International Transport Forum

Valuing Convenience in Public Transport

Roundtable Report

OECD

Valuing Convenience in Public Transport

156

Roundtable Report

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The International Transport Forum at the OECD is an intergovernmental organisation with 54 member countries. It acts as a strategic think tank with the objective of helping shape the transport policy agenda on a global level and ensuring that it contributes to economic growth, environmental protection, social inclusion and the preservation of human life and well-being. The International Transport Forum organises an Annual Summit of ministers along with leading representatives from industry, civil society and academia.

The International Transport Forum was created under a Declaration issued by the Council of Ministers of the ECMT (European Conference of Ministers of Transport) at its Ministerial Session in May 2006 under the legal authority of the Protocol of the ECMT, signed in Brussels on 17 October 1953, and legal instruments of the OECD.

The Members of the Forum are: Albania, Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Chile, People's Republic of China, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Former Yugoslav Republic of Macedonia, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Italy, Japan, Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Mexico, Republic of Moldova, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States.

The International Transport Forum's Research Centre gathers statistics and conducts co-operative research programmes addressing all modes of transport. Its findings are widely disseminated and support policy making in Member countries as well as contributing to the annual summit.

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Executive summary

It is straightforward that making public transport more convenient raises the probability that it will be chosen over alternative transport modes and can raise overall transport demand. Convenience is one of the strongest attractions of the private car for passenger transport. For users of public transport, convenience is also clearly important but not always clearly defined and not often measured in designing transport systems or monitoring their operating performance.

It is less straightforward but crucial to understand how users value convenience compared to other characteristics of service, and to produce operational and measurable indicators of convenience. The experience of transport systems users, in terms of comfort, reliability, safety and above all convenience, is critical at least when there is a choice of alternative ways to travel.

In many situations, an increase in public transport convenience reduces the generalised costs of travel (euros/dollars per hour or cents per minute) and so provides benefits equivalent to an increase in travel speed. This report focuses on convenience and its importance to the user experience. It reviews operational definitions of convenience, evidence for the willingness of users to pay for convenience and the use of indicators to assess and improve the convenience of public transport, with a view to making it more effective and more competitive.

Main findings

Convenience is related to ‘absence of effort’ in utilising transport services that are ‘fit for purpose’ in the way they are operated. The concept is narrower than service quality, and transport analysts have long distinguished cost, time, convenience and comfort, where the latter has to do with how bearable the trip is. There is, however, no general consensus of what convenience represents in a public transport context, and the term is used even without explicit definition. The Roundtable felt that a pragmatic way forward was to prioritise what we regarded to be key elements that will add most to a fuller representation of the attractiveness of public transport and, importantly, can be measured and valued. It regarded these to be the inconvenience related to:

- Access and egress time, and in particular walking time at any stage of the journey;
- Waiting time, including that spent transferring between services or modes;
- Not being able to travel at the desired time, covering service headway and displacement time;
- Having to transfer during a journey;
- Travel time variability;
- Absence of good information;
- Crowding.

In many countries, official values are specified to be used in the appraisal of transport investments and policies, particularly where public funding is involved. The primary focus of attention over the years has been valuation of in-vehicle travel time savings. This report focuses on multipliers for travel time savings that can be used to reflect convenience factors in appraisal.

The report provides an account of current understanding regarding multipliers for walk and wait time, service headway and displacement time, interchange, reliability, crowding and information. This is based on existing review material supplemented with evidence from specific studies where appropriate.

At the outset, we recognise that multipliers might vary across countries, although they are inherently more transferable than monetary based valuations. And variations are not restricted to cultural differences, but may stem from different standards and expectations, operating practices, travel conditions and socio-economic composition of the travelling (and sampled) public.

Clearly, what matters most to individuals will depend on specific circumstances but in generalising the results, it seems that the most important convenience issues for public transport users are:

- waiting in crowded conditions;
- walking in crowded conditions;
- walking that involves more than normal levels of effort;
- travel time reliability.

The next most important aspects of convenience are:

- walking and waiting in normal conditions;
- having to stand while travelling, although its inconvenience might be expected to exceed normal walking and waiting when there is severe overcrowding;
- travel time and headway between vehicles, with displacement time being more of an issue for longer journeys where planning is more commonplace and headway being more important for shorter journeys where there is less planning and perhaps an expectation of better frequencies.

The two variables that generally make the least contribution to convenience are:

- the penalty involved in having to interchange
- information provision at stations and stops. However in a digital age there are ever increasing expectations that information is not only of a high standard but is easily accessed. The findings suggest that on-vehicle information is more important than at-station or stop information. Information relating to disruptions seems particularly important. The relatively new area of real-time information on services available on-line before leaving home or the office appears particularly important, although empirical studies were not found to have been undertaken.

Final conclusions

1. The view of the Roundtable was that convenience is not generally covered as well as it should be in policy and project assessment, either because of the absence of official economic appraisal procedures or else because of limitations in coverage of existing appraisal methods. This is disappointing given the importance of convenience terms in the overall attractiveness of public transport. This skews planning and investment decisions. Some cost-effective transit improvement strategies are overlooked and undervalued; resulting in underinvestment in transit service quality makes transit less attractive. Opportunities for modal integration are overlooked, since many transit quality improvements involve improving walking and cycling conditions, or improving connections with other modes. This reduces the attractiveness of public transport in relation to use of the private car contributing to a cycle of increased automobile dependency and sprawl and reduced transit ridership and revenue.

2. There are two main aspects to a forward research agenda in the area of valuing public transport convenience:

- Consolidating and particularly adding to the evidence base on convenience multipliers
- Monitoring, validating and ex-post analysis of the use of the convenience multipliers

3. In addition to addressing research themes, there is also a need to exploit new and emerging sources of data and information that reveal people's choices, preferences, implied valuations and indeed deterrents. For example, mobile phone data for the Paris underground has recently been exploited to provide reliable insights into passenger behaviour. The Roundtable identified promising new behavioural data sources as:

   - check-in and check-out data;
   - mobile phone data;
   - CCTV data;
   - mobile phone applications to contact travellers regarding their ongoing experiences and also to undertake post-journey market research.

The review findings should be a valuable resource to planners and policy makers, operators and funding bodies, facilitating access to a significant body of empirical evidence on travel quality attributes often overlooked.

