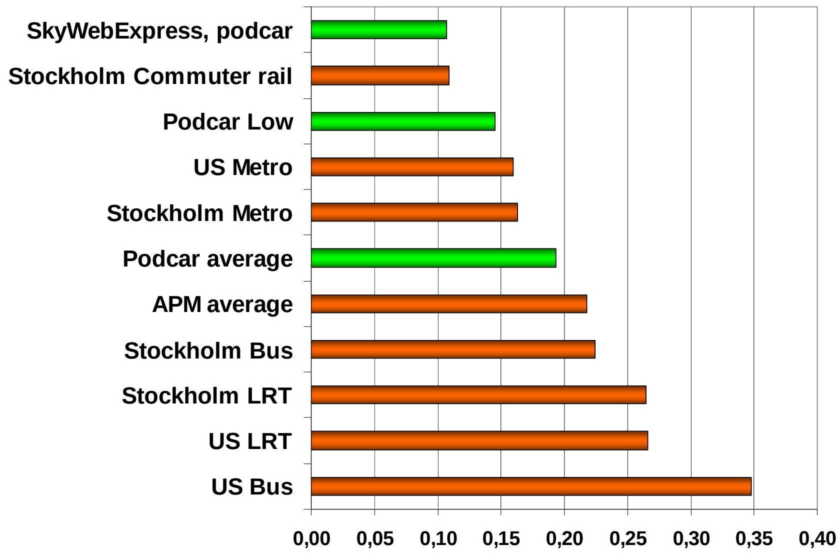

Figure 20. Comparison of operating and maintenance costs in € per passenger-kilometer. Source: See footnote.[23]

There are several explanations to the low operation costs of podcars. One is the lack of driver costs, another its energy efficiency, see **Table 4** above.

[21] See www.skywebexpress.com

[22] ”Viability of Personal Rapid Transit in New Jersey: Final Report. By J.A. Carnegie, AICP/PP; Alan Voorhees Transportation Center; Rutgers, the State University of New Jersey; and Paul S. Hoffman, Booz Allen Hamilton, Inc.

[23] Own calculations of Stockholm data from the Greater Stockholm Transit Co (SL AB) and Viability of Personal Rapid Transit in New Jersey: Final Report. By J.A. Carnegie, AICP/PP; Alan Voorhees Transportation Center; Rutgers, the State University of New Jersey; and Paul S. Hoffman, Booz Allen Hamilton, Inc.

[25] i.e. Automated People Movers, such as AGT.

5.3 Total costs depend on the size of the network

A bus system that runs on an existing road infrastructure has almost only variable costs, such as vehicle capital cost, and costs for manpower and fuel. These costs can be seen as proportional to demand. However, for the rail systems, such as busways, APM,[25] LRT, metro, podcars and rail, significant parts of their total cost represent fixed costs for the guideway as well as for stations.

The total annual cost, as well as the cost per trip or passenger-kilometer therefore becomes a function of demand. In a recent study on costs, a comparison was made between podcars, bus, LRT, and heavy rail.[26] The cost model used considered capital costs on the basis of a 10 km trip, in which vehicle costs as well as operating and maintenance costs were viewed as costs proportional to the demand for trips per day.

Below, this cost model has been updated to the price level of 2005, and includes updated costs for podcars and busways.

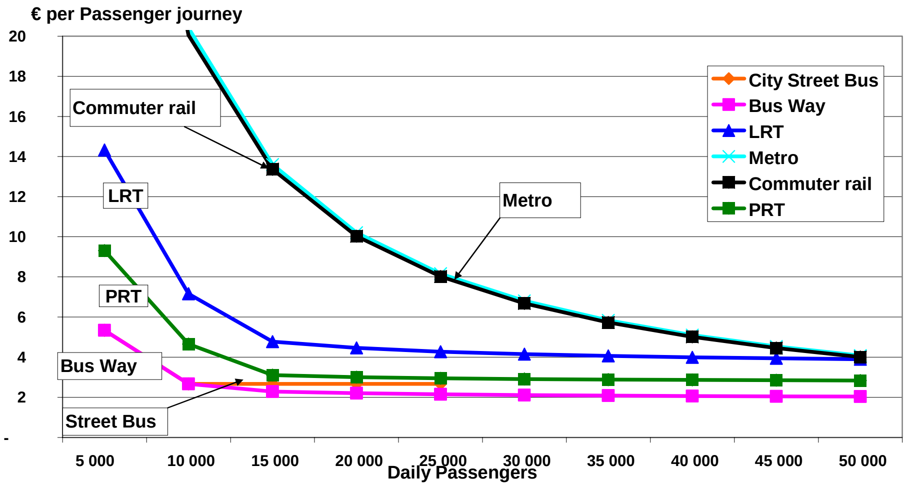

Figure 21. Annual investment, operating, and maintenance costs per passenger-trip (10 km) for various transit modes. Source: Own calculations, partly based on data from Greater Stockholm Transit Co.

