Passenger assessments of quality in local public transport- measurement, variability and planning implications

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Keywords:
public transport, passenger, quality, survey, Stated Preference, assessment, assignment, planning, questionnaire

Abstract:
The aim of this work was to get a more detailed basis for planning of local public transport. With more knowledge of how segments of travellers assess different parts of a journey, bus routes can be planned to fit either all passengers or selected groups better. It will also be possible to evaluate perceived travel utility separately for each category of passengers. Stated Preference questionnaires were distributed to passengers on buses to test different designs of questionnaires and to measure passengers' assessment of quality. It was found that in mail-back surveys, binary choices are recommended over other Stated Preference methods. It was also shown that the ordering of attributes in the alternatives did not affect the assessment results. Another methodological question was how to express the travel cost to passengers travelling with monthly cards, as cost per month or cost per trip. The study showed that the estimated assessments differ depending on cost expression. The assessment studies showed that most passengers find a bus transfer much more inconvenient, than what we have believed before, except from young people and students. Especially elderly passengers found the waiting time much more uncomfortable than in-vehicle time. Most passengers did not find the walking time more inconvenient than the time in the bus. Finally, it was shown how passenger assessments for specific groups can be combined with each groups' origin-destination-matrix in an assignment model to evaluate effects of different planning strategies for each group separately. In this example, a trunk route system gave smaller generalised times, than a traditional radial network, not only for the population as a whole, but also for the four studied traveller groups. To summarise, this thesis has shown that a Stated Preference survey may give increased knowledge about how segments of passengers assess different parts of a journey, which is useful for planning of more efficient public transport.

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Resenärernas värderingar av kvalitet i lokal kollektivtrafik – hur man kan mäta dem, hur de varierar och hur man kan använda dem i planeringen

Sammanfattning

Syftet med arbetet har varit att ta fram ett mer detaljerat underlag för planering av lokal kollektivtrafik. Med mer kunskap om hur olika grupper av resenärer värderar olika delar av en kollektivtrafikresa kan kollektivtrafiknätet planeras att passa alla resenärer eller utvalda resenärsgrupper bättre. Det blir också möjligt att beräkna upplevd reskvalitet för respektive grupp separat vid utvärdering.

Flera undersökningar med värderingsmetoden Stated Preference (SP) har genomförts. Metoden innebär att respondenten ska ta ställning till hypotetiska alternativ, som i det här fallet beskriver bussresor med olika egenskaper (attribut). De egenskaper som ingått har främst varit reskostnad, restid, gångtid till hållplats, turtäthet, byte och väntetid vid byte. Med SP-metoden kan man beräkna hur viktiga egenskaperna är relativt varandra.

I den första undersökningen skickades SP-enkäter ut till bussresenärer, som kontaktats i förväg på busshållplatser i Jönköping, för att pröva olika former av enkäter. Undersökningen visade metoden kan användas i brevenkäter med gott resultat eftersom det var möjligt att anpassa frågorna genom kontaktintervjuer. Enkäter med parvisa val var bättre än de andra SP-typerna rangordning och betygsättning.

I den andra undersökningen användes SP främst för att se hur värderingarna varierar för olika resenärer och på olika resor. Samtidigt gjordes ett par tester för att se hur enkätutformningen påverkar resultatet. I den här undersökningen delades enkäter ut direkt till passagerare ombord på bussar i Göteborg efter en kort intervju. Svaren skickades in med post. Resenärerna fick olika enkäter beroende på deras aktuella restid, bussens turtäthet och använd biljett. En av metodfrågorna gällde om det spelade någon roll i vilken ordning som attributen (kostnad, restid, osv) presenterades i alternativen. Därför hade ordningen av attributen varierats bland enkäterna och resenärerna fick en slumpvis vald enkät. När svaren jämfördes hittades inga skillnader beroende på attributens ordning. Ordningen kan alltså vara samma i alla enkäter och attributen kan presenteras i den ordning som verkar lätt att förstå.

En annan metodfråga som undersöktes samtidigt var hur reskostnaden ska beskrivas för de som reser med månadskort. Bland de resenärer som reste med månadskort delades olika enkäter ut som beskrev kostnaden på tre olika sätt, som kostnad per resa eller kostnad per månad. Resultatet blev olika beroende på hur kostnaden var beskriven och vilket sätt som bör användas beror på hur resultaten ska användas. Om resultaten ska användas för att mäta relativa värderingar bör kostnad per resa användas, medan om resultaten ska användas för att beräkna intäkter bör kostnad per månad användas.

Värderingsstudien visar att värderingarna av bussresans olika delar varierar både beroende på resenären (t ex kön, ålder och sysselsättning) och beroende på resans egenskaper (t ex ärende och resans längd). Undersökningen visar bland annat att de flesta av resenärerna upplever ett bussbyte mer negativt än vad vi hittills trott och att gångtid till hållplats inte upplevs som mer obekväm än tiden i bussen av de flesta.

På väg till arbetet vill man hellre gå en längre sträcka eller vänta längre tid, för att ta en buss som ger en direktresa utan byte. För att ge arbetspendlare den bästa servicen, ska det alltså vara möjligt att resa utan att behöva byta buss, men det är mindre viktigt att hållplatserna ligger nära.

Ett busslinjenät anpassat till studenters behov kan innehålla både byten och vissa gångavstånd, så länge man inte behöver vänta vid bytet. Väntetiden vid bytet värderas nämligen mycket negativt av studenter.

För äldre resenärer är det stora variationer mellan hur de olika delarna av resan värderas. Både täta turer och kort väntetid vid byten är mycket viktigt jämfört med restid. Det är också viktigt med kort gångtid till busshållplatsen och att undvika byten, eftersom ett byte upplevs som lika ansträngande som 20 minuter extra i bussen. Ett busslinjenät anpassat efter äldre resenärers behov ska enligt denna studie erbjuda både korta gångavstånd och direktresor. Dessutom ska bussarna gå ofta.

På fritidsresor liknar värderingarna de äldres värderingar och samma linjenät lämpar sig för fritidsresenärer och för äldre. En skillnad är dock att tidsvärdet är högre på fritidsresor. Det innebär att fritidsresenärer är beredda att betala mer än äldre resenärer för att komma fram fortare. Ingen av de här båda grupperna har emellertid så högt tidsvärde som arbetsresenärer och studenter.

En vanlig jämförelse är den mellan kvinnors och mäns värderingar. I den här undersökningen finns inga signifikanta skillnader i det här avseendet, förutom mellan kvinnors och mäns tidsvärde. Precis som i tidigare undersökningar har män högre tidsvärde än kvinnor. Samma busslinjenät passar alltså både kvinnor och män. Enda skillnaden är att män är beredda att betala mer för att komma fram fortare.

För de som åker buss sällan är det viktigt med korta gångavstånd och att slippa byta buss. Däremot är inte täta turer så viktiga. Den viktigaste åtgärden, för att få de som åker buss sällan att resa mer buss, är att förkorta restiden eftersom den här gruppen har mycket högt tidsvärde.

Slutligen visades hur värderingarna kan användas för att utvärdera kollektivtrafiknät. Fyra resenärsgruppers värderingar och deras respektive resmatriser kombinerades i fördelningsprogrammet VIPS, för att beräkna gruppernas generaliserade restider i ett radiellt nät och ett stomlinjenät. Analysen visade att alla studerade grupper fick bättre service med stomlinjenätet, främst på grund av högre turtäthet.

Avhandlingen har visat att resultat från Stated Preference-undersökningar kan ge ökad kunskap om hur olika resenärsgrupper värderar olika delar av en kollektivtrafikresa. Kunskapen kan användas för att planera en mer effektiv kollektivtrafik.

Acknowledgements

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My thanks and thoughts now go to you who in some way or other have been participating in my work after my licentiate degree in 1999. Professor Bengt Holmberg for important advice about how to make a thesis out of my surveys and for encouraging me to proceed and finish, even though I moved away to Göteborg for the last two years. Assisting professor Karin Brundell-Freij for your generous care for me and for my thesis. I am not at all sad for all your comments on my work! Just grateful for you letting me benefit from your cleverness and knowledge. Thank you Jönköpings Länstrafik and Västtrafik in Göteborg for letting me use your passengers for my questionnaires. The staff at the department of Water Environment Transport at Chalmers University of Technology for letting me into your fellowship and being part of your daily working life, even though I was some sort of an alien from Lund. (I do remember that when I first came to Lund in 1992, I was an alien from Chalmers). Thanks to all of you who opened your homes for me when I needed somewhere to sleep after intense days at the department in Lund. Welcome to stay with us in Göteborg! Thank you also everyone else at the department of Technology and Society for filling my time in Lund with pleasant memories!

Finally, I want to thank my family (both Thomas, Susanna & Pontus, my parents and sisters, and in-laws) for letting me spend so much time on my thesis. Now, I am finished!

Göteborg in September 2001
Helena Sjöstrand

Contents

Passenger assessments of quality in local public transport - measurement, variability and planning implications

1 Public transport planning and passenger assessments

1.1 Reasons for public transport planning

Public transport is one of the fundamental services in society (Vägverket, 1998). A well designed public transport gives improved welfare, better economy for society, the individual and industry; increased availability; improved environment and improved traffic safety, and it contributes to regional development. The public transport systems is a means and a tool to reach the overall transport political goals.

The subject of public transport planning is also interesting and important to study because

- many people use public transport, and many of them do not have any choice
- often, about half the costs of local public transport in Sweden are subsidised through taxes while the other half is paid by tickets and advertising revenues (SIKA, 1998). According to Vägverket (1998), the annual subsidy to road public transport is 12 billion SEK. As we are all, as taxpayers, paying for the public transport system, we want the money to be used in an efficient way.

Whether or not public transport can be considered as efficient depends on goal fulfilment. Therefore, a goal has to be defined, and there must be a way to measure the extent to which the goal is reached. At the same time, the cost must be considered. Thus, efficiency is the extent of goal fulfilment in relation to cost.

Society pays for public transport to reach the following common goals (Holmberg, 1995):

- to guarantee accessibility to different activities in the society, especially for people who do not have access to a car
- to improve the environment, i.e., to reduce air pollution and noise, to create a more attractive cityscape
- to reduce the consumption of energy and thus the emission of carbon dioxide
- to reduce congestion on streets and highways

To reach these goals, society takes a more active role when planning public transport, than when planning individual transport (Holmberg *et al.*, 1996). While planning public transport, as well as other transport, information about total travel demand, origin-destination-matrix, mode choice and route choice is needed. This information can be seen as steps in a transportation forecast model, such as the one in figure 1. The model in figure 1 aims to describe behaviour of travellers and is based on the four steps often used in transport modelling (see e.g., Ortúzar and Willumsen, 1990). The first step, trip generation, estimates total number of trips generated in the investigated area. Step 2, choice of destination, estimates between which pairs of origins (O) and destinations (D) in the total area that these trips will be performed, that is the OD matrix. In step 3, mode choice, the trips are distributed according to modes, i.e., car, bus, bike, etc. In the fourth step, route choice, finally, the trips are distributed on specific roads and bus routes. Between each two of these steps the connection to the next step is dependent on personal preferences. Mode choice and route choice are also affected by the standard of the supplied public transport network, that is, bus routes with bus stops and headway, etc. The right-hand side of the figure shows how each step is connected to the goals of public transport mentioned above.