Chapter 1

Summary of discussions

Mark Wardman [1]

This report serves to:

- *Highlight the importance of convenience for public transport services;*
- *Provide empirical evidence that can be used to improve services;*
- *Serve as a stimulus to operators, planners and policy makers to take convenience attributes into account in their decision making;*
- *Encourage research in the area to derive locally relevant parameters;*
- *Improve understanding in contexts where evidence already exists through additional research that provides more detailed or better insights.*

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Glossary of terms:

Valuing convenience in public transport

GC:	Generalised Cost, reflecting the quantified disutility of a travel option in money units
GT:	Generalised Time which is Generalised Cost converted into time units
IVT:	In-Vehicle Time
Late:	Mean lateness on schedule
OVT:	Out-of-Vehicle Time
RP:	Revealed Preference
RR:	Reliability Ratio (Relative value of the standard deviation of travel time and mean travel time)
SD:	Standard Deviation of Travel Time (or Lateness)
SDE:	Schedule Delay Early which is the mean amount of arriving early relative to the preferred arrival time
SDL:	Schedule Delay Late which is the mean amount of arriving late relative to the preferred arrival time
SP:	Stated Preference
WTP:	Willingness-to-Pay

Introduction

Aims and Needs

It is straightforward that making public transport more convenient raises the probability that it will be chosen over alternative transport modes and can raise overall transport demand. It is less straightforward but crucial to understand how users value convenience compared to other characteristics of service, and to produce operational and measurable indicators of convenience. The International Transport Forum therefore convened a roundtable meeting in September 2013 to review international experience with measurement of convenience in order to establish best practice and extract common messages. It also looked into practical use of convenience measures in cost-benefit analysis and in performance measurement.

This report summarises the issues discussed at the roundtable and aims to consolidate evidence on the valuation of public transport convenience for the broader benefit of the transport community of policy makers, operators, academics and consultants, and ultimately public transport users.

The Roundtable was of the view that the practice of accommodating convenience in transport planning, forecasting, policy and appraisal across the world is very variable and often absent. This document serves to:

- Highlight the importance of convenience;
- Provide empirical evidence that can be used to improve services;
- Serve as a stimulus to operators, planners and policy makers to take convenience attributes into account in their decision making;
- Encourage research in the area to derive locally relevant parameters;
- Improve understanding in contexts where evidence already exists through additional research that provides more detailed or better insights.

Where cost-benefit analysis has been used to appraise transport investment projects, the value of in-vehicle time (IVT) has historically dominated, not least because it was the first element of time to be valued in money terms, and remains the single most important parameter in appraisal. This is also because of the dominance of car schemes in transport appraisal where there is no need for convenience terms. As a result, there have over many years been numerous reviews of the value of in-vehicle travel time savings, (Hensher, 1976; MVA et al., 1987; Lawson, 1989; Waters, 1992; Wardman, 1998, 2001, 2004; Miller, 1996; de Jong et al., 1998, 2004; Booz Allen and Hamilton, 2000; Bickel et al., 2004; Shires and de Jong, 2009; Abrantes and Wardman, 2011; Douglas and Wallis, 2013; Wardman et al., 2013).

In many countries that conduct appraisal of transport investments and policies, public transport has at some times in the past been seen as a ‘private’ good with fare-box revenue for which financial appraisal is sufficient, in contrast to the provision of road capacity that is essentially a ‘public’ good which requires a broader cost-benefit analysis.

The world has now moved on and there is broader acceptance that public transport schemes should be appraised in a similar fashion to highway schemes[1] which therefore brings into play a broader range of attributes that are critically important in determining the attractiveness of public transport. In addition, and importantly, there is now a large body of evidence relating to the valuation of the drivers of convenience. However, it is not clear that best use is being made of evidence to identify and justify improvements in public transport convenience.

An overview and review of travellers' willingness to pay valuations for convenience improvements is therefore timely and it is this purpose that this document seeks to serve. We do not aim to provide recommendations but rather summarise the evidence so that:

- It provides a useful resource for planners and public transport operators;
- It serves as a benchmark against which to assess emerging evidence;
- It inspires both greater inclusion of convenience measures in appraisal and further research to provide local parameters or improved insights.

Scope

A discussion of what is meant by convenience is provided in section "What is Convenience?" below. Suffice to say at the outset that the Roundtable took as its remit the following time-related attributes other than IVT that impact on the convenience of public transport:

- The inconvenience of public transport not being immediately accessible and available, which might be termed Out-of-Vehicle Time (OVT). This covers:
  - *Walking time to, from and during a public transport journey*
  - *Access to public transport modes more generally that is not necessarily walking*
  - *Waiting time, either at the origin point or subsequently transferring between services or modes*
- The inconvenience of not being able to travel at the desired time. This covers:
  - *Differences to and variations upon desired departure times*
  - *Service Frequency*
- The inconvenience of having to interchange, independent of the walk and wait time involved.
- The inconvenience of unreliable services and arriving late.
- The inconvenience of the absence of good user information relating to factors such as wayfinding, real time arrivals, timetables, payment options and the like.
- The inconvenience of crowding and having to stand and the inconvenience of the longer journey times that can stem from crowding.

Whilst other elements of inconvenience could be added, there are practical limitations to the scope of the Roundtable discussion and the convenience factors covered are considered to be the most important aspects.

Although valuations can be used in forecasting the demand consequences of changes in convenience, that is not the focus of this document which is instead focused firmly upon travellers' willingness to pay for more convenient public transport services suitable for use in cost-benefit analysis for appraisal purposes.

The Potential Benefits of Transferability

Valuations of convenience factors such as walking and waiting are typically expressed in equivalent units of IVT rather than as monetary values. Thus if walking time savings are regarded to be twice as important as the same amount of IVT savings, the walk time multiplier is two.

An attraction of working with time multipliers is that they are potentially much more transferable across different contexts and cultures than are monetary values that suffer from the vagaries of the currency markets, different income levels and living standards, and the income levels of the travelling public differing from average income levels which can be particularly acute in less developed economies. Multipliers are also far more readily interpreted and assessed and there is now a significant amount of evidence relating to them.

Money values of IVT exist in numerous countries, either as the outcome of specific studies or, more importantly, because they can be proxied by reference to wage rates since much value of IVT evidence is expressed in terms of the wage rate. It is then a straightforward matter to obtain the monetary valuations of the convenience variables needed by cost-benefit analysis by applying the multipliers to the money value of IVT used.

In addition to the direct or deduced evidence on values of IVT in many countries, some have evidence on convenience multipliers, most usually for walking and waiting time. Even then it remains useful to assess the values used against other evidence, of which there is now a significant amount, and also to extend coverage to elements of convenience for which local values do not exist.

