PRT mode share estimations using a direct demand stated preference method

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Abstract

Contrary to the widespread assumption that car use is inflexible, we find that a vast majority of the population are in fact ready to change to public transport (PT), if its service characteristics feature an easily accessible, clean, frequent transport without transfers and with seated comfort – characteristics that have proven impossible to satisfy with conventional collective transport. Personal Rapid Transit (PRT) can provide all of these features. In the BICY project, our direct-demand estimate finds that PRT share would become dominant after the provision of a citywide PRT network, and that more than half of the 10 cities, private transport (car and motorcycle) would drop below 15%. We also find PRT ridership will depend strongly on the level of present PT usage: a high current share of PT usage results in a high potential share of PRT ridership, once introduced. This confirms previous findings of studies on PRT mode shares. The difference is that the present study, using direct demand estimation, shows generally higher PRT (and therefore PT) shares.

1. Introduction

PRT is an emerging transport technology, based on small-size, fully automated electric vehicles (see Figure 1). With PRT, up to 6 passengers travel together, by choice; vehicles can be made available on demand and 24h a day; the trip is non-stop to any station connected to the network; and passengers travel both in seated comfort and in a private atmosphere. PRT requires new infrastructure to be installed: PRT guideways are grade separated, which means that they are either elevated, underground or on dedicated on-ground corridors. Guideway dimensions are slim (typically 1.4m width). The most advanced existing systems are: ULTra, in public operation at London’s Heathrow airport (ULTra, 2010); 2getthere, with a circuit in public operation at the sustainable city of Masdar, Abu Dhabi (2getthere, 2010); and Vectus PRT with a full-scale test track in Uppsala, Sweden and an additional system under construction in Suncheon, South Korea (Vectus 2010).

Because only a few, small-scale PRT networks exist at this time, generating ridership estimates faces the “chicken-and-egg” problem, in that a survey respondent is not able to refer to experience when asked whether she/he would choose a future PRT system instead of a car. This lack of experience has frequently prevented a proper calibration of mode share models. Mode share models allow determination of pro-
spective future shares of ridership for all available modes, given a specific scenario. Usually the shares are a function of trip times, trip costs and a mode-specific constant, MSC (also known as mode-specific “convenience”).

Attempts to include PRT in mode share models have been limited in the past. In 1978, Ed Anderson proposed a Logit-type mode share model for PRT ridership estimation. He also showed that the probability to choose PRT increases with station density (or network coverage). However, the PRT share was estimated using public transport mode share models where the MSC was calibrated on the characteristics of bus and car offers. Nevertheless, studies examining several Swedish cities using Anderson’s modeling technique showed that public transport ridership would almost double using a PRT network instead of bus/tram lines.

The first utilization of stated preference interviews to model PRT was conducted within the EDICT project (EDICT 2004), where a large increase in PT share was also projected, confirming the Swedish findings.

In the BICY project, our direct-demand estimate has been used to analyse general mobility behavior, which allows new findings for PRT.

![Figure 1. The three most advanced PRT systems.](image)

In this process we generated mode share estimates from the BICY project and compared it with previous findings, validating the survey methodology. These results combine well with the stated preferences of survey respondents, to estimate mode share given a PRT scenario. A fundamental problem has been to quantify the increase in PT mode share after the installation of a PRT service. In Europe, larger cities achieve a PT mode share of 25-45% in city centers and 20%-30% in larger urban areas. However, in smaller cities the mode share of PT is often much lower. PRT may offer a strategy to increase the PT share as PRT could potentially attract many automobile users due to its high service quality. At the same time, unlike motorized personal transport including buses and surface level trains and trams, PRT would not conflict with other more sustainable modes such as cycling and walking because of its grade-separated guideways.

Section 2 explains the methodology of the survey, and the results are presented and discussed in Section 3, while Section 4 draws the conclusion.

2. Methodology
As part of the Central Europe project BICY, street surveys have been conducted in 10 cities, located in seven central European countries: Ferrara (FE), Comacchio (CO) and Ravenna (RA) in Italy; Graz (GR) in Austria; Košice (K), Michalovce (MI) and Spišská Nová Ves (SNV) in Slovakia; Prague (P) in the Czech Republic; and both Koper (KO) and Velenje (VE) in Slovenia. This survey collected data about the present use of transport modes, and under which conditions interviewees would change from car and motorcycle use, to PT and/or bicycle use.

As a first step, the current modal split has been determined for each city. By modal split we mean the share of regular trips performed by each mode. The modal split has been calculated in the following way: the questionnaire contained a table aimed at gathering information about modes, frequency of usage and trip purpose, see Figure 2. The currently used mode has been the mode used every. In cases where two or more modes have been indicated for everyday’s usage then the mode associated with the longest daily distance has been selected. For this reason, there has been an additional table where the interviewee has indicated how much time she/he spends for each mode on a regular workday. From the time information the daily distance per mode has been estimated, assuming average urban speeds for each mode.