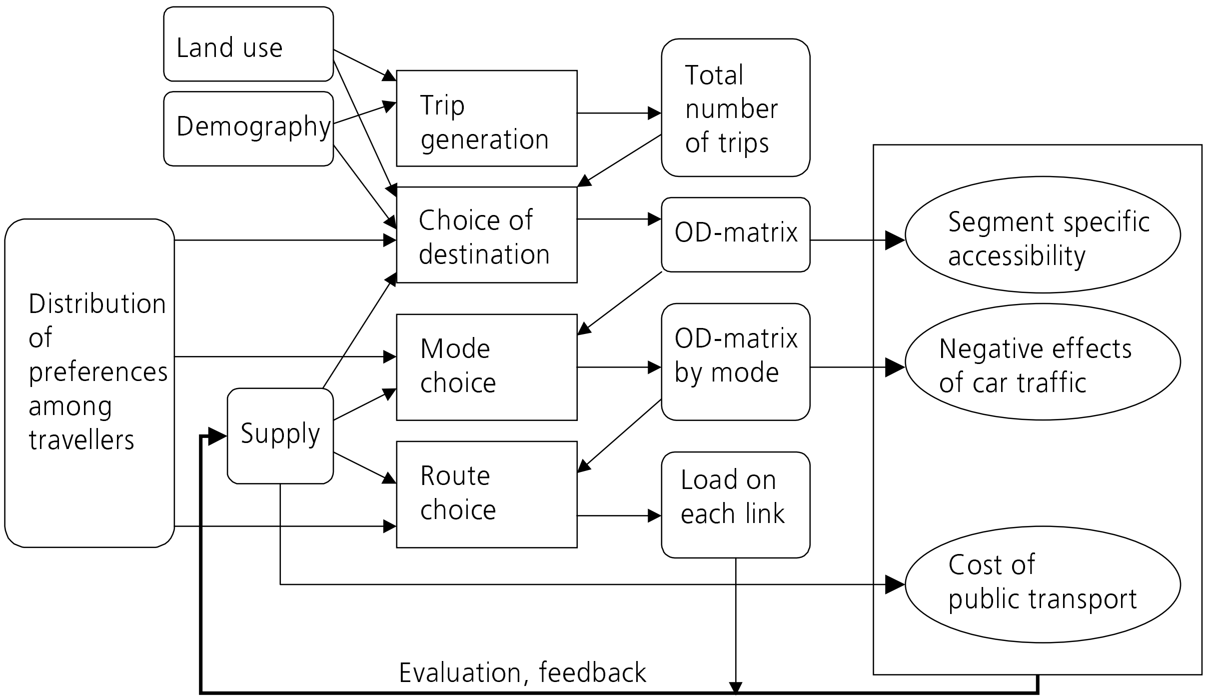

Figure 1 Steps in the model for estimation of traffic load, where traveller preferences come in and how the steps relate to the goals of public transportation.

To make the planning effective and to fulfil demands from passengers as well as possible, it is necessary to have knowledge about what the passengers want, that is, their assessments or preferences. Passenger assessments are thus an important piece of information when evaluating suggestions or when assessing whether the goals of public transport have been reached.

1.2 Literature about planning strategies

This section reviews literature about different planning strategies, with a focus on Sweden. Planning of public transport is often a trade-off, balancing within certain dimensions (see e.g., Bates, 1986). The dimensions can be divided into

- level of route differentiation
- area coverage
- transfer rate
- headway
- distance between bus stops

Within each of these dimensions there are often two extreme principles. Due to budget or other reasons public transport planning is often a question of finding an optimum between extremes. All the dimensions interact and therefore they are described under only three headings below.

1.2.1 Level of route differentiation

The extremes can be described as

- to provide the same route network to all passengers during the entire day
- to provide separate networks with special routes, for example for elderly or during off-peak periods

Traditionally, the route network in a town has consisted of one type of route to serve the demand for all types of passengers. But during the 1980s a development towards differentiation of routes started, after a Swedish law in 1979 stating that planning and operation of public transport must consider the needs of differently abled people (Ståhl *et al.*, 1993). To satisfy the demands of elderly or impaired people, new routes were added to the traditional network. The new routes were characterised by short walking distances, low-floor vehicles and a timetable that allows drivers to help passengers as much as they need. This concept was called "Service routes" and was introduced abroad as well. Passengers on these routes are very satisfied, but the system is expensive to operate.

Another kind of differentiation is to provide different networks during different parts of the day to accommodate both those commuting to and from work, and those travelling for the purpose of recreation or shopping, as recommended by Stokes (1988). The author concludes that bus services should be both very frequent, have good penetration into residential areas, and have good interchange to other services. If priorities have to be made because of budget constrains, rush hour services should be frequent and direct with less residential area penetration, while services during other times of the day should concentrate more on reducing the need for walking (Stokes, 1988).

The reason for having different networks is thus to adapt the public transport supply as much as possible to the demand, both because of passenger characteristics, vehicle size and time period.

In Malmö a differentiated network system was introduced in 1989 (Lundblad, 1989). The new networks were differentiated in that special services were targeted to specific groups, for example, to commuters or to elderly passengers, and they varied depending on the time of day. The aim of the new system was to adapt the public transport to the demand and thereby provide a higher quality of service to the passengers. But passengers did not catch the commuter express buses as was expected. Instead, most of them used the somewhat slower basis routes. The reasons for this were probably due to information problems, in that passengers only managed to learn one of the two time-tables and they then chose the basis routes that operated all day.

In other words, over the years there has been a trend from having one basic network serving all passengers' needs towards a differentiation of networks for passengers with specific needs. However, now the trend is swinging back again to one common network, according to Börjesson and Eriksson (2000), who summarise the research done in Sweden from 1993-1998 about public transport. They see that route networks are no longer differentiated according to different traveller groups, but many cities have introduced trunk routes with supporting routes covering the area. Because of legislation concerning availability for the elderly and impaired, almost all buses now are low-entrance buses or low-floor buses. As a consequence, the need for special service routes has decreased.

Except for the legislation, another important reason for having only one network is the information problem, especially among infrequent users. It is of course confusing if buses from one bus stop go to different destinations during different periods of the day, or the bus route is differently signed on specific days.

In some cities, though, for example in Göteborg, new special services for the elderly and disabled have been introduced during the last years; these are called Flexlines (Westerlund and Jonsson, 2001). These systems are operated by mini-buses and are demand-responsive. Buses only go to bus stops where a trip has been booked. The booking should be made no later than 15 minutes before the bus leaves the main bus stop. A sophisticated computer programme then determines the optimal route and calls the passenger back to confirm the departure time. The most important factor is the behaviour of the bus drivers, who are known to be very helpful on these buses.

1.2.2 Area covering

The extreme points in this dimension can be expressed as

- to make the routes as fast and straight as possible
- to reach all possible destinations without requiring large walking distances, with an extensive winding route network

This dimension is, of course, linked to headway (TRRL, 1980). If the number of available vehicles is fixed, there is a choice between either concentrating the vehicles on to just a few routes with high-frequency services, or spreading them thinly over a larger network. As we will see below, the third dimension, too (transfer rate), is related to walking distances and headway.

In Denmark, the trend during the nineties has been to increase the frequency of train and bus services instead of shortening walking distances to stops (Trier, 1999). According to Trier (1999), travellers prefer a shorter headway to having the bus stop close by. Then travellers do not need timetables, and transfers are no problem because of short transfer waiting times.

In contrast, earlier work by Fielding *et al.* (1976) found that proximity to a bus route is more important than price, travel time and transfers for providing a competitive public transport alternative.

A comparative study of accessibility to public transport for inhabitants in 45 Swedish towns in 1980 and 1995 was made by Reneland (1998). According to this report, route networks covered the town areas well both in 1980 and 1995, and most municipalities have extended their public transportation service during this period. The extension, however, often consisted of increased frequency of service, which did not contribute to covering the town areas, that is, it did not reduce walking distances to bus stops. When comparing different town sizes it was found that in larger towns the average distance to a frequently operated public transportation route was about one third of that in the smaller towns.

1.2.3 Transfer rate

The extreme types of networks to consider under this dimension are

- to provide a route network that allows most of the passengers to travel without transfers
- to provide a system with local buses feeding larger trunk buses, which implies transfers for many passengers, but probably also reduction of cost per passenger kilometre

Van Nes *et al.* (1988) indicate that the two constraints when optimising a bus route network are that a) transfers affect the number of passengers negatively, and b) the number of vehicles depends on the available budget. Therefore they formulate their optimisation problem as to "Maximise the number of direct trips given a certain fleet size".

Other networks rely on fast, frequent trunk routes with feeder traffic, which implies more transfers. See for example Cederberg (1999) for discussions about routes, or Svensson (2001) for a discussion of the effects on the elderly passengers of this kind of system.

The two extremes, with either direct services or transfers, are also discussed by Jara-Díaz and Gschwender (2001). They show that optimal route structure depends upon many aspects, some related to the relative values of waiting and in-vehicle time, and some related to the particular spatial shape of demand and its level. A mathematical model is formulated, which includes a fixed demand and the mentioned assessments (but not how assessments vary among passengers). It is further concluded that if passengers' negative assessments of transfers are not taken into consideration, a system based on transfers is always more efficient than a system that provides direct trips between all destinations.

1.2.4 Use of assessments in planning

As shown above, there are many trade-offs to consider and decisions to make when planning public transport. Trends have come and gone, and their appearances have depended on what was believed to be right for the moment. These choices are often made without asking passengers about what they want. Irrespective of which kind of system a city or the planners are aiming for, more knowledge of passenger assessments and OD matrices will enable higher perceived travel quality for passengers and more efficient planning.

Some network planning questions were described above. How passenger assessments can be of benefit in the planning procedure when, for example, balancing walking distances to bus stops against bus frequency, is shown by Lundberg (1977). It is shown that the average passenger would get lower generalised cost if bus frequency were increased at the expense of longer walking distances. It is, however, pointed out that a route network that gives the best average trip quality is not necessarily the "best network", depending on which group the network is planned for. Quality for passengers with disabilities is assumed to be higher in route networks with shorter distances to bus stops, even if bus frequency is lower. Lundberg accordingly states a weakness associated with using average assessments instead of group-specific assessments.

There are also some other planning issues with which passenger assessments can be used. One example is the planning of timetables, which is described by de Palma and Lindsey (2001). They analyse the optimal timetable on a single public transport route, depending on passengers' preferred travel time and scheduled delay costs.