Approach

We are not here claiming that there have been no reviews of convenience attributes, although there is little on the scale of the review of IVT values. Notable reviews exist of multipliers associated with walk and wait time (McKnight, 1982, Waters, 1992; Wardman 2004; Australian Transport Council 2006; Abrantes and Wardman, 2011, Wardman, 2013), travel time variability (Noland and Polak, 2002; Tseng, 2008; Li et al., 2010; Carrion and Levinson, 2012; Wardman and Batley, 2014), headway (Wardman, 2004, 2013; Australian Transport Council, 2006; Wallis et al., 2013), and crowding (Li and Hensher, 2011; Wardman and Whelan, 2011; Wallis et al., 2013).

We recognise that the literature containing specific results on the multipliers of interest here is now large and that it is clearly far beyond the scope of this piece of work to review it. But neither is it particularly authoritative to cover an arbitrary selection of studies that have provided evidence whilst identifying a selection of what might be regarded to be the 'key' studies in the area can be a subjective matter.

The approach we have adopted is to build upon the review evidence that exists and then to draw upon specific, readily accessed, material to provide supplementary detail on specific issues.

Structure

Next Section provides background discussion on what is convenience in the public transport market, clearly setting out what we regard to be the principal convenience variables and why they are important, along with a summary and discussion of current official recommendations and other guidance.

In section " Measuring and valuing convenience ", we address the issue of measuring public transport convenience variables, how we go about including them in a measure of the attractiveness of public transport and how these inclusions are valued in terms of travellers' willingness to pay for improvements.

Section “Review of evidence” provides an overview of empirical evidence for multipliers of walk and wait time, displacement time and headway, transfer penalties, reliability, crowding and information provision. We here make use of existing review material supplemented with studies that provide detailed insights.

Section “The research agenda” deals with the future research agenda whilst section “Policy implications” considers the policy implications. Concluding remarks are set out in section “Concluding remarks”.

Background

What is Convenience?

Convenience is related to ‘absence of effort’ in utilizing transport services that are ‘fit for purpose’ in the way they are operated. The concept is narrower than service quality, and transport analysts have long distinguished cost, time, convenience and comfort, where the latter has to do with how pleasant the trip is (Hensher, 1975). There is, however, no general consensus of what convenience represents in a public transport context, and the term is used even without explicit definition. Nor is it unknown that studies that review a large amount of international valuation evidence do not specify what convenience is or indeed rarely use the term (VTPI, 2009; Wardman, 2013).

This lack of clarity on what precisely is convenience is not confined to transport. In the broader marketing literature, and comparatively recently, Berry et al. (2002) stated that:

> *“Convenience is acknowledged to be increasingly important to consumers, yet no known research has defined the service convenience construct or examined how it is evaluated. Although most researchers and managers consider service convenience to involve more than locational proximity or hours of operation, the specific types of service convenience have not been established”.*

They go on to define five types of convenience: decision convenience, access convenience, transaction convenience, benefit convenience and post-benefit convenience. At least the first four resonate closely with factors underpinning the attractiveness of public transport.

Claffey (1964) provides one of the earliest definitions of convenience in a travel context. It is stated as being “greatest when users least have to adjust their personal plans and living habits to use transit, and when the difficulties of getting to transit stations and aboard transit vehicles are minimized”.

Another early study (Stopher et al., 1974) pointed out what has become something of a recurring theme of varied definitions of convenience across studies, recognising that, “It is most probably that each individual respondent to a transportation survey defines comfort and convenience in an individual fashion”. They suggested that the attractiveness of public transport can be decomposed into four generic elements; safety, cost, comfort and convenience. Comfort was defined to “refer to the environment in which the trip is made, the extent to which a trip may be enjoyed or not” whilst in contract convenience “refers to the efficiency and effectiveness with which a person can be transported from origin to destination”. The latter was stated to cover access and egress, in-vehicle time, walking, waiting, reliability and the number of changes.

The resource paper prepared for this roundtable by Anderson et al. (2013) provides a very thorough coverage of how convenience has been interpreted. They point out that convenience is an “ambiguous concept" and that the car serves as a benchmark as "the very essence of convenient travel". The latter is invariably characterised by being door to door, with very limited access and egress, the absence of waiting and the ability to travel at the desired departure time in one's own space or shared with friends or family. Admittedly, car travel can have its inconveniences, ranging from congested traffic conditions through to difficulties finding a place to park through to having to clean the car on a weekend! But linking convenience to the features of car travel points towards it covering time-related characteristics such as access and egress time, service frequency, the need to transfer during a journey interchange and crowding. We might also add the 'time invariant' costs of hours of operation, acquiring trip information and tickets, and accessibility for people with special needs.

Anderson et al. (2013) pointed us to relevant definitions of terms. The Oxford English Dictionary defines **convenience** and **convenient** as:

> **"convenience** [noun]... the state of being able *to proceed with something without difficulty* ..... the quality of being *useful, easy*, or *suitable* for someone … a thing that contributes to an easy and *effortless* way of life..."
>
> "**convenient** [adjective]…fitting in well with a person's *needs*, *activities*, and *plans* involving *little trouble or effort. helpfully placed* or *occurring...*"

As such they state:

> Thereby a *suitable* public transport service would offer the correct capacity and design which is comfortable for its purpose. A reliable, punctual, safe service, offering necessary information, appropriate ticketing and integration will allow the traveller to *proceed without difficulty*. Access and egress to public transport is facilitated by *helpfully placed and available* (occurring) boarding points, *fitting* with *activities* which give rise to travel demand.

They conclude that essentially "proceeding without difficulty" or "with little effort" is synonymous with the attributes of generalized cost. They cite Crocket and Hounsell (2005) who claimed that "it is possible to consider convenience in rail travel as an embodiment of four themes: access/egress, station facilities/environment, frequency of service/scheduling and interchange between train services."

The Roundtable took the view that convenience is a function of the time aspects, other than scheduled in-vehicle time, along with the ability to travel at the desired time. Arriving late and having to transfer were indisputably seen as sources of inconvenience. The level of crowding chiefly affects comfort but we include it here since there is an element of inconvenience in crowding, such as when it impinges on the ability to undertake activities during the course of a journey[2]. In common with the preceding variables it can be expressed as a time multiplier and can be expected to be a significant element of generalised cost.

Our coverage is therefore based on an 'enhanced Generalised Cost approach', as set out in equation 1 in section "How Do We Value Convenience?" below. The Roundtable felt that a pragmatic way forward was to prioritise what we regarded to be key elements that will add most to a fuller representation of the attractiveness of public transport and, importantly, can be measured and valued. It regarded these to be the inconvenience related to:

- Access and egress time, and in particular walking time at any stage of the journey;
- Waiting time, including that spent transferring between services or modes;
- Not being able to travel at the desired time, covering service headway and displacement time;
- Having to transfer during a journey;

- Travel time variability;
- Absence of good information;
- Crowding.

Why do we care about convenience?