The average cost per passenger is € 2.67 for the *street bus* in its capacity interval up to 25,000 daily trips. All other modes show declining average costs as ridership grows.

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[26] ”PRT costs compared to bus, LRT and heavy rail - some recent findings”, Paper presented at the AATS European Conference in Bologna 7-8 Nov, 2005 ”Advanced Automated Transit Systems designed to out-perform the car”. By Göran Tegnér, Transek Consultants

The *busway mode* (buses on bus-only lanes or on dedicated bus guideway) is the cheapest of all the traditional modes. At 25,000 passengers per day, the overall cost per passenger amounts to about € 2.15 per 10-kilometer trip. The Bus Way costs are calculated as an average of six various systems.

The *podcar mode* is also one of the cheapest modes, with a total producer cost per passenger trip of € 2.95 at 25,000 trips per day (2,500 peak hour trips). *Podcars are about 30 % cheaper than the LRT mode*. Thanks to the higher attractiveness of Podcars, this system could attract more passengers for a given track length compared to the other line-haul modes, which would aditionally lower the producer cost per passenger trip.

The *LRT mode* is the third cheapest traditional urban mode up to the same passenger load, 25,000 passengers per day (both directions). The average cost for LRT varies from € 7.2 per trip (at 10,000 trips) to € 4.28 per trip (at 25,000 passengers). At 25,000 passengers per day, LRT is about 64 % more expensive per passenger trip than the city street bus.

The two heavy rail modes, *Metro and Commuter rail* show a rather similar cost pattern. These two systems are built to handle high passenger volumes, even much higher than the 50,000 passengers per day shown in Figure 21 above. At higher loads, say from 25,000 passengers per day, the commuter rail is 4 % cheaper then the metro system; € 8.02 compared to € 8.16 per trip. At even higher loads than 25,000 passengers per day, the commuter rail system becomes even cheaper than the metro system. The reason for the high costs per passenger trip for all modes, and especially for the heavy rail modes, is that we have assumed a minimum level-of-service at 15 minutes headway, and a 10 % peak hour factor.

5.4 Podcars offer lowest producer and user costs

As we have calculated the user costs for various public transportation modes (see section 4.3 above), we can now sum up both the producers' costs (capital costs for infrastructure and vehicles, operating and maintenance costs for the operations) and the user costs in terms of walk, wait, transfer and in-vehicle travel times. These so called *user costs* (or generalized time), usually consist of the following components:

- Walking time
- Waiting time
- In-vehicle time
- (sometimes also Transfer time)
- Fare

The generalized costs in the table below have been derived from realistic averages for travel time components, headway and fare level from the Metropolitan Stockholm Area.

Table 7. Travel time components and generalized times and costs for traditional and PRT modes in Stockholm. Source: Stockholm data and own calculations.

	Time components in minutes				Generalized total time	Generalized time incl. a 2 € fare	Generalized cost in € per 10 km trip
Mode of transport	**Walk**	**Head way**	**Wait**	**In-vehicle**			
Bus	15	30	15	40	100	100	12.6
LRT	5	10	5	24	44	44	6.7
Metro	10	4	2	14	29.6	38	6.0
Commuter rail	15	15	7.5	12	49.5	57	8.1
PRT	5	< 1	0.5	17	22.2	29	5.0
Travel time weight	2		2	1			
Travel time value, €/hour						6,4	

The generalized times have been calculated with the weight of two (2) for walking and waiting time, while the generalized cost has been calculated with an average travel time value of € 6.40 per hour. A € 2 fare per trip has been assumed for all transit modes.

As can be seen, *the podcar mode shows the lowest user cost per trip of all modes*. The bus mode shows a 2.5 times higher generalized cost than podcars. The metro mode has a 19 % higher generalized cost compared to the podcar mode.