Another phase of supply planning that can benefit from assessment studies is vehicle design. Kottenhoff (1999) uses results from Stated Preference surveys to tell which measures on passenger trains are cost efficient, depending on passengers' preferences in relation to cost. Calculations reveal that the increased utilisation of space and higher speeds are two of the most important factors when it comes to cutting costs.

Widlert *et al.* (1989) show that assessment studies can be used to compare passengers' willingness to pay for improvements of public transport (e.g. rain shelters, cleaner vehicles, regular service, etc.) with the cost for the improvement in case. In a similar way, Kjörstad (1995) shows how many passengers a bus stop needs to make the utility of a rain shelter higher than the cost for building and maintenance.

Above, assessments are shown to be important in development of public transport. Lately, benchmarking of public transport has also become an interesting topic (European Commission, 1998). For example, in Prioni and Hensher (2000), a Stated Preference survey is used to develop a Service Quality Index for bus trips. The index enables the regulator and bus operator to benchmark service effectiveness.

Many important planning problems require information about how traffic is distributed in a network. The distribution can be modelled in assignment models. For car traffic, assignment is typically about minimising travel time. The most commonly used car assignment model in Sweden is EMME/2. Assignment models for public transport are more complex since they usually take care of the fact that different components of the trip are differently assessed by the passengers. For example, the Swedish assignment model VIPS (2000) takes the relative weights of walking, waiting and in-vehicle time into consideration. But, exactly as with the corresponding car models, homogeneous preferences are generally assumed. There is ongoing work, though, about considering differences in passengers' utility functions, see Nielsen (2000). Assignment models provide the key to solving the network planning problems introduced in sections 1.2.1-1.2.3 above. Passengers' points of origin and destination are combined with spatial distribution of supply, which greatly affect the perceived travel quality.

1.3 Swedish planning in practice

I conducted a telephone survey in 1994 as part of preparatory work for a research proposal. One of the aims of the survey was to find out which planning tools and knowledge of demand were used at that time when planning public transport. The second aim was to investigate the need for new computer-based tools and which information they were lacking when planning local public transport. A limited follow-up study was conducted in 2001.

1.3.1 Method 1994

In the autumn of 1994, 29 persons responsible for local public transport planning either at local or regional authorities were interviewed by telephone. The regions and towns included represent a large proportion of towns in Sweden; they are listed in appendix 1. The interviews were conducted following a questionnaire with open-ended questions regarding which kind of public transport routes and networks they had, which kind of planning tools they were using, and how they learned about the travel demand in their towns.

1.3.2 Method 2001

In 2001, 9 planners at either local or regional authorities for public transport were contacted. I asked for their aims when planning local public transport, and whether and how they were trying to give priority to any specific traveller group. Just as in the study in 1994, open semi-structured interviews were held to gain impressions about current planning trends. The represented towns are listed in appendix 1.

1.3.3 Results about planning tools and basis for decision-making

In 1994, advanced computer programmes as VIPS and EMME/2 were used only in the largest cities. Smaller cities used the computer-aided planning and database system REBUS to create timetables, and customised procedures in Excel to estimate number of required vehicles, etc. Many planners in smaller cities indicated that their city was too small to need an advanced planning system. Instead they relied on manual methods and tradition. In 2001 assignment model VIPS was in use in more places, but smaller cities still did not think they had the need.

Already in 1994 electronic ticket systems collected statistical data on all performed trips in most of the cities. In the largest cities automatic passenger counting, ATR, was used. Often, rather old travel surveys were used as a basis for planning. Planners said that they were lacking information about what travel standard passengers expected and where passengers leave the bus. They were also interested in knowing more about people who never use the bus, how they choose their travel mode and in which relations they want to travel.

1.3.4 Results about planning philosophies 2001

In 2001, most planners stated that they provided a base network that should fit the demand for all passengers; other planners stated that they provided different networks for groups with different needs, for example, the elderly. The reason for providing only one network was to make the system as simple to understand as possible, and easy to inform people about.

One aim mentioned was to keep public transport fares low. Larger cities had the aim of providing fast connections without transfers between residential areas and working areas. Other planners indicated that they had an extensive route network within which nobody was far from a bus stop.

Tools for supporting the balance between goals and for evaluating how well the goals are fulfilled still seems to be rare.

1.4 Aim, contents and limitations of this thesis

Against the background above (literature, my telephone survey and actual development) it can be said that a more detailed basis for planning of public transport is important and useful. The aim of this thesis is to describe passengers' assessments of quality in local public transport. It shows how to measure the assessments, how assessments vary among passengers, and finally, what implications the assessments may have for planning. To measure assessments, I have used Stated Preference methods, which will be described in chapter 2. The quality aspects studied are cost, in-vehicle time, walking time to bus stop, headway, transfer and transfer waiting time. My results are generally presented in terms of importance relative to in-vehicle time. These aspects are the key aspects both for planners and for passengers (Holmberg, 1977). Other often-studied variables that affect the level of comfort on public transport and whether or not a trip can be made are cleanliness, helpfulness of driver, design of vehicle and bus stop, information, lighting, noise and vibrations (e.g., Johansson, 2000). These aspects are implicitly incorporated into the value of time, although they are not explicitly valued.

The assessment surveys that are available often concern only trips to work (e.g., Widlert *et al.*, 1989), and passengers are seldom segmented into groups. Some studies deal only with regional trips (e.g., Algers *et al.*, 1995 and Widlert, 1992) and some do not consider transfers (Wardman, 1998). TÖI has conducted many studies in Norway, which will be referred to later on. A Swedish assessment survey, which presents relevant results, was done by Blomquist and Jansson (1994). The focus of that report, however, is on whether or not passengers used timetable.

In any case, it is known that surveys of consumer attitudes can assist management in designing competitive services (Fielding *et al.*, 1976). Referring to an American handbook (Transportation Research Board, 1998) it can be seen that very few public transport agencies presently conduct rigorous market and customer research. Even fewer of them act effectively on the results of the research. An effective program of market and customer research would make a major contribution to choosing among decision alternatives when resources are diminished, and the question has become how to acquire the most new riders for the lowest cost.

In Sweden, the Swedish National Road Administration (SNRA) was given the overall responsibility for public transport on roads some years ago. SNRA states that one necessary improvement in public transport would entail a more thorough study of customer demands by means of interviews, questionnaires, etc. (Vägverket, 1998). One important effort of SNRA concerns increasing knowledge about customer demand in public transport.

With more knowledge of how different segments of travellers like or dislike parts of the journey, bus routes can be planned to fit either all passengers or selected groups better. To be able to study segments, more detailed survey results than the ones available were needed. And to carry out a more detailed survey, the Stated Preference method was used. As the Stated Preference-method still needs to be developed, some methodological tests have also been accomplished in this thesis. Figure 2 shows this relationship and identifies which problem is handled in which of the papers in this thesis.

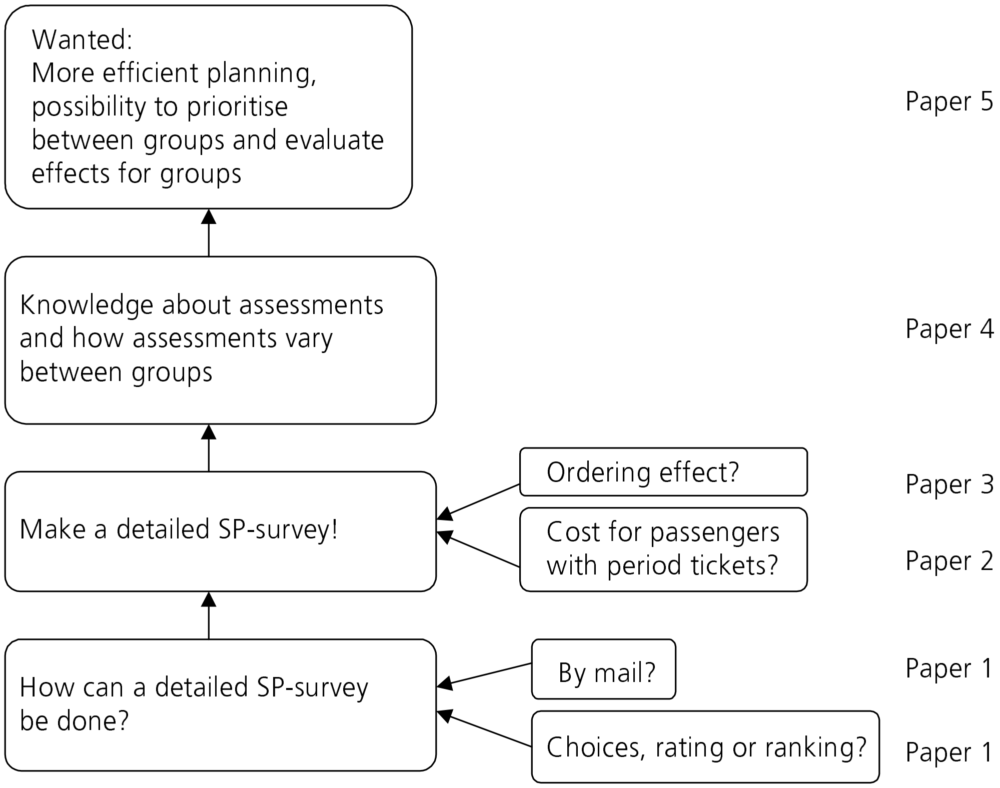

Figure 2 How different papers in this thesis are connected to each other. The boxes to the right relate to the methodological issues in the papers and will be explained below.

Papers 1-3 deal with methodological problems of the employed Stated Preference method. The first paper shows how a Stated Preference-study, adapted to respondents' conditions can be carried out. Paper 2 discusses how the travel cost shall be presented to passengers using monthly tickets, and paper 3 investigates whether the ordering of attributes within alternatives has any effect on results. Paper 4 shows the actual results of the Stated Preference-studies, how assessments vary among passengers. Finally, the fifth paper shows how the assessments can be used to evaluate public transport systems. The results from the demand study are thus brought over to the supply side to show how quality assessments can be used as a basis for planning. With more knowledge about how many passengers are going to use each route (the assignment), the fleet of vehicles can be more efficiently used because we can predict where larger or smaller buses must be used. Furthermore, the choice of which parts of route-segments to combine can be optimised.

This thesis describes the demand for public transport in greater detail than most studies. Passengers are segmented in different ways to make it possible to study how assessments vary depending on personal characteristics such as gender, age and frequency of travel by bus, and on trip properties, such as purpose and duration. It is assumed that looking at various segments of passengers will provide more accurate estimations than would be the case if only an average value were used for all passengers. The segmentation also allows for group-specific evaluation, which is important in view of the goals mentioned above.

This thesis does not, however, deal with mode choice, that is, the circumstances under which a person will choose to travel by bus, car or bike. A fixed total demand of bus trips is assumed, and, instead, the investigation concerns which bus route will be chosen (the assignment problem) and what level of travel quality will then be perceived. This limitation is admittedly a weakness. But public transport users are interesting in their own right, and they are also interesting in that many of them are captive, that is, they do not have any choice. However, in paper 5 the mode choice is considered to some extent.