Convenience is important because it matters, or should matter, to existing and potential public transport users, policy makers and regulators, funding bodies, and operators. It matters because:

- It is a significant element of the overall attractiveness of public transport, directly impacting on the wellbeing of travellers;
- Poor performance provides a significant barrier to use, thereby thwarting policy efforts to switch more people to sustainable modes of travel;
- There are ever-rising expectations for convenience;
- Improving convenience is particularly important in efforts to attract discretionary travellers, such as those who would otherwise drive, to public transport, and therefore contribute to strategic planning objectives such as reduced traffic and parking congestion, vehicle accidents and pollution emissions;
- There is a relationship between improved convenience and the financial performance of public transport;
- Transportation planning in practice often involves trade-offs between public transport convenience and other objectives;
- Convenience affects broader mobility objectives.

Public transport travel time unit costs (Euros/dollars per hour, or cents per minute) are highly variable. When travel conditions are favourable (good walking and waiting conditions, clean and comfortable vehicles, convenient user information, etc.), the generalised journey time cost of public transport travel can be lower than that of car travel, since passengers experience minimal stress and can use their travel time productivity (resting, working, socialising, etc.); for this reason travellers will sometimes choose a longer duration public transport trip than would be required to drive so they can use their time in a worthwhile manner. However, if public transport conditions are unfavourable (uncomfortable, unpleasant, unsafe, difficult to use, etc.) unit travel times tend to be higher than for car, which inevitably reduces public transport use.

Sommers (1969) was an early attempt at examining users' attitudes to various dimensions of public transport, and convenience featured highly. The rank ordering of importance was time, convenience, comfort, safety, weather based reliability, cost, noise and mechanical reliability. Another early study (Paine et al., 1969) was more extensive with importance ratings covering 33 time, cost, convenience, comfort, safety and attitudinal terms. Again convenience issues rated highly, with reliability and travel time being the two most important attributes.

Public transport users regularly prioritise convenience improvements. Recent market research of bus users in the UK (Passenger Focus, 2010a) explored 30 possible improvements to bus services. Convenience factors featured highly, including reliability (1st), frequency (2nd), seat availability (3rd) and buses that cover a wider range of destinations (5th). Notably a 5 minute journey time reduction, outside our definition of convenience, was rated as the 23rd most important improvement! As for rail passengers (Passenger Focus, 2010b), the most important priority for improvement amongst the 31 attributes covered was prices followed by reliability (2nd), sufficient trains at the time of travel (3rd), availability of seats (4th), information on delays (5th), information on train times and platforms (6th) and queuing time (7th). A journey time reduction of 5 minutes was 11th.

Trompet *et al*. (2013) provide an international dimension across 10 different cities using a standard set of questions relating to the three most important features of bus service quality out of eight presented. The range across the cities (in 2012) of the percentages of respondents citing an aspect of service quality as amongst the three most important criteria were:

- Availability (frequency and reliability of service, hours of operation): 86-98
- Accessibility (ease of getting on and off): 8-17
- Information (availability and quality of maps, timetables, delay information): 32-50
- Time (travel time and on-time running): 66-78
- Customer care (helpful staff, responding to suggestions/complaints): 6-20
- Comfort (temperature, ventilation, comfortable journey, clean, crowding): 25-42
- Security (feeling safe and secure): 19-34
- Environment (effect on pollution, noise, congestion): 5-17

These figures demonstrate the importance of convenience related factors. For example, availability is the most important issue, even more than journey time whilst these two and information are more important than comfort and security and far more important than customer care, environmental considerations and ease of getting on and off...

As we have defined it here, convenience is an important aspect of the attractiveness of public transport. Let us give an example. A typical commuting journey might be made up of 30 minutes of in-vehicle time, with 5 minutes of access and 10 minutes of egress, added to which is 5 minutes waiting. At what might be deemed conventional values where out-of-vehicle time is double weighted, this amount to 70 minutes of generalized journey time of which the convenience element makes up 57%. If we added to this average lateness of one minute, with a multiplier of 3, and crowding conditions tending to add 25% to the value of time spent in-vehicle, then the proportion that convenience forms of generalized journey time is 63%. Other scenarios will yield other proportions but it is not unreasonable that convenience is a significant portion of the time element of travel. This will also be the case with regard to the generalized cost of travel. Once the money elements are included, convenience should reasonably form 25-50% of total generalized cost. Crowding alone forms 8-12% of GC for Tokyo commuters (Kato, 2014).

Convenience variables are significant features of public transport journeys and their relatively large values underpin a disproportionately large contribution to its attractiveness. Their importance also opens avenues for making public transport more competitive.

Firstly, as Krygsman *et al*. (2004) state, “Access and egress are the weakest links in a public transport chain and determine the availability and convenience of public transport. Initiatives aimed at improving access and egress hold potential to significantly reduce public transport trip time and are inexpensive options compared to the expensive infrastructure and vehicle enhancement alternatives frequently considered”. Not only might it be possible in some circumstances to be more cost-effective to achieve overall journey time reductions by operating on OVT terms but the greater valuation of OVT savings ought to reap greater dividends.

Secondly, Litman (2014) provides interesting examples of how the travel time costs of transit can exceed those of the same car journey but, with incremental improvements in convenience due to the conditions in which the journey is made, can significantly improve the attractiveness of transit to be competitive with car without any reductions in the journey time itself.

Thirdly, if convenience is important to users of public transport, how much more is it an issue for non-users who do not use public transport precisely because they regard it to be inconvenient?

We can therefore conclude that convenience is a ‘big issue’, and if convenience is important to users and potential users, then it can be expected to have an impact on the financial bottom line of operators, and therefore be of concern to a broad range of stakeholders. Indeed, there are several indications that service quality improvements trigger larger demand responses than fare changes (see the resource papers by Anderson et al. (2013) and by Lee (2013)). Service quality management can affect the financial sustainability of public transport, particularly if accompanied by fare management.

Operators may regard convenience often as beyond their control, thereby introducing an unwelcome level of uncertainty. Train operators are faced with a fixed network and hence find it difficult to influence access and egress times and other costs that have a significant bearing on their attractiveness. Whilst bus operators can be more flexible in their networks, they suffer the vagaries of traffic congestion and buses can as a result be notoriously unreliable particularly at times when most people wish to travel.