When combining both the producer cost and the user cost into a *total cost per 10 km trip*, a quite different picture show, as can be seen below:

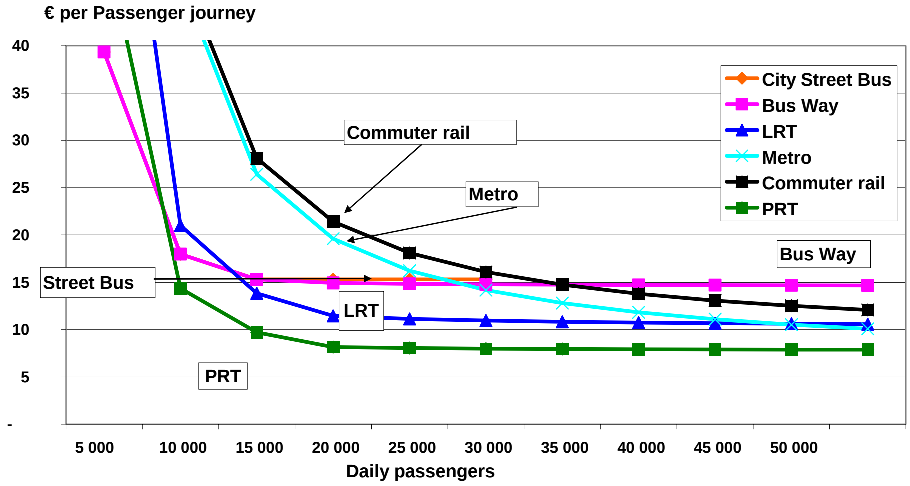

Figure 22. The combined producer and user costs per passenger-journey (10 km) for various transit modes. Source: Stockholm data and own calculations.

Compared to the bus mode, the total producer and user cost for podcars is 48 % lower. Compared to LRT, the PRT cost is 27 % lower, and compared to the heavy rail modes, the PRT cost is 44 % and 50 % lower, respectively. For the bus mode, the user cost is 5 times higher than the producer cost. The user and producer costs of the heavy modes are fairly equal, while for LRT, PRT and AGT, user costs are between 1.6 and 3.2 times higher than the producer costs, and, thus, much lower than for bus. *PRT is the cheapest mode when the user costs are included.*

To sum up: Podcar systems offer twice as high level-of-service at about half the total cost per trip for producers and users taken together, compared to the current public transportation modes.

6 Benefits and costs - recent case studies

In this chapter, results from a small number of cost-benefit analyses on PRT networks are presented. The methods and monetary values used to make these CBA:s differ, since the calculations were made in different countries at different points in time. All costs and benefits are discounted sums corresponding to the entire calculus periods (except for the Kista CBA). However, all effects of PRT systems cannot easily be estimated, and consequently, all have not been included in the calculations. Instead, some points will be made on these at the end of the chapter.

The Swedish CBA:s include tax factors 1 (23 %) and 2 (30 %), meaning that the investment costs have been multiplied with 1.54, to include VAT in the costs (otherwise not included as long as the investment is paid with tax incomes), and to compensate for tax distortions.

In the tables below the indicator: "*Benefit/Cost Ratio*" is used. This is calculated as (Benefits-Costs)/Costs, usually in terms of present values. If the value is above 1.0, then benefits are higher than costs, and the projects are economically viable from a socio-economic point of view.

6.1 Gothenburg

In the CBA for a PRT network in Gothenburg,[27] time gains make up for the largest benefit. The growing number of trips is believed to have large effects on ticket sales, and the increase in ticket revenues more than compensates for the increase in maintenance costs. The decrease in the external effects of car traffic is significant (i.e. a decreased number of accidents and decreased air pollution) but is balanced by the decrease in tax incomes from fuel and vehicle taxes. The analysis is conservatively made and does not include comfort gains, which are often included in public transportation CBA:s.

[27] "Are Personal Rapid Transit Systems Socially Profitable? Olof Johansson, Institution of Economics, University of Gothenburg.

Table 8. CBA results for a PRT network in Gothenburg. Source: "Are Personal Rapid Transit Systems Socially Profitable? Olof Johansson, Institution of Economics, University of Gothenburg.

Effect	Million SEK
Ticket revenues	149
Time gains	180
External effects	25
Capital cost	192
Operation and maintenance	111
Deadweight loss (tax factor 2)	46
Benefit/Cost Ratio	**1.02**

6.2 Kungens Kurva, south of Stockholm

In a study on a PRT network in the commercial center Kungens Kurva,[28] the CBA indicated that the project would give net socio-economic benefits. Also in this case, time gains turned out to be the dominating benefit, followed by decreased external effects from car traffic (this time, however, tax incomes were not decreased, which makes the post overvalued). Land previously used as parking space (and not longer needed) is valued at 135 million SEK, but of which 70 % are instead needed to build car parks in the outskirts of the network. This time, benefits of increased comforts were included. On the other hand, the increased number of travelers was assumed not to give increased ticket revenues.