2 Measurement of passenger assessments

Chapter 1 concluded that assessments can be of great use in planning. This chapter will show how assessments can be measured.

Assessments of trips are often made in terms of the perceived utility of a performed trip. The utility of a trip consists of the utility of trip components; some of them are inside a vehicle and some of them are outside a vehicle. The components have properties such as time, cost, etc., which are called attributes. The separate contribution to utility from each of them is a combination (product) of experienced relative importance of one unit of the attribute and amount of the attribute. By dividing two quality importances with each other (e.g. walking time to bus stop and travel cost), the relative weight of the first one (walking time) can be expressed in the second (in SEK/hour).

A comparison of passengers' utility can not be made directly, but we have to find an equivalent measure. This measure is often equivalent time or equivalent cost. In these measures all components of the trip are recalculated to either time or cost. A component such as a walking time that is 5 minutes shorter, for example, can be expressed a being equivalent to either 7 in-vehicle minutes or 2 SEK.

According to the theory referred to in Mackie *et al.* (2001) there is a strong relationship between value of time and experienced travel comfort. The subjective value of time comprises three components of which one is directly related to marginal (dis)utility experienced when travelling, that is travel comfort. Thus, if comfort is satisfactory, the value of time is low, and if comfort is unsatisfactory, the value of time is higher. This is why in-vehicle time normally has a smaller value than has out-of-vehicle time. The second component is related to the amount of marginal utility of leisure time. The third component is related to the marginal utility one gets from money.

Generally two kinds of methods are available for assessment studies: Revealed Preference studies (RP) and Stated Preference studies (SP). In RP, real behaviour is studied, while, in SP, respondents are given hypothetical alternatives to react to.

Another kind of survey is satisfaction scale surveys, which measure satisfaction more directly. But, as claimed by Hensher (2001), if service providers are to establish a mechanism for prioritising the improvements in services that produce the greatest gains in consumer satisfaction, it makes good sense to understand the relationships between the attributes, given a knowledge of the weights that individuals place on each attribute. These weights can be estimated from SP- or RP-studies.

SP methods can generally be divided into contingent valuation methods, CVM, and conjoint analysis, CA. In CVM, a scenario is described and the respondents are asked to state their willingness to pay to get the described improvement, or how much they, at a minimum must be compensated to accept deterioration. In CA, several alternatives are described and the respondents' preferences are shown either as choices between alternatives, or as rating or ranking of alternatives. The most common type of CA (Sheldon, 1999) is the type which is used mainly in this thesis, namely binary choices. An example of such a choice situation is shown here, presenting two alternatives, each of them describing a bus trip with travel cost, travel time and bus headway, figure 3. The respondent is supposed to choose the preferred alternative, that is, the alternative that gives her or him the highest travel utility.

Choose one of the alternatives in each pair!

Your ticket costs 15 SEK The bus trip is 15 minutes There is a bus every 10 minutes	Your ticket costs 10 SEK The bus trip is 20 minutes There is a bus every 15 minutes
I prefer ☐	☐

Figure 3 Example of a choice between two hypothetical bus trips.

By letting the levels of the attributes vary between questions and collecting many answers, the relative importance of each attribute can be estimated.

Before SP methods were known, RP methods were used to estimate people's value of time, and other weights. This has traditionally been done by watching their choice between travel modes and knowing the in-vehicle time, access time, cost, etc. of each alternative involved. The weights passengers lay on different time components can also be found by observing their route choice in an existing public transport network, knowing the properties of each route alternative.

The problems with RP data with respect to this aim are several:

- often some variables such as time and cost are correlated,
- it is difficult to know properties of unused alternatives,
- not many people really have a choice,
- many choices are obvious with a choice probability close to 1, and
- the number of observations per individual is limited.

Because of these restrictions RP methods seldom allow for the study of segments of passengers and their assessments. When SP methods were introduced, many advantages compared to RP were reached. Each individual could give more than one observation, levels of attributes could be presented un-correlated (Hensher, 1994), and the choice of attributes to assess was unlimited. SP methods even give opportunities to find the valuation of products that are not yet present on the market (such as new vehicles) or for products not traded in the real market (such as environment and safety). SP data can reveal the importance of more subtle characteristics such as that savings and losses of travel time are valued differently (Gunn, 2001). See for example

Louviere *et al.* (2000) for a profound comparison between Revealed and Stated Preference methods.

The most important disadvantage of SP compared to RP must be that we cannot be sure that people would react in reality as they say they would, according to the SP survey (cf. Louviere *et al.*, 2000). The validity of an SP survey can be increased in several ways; some of them are described further down.

Monetary values for time, frequency and other hard variables derived with SP methods have been acceptably consistent between studies (Bates, 1994). Valuation of soft variables such as comfort and cleanliness is more uncertain and more affected by the "packet problem" (see below).

According to de Jong (2000), the general results for values of time in the UK and the Netherlands from SP were very similar to the RP outcomes, but the former had much smaller standard errors. The reason for the smaller standard errors is believed to be that the researcher can control the statistical design of the SP survey, but in RP there is usually correlation between variables of interest.

Both RP and SP methods rely on simultaneous information about the choice and the amount of each attribute (e.g., cost, time) for both chosen and unchosen alternatives being given.

Often a linear utility model is formulated for each available alternative as

$$U = \Sigma (a_i * x_i) + \varepsilon$$

where
a_i are the relative importance attached to each attribute
x_i are the amounts of each of the included attributes
ε is the random or unobservable error effects associated with the utility of an alternative

The a_i:s are now the basis for describing the assessments and express them as weights relative to either in-vehicle time or travel cost.

We assume that each individual has chosen the alternative that gives him or her the highest utility. Then, after having asked many respondents about their choices, we, intuitively, have many constraints on the U:s. Based on this information, the a_i:s may be estimated so that the constraints are fulfilled as well as possible.

The probability of choosing an alternative depends both on the utility of this alternative and of the other, competing alternatives. From the definition of utility we see that those utilities, on top of the level of attributes, and the importance attached to them, also depend on the distribution of ε. Common assumptions about these distributions give the multinomial logitmodel

$$P_1 = \frac{e^{(\Sigma a_i x_i)_1}}{\sum_j e^{(\Sigma a_i x_i)_j}}$$

P_1 is the probability of choosing alternative 1 among all alternatives j

The parameters a_i of logitmodels are often estimated (maximum likelihood) by using the computer package Alogit (1992).

2.1 Computer or paper questionnaire and choice, rate or rank

Often, Stated Preference surveys are conducted as home interviews because of the rather complex questions involved. Home interviews are, of course, rather expensive and time consuming to do, and therefore alternative survey locations have been tested. When long-distance or regional travel is the subject of the interview, it is possible and very valuable to interview respondents on board the train or bus. Passengers are then often happy to offer their time, and while they are travelling they are in the right environment and it is easy for them to remember the present journey and what made them choose this specific route etc. When local public transport is studied, however, the environment on the vehicle is too disruptive, many passengers are standing, and the trip is often too short to allow a survey there. Another means is to approach people on the street or on public transport and invite them to an interview in an adjacent hall; this is called a "hall test".

Computer-assisted interviews have many advantages over such other survey media as paper or face-to-face interviews (Bradley, 1988). Questions can be attractively presented and they can be customised according to previous answers, which is well known to be very important for quality of results. The surveys made in Norway by TÖI have mainly used computer-interviews (e.g., Norheim and Stangeby, 1993, and Kjörstad, 1995).

Mail-back questionnaires / paper questionnaires, on the other hand are expected to give low quality results because of the low response rate and difficulties in customising Stated Preference experiments to respondents' conditions (Sheldon, 1999). Mail-back surveys, however, are not as expensive as personal interviews and therefore they make it possible to include a larger number of persons in the sample. A larger sample is desirable for several reasons:

- as mentioned above, there is a desire for more detailed information about how different passenger groups assess quality
- individual respondents cannot answer too many questions because the quality of answers decreases when a respondent gets tired or bored
- individual respondents should not give to many answers, because standard errors of estimated parameters are more underestimated the more questions each respondent has answered (e.g., Ouwersloot and Rietveld, 1996, or Bates and Terzis, 1997)

To combine the advantages of computer-assisted interviews and mail-back questionnaires, a customised mail-back survey was performed (paper 1, Sjöstrand, 1999b). The aim was to see how a Stated Preference study by mail, adapted to the respondents' conditions, can be carried out. Six different Stated Preference questionnaire types were created to see if the game type had any influence on response rate and quality of answers. The study was performed in Jönköping.

As the subject of the study was quality in local public transport, potential respondents were approached at bus stops. When they were approached, they were asked about their travelling time on the bus this time, and for their name and address. The travelling time was used to customise the Stated Preference experiment regarding this attribute, and the address was used to mail the questionnaire to the person's home. The questionnaires would be mailed back. This approach was also used by Bradley and Gunn (1990) in a Dutch Value of time-study. The alternatives in the SP experiment described a bus trip with attributes such as in-vehicle time, walking time to bus stop, headway, travel cost, etc.

Alternatives were to be judged by respondents in different ways, either as

- six binary choices, printed either on one paper or on separate cards, or
- as rating of six alternatives, on a scale either between 0 and 100 or between the best and worst possible alternatives, or
- as ranking of six alternatives, either printed on six cards or on six sticker labels.

Each of the six questionnaire types was sent to 70 passengers. Two reminders were sent out. The results from each of the six questionnaires were then compared with respect to response rate, number of useful observations, share of lexicographical answers, scale factors, reasonability and precision of assessments, and comments from respondents.

The study showed that it was possible to carry out a SP survey by mail and get a fairly high response rate (up to 90%). The questionnaire type that showed best results was the binary choice type. This type appeared easiest for respondents to understand; it gave reasonable assessments and acceptable standard errors. Rating on a scale between 0 and 100 had advantages such as low share of lexicography and small standard errors of estimates, but gave a lower response rate. Rating between the best and worst possible alternatives seemed too difficult to perform for many respondents. Both ranking types had high response rates and were considered interesting by respondents, but they were lacking with respect to quality of estimates. Also Sheldon (1999) recommends choice methods as choices are closest to real choice situations and therefore thought to be most reliable.

2.2 Attributes and levels

When choosing which attributes to assess and how to describe them, it is very important that respondents recognise and understand them. After estimating the assessment of each of them, one must not forget that their values cannot be added to each other. This so-called package effect has a number of causes (see e.g., Kottenhoff and Schmidt (2000) for a summary of the findings regarding this problem). Travel time assessments, however, seem to resist the package effect.