Convenience is also an important issue for regulators that seek to incentivise operator performance. Contracts between authorities and operators that are based on indicators of convenience can lead to improved convenience. In the UK, for example, the Schedule 8 payments mechanism means that train operators and the infrastructure provider are fined and compensated according to the degree of delay that they cause or incur. In Transantiago, bus operators receive significant fines if the frequency offered per line is below that requested, and if headway variability exceeds a threshold. The STIF (the public transport regulator for the Ile-de-France region) recently signed a 4 year contract with the RATP and the SNCF (the public transport operators for the Central Paris area and the regional railway network respectively). If we limit consideration to the STIF/RATP contract, signed for the 2012-2015 period, the total financial envelope for the service provision and the investments planned is around 15 billion euros, among which 28 million are related to a bonus-penalty system, depending on the quality of the service provided to users (in the previous contract for 2008-2011, this amount was 21 million). Punctuality's weight within this bonus-penalty scheme is 50%, the information for users corresponds to 14% and the users' satisfaction with service quality forms 10%. The latter is now assessed through a survey of 120 000 users per year covering the three main issues of environment, accessibility and information. For the regional railway network (RER), users will be refunded (50% of the Navigo travel pass) if the service delivery becomes ‘unacceptable’.

A perverse incentive of some performance regimes has been the padding of timetables with additional recovery time. With regard to Dutch railways, Kroon et al. (2009) point out: “To increase the robustness of the timetable, we increased the running times, dwell times, and headway times by time supplements based on experience and expert opinions. Time supplements in the running and dwell times absorb small disturbances in the real-time operations, allowing trains to recover from delays. Time supplements in the headway times, also called buffer times, reduce the propagation of delays from one train to another.” A balance has to be struck between speed and reliability.

It is widely regarded that consumers have ever rising quality expectations in all markets and thus whatever importance public transport convenience currently has, and we would argue it is significant; it will become more of an issue in future, particularly in the light of increases in the attractiveness of car travel. Improving public transport convenience can be virtuous: it increases demand, revenue, public support and acceptability, helping to ensure its long term viability.

Finally, adding convenience to CBA can lead to appreciable increases in benefits. For example, the resource paper by Kroes et al. (2013) integrating the value of crowding in the socio-economic appraisal of the extension of RER line E increases total benefits by 6%. Similar orders of magnitude are found in studies for Japan, as were discussed in the presentation at the Roundtable by Kato.

Official multiplier values

In some countries, official values are specified to be used in the appraisal of transport investments and policies, particularly where public funding is involved. The primary focus of attention over the years has been valuation of in-vehicle travel time savings. We are, however, here concerned with recommended multipliers for the convenience factors set out in section "What is Convenience?"

Bickel et al. (2004) as part of the EU funded HEATCO project concerned with transport costing and project appraisal provided a useful summary of the state-of-play in Europe early in the 21st century regarding convenience multipliers. They stated:

> *"Four countries include guidance weights or values for the treatment of walk, wait and transfer times (Denmark, Sweden, Switzerland and the UK). Other countries, such as France and the Netherlands, make reference to the fact that walk, wait and transfer times may have different values from in-vehicle-time but do not suggest any weights. Denmark and Sweden weight walk-time the same as in-vehicle-time, but weight wait-time and transfer-time at twice the value of in-vehicle-time. For air trips Sweden values transfer-time at 1.7 times the value of in-vehicle-time. Switzerland also values transfer-time at twice the value of in-vehicle-time but does not give specific guidance on the treatment of walk-time and wait-time components. The UK values time spent walking at twice the value of in-vehicle-time, whilst time spent waiting at 2.5 times the value[3]"*

On the matter of crowding and reliability they added:

> *"Sweden, Denmark and the UK include valuations of travel time that is in excess of that expected (i.e. delay) for public transport trips only. Denmark and the UK value delays at the same as that spent waiting for public transport (i.e. twice in-vehicle-time for Denmark and 2.5 times in-vehicle-time for the UK). Sweden on the other hand uses a range of values (from 1.6 to 3.7 times in-vehicle-time) depending on the journey purpose (work/non-work) and the mode. French guidelines value travel in overcrowded conditions on public transport at 1.5 times the value of standard in-vehicle-time. The UK guidelines distinguish between passengers who sit in overcrowded conditions and those who stand. For non-work travel the values range from 1.1p/min to 30.8p/min which reflects a range of about 1.1 times in-vehicle-time to 4.5 times in-vehicle-time".*

The position some ten years ago was therefore that even in the developed economies of Europe there was limited recognition of convenience related variables in official recommendations.

The more recent Mackie and Worsley (2013) 'benchmarking' report extends coverage to some Non-European countries but with fewer European countries included, and we drew on this material in collating the official values contained in Table 1.1 We also asked Roundtable participants if they were aware of official multiplier values relating to public transport as well as approaching academics and organisations in Canada, Italy, South Korea, Spain, Switzerland, Portugal and Chinese Taipei.

The current situation regarding official multiplier values is, to the best of our understanding, that few countries worldwide have them. Indeed, no country has recommendations for all the convenience variables of interest here. For those that have official values, walk and wait multipliers are the most common followed by reliability and crowding. We are not aware of official values relating to displacement time.

We do not here comment on the official recommendations but defer it to a broader discussion within the review of empirical evidence in section 4. But we note that official appraisal values do not tell the whole story for the following main reasons:

- Some countries differ quite markedly in their approaches to appraisal and to forecasting;
- In several countries, sub-national organisations and operators provide guidance;
- Specific schemes and policies, and invariably major ones but even more routine ones, have developed bespoke models to support forecasting and appraisal;
- Partly as a result of these points, and also because of academic investigation, there is now a wealth of evidence on the subject.

Appraisal and forecasting

Several countries differ quite markedly in their approaches to appraisal and forecasting, as we have pointed out in notes to Table 1.1 In Chile, no distinction is made between different elements of travel time in appraisal but demand modelling uses walk time and wait time multipliers of 3.6 and 1.9 respectively along with a transfer penalty of 7.5 minutes. Reliability and crowding are not explicitly included but are assumed to be discerned by mode specific constants.

Appraisal in the Netherlands also uses door-to-door time where the value of time does not distinguish by the type of time, although reliability is accounted for. However, the national model (LMS) does distinguish between different components of time.