![Figure 2: Part of the survey to ask for transport mode and trip purpose.](image)

The street surveys are not perfectly representative, even though representative groups such as supermarkets and schools have been targeted for the interviews. Statistical corrections have been performed by applying relative weights to interviewees belonging to different groups (males, females, minors, adults, seniors, and car owners. Additionally we validated our modal split results through comparison with others’ findings or by “reality check” where no alternative source for modal split was available. The surveys of three cities (not included here) were rejected either because some groups were not represented or because the modal split was not deemed realistic.

Once the currently used mode was established, we wanted to know how many of those who currently do not use PT would use PT on a regular basis, in a scenario where the PT would provide certain features. In particular we asked: “What are the minimum requirements that would convince you to use PT for your daily trips?”
The interviewees could define their set of requirements by selecting one or more out of five required characteristics (R\textsubscript{m}) from the following list:

R\textsubscript{1}: “the stops or stations can be easily reached on foot (in less than 5 minutes)”
R\textsubscript{2}: “buses, trams or rail are always clean and have air-conditioning when needed”
R\textsubscript{3}: “waiting time is never more than 5 min at a stop or station”
R\textsubscript{4}: “direct connection, no transfers”
R\textsubscript{5}: “there is always a place to sit”

Alternatively, interviewees could choose: “under no circumstances I would make regular use of public transport”. This answer would cancel all previously stated requirements. Further, if no R\textsubscript{m} requirements were given, we assumed that the interviewee is not inclined to change to PT.

Next we find out the relation between PT service characteristics and the share of users who would switch to PT, if certain characteristics were provided. We have defined five scenarios (PT\textsubscript{j}), where each scenario represents a PT service offer, defined through a set of characteristics that the offer satisfies:

- Scenario PT\textsubscript{1} is an area covering network that satisfies only requirement R\textsubscript{1}. Scenario PT\textsubscript{2} assumes the same area covering network, and clean and air-conditioned vehicles (thus R\textsubscript{1} and R\textsubscript{2} are both satisfied).
- Scenario PT\textsubscript{3} satisfies the requirements of PT\textsubscript{2} and includes R\textsubscript{3}, hence waiting times are less than 5 min across the network. (Scenario PT\textsubscript{3} can be considered a best case traditional, line-oriented PT.)
- Scenario PT\textsubscript{4} satisfies R\textsubscript{1}, R\textsubscript{2}, R\textsubscript{3} and R\textsubscript{4}. This is Scenario PT\textsubscript{3}, but without any transfer between any stations. These characteristics can only be satisfied by an on-demand type service, for example a “call-a-bus” where origins and destinations are booked in advance.
- Scenario PT\textsubscript{5} satisfies all the requirements, R\textsubscript{1}, R\textsubscript{2}, R\textsubscript{3}, R\textsubscript{4} and R\textsubscript{5}; which means that it also offers a guaranteed place to sit. The service assumed in PT\textsubscript{5} is de facto either an on-demand taxi service, or a PRT network. But it is worth noting that PRT has never been mentioned to the interviewee. This suggests when answering the questions, the interviewee has been thinking about an ideal bus, train or tram system rather than a completely different transport mode, like PRT.

For the estimation of the PT mode share produced by each scenario PT\textsubscript{j}, we have applied the following algorithm: for each interviewee, his/her PT characteristics that he/she requires for a mode-change have been compared with the characteristics provided in the given scenario. If all of the respondent's stated requirements are provided by the scenario, and the respondent did not negate the possibility of using public transport, then and only then is the interviewee expected to switch to PT. Otherwise, the respective interviewee is expected to continue to use the present mode. It is further assumed that those who already use PT on a regular basis will continue to use PT. With this procedure we obtained a “stated” modal split for each PT scenario, and thus a relation between PT characteristics and PT mode share. Note that any
scenario PT\textsubscript{1} needs to satisfy the associated characteristics in all parts of the city.

4. Main results and discussions

The mode shares obtained from the survey are shown in Figure 3. Note that all Slovakian cities (Košice, Michalovce, SNV) have a higher PT share than similar Italian and Austrian cities. Prague has an even higher PT share, but as stated previously, larger cities do have a higher PT share as they typically have a more dense PT network. The Slovenian cities of Koper and Velenje have a modal split similar to Western European cities. This result is in line with car ownership in Slovenia, which is similar to Western European levels.

![Figure 3. Current modal split as obtained for 10 of the surveyed cities.](image)

Next we discuss the results of the stated PT share for scenarios PT\textsubscript{1} through PT\textsubscript{5}. Figures 4 and 5 show the results for Western and Eastern European countries, respectively. Almost all cities have in common that the PT share of scenario PT\textsubscript{1} and PT\textsubscript{2} remains practically the same as current levels. This means the requirements satisfied by PT\textsubscript{1} and PT\textsubscript{2} (nearby stations and clean vehicles) cannot convince many to change to public transport. The exceptions were Ferrara and Comacchio, where additional stops and cleaner vehicles could attract more passengers.