When choosing the levels of the attributes, realism is also necessary. To make the alternatives realistic the attribute levels often need to be adapted to respondents' conditions. Attributes frequently customised are in-vehicle time and travel cost. A question is how to describe the travel cost to passengers who are using period tickets, valid for unlimited travel during a specific period, often a month (paper 2, Sjöstrand, 2000). These passengers have lower average costs per trip and no marginal cost per trip at all. Often they are treated together with per trip paying passengers with cost expressed as per trip. But as already mentioned, validity of results is violated if respondents do not find alternatives realistic. Paper 2 aimed to investigate how the presentation of fare levels among period ticket holders influenced the passengers' estimated assessments. The study was made among monthly ticket holders on buses in Göteborg. Questionnaires were distributed to passengers on buses after short contact interviews during which ticket type used and travel times were recorded. All questionnaires contained a Stated Preference experiment with six binary choices. Each alternative described a bus trip with attributes in-vehicle time (adapted to respondent's conditions), walking time to bus stop, headway and travel cost. The travel cost was expressed in three different ways and the three types were randomly distributed among respondents. The cost was expressed either

- as a per month cost at three levels, or
- as a per trip cost at three levels, which were set such that they varied around the monthly card cost divided by the number of trips an average passenger takes per month, or
- as a per trip cost at three levels, with the levels set such that they varied around the cost per trip when paying per trip.

Among those mailing back their responses, 400 persons belonged to the group with the ticket type of interest, resulting in a response rate of 50-56%. Various aspects of the results of each of the three questionnaire types were investigated, regarding both reliability and validity of results. Different assessments were estimated depending on whether travel cost was expressed per month or per trip but could not be shown to be different depending on presented sizes of per trip cost. Cost expressed per month gave lower assessments than cost per trip. Determining which assessments are correct depend on what is to be investigated and on where the findings are to be used. If values of travel time are to be assessed, it is probably most appropriate to use per trip cost, while if results are to be used for prediction of incomes of transport companies, it is probably more appropriate to use per month cost. The study indicated that passengers paying per month find it more realistic to state their preferences, when cost is expressed per month.

2.3 Experimental design

How levels of attributes are combined into alternatives and which alternatives each respondent is to judge is called experimental design. The number of possible alternatives is m^n, if the number of attributes is n and the number of levels each attribute takes is m. In the Göteborg survey, the attributes were 4 and each attribute had three levels, implying that the number of possible alternatives was $3^4 = 81$. To require only a reasonable effort of respondents and avoid fatigue problems it is not feasible to let respondents judge that many alternatives. Instead, usually a fractional design is used, which means that each respondent sees only a fraction of all possible alternatives (Hensher, 1994). The choice of which alternatives to present can be made either by using a handbook of statistical design aiming for optimal efficiency, by choosing alternatives by hand, or at random, or combinations of these.

There are demands of a design both regarding cognition among respondents and estimation of coefficients. The cognitive demands are that the alternatives have to be realistic and differences between levels must be big enough to be interesting to imply a choice. Demands on the statistical design to enable accurate estimation of results, both of coefficients and possible interactions, consider balance, orthogonality and choice probability.

Balance considers the number of times each of the existing levels appears, which should be equal.

The use of orthogonal designs to be able to estimate all possible interaction effects is well documented and understood (Fowkes *et al.*, 1993). Often fractional factorial designs are used to decrease the burden for respondents or to save resources by using a smaller sample. Fractional orthogonal designs with too few alternatives, however, do not allow for the investigation of interaction effects. Interaction effects mean that the assessment of, for example, walking time depends on the presented value of in-vehicle time. Fowkes *et al.* (1993) discuss the use of non-orthogonal designs and show an example in which non-orthogonal designs reduced the variance of the value of time. According to Toner *et al.* (1998) orthogonal designs should be used when calibrating models for forecasting purposes, but departures from orthogonality can be beneficial when the purpose is to obtain monetary valuations.

The probability of choosing either of the alternatives in a binary choice (if binary choices are used) should be about 0.917/ 0.083 (Toner *et al.*, 1998, further discussed in Toner *et al.*, 1999). In contrast, earlier research (Bradley, 1988) showed that choices between closely competitive options are more interesting for the respondents and more reliably answered, even though they are somewhat more difficult. Independent of which choice probability is aimed for, the probabilities for most people are, of course, difficult to know in advance.

Since all those demands are difficult to combine, some of them to some degree have to be discarded.

In the first study presented in this thesis the experimental design was created by hand, but in the main study, alternatives were created and paired at random. Pairs containing one dominating alternative were rejected, however.

Since only paper questionnaires were used in this thesis, adaptive designs, where the options offered can be modified as a result of the responses to previous comparisons, were not possible. The use of adaptive designs is discussed in Bates (1994). It was concluded that adaptive designs should be avoided because each response cannot be treated as totally correct. Therefore, because a mistaken choice can lead to some options not being presented against each other, a great deal of information about assessments remains unrevealed.

Independent of how design is chosen, simulation is a useful tool for testing whether the design is effective enough to be able to produce reasonable estimates with the number of observations forecasted. Another useful tool when designing the survey is a pilot survey. Tudela (2000) warns of putting too much effort into a simulation process that cannot ensure the real quality of a design. The reason is that a simulation may lead to false impressions regarding the quality of the design. If the assumed coefficients used as input in the simulation process are wrong, the design may look good even if it is not. Instead, Tudela (2000) recommends carrying out a pilot survey. However, a pilot survey normally requires more time and money than a simulation procedure, which is why we recommend first a simulation and then a pilot survey. A pilot survey gives not only information about the efficiency of the experimental design, but also valuable knowledge about other, more practical issues.

2.4 Typographic design

The typographic design, that is, how alternatives are presented to respondents, may also affect the result. For example, Widlert (1994) has shown significantly different values of time when different questionnaire types and computer interviews were used. A special issue regarding typographical design was studied in paper 3 (Sjöstrand, 2001a). The aim was to analyse whether the ordering of attributes within alternatives in a binary choice experiment had any effect on the results. In computer assisted Stated Preference experiments the vertical ordering of attributes is typically varied randomly to avoid possible ordering bias (MINT, 1994). According to the manual (MINT, 1994) there is a risk that respondents will tend to place more importance on the top variable.

Reasons for paying more attention to any of the attributes only because of the order in which they appear were assumed to be that

- the respondent focuses on one of the attributes only because of the place of the attribute
- the respondent does not read all the attributes, but maybe only the first or the last attribute
- some orderings seem more natural and thus make the choice task easier to understand

Both possible over-estimations and possible under-estimations of assessments as a result of placing the corresponding attribute in the top, in the bottom or at either edge, were investigated.

Four different questionnaire types were created with four different orderings of the attributes (travel cost, walking time, in-vehicle time and headway). Questionnaires were identical, with six binary choices concerning a local bus trip, except for the ordering of attributes. Almost 2000 questionnaires were distributed to passengers on local buses in Göteborg. For each interviewee, a specific ordering of attributes was randomly chosen. Fifty-six percent of the delivered questionnaires were answered and returned by mail. These responses from each ordering type were then compared with respect to response rate, rate of lexicographical answers, parameter estimation (with special attention paid to inexperienced travellers), scale factors, and values of time.

The ordering of attributes had no significant effects, not even among less experienced respondents, as launched by Boyle *et al.* (1993). When making a Stated Preference survey, the ordering of attributes does not need to be varied to avoid bias, according to the results of this study. In a Stated Preference study using paper questionnaires, much work can be saved if the same ordering of attributes can be used for all respondents.

2.5 State dependency

Another problem that one needs to be aware of when making valuation studies is that of state dependency, which means that a person's assessment depends on present conditions (also discussed in Kottenhoff, 1999).

Many studies have shown that the assessments vary depending on passengers' present conditions (e.g., Kjörstad and Renolen, 1996 or Sjöstrand, 1999a). Because of passengers' different experiences of such aspects as travel time, bus frequency, access time and bus transfers, quality is assessed differently. This, so-called, state dependency effect has several explanations.

- A decrease in quality is often assessed higher than the corresponding increase (Ampt *et al.*, 1995), which can be a result of budget restrictions or justification.
- It may be difficult to imagine situations of which one has no experience (Widlert, 1994).
- There is a resistance against changes, a perceptual threshold (see Hultkrantz, 1998).
- Decreasing marginal utility (e.g., Hultkrantz and Mortazavi, 1998). A 10-minute reduction in the length of a journey means more if total travel time is 20 minutes than if total travel time is 2 hours.
- Self-selection bias: e.g., if a person who finds the bus too slow therefore chooses not to use the bus, we will not be able to interview her or him on the bus.

As this effect has been shown earlier in various areas, there is likely an effect also in assessments of local public transport. It would be interesting to investigate this effect more closely, looking at how large it is and under which circumstances it emerges as a function of the basic trip characteristics.

In Sjöstrand (1999a), passengers on airport buses in Stockholm were asked to state their preferences regarding having to change buses. Both passengers who actually had to change buses and passengers who were travelling on a direct bus were interviewed on-board the buses. In both cases, the total bus trip lasted about 50 minutes. For those who had to change buses, the transfer was arranged to be as convenient as possible: under a roof, without waiting time, and with bus drivers carrying the luggage. The survey was carried out as a computer-assisted Stated Preference experiment with binary choices concerning the bus trip to or from the airport. About 700 passengers participated; among those, one third were airport or aircraft crew, one third were business air travellers and one third were private air travellers.

On average, those passengers who could go directly to the airport would rather travel for up to 22 additional minutes than have to change buses. Those who are used to changing buses evaluate the difference between being able to travel directly and having to change buses as 7 minutes. There are several reasons for this big difference. It may be due to any of the reasons above.

In addition, the evaluation of transfer waiting time was very different for the two groups, those who could go directly and those who had to change buses, but in the opposite direction. Those who had not tried the comfortable transfer had much lesser resistance to waiting time than had the passengers who were used to a comfortable matched transfer without waiting time. To wait some minutes for the second bus would imply deterioration for the latter group, and that is probably the explanation for this phenomenon.

Other assessments, such as of in-vehicle time, headway, and bus stop design, could not be shown to have different values in the two groups.

2.6 Answering strategies - lexicographical answers

If the respondent finds the Stated Preference task too difficult, he or she tries to simplify it. One way to do this is to choose between options according to only one of the attributes, irrespective of the level of other attributes, so called lexicographical choices (cf, Bates, 1994). However, the sorting may also have been done this way because the respondent actually finds this attribute that important. In that case, and in some other cases, the fault should be laid on the surveyor. The experiment should be created such that the differences between levels of the attributes are similar to each other in utility. A bad experimental design may not give respondents any possibility to show real preferences, when, for example, the experiment is unbalanced so that one attribute dominates the others.

2.7 My conclusions about measurement

Papers in this thesis

- show how a mail-back survey with Stated Preference experiments can be adapted to travellers' conditions and give reliable assessment if binary choices are used
- discuss how the travel cost shall be expressed among passengers travelling with period tickets
- show that the ordering of attributes within an alternative does not affect the results.

3 Variability

3.1 Reasons for studying variability

As stated before, more differentiated information about passengers' assessment is needed. The information can be used for more cost effective planning, to prioritise between groups and to study effects for groups. This chapter will summarise the findings of paper 4 (Sjöstrand, 2001b) about how assessments vary among passengers in local public transport.