Table 1.1 **Official multipliers for public transport convenience terms**

	Walk	**Wait**	**Headway**	**Reliability**	**Crowding**	**Interchange**
Australia	1.4 1.2 < 5min 1.8 > 20min	1.4 2.0 Congested 1.2 Transfer		3.0 Late 6.0 Late at stop 1.5 Late in-vehicle	1.0 LF < 70% 1.1 Seat 1.4 Stand LF=100% 1.3 seated 2.0 stand Crush	5 within mode 7 between mode 10 different facility
Chile[A]	1.0	1.0			1.0	
Denmark	1.5 Transfer	2.0 1.5 Transfer	0.80	2.0 Late		6
France	2.0	1.5		[B]	Seat $1+0.08PM^2$ Stand $1.25+0.09PM^2$	
Germany[A]	1.0	1.0			1.0	
Japan	1.25 Transfer on flat 1.65 Transfer upstairs 1.53 Transfer downstairs 0.89 Transfer using escalator	1.0		1.0 Late	1+0.027LF[C] (LF<100%) 0.9442+0.0828 LF (100%<LF<150%) 0.8+0.179LF (150%<LF<200%) -0.22+0.690LF (200%<LF<250%) -1.37+1.15LF (250%<LF)	2.0 (multiplier approach) or 10 min per transfer
Norway	1.0 Access < 50km 1.36 Access > 50km	Based on headway	As Sweden	RR[D] 0.67 PT<50km RR 0.42 Bus>50km RR 0.54 Train>50km	[E]	2-10 <50km 10 >50km
Sweden	1.36 Access 2.5 Transfer	2.5 Transfer	< 100km 1.13 <10m head 0.92 11-30 head 0.45 31-60 head 0.28 > 61-120 head 0.13 > 120 head > 100 km 0.51 < 60m head 0.26 61-480m head 0.21 >480m head	3.5 Late	1.0-3.0 depending on crowding	
Netherlands[A]	1.0	1.0		RR 0.4 Commuting RR 1.1 Business RR 0.6 Other		

Table 1.1 **Official multipliers for public transport convenience terms (cont)**

	Walk	**Wait**	**Headway**	**Reliability**	**Crowding**	**Interchange**
New Zealand	1.4 Access 2.0 Transfer	2.0 Transfer		3.9 Late 5.0 Late at Stop 2.8 Late En Route	1.4	
United Kingdom	2.0 for Non EB 1.0 for EB	2.5 for Non EB 1.0 for EB	Full:Reduced Tickets[F] 1.0:1.0 ≤15m head 0.95:0.85 20m head 0.87:0.70 30m head 0.65:0.45 60m head	Lateness 2.5 RR[G] 1.4	1.0 LF < 70% 1.0-1.05 Seat 70%<LF<100% 1.06-2.12 Seat 1-3 PM^2 1.45-2.80 Stand 1-3 PM^2	[H]
United States	2.0 for local travel and Non EB	2.0 for local and Non Business				

[A] In Chile, the Netherlands and Germany, appraisal deals in door-to-door time, thereby not using multipliers for other elements of time.

[B] Complicated functions for late time are implied according to the base share of the journey affected by lateness and the amount of delay time.

[C] In Japan, the load factor (LF) is defined as the number of passengers relative to the seating capacity plus the space for standees.

[D] RR denotes reliability ratio, the ratio of the value of the standard deviation of time to the value of time.

[E] Values exist for standing but they are in monetary units and the implied multipliers are not clear.

[F] Official railway industry values.

[G] Here RR is defined as the standard deviation of lateness relative to mean lateness.

[H] Official railway industry penalties exist but they are not pure transfer penalties but also include the consequences of not premium weighting the amount of time spent transferring.

In Germany, rail investments at the national level include transfer time in the travel times and in appraisal the various components of time are given the same weight. These are different to the weights used in forecasting which tend to be unpublished. For public transport investment at the local and regional level, walking, waiting and transfer times are calculated and included with a weighting of one.

British official multiplier values until recently related only to walk and wait time, whereas the railway industry in its standard forecasting procedures has for over 25 years been using headway, interchange, crowding and reliability multipliers (ATOC, 2013).

Sub-national recommendations

Table 1.1 does include some values that originated in railway administrations and there are some significant regional organisations and operators that provide guidance on multipliers for use in transport investment, planning and policy appraisal.

Transport for London has its Business Case Development Manual (Transport for London 2013) which involves a mix of Department for Transport standard recommendations but with, as we shall see below, a significant amount of detail added to cover station and train crowding, the precise walking and waiting conditions, and a wide range of information provision.

In the Ile-de-France, STIF use multipliers of 2 for waiting time, access/egress walking time to public transport and transfer time. For reliability, STIF value a 5% improvement in reliability as equivalent to 4.6 minutes of travel time saving. The current ANTONIN model uses a multiplier of 2.5 for transfer walking time and 2 for waiting and access/egress walking time (Kroes et al., 2006).

In Hong Kong, MTR use multipliers for walking and waiting of 2 in their rail demand forecasting, but there are no specific multipliers for the other elements of convenience covered here, whilst Metrolinx in Ontario has used walk and wait multipliers ranging from 1.5 to 2.5 with transfer penalties ranging from 2.5 to 10 minutes.

In New York, MTA and NYCT have a range of models available to them. The assignment model weights, across all purposes, walk time by 1.5, wait time by 1.25 and uses a transfer penalty of 1 minute. The weighting of time at 100% capacity at 1.15 is though recognised to not fully reflect the discomfort of crowding. As for MTA's Regional Transport (Mode Choice) Forecasting Model, walk, wait and transfer multipliers of 1.5 are used with a transfer penalty of around 5 minutes. Road access to rail has a multiplier of 2, rising to 2.5 for accessing transit. Their 'Best Practices Model' covering the journey to work weights wait time and transfer time for rail at 2.6 for wait times of 7 minutes or less and at 1.42 for more than 7 minutes; the reasoning being at higher headways people are more likely to consult the timetable. Walk time has a multiplier of 3.36.

The Barcelona metro places multipliers of 1.5 on walking access and egress time, 1.5 to 2 on waiting time, 1 on headway, and between 2 and 4 on interchange time.

Bespoke scheme evidence and other research outputs

There is now a considerable amount of evidence, as our review below demonstrates, into multiplier values for convenience variables, and much of this comes from models developed to address specific projects, issues and unknowns rather than informing national policy.

Summary

It was the view of Roundtable participants that the use of the GC measurement, as proposed here, by operators and authorities is generally poor in practice, although better in some European metros than elsewhere.

It was felt that considerable benefit could be obtained by making use of the evidence that exists or deriving local evidence.

Measuring and valuing convenience

There are two ways that improvements in convenience can come about. One is essentially customer focused, responding to what travellers want, and the other is product led, driven by investment and replacement, new technology and external factors such as competition and policy directives. In both cases, it is essential that we can measure the changes that will be experienced by travellers and that we can place a value on them. In this regard, the Anderson et al. (2013) resource paper usefully points out:

> *"To make public transport services more convenient and therefore attractive to passengers, public transport operators and authorities should be keen to ensure a high quality of service on the public transport system. This may require an improvement in service quality, which can only be achieved by a clear understanding of travel behaviour and consumer needs and expectations. Therefore, it becomes essential to measure the level of service in order to identify the potential strengths and weaknesses of the public transport system. This can provide clues to public transport management in the process of evaluating alternative service improvements aimed at enhancing user satisfaction and increasing market share".*

We first consider issues of measurement prior to discussing how valuations are obtained

Measuring convenience

Three approaches can be adopted here:

- Measure perceptions and attitudes;
- Measure the strategic key performance indicators;
- Measure the detailed elements of an 'extended generalised cost' expression.