[28] European Commission, DG Research, 5th Framework Programme, Key Action: "City of Tomorrow and Cultural Heritage", EDICT Huddinge Site Assessment Report, June 2004 (EDICT-values changed into values used in the Swedish transport sector by G Tegnér, I. Andréasson, and N.E. Selin).

Table 9. CBA results for a PRT network in Kungens kurva in Huddinge, south of Stockholm. Source: See footnote [29]

Effect	Million SEK
Time gains	1 533.9
Comfort gains	83.8
Improved air quality	2.5
Improved safety	102.5
Land use	134.7
Capital cost	511
Operation and maintenance	467.7
Car parks	93.6
Benefit/Cost Ratio	**1.43**

6.3 Kista, north of Stockholm

The largest of the calculated networks is the Akalla-Husby-Kista-Helenlund-Sollentuna network north of Stockholm. Investment cost data were obtained from Raytheon’s PRT2000, as well as from two conceptual Swedish systems - Swedetrack’s FlyWay (a suspended PRT system) and SkyCab (a supported system).[30]

The same benefit levels were assumed for all systems, while capital and operating costs differ in the calculation. As opposed to the other CBA:s, the results are presented as million SEK per year, instead of discounted sums over the economic lifetimes of the projects.

Once again, the time travel gains dominate among the benefits, followed by decreased external effects from car traffic. In this analysis, effects on congestion were also included, quite correctly. The reason to why it is most often *not* included is that they are difficult to calculate.

The table below shows that the calculated PRT network north of Stockholm would be socio-economically viable and well justified in the low-cost alternatives SkyCab and FlyWay. The cost-benefit ratio is calculated to be 1.5, which means that one dollar spent on PRT in this area yields one dollar and 50 cents in total benefits. The more expensive Raytheon PRT2000 system would, however, not be socio-economically efficient.

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[29] As above.
[30] KFB-rapport 1999:4: ”Spårtaxi – Ett effektivt och hållbart trafiksystem - Analyser av en pilotbana i Stockholm – marknad och ekonomi”. G.Tegnér, .J. Henningsson, V. Loncar-Lucassi, G.Lind, Transek AB, I.Andréasson, LogistikCentrum AB.

Table 10. CBA results of a PRT network in Kista, north of Stockholm. Source: See footnote [31]

	SkyCab	Fly-Way	Raytheons PRT2000	Raytheons PRT2000(*)
Effect		**Million SEK per year**		
Capital cost	37	63	152	116
Operation and maintenance	73	81	133	106
VAT tax burden (Tax factor 1)	25	33	65	51
Cost of public capital; shadow price (Tax factor 2)	40	53	105	82
Travel time gains			145	
Comfort			35	
Traffic safety			42	
Health and environment			16	
Ticket revenues incl. decrease in tax incomes			26	
Congestion car traffic			17	
Benefit/Cost Ratio	**1.6**	**1.2**	**0.4**	**0.8**

(*) Including development costs.

6.4 Cardiff Bay, Wales

The Cardiff CBA[32] was made according to recommendations from the British department for transport. The British recommendations on discount rates are higher than the rates used in Sweden (6 % rather than 4 %), and the calculation periods (30 rather than 40 years), decreasing profitability. Also, air pollution is not valued. On the other hand, the British use lower tax factors than the Swedes, which increases profitability.

Valuing the energy savings separately probably leads to counting this effect twice, since it is also part of the operating costs. However, omitting this post would only have marginal effect on the net value quota.

According to this CBA, the Cardiff PRT project is socio-economically very profitable, with total benefits amounting to approximately 4 times the costs.

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[31] As above.

[32] European Commission, DG Research, 5th Framework Programme, Key Action: "City of Tomorrow and Cultural Heritage", EDICT Cardiff Site Assessment Report, Deliverable 6; June 2004.