Previous studies have shown average assessments for bus passengers, but it would be interesting to study the variability of assessments of different parts of a bus trip. Reasons why assessments vary are several:

- because of trip characteristics (purpose, how often it is made, ticket type)
- because of passenger characteristics (gender, age, occupation)
- because of state dependency (depending on present conditions of trip)

Reasons to study the variability are

- assessments may be different, and if they are: an average value can lead to false conclusions
- model estimations may lead to low accuracy and biased estimates if there are large variations within data
- if a median value is used, for example, when setting a fee, then by definition only one half of the travellers are prepared to pay it (Jones, 1999). Mean values are thus not enough, we need to know more about the shape of the demand curve.
- we may want to study effects for a special group or plan a route to fit a special group
- different segments of passengers have different origin-destination matrices

3.2 Method

To find passengers' assessments, an extensive Stated Preference (SP) study was carried out in Göteborg during 2000. Delivery of 2367 questionnaires was made to passengers on board buses after a short contact interview. The contact interview made it possible to adapt levels of in-vehicle time to the passengers' actual conditions. Headway was also customised such that different questionnaires were delivered on buses with different headway. It was not aimed to get a representative sample of the total population on buses, but to reach a large enough number of passengers representing different dimensions of travellers to enable analyses over each dimension separately.

All questionnaires contained one SP experiment with six binary choices. Each alternative described a bus trip with four attributes, either in-vehicle time, walking time to bus stop, headway and travel cost, or with walking time exchanged to bus transfer and transfer waiting time. The response rate was 55%.

It was decided to include fare as one of the attributes in the SP games, even though only the relation between the assessments of in-vehicle time and headway, walking time, etc. was the main interest. The inclusion of fare made it possible to estimate a value of time as well. These values were used to control the validity of results against other studies, and as the value of time varies uncorrelated with other assessments, other conclusions were made when comparing generalised cost instead of generalised time. According to Bates (1994) the relative valuations of a set of quality attributes are unaffected by the presence or absence of fare in the SP experiment.

The discrete choice data was analysed through the estimation of a binary logit model in Alogit (1992), assuming that choices are made on a random utility with certain stochastic properties (Ben-Akiva and Lerman, 1985). The results are generally presented as importance weights compared to in-vehicle time. If presenting weights instead of values (e.g., SEK/hour), comparisons with other countries and other years can be done more easily. But, of course, when results are to be used in cost benefit analysis, monetary values are of interest. When results are used for assignment of passengers in a bus route network, relative weights between in-vehicle time, headway and walking time are of interest.

3.3 Results

Assessments were compared between groups under the headings in table 1. Since work trips constituted a large share of all trips, they could be divided into subgroups.

Table 1 Dimensions with subgroups whose assessments are to be compared.

Dimension	Subgroups						
trip purpose	• work	• study	• leisure				
gender	• women	• men					
age	• 0-25	• 26-40	• 41-65	• >66			years
occupation	• student	• worker	• retired or sick-listed				
bus trips per month	• 0-19	• 20-39	• 40-59	• >60			
in-vehicle time	• 0-15	• 16-25	• 26-40	• >41			min
headway	• 8	• 10	• 15	• 20	• 30	• 60	min
walking time to bus stop	• 0-2	• 3-5	• 6-10	• >11			min

Only work trips have been possible to segment further into subgroups, as shown in table 2.

Table 2 Sub-segments within segment of work trips whose assessments are to be compared.

Dimension	Sub-segments within segment of **work trips**	
gender	• women	• men
	• young (<25yrs)	
	• seldom bus	
time period	• peak hours	• off peak hours

Estimated assessments on different trip purposes may not only depend on the actual trip purpose, but also on other explanatory variables, such as gender, OD pattern, income or age. These dimensions partly overlap, as will be seen below, and one specific respondent will be found in several groups. Further, several dimensions are correlated (retired are mainly old, etc.) Thus, this study does not aim to determine the cause of preference differences. By studying assessments along many dimensions, different kinds of variations can be found that can help us to understand variability in travel quality for passengers.

In sections 3.3.1-3.3.5 assessments of in-vehicle time, walking time, headway, transfer and transfer waiting time are shown for the passenger segments in the dimensions mentioned above. Estimated values are shown. For confidence intervals of those estimates, see paper 4 (Sjöstrand, 2001b).

3.3.1 Value of time

Segments that showed significantly higher values of time than comparable segments were people who work but seldom take the bus, men and passengers on buses with the shortest headway, figure 4.

Groups that showed significantly lower values of time than comparable groups were passengers on leisure trips, women, people older than 66 years as well as retired or sick-listed passengers.

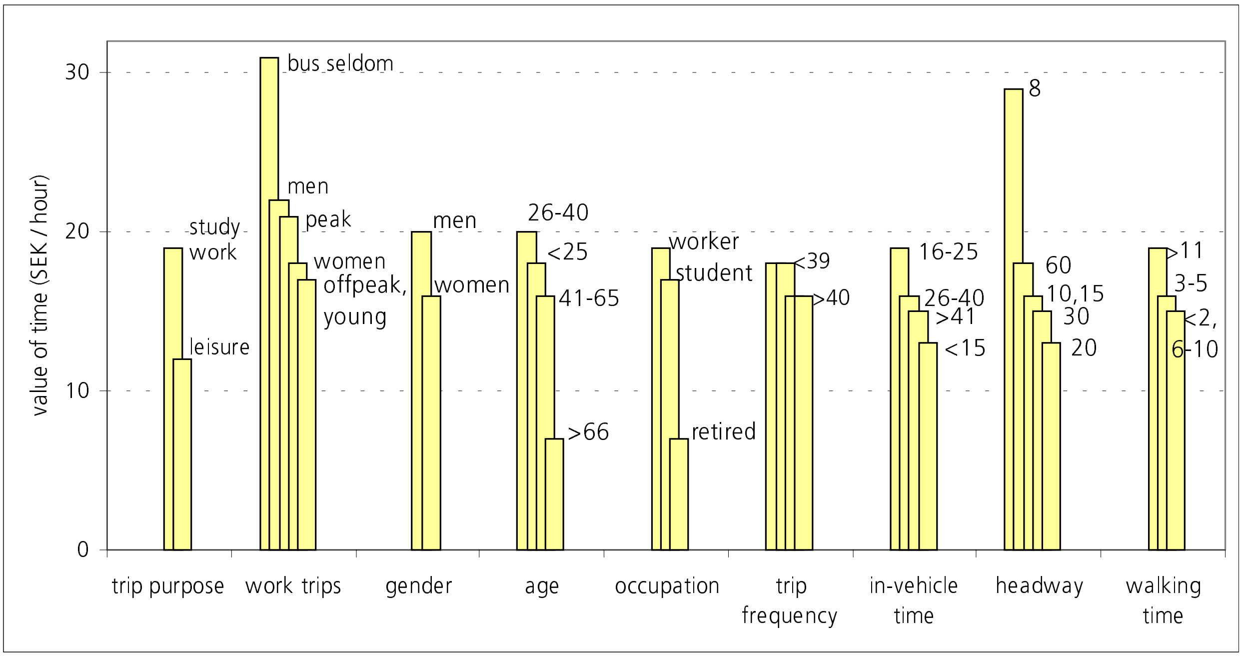

Figure 4 How the value of in-vehicle time varies across dimensions.

3.3.2 Walking time

Assessment of walking time is expressed as a weight relative to in-vehicle time. If the weight is 1, it means that each minute spent walking to a bus stop is assessed as just as comfortable or uncomfortable as one minute riding in the bus. If the weight is 1.5, 1 minute's walking time feels just as onerous as 1.5 minutes' riding in the bus.

Segments that have significantly higher walking time weights then comparable segments are passengers on leisure trips, young people on work trips, people who work but seldom use the bus, retired or long-term sick-listed persons, people with very short walking times, and people with short in-vehicle times. See figure 5.

Groups that have significantly lower assessment of walking time, that is, have little against walking, than comparable groups, are people who go to work during off-peak hours, people who have long walking times, and people with long in-vehicle times.

The relations between current walking time and walking time weights are probably due to self-selection.

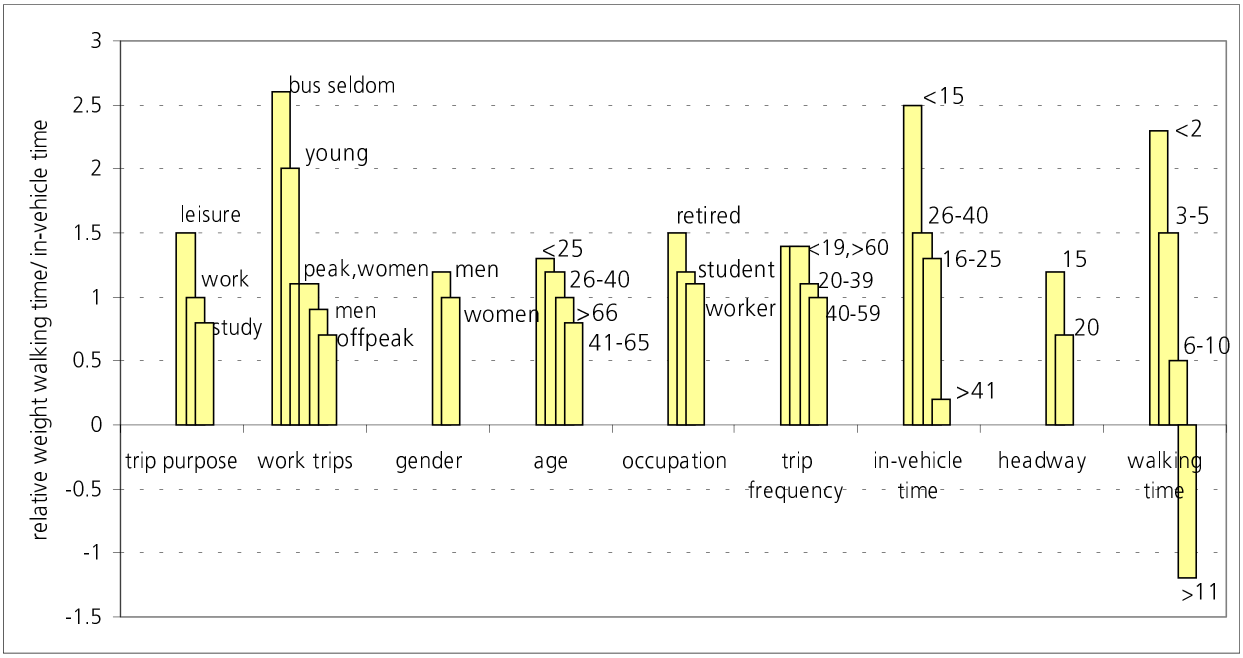

Figure 5 How the weight of walking time relative to in-vehicle time varies across dimensions.