Measure perceptions and attitudes

Without doubt, measuring how public transport users and indeed non users perceive public transport convenience, and their attributes to it, would yield important insights for key stakeholders, and indeed it is hard to envisage that it would be absent from a customer focused approach to investment decisions and planning. As Anderson et al. (2013) state:

> *"However, developing accurate and valid measures of service quality is a complex task, since it deals with perceptions and attitudes. Hence, gaining a better understanding of consumers' perceptions of the quality of the service provided by public transport is important"*

Whilst the measurement of perceptions and attitudes is now quite widely used to provide important management information in its own right, it also has a long history of use in enhancing demand travel models.

In an early study (Paine et al., 1969), "an attempt was made to provide a more comprehensive coverage of significant variables affecting mode choice decisions", recognising that at the time it was not atypical that mode choice models contained only the two terms of time and cost. Importance and satisfaction ratings were used to evaluate a wide range of attributes relevant to mode choice.

Another early attempt to extend beyond the simple time and cost mode choice models by using survey based psychometric rating scales to represent the effect a broader range of measures, including convenience is provided by Spear (1976). He derived importance scores and satisfaction ratings for 14 attributes, almost all of which related to convenience such as, arriving at the intended time, avoiding long waits, avoiding leaving early for work, avoiding long walks, journey time and having a choice of departure. A convenience index was constructed and used to enhanced mode choice model. The goodness of fit was significantly better than a model based solely on time and cost.

Early models based on RP data did tend to be weak in terms of convenience variables, largely due to data, computing and sample size limitations, although inclusion of convenience terms was certainly not absent and as is apparent from the review material covered below.

It was though the advent and widespread acceptance of Stated Preference (SP) data that meant that convenience terms could be routinely and successfully included in behavioural models as objectively measured terms. This again becomes apparent from the review discussion below.

The advances in choice modelling, which benefitted RP as well as SP approaches, meant that it is not necessary to rely on psychometric measurement, and the ability to use objectively measurable terms in analysis and forecasting for the convenience variables of interest here has clear advantages.

Where psychometric approaches still have considerable attractions is in the valuation of comfort rather than convenience related variables. This is because comfort variables, covering issues such as ride quality, noise levels, seat comfort, rolling stock, safety and security, cleanliness and décor, often have no natural units or else have natural units which cannot be meaningfully used. If we are to generalise from categorical approaches, based on the valuation of specific attributes such as leather seats or a particular type of train which are not inherently transferable, then use must be made of psychometric scales. This becomes even more critical if we want to understand the psychosocial factors that drive people's travel behaviour (Ellaway et al. 2003). However, this is not the case here. We can objectively measure almost all convenience terms and we can value them and hence we can extend the generalised cost term beyond the simplistic time and cost representation.

Admittedly, some convenience factors, such as information acquisition and the ease of obtaining tickets, are not so easily measured in an objective fashion and instead survey based rating methods are required.

Measure the strategic key performance indicators

The Anderson *et a*l. (2013) resource paper provides considerable detail on how public transport operators measure their performance, including various convenience related terms. These tend to be in the form of key performance indicators (KPIs) which have particular attractions for monitoring how well an operator is performing, and might be important for contractual, regulatory and strategic reasons.

Without the right indicators, operators, planners and transport authorities cannot determine accurately the level of convenience they are providing to their customers. And as the old adage goes, "what gets measured, gets managed". Common convenience related KPIs include the number of passengers affected by delay, the percentage of rolling stock available for service, the percentage of ticket machines and escalators in operation, the number of occasions when passengers exceed the maximum capacity of stations or the proportion of peak services above some seating capacity threshold, the percentage of passengers delayed by X minutes or more, and such like. The problem with some KPIs is that they tend to be strategic, aggregate or categorical in nature and hence not readily used alongside valuations in appraisal. Some are collected because they are easy to collect.

However, some KPI information can be operationalised with valuation data, such as mean load factors and excess journey times. Nor is it essential for operators to measure how they deliver on their objective using a GC approach; they can use more direct measures of service quality such as the percentage of passengers arriving on time or who have to stand. And as data systems get better and more granular, operators and planners will have much more data to turn into information on how convenient their services are. Smartcard and mobile phone data will provide much more detail on journey times and their variability, train weighing systems will improve crowding data and GPS information will increase the accuracy of bus reliability information. These performance indicators are not always well measured today, but technology will allow them to be better measured and managed. Such data will provide valuable management, performance and regulatory information in its own right, and will be more suited for inclusion within the GC expression that underpins the appraisal of schemes and to which we now turn.

Measure detailed elements of the generalised cost expression

Our central approach here is to use an enhanced GC approach to cover more convenience terms. This was essentially the approach advocated many years ago by Hensher and McLeod (1977) who sought explicit rather than attitudinal representation of convenience (as well as comfort and effort) and reported (RP) models to this effect that contained the convenience terms of walk time, wait time, number of transfers and seat availability amongst a range of other factors. They did not have the benefit of large amounts of SP data to explore the issue, but nonetheless demonstrated how what they termed variables measured in 'policy sensitive units' can replace the reliance on 'attitudinal schema'. We might usefully summarise this position in terms of Hensher and McLeod (1977) stating:

> "*There is a growing literature on the use of various attitudinal measurement techniques in identifying the influences on travel choices, yet this useful work falls short of meeting the requirements of a policy-sensitive model.*"

Way forward in the context of valuing convenience variables

We are not here arguing that KPIs do not have a role, nor that measuring perceptions and attitude is irrelevant. They both have important roles to play in:

- Alerting operators and authorities of the need for action;
- Informing operators and authorities of the consequences of any action;
- Providing valuable management information for benchmarking, contractual and funding purposes.

The KPIs can provide very important management information, but then one KPI cannot be directly compared with another without converting to some ‘common currency’ such as GC or else applying ‘political’ weights to different aspects of convenience. If we are to extend the GC expression to cover a broader range of terms, then it seems natural to measure these variables, and not just for the appraisal of specific schemes but more broadly in managing and evaluating performance. These variables can be measured in objective terms and do not need the expense and difficulty in application of psychometric approaches. Some of the KPIs typically recorded are difficult to apply within the extended GC approach but improvements can be expected with technological developments in monitoring and measurement,

How do we value convenience?