Table 11. CBA results of the Cardiff Bay PRT project. Source: See footnote [33]

Effect	Million €
Capital cost	68
Operation and maintenance	49
Ticket revenues	105
Travel time gains	122
Congestion	52
Energy savings	23
Traffic safety	16
Benefit/Cost Ratio	**3.9**

6.5 Gävle, on the Swedish east coast

The Gävle CBA differs from the other ones in that it does not include estimates on how PRT would affect the number of travelers. Instead, the consequences are described at four different levels of passenger numbers with the new system, while the judgment on whether the levels are reasonable or not are left to the reader. The main result was that the investment seems to be profitable if 15 per cent of car travelers would change mode to PRT, meaning that the public transit system in Gävle would increase its number of travelers by 125 percent.

6.6 Summing up the socio-economics

The benefits of PRT are first and foremost related to time gains, followed by decreased external effects from car traffic, i.e. pollution, traffic accidents, and congestion. It is, however, important to note that all effects of PRT are not included in the cost-benefit analyses, the most significant being encroachment effects (in Swedish ”intrångseffekter”); including for example land use, barrier effects, and visual intrusion. PRT investments tend to lead to land being made available due to decreased car traffic and the possibility of elevated transit. They also affect the cityscape, but whether this is positive or negative is partly a factor of design, and in the end up to the individual to decide. Important to note is that the relative intrusion, compared to the intrusion of other modes, is what matters in this context.

Also, effects on the labor-market from increased accessibility are largely omitted in the CB-calculations. The individual's own appreciation of a job (or perhaps a better one) may be said to be indirectly included in the net value, through

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[33] European Commission, DG Research, 5th Framework Programme, Key Action: "City of Tomorrow and Cultural Heritage", EDICT Cardiff Site Assessment Report, Deliverable 6; June 2004.

the value of time. Effects that the individual does not value, however, are difficult to calculate, such as that higher individual incomes imply larger tax incomes, and that larger labor-market regions are less vulnerable in difficult times.

In addition, PRT may give both positive and negative effects to the vulnerability of the transport system. Positive, since it may prove helpful or even crucial when other parts of the transport system fail. Negative, because PRT would imply still another system that might fail, too.

Lastly, CB-analyses do not pay attention to distributory effects, meaning that no consideration is made in respect to which groups that profit from the benefits, or suffer from the costs. Instead, the results show only the net benefit, as if evenly spread upon all society.

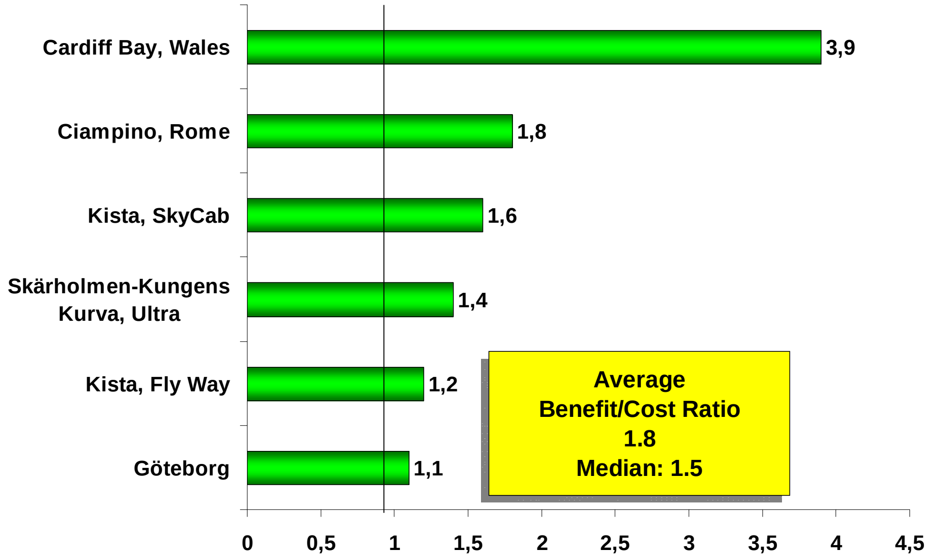

Figure 23. Socio-economic profitability of a number of PRT projects, in terns of Benefit/Cost Ratio. Source: Own calculations. (Nota Bene: There is no text about Pocdars for Ciampino, outside Rome, Italy, due to lack of references).

In conclusion, Podcar projects in general show very good possibilities to prove socio-economically profitable. As with other infrastructure investments, however, each case must be put to trial on its own accounts and merits.

There is no easy-fix solution to the major transport challenges that face us today. However, if wisely planned and implemented, podcars could contribute as a more attractive, cost-efficient and environmentally-friendly mode for individual trips on a common network, available for all, in the striving towards a sustainable urban and inter-urban transport system.

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