3.3.3 Headway

Instead of waiting time, which is often used as a quality variable in public transport studies, headway is used in this study as a measure of the quality of a bus route. A deterioration of the headway is easier for respondents to imagine than an increased waiting time (Bradley, 1988). It is also the headway that the bus company planner can plan, not the waiting time. Assuming random passenger arrivals and constant bus headways, the average passenger wait time at the bus stop is equal to half the headway (e.g. Kaysi and Bassil, 1995).

Just as with the assessment of walking time, described above, assessment of headway is expressed as a weight relative to in-vehicle time. If the relative weight of headway is 1.0, the difference in quality between a bus route's headway of 15 and 20 minutes is equal to a 5-minute difference of in-vehicle time. If the relative weight of headway is 2, a 10-minute difference in in-vehicle time is equivalent to the difference in travel quality between 15 and 20 minutes headway.

Headway minutes are assessed significantly higher, than on comparable trips, on leisure trips, by working women, by passengers who are older than 66 and retired, and when in-vehicle time is short, see figure 6. Short headway is assessed significantly lower for working men and passengers who have either very short headway (8 minutes) or very long headway (60 minutes).

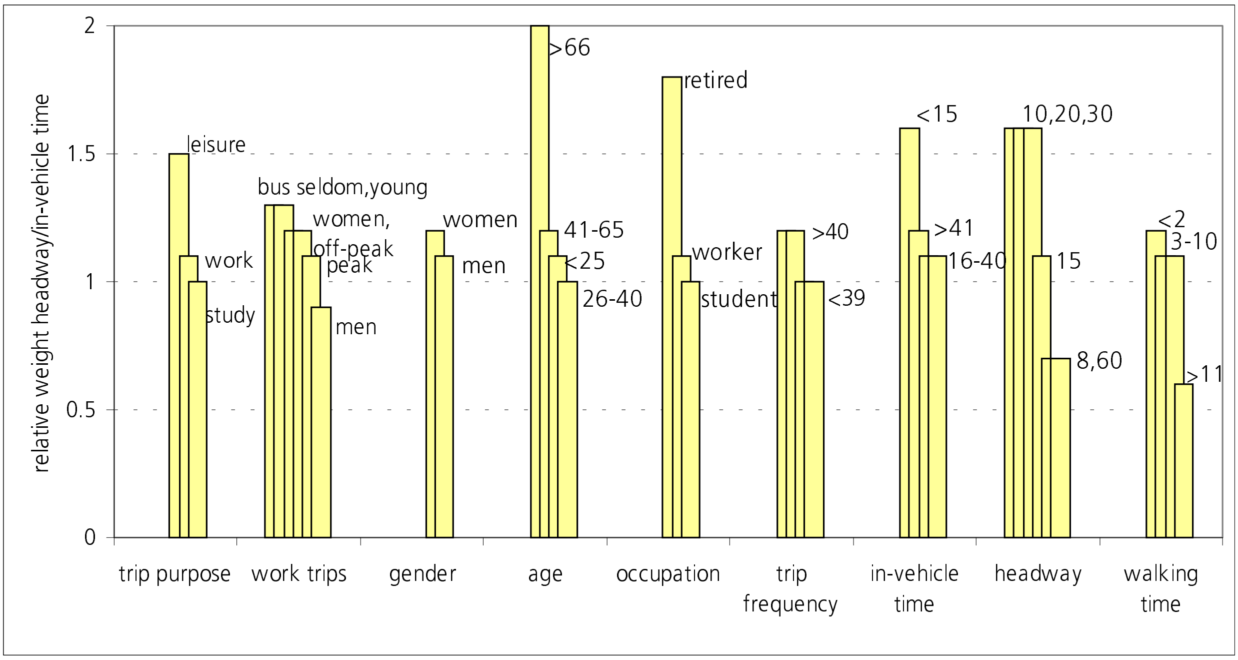

Figure 6 How the weight of headway relative to in-vehicle time varies across dimensions.

3.3.4 Bus transfer

The assessment of a transfer is also expressed in in-vehicle minutes. The corresponding in-vehicle time minutes express how many extra minutes a passenger is willing to spend in the bus, if a transfer is avoided. The value is also known as a transfer penalty.

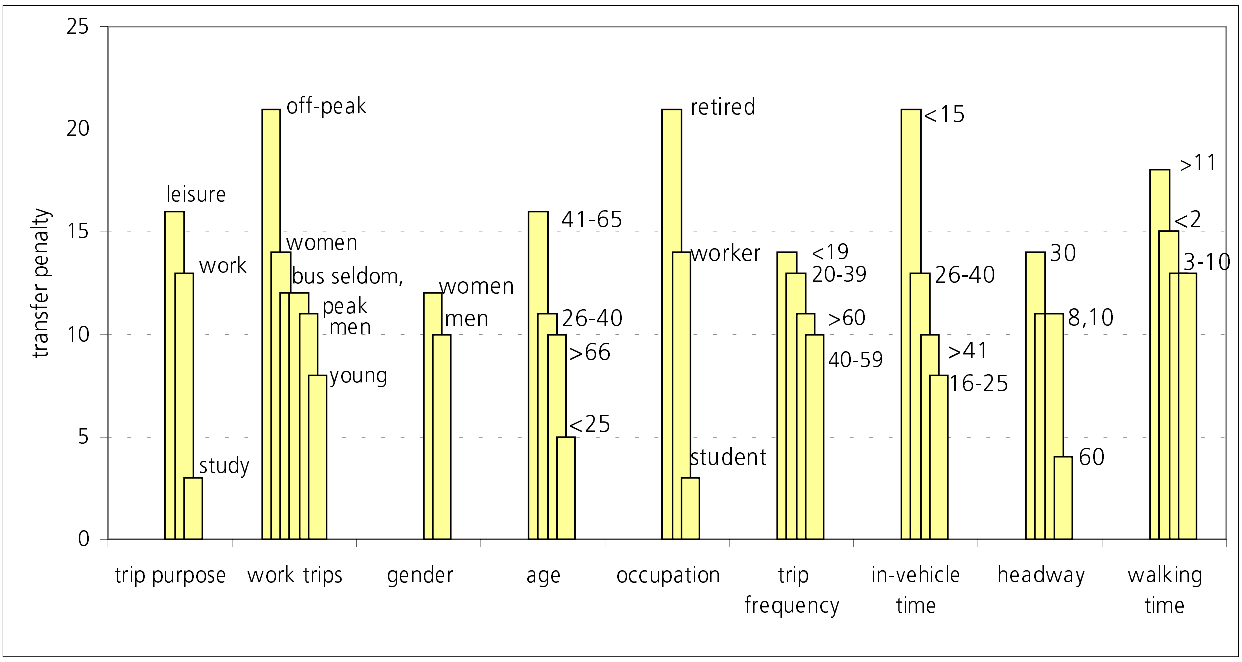

Figure 7 How the transfer penalty expressed as in-vehicle time minutes varies across dimensions.

The transfer penalty is significantly higher for work trips during off-peak hours, for retired and long-term sick-listed passengers (figure 7), for passengers who currently do not need to transfer (16 minutes) and for passengers with short travel time. On the other hand, students and passengers younger than 25 years of age have significantly lower resistance to a bus transfer than the average passenger.

3.3.5 Transfer waiting time

Apart from the inconvenience associated with transfers, they also often imply waiting for the second vehicle to come. How inconvenient this waiting time is assessed for different groups is shown in figure 8.

The waiting time by transfer relative to in-vehicle time is significantly higher than the average assessed on leisure trips, by passengers older than 66, by retired or sick-listed passengers, and for people making few bus trips per month. The waiting time by transfer is assessed significantly lower among passengers who make many trips (more than 60) per month.

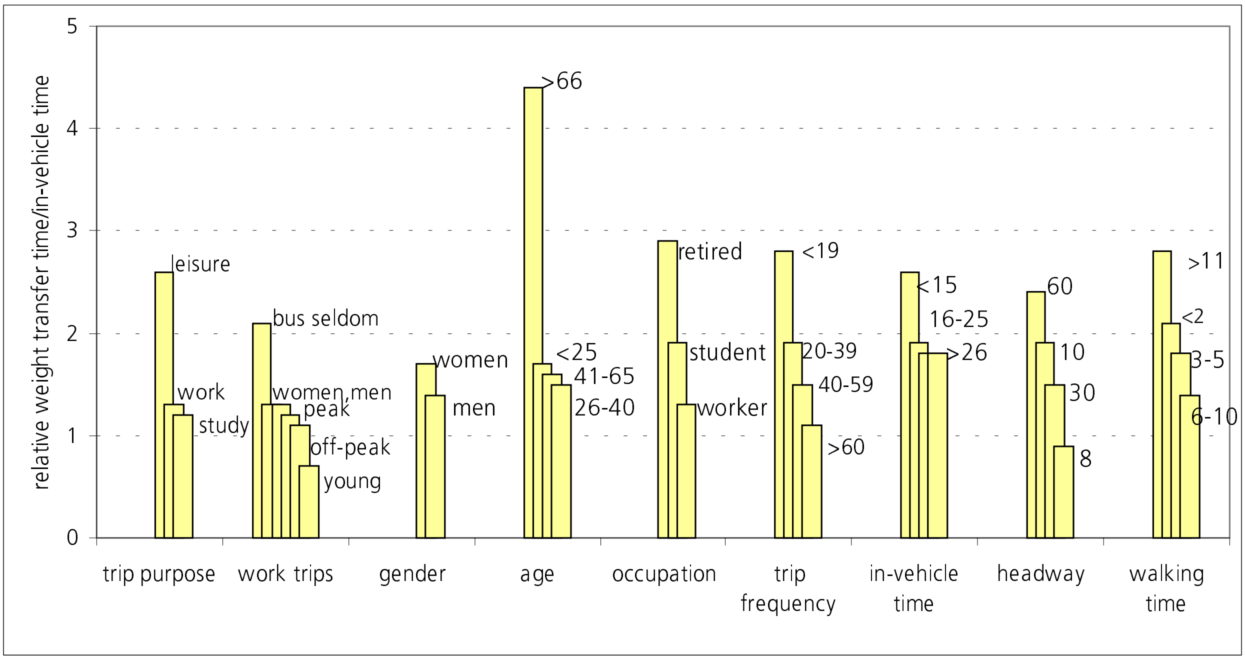

Figure 8 How the weight transfer waiting time relative to in-vehicle time varies across dimensions.

3.4 Conclusion of this chapter

Travellers have different preferences. If a route network is to be planned to meet a special group of passengers, it is important to know the assessments of this group and which origins and destinations they have. When evaluating a route network it is essential to know assessments of different groups in order to know effects for the groups and where they are travelling.

On trips to WORK, every minute, either spent walking to a bus stop, waiting for the bus, sitting in the bus or waiting for a second bus during transfer, is about equal in importance. Each transfer is as uncomfortable as 13 extra minutes in the bus, and should hence be avoided.