By value we mean how much an individual is prepared to per for a ‘one unit’ improvement in some convenience variable. Thus if someone is prepared to pay €1.20 to save 15 minutes of walking time, then the money value of walking time savings is 8 cents per minute. Convenience attribute values are typically expressed as multipliers to IVT. If therefore the money value of wait time is 20 cents per minute and the money value of IVT is 10 cents per minute, wait time is valued at twice the rate of IVT and the multiplier is two.

Transport planning practice the world over has invariably represented the overall attractiveness of a public transport mode (or indeed any mode) as being composed of a range of time, cost and other factors each expressed in common monetary units using the weights described in the previous paragraph. This is termed the Generalised Cost (GC) of travel which we could illustrate as:

$$GC = P_I + P_O + \lambda(IVT + \alpha A + \beta E + \gamma WT + \delta D + \theta C + \mu T) \qquad (1)$$

P_I and P_0 denote the prices for in-vehicle and out-of-vehicle travel. The remaining terms are weighted to convert them to common monetary units. So λ is the value of IVT and α, β, γ, δ, θ, μ and ω are multipliers to be applied to the λ to represent in money terms the additional ‘unattractiveness’ of access time (A), egress time (E), wait time (WT), expected delay time (D), mean crowding (C) and the number of transfers during the journey (NT), and the benefits of information (I)

It is quite straightforward to have variants upon this term. So where journeys are planned, and travellers do not arrive at random for their journey, wait time might be replaced with headway, although wait time involved in transfers is still relevant, whilst where there are restrictions on the actual time of travel, then it would be more appropriate to enter terms explicitly relating to the inconvenience of not being able to travel at the desired time. As we shall see, alternative representations of reliability are possible.

Additional terms could be included to cover comfort variables, transaction costs, safety and such like, although care needs to be taken to ensure they are independent effects. As terms become more subjective, and are less easily measured or indeed have no natural units of measurement, the GC term might include ratings to reflect how well a travel option performs in terms of factors such as internal noise, ride quality, seating comfort, décor or perceived safety. Even then though, it would be necessary in an enhanced GC term to attach weights to these rating terms in much the same way as for the terms in equation 1 to convert them into equivalent money units. We shall discuss examples of such models in section “ Review of evidence ”.

The overall attractiveness of a means of travel as represented by equation 1 could be expressed in time units, the so-called Generalised Time (GT), by dividing through by the value of time (λ).

Note that the various parameters can vary across different travellers and types of journey. As examples amongst many types of possible variations, we might expect the value of time for business trips to be somewhat higher than for non-business trips, reflecting the benefits to employers of being able to use saved time productively, whilst those with higher incomes can be expected to have higher money values as can those travelling in less pleasant conditions.

Nor is the function necessarily linear-in-parameters; the value of time and the other multipliers might depend on the levels that the variables take, so that say a minute of IVT saved on a 60 minute journey has a different value to a minute of IVT saved on a 10 minute journey. In particular, we might expect a given increase in occupancy to have a larger impact at higher levels of crowding. There might also be interactions between variables (as opposed to interactions with socio-economic and trip characteristics defined above) so that, for example, the value of time is lower where the fare is higher because travellers are less willing to pay for time savings where the service is deemed to provide poor value for money. It is widely regarded that the inconvenience of unreliability can be reduced by the provision of good information.

The various transport system variables in equation 1 can be objectively measured by some means or another, although there might be a divergence between the actual times and costs and what individuals perceive. So, for example, there might be improvements to public transport convenience but some travellers remain unaware of them, whilst it is not unknown that non-users regard public transport to be less convenient than it actually is. But what about the other components of equation 1; how are its various parameters estimated?

The valuations are relative terms expressing the satisfaction obtained from improvements in one attribute relative to improvements in some other. This is why they are sometimes termed relative valuation. A willingness to pay €0.80 to save 10 minutes means that the traveller is indifferent between the current travel situation and one where the cost is €0.80 more but with a 10 minute lower journey time[4]. In this context the value of a travel time saving relative to money is €0.08 per minute. The same reasoning applies to being prepared to walk 5 minutes longer to access a through service and save 15 minutes journey time. Obtaining estimates of how much travellers are prepared to trade-off one attribute against another is dependent upon information on their choices when confronted with such trade-off situations. Mathematical models can be estimated to explain the choices made in such trade-off situations from which the implied valuations can be obtained by comparing the rate travellers are willing to trade-off.

The first sorts of models to be estimated in order to yield relative valuations, in the 1960s and 1970s, were based around the travel choices people actually make, so-called Revealed Preference (RP) methods. These were usually mode choice models although route choice models also feature. Economists in particular are keen to base empirical analysis and inferences on what people do in the real world.

In the late 1970s, methods based upon hypothetical scenarios, imported from the marketing research literature and particularly experience in the United States, started to attract attention and grew in popularity through the 1980s to the extent that what are termed Stated Preference (SP) approaches have been for many years, and certainly since the 1990s, the principal means of obtaining valuations in the transport market. These methods mimic the real market conditions we ideally want for valuation purposes by offering people multiple choices that require them to trade-off one relevant attribute against another.

RP methods are attractive because they are based upon what travellers actually do, and in well-defined choice contexts where travellers are familiar with the travel alternatives confronting them and their characteristics and where large samples can be obtained, they can yield important insights. However, they can struggle to provide robust estimates where travellers are unfamiliar with the choice context, where there is insufficient reliable information on how travellers perceive the choices confronting them, where sample sizes are small, and where there is limited variation in some variables, high correlation between others or poor trade-offs. Indeed, RP methods cannot provide evidence on variables and travel options that do not currently exist.

The reliability of values obtained from SP methods is critically dependent upon respondents doing what they say they will do, and in particular the absence of strategic bias where respondents exaggerate their responses to, say, time savings or cost increases in order to influence policy makers. Other problems can arise, due to unrealistic designs or choice contexts, failure to bear in mind real-world constraints or simply finding the exercise too difficult, whilst the very nature in which SP information is presented breaks the habit effects that exist in the real world.

The evidence on whether values obtained from SP exercises are robust is mixed. Whilst SP is ‘the only show in town’ for aspects of comfort, that is not the case for the convenience factors of interest here. Its advantages in this context are that it can be based around real-world choice contexts, thereby achieving a greater element of realism than otherwise, it can achieve much larger sample sizes, and it can control the trade-offs that are offered to respondents thereby increasing the quality of the data. SP methods are now dominant on the grounds of cost-effectiveness, statistical efficiency and particularly the ability to examine issues that are not possible in real markets. Nonetheless, we counsel caution since it not unknown that such methods can provide results that are not entirely credible whilst some of the evidence reviewed below indicates that discrepancies