If a citywide PT network would guarantee 5 minutes maximum waiting time, the survey suggests that this would increase PT share by approximately an additional 10% on average (see scenario PT\textsubscript{3}). In absolute terms, these are PT mode shares jumping to between 20%-45%, depending on the current mode share. An exception is Graz, which remains fairly flat through PT\textsubscript{3}, suggesting there is already a high level of transit service.
Finally, the additional requirements in scenarios PT4 and PT5 are those that would most dramatically increase the PT share – namely, the provision of a citywide network where all destinations can be reached without transfers and always in seated comfort. It is worth noting the main difference between Western and Eastern European cities: the eastern cities reach consistently higher PT mode-shares than western cities. This is true even if cities had similar current PT mode shares: for example, comparing Ravenna with Koper, Ferrara with Velenje, or Graz with Michalovce, we see that the eastern cities show a higher PT share for scenario PT5.

Focusing on scenario PT5 we can state that the requirements cannot be satisfied by line-oriented collective transport. In fact, this level of service can only be satisfied
either by a well-organized and high volume taxi service, or by an area-wide Personal Rapid Transit (PRT) network.

The survey did not ask how much the user is ready to pay for the requested PT service. This means a taxi-service with a much higher price-level than current PT fares is unlikely to attract more demand as it does today. However, if a PRT service was offered at prices similar to current PT fares and if there were no additional congestion-related delays (for example, queues at PRT stations), the present survey predicts a significant modal shift to public transport. The scale of such a modal shift can be seen by comparing Figure 6, showing the current modal split for PT and individual transport (IT = mode share of car + Motorbikes) with Figure 7 showing the modal split of PT scenario PT_5.

![Figure 6. Comparison of current PT mode share and current Individual Transport (IT) mode share for all surveyed cities.](image)

![Figure 7. Comparison of stated PT mode share of PT scenario PT_5 (PRT scenario) and Individual Transport (IT) mode share for all surveyed cities.](image)

It can be seen that the share of PT in the PRT scenario becomes dominant in all cities. Individual transport (IT) becomes almost marginalized in Eastern European countries.

As promising as this appears, it is important to address the limitations of stated
preference surveys, as the results are based on some naive assumptions: it is by no means certain whether people who claimed they would change to PT while compiling the questionnaire, will eventually do so once all their stated PT requirements are met. Yet people have been asked questions about realities that almost everybody has already experienced (we did not asked if they prefer to ride a PRT), strengthening the likelihood that respondents were sure of their replies. Further, the survey first asks detailed time estimates for all regular travel, so respondents have already recalled and quantified their daily travel times before considering PT preferences.

Another assumption has been that PRT will have fares similar to current PT and that the PRT network has the capacity to cope with the generated flows. The PRT systems on the market (see Figure 1) may not have the required capacity for a widespread urban application and are currently likely to be more expensive than an urban bus. (However, the true and total costs of automobile travel should be compared with the prospective provision of a comprehensive PRT system before excluding the possibility of the latter being a more affordable system.)

There is also a secondary effect to consider: even if a citywide PRT network with grade-separated guideways were installed, and a noticeable modal shift towards PRT had taken place, the public would experience less traffic congestion on the road network and it would be more attractive to return to use the car. To prevent this secondary effect, the introduction of any PRT network should be accompanied with measures to reduce road space (conversion to green space, cycle tracks, etc.).

In its further defense, PRT promises even more key characteristics than were represented in the survey: 1. PRT allows travel in a private space without having to share with strangers; 2. The service is available 24 hours a day, on demand. These features could convince even more people, and even further increase PT mode share.

5. Conclusion
A stated preference survey has been conducted in ten central European cities in order to quantify the mode share of public transport (PT) as a function of PT service characteristics.

The maximum share of Personal Rapid Transport (PRT) ridership achievable based on respondent preferences depends strongly on the present level of PT usage: a high present PT results in a high potential share of PRT ridership, if a PRT system were to be introduced. This confirms previous findings on potential PRT mode shares. The difference is that the present study, using direct demand estimation, predicts substantially higher PRT shares.

In the BICY project, our direct-demand estimate finds that PRT share would become dominant after the provision of a citywide PRT network, and that in more than half of the 10 cities, private transport (car and motorcycle) would drop below 15%.
A secondary finding is: even if all PT services had the service characteristics of a state of the art public transport, the PT mode share would remain within the limits of best practice cities in Europe. In contrast, if a comparably-priced PRT system were to provide citywide service, the PT mode share should see significant increases and become the dominant mode. In all surveyed Eastern European cities, car trips would become insignificant.

For policymakers hoping to improve the sustainability of the transport system, major investments in PRT systems deserve further review.

References