Also for trips to STUDY, all time components are assessed as being as comfortable as the in-vehicle time. One exception is waiting time during transfer, which is assessed as worse. The actual transfer, however, causes hardly any inconvenience to students.

On LEISURE trips, passengers do not want to change buses, and if they must do so, they assess the waiting time by transfer as very inconvenient. Both headway time and walking time are assessed as being more inconvenient than in-vehicle time. On leisure trips the value of time is higher than elderly passengers' value of time, but lower than students' and workers' value of time.

For ELDERLY passengers there are larger variations between how different parts of the trip are assessed. Headway of buses is very important relative to in-vehicle time and also the waiting time by transfer. The walking time to bus stop is also quite burdensome, and a bus transfer is equivalent to spending 20 additional minutes on the bus. Elderly passengers' value of time is, however, significantly lower than other passengers' value of time. Thus, if assessments were expressed in cost rather than in time, I would have characterised elderly passengers' out-of-vehicle time as being assessed like that of other groups, but the in-vehicle time is assessed very low.

This thesis has shown that irrespective of whether the purpose for segmentation of passengers was

- to plan different route networks for different groups, because of varying assessments or different origin-destination-matrices
- to customise bus routes for a particular group for political reasons, or
- to make public transport a competitive alternative for frequent car users

there are relevant passenger groups who have assessments that differ significantly from those of average passengers.

As assessments vary significantly among groups, it would be misleading to use average assessments in the planning process. This could potentially lead to inefficient planning decisions.

4 Planning implications

Results of Stated Preference surveys, for example the relative weights between travel cost, in-vehicle time, walking time, headway, transfer waiting time and transfer penalty, can be used to estimate so called generalised times or costs.

The generalised time is a measure of standard of a trip, estimated as the sum of the various time components multiplied by their appropriate perceptual weights plus the transfer penalty, that is, an extra number of minutes every transfer corresponds to in terms of inconvenience. See paper 5 (Sjöstrand, 2001c) for an example of an estimation of generalised time. When estimating generalised costs, the value of time is also taken into consideration, along with the cost of the trip. Generalised cost or time is thus a means to express the perceived travel utility. Either generalised times or costs can be compared between networks or between groups of travellers. As assessments of walking time, waiting time, transfer and transfer waiting time differ between groups of travellers, so, too, do the generalised time and cost. Further, OD matrices may differ between groups. Estimation of relevant generalised times or costs can therefore give indications of effects on quality for specific groups, when introducing new routes, new bus stops, etc. To make correct evaluations and forecasts, it is essential to know assessments for each group.

Paper 5 (Sjöstrand, 2001c) shows an example from Jönköping of how results from Stated Preference studies can be used when comparing different route networks and different traveller groups. Different settings of assessments for the four traveller groups, presented in section 3.4

above, were input data in an assignment model for public transport (VIPS). In addition to the different time weights, information about the route networks and separate OD matrices for the four groups were also input in the assignment model. Where more than one travel possibility existed, the model assigned passengers to the route that gave the smallest generalised time, assuming that their departure times were evenly distributed over the headway.

Two route networks were compared in this study, one traditional radial network and one new trunk route network. The trunk route system gave lower generalised times not only for the population as a whole, but also for all studied traveller groups. That depends mainly on shorter waiting times due to smaller headway on many routes in the new network. In this case the share of direct trips was not affected, as is otherwise common when introducing trunk routes.

Since OD matrices were available for all travel modes, it was possible to compare actual trips accomplished by public transport and “potential bus trips” now being made by car. It was shown that the average generalised time for accomplished bus trips is lower than the average generalised time would have been for car trips, had they been made by bus.

To conclude, the study, described in paper 5, showed how Stated Preference results and OD matrices combined with route network information in an assignment model can be used to estimate effects of different planning strategies for different passenger groups. Intuitively we might have expected that the trunk route system decreased travel quality for the elderly passengers, which did not turn out to be the case. Without the separate settings of assessments and separate OD matrices, we still would not have known the effects on perceived travel quality for different passenger groups.

5 Conclusions

Stated Preference methods offer possibilities to measure and analyse people’s assessments of quality. The method can be inexpensive and reliable if special care is taken when designing the survey. In mail-back surveys, binary choices are recommended over other Stated Preference methods, as has also been suggested by others. The question of whether the ordering of attributes in the presentation of alternatives matters has previously been discussed in the literature. Often, for security, the ordering has been randomly varied. But this thesis shows that the ordering of attributes in the alternatives does not affect the assessment results. This information simplifies the preparation of paper-and-pen questionnaire studies significantly. Another methodological question investigated in this thesis was how to express the travel cost to passengers travelling with monthly cards as cost per month or cost per trip. The study showed that the estimated assessments differ depending on cost expression, which was not surprising since many previous studies have shown that the design of a Stated Preference-survey affects the result. The kind of cost expression to choose depends on how the results are to be used. It any event, it was clear that the precision of estimations increases when attributes are expressed in a way that respondents recognise.

Assessments have been studied before, but most often assuming homogeneous preferences and seldom focusing on local public transport. Thus, previous knowledge has been limited and the relevance for local public transport has been questionable.

The results from my assessment studies showed that most passengers find a bus transfer much more inconvenient than we have believed in the past. Apart from young people and students, who show a transfer penalty of 3-5 minutes, all other groups find a transfer to be as burdensome as 10 additional minutes in the bus. Recently, networks based on a few trunk routes have been introduced. This introduction is based on an assumption that transfers are not very uncomfortable due to modern transfer bus stops and short headways. My SP results, however, show that a transfer is assessed as a large inconvenience for most of the passengers.

Special services for elderly people are often planned to have a low frequency of service. But the results of this study show that elderly passengers in particular find the waiting time much more uncomfortable than in-vehicle time. In some cases there may be a trade-off between these two types of time on the supply side. If so, priority should be given to increased bus frequency (rather than short travel times) for the network to fit the preferences of the elderly.

An earlier recommendation for walking time weight is that walking time is twice as inconvenient as in-vehicle time (Vägverket, 1992). My study, however, shows that most passenger do not find the walking time more inconvenient than the time in the bus. Exceptions are passengers on short trips and people on work trips who seldom use the bus. In this study, elderly passengers could not be shown to have a larger walking time weight than others. This is probably due to the way walking was expressed in the SP experiment, as time and not as distance. As elderly persons often walk slowly, a long walking time does not imply a long distance.

No significant differences could be shown between men's and women's assessments, except for the value of time. As previous studies have shown, men have a larger value of time than women have.

Finally, paper 5 showed how passenger assessments for separate groups can be combined with each groups' OD matrix in an assignment model to evaluate effects of different planning strategies for each group separately. In the example of Jönköping, a trunk route system gave smaller generalised times, that is, better service, than a traditional radial network, not only for the population as a whole, but also for the four studied traveller groups. The improvement was a consequence mainly of more frequent bus services.

To conclude we may, based on the findings in this thesis, say that:
Results from Stated Preference studies make a useful contribution to public transport planning. By using assessment studies and segmentation of results, more efficient planning of public transport can be achieved. Specific traveller groups can be favoured. When evaluating a system, effects for different groups can be studied if assessments of each group are known.

6 Future research

Now, when we know how to use the Stated Preference method among local public transport passengers, further studies can give valuable information about other attributes. This thesis has focused on the time parameters, but for both passengers and operators, comfort attributes are also important. The value of time can be seen as a sign of comfort, such that it is higher when comfort is low, for example, during congestion. But comfort attributes may also be assessed separately from time. In addition to crowding, there is a long row of attributes for comfort both inside and outside vehicles. To mention just some of them: seat availability, information systems, low-floor buses and bus stop shelters (see also Olsson *et al.*, 2001). A time component that needs more research is that of reliability, as much less research on the value of reliability has been performed compared to value of travel time itself Wardman (2001). A benefit that would also be possible to assess by the Stated Preference method is the existence of regular timetables (Andersson, 1992). This thesis assessed only the walking time *to* the bus stop. It would be interesting to see if, and under which conditions, the walking time *from* the bus stop is assessed differently. I have used walking *time* as the attribute describing the access to a bus stop. But, it may have been more appropriate to use walking *distance*, as walking speed differs significantly among people.

It would also be interesting to make similar assessment studies in smaller cities, to test the transferability of value of time results, which is discussed by Gunn (2001). Stangeby and Norheim (1995) show that the value of time varies considerably between Norwegian cities. Another issue to be further investigated is differences and similarities between women's and men's travel patterns and assessments. This is an issue related to gender equity. It is well-known that most public transport passengers are women. Why is this so, and how can more men be attracted to use public transport? As one of the goals of public transport is to reduce congestion and negative environmental impact, it is important to learn more about assessments of non-users as well.

This thesis has focused on the demand side of public transport. An exciting theme would be to use these results on the supply side, even more than I did in paper 5. How can planners use the information about the variability of passenger assessments when planning the operation of public transport?

It is essential to have a more detailed basis for the planning of local public transport. It has been shown that increased knowledge about how segments of passengers assess different parts of a journey would be useful for the planning of a more efficient network. Although this thesis gives substantial information to the subject, much remains to be understood about the variability of assessments within the population.

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Appendix 1

Telephone interviews 1994 and 2001.

Table 1 Represented authorities in 1994 and 2001.

Name of regional or local authority or operator	1994	2001	regional (R) local (L)	authority (A) operator (O)
Upplands lokaltrafik	x		R	A
Uppsalabuss AB	x	x	L	A,O
Länstrafiken Sörmland AB	x		R	A
AB Östgötatrafiken	x	x	R	A
Jönköpings Länstrafik AB	x	x	R	A
Länstrafiken Kronoberg	x		R	A
Kalmar Läns Trafik AB	x		R	A
Gotlands kommun	x		R	A
Blekinge Länstrafik AB	x		R	A
Kristianstads Läns Trafik AB	x		R	A
Länstrafiken Malmöhus/ Skånetrafiken	x	x	R	A
Lunds Gatukontor	x	x	L	A
Helsingborgs stad	x		L	A
Swebus, Helsingborg		x	L	O
Hallandstrafiken AB	x		R	A
Stadstrafiken Göteborg/Västtrafik Göteborg	x	x	L	A
Älvsborgstrafiken	x		R	A
Skaraborgs Läns Trafik AB	x		R	A
Värmlandstrafik AB	x		R	A
Karlstads kommun		x	L	A
Länstrafiken Örebro	x	x	R	A
Västmanlands Lokaltrafik AB	x		R	A
Dalatrafik	x		R	A
X-Trafik AB	x		R	A
Västernorrlands län Trafik	x		R	A
Jämtlands län AB	x		R	A
Jämtlandsbuss AB (Östersund)	x		L	A,O
Länstrafiken i Västerbotten AB	x		R	A
Umeå Lokaltrafik AB	x		L	A,O
Länstrafiken i Norrbotten AB	x		R	A
Luleå Lokaltrafik AB	x		L	A,O

In addition, written information was received from AB Storstockholms Lokaltrafik, SL, in 1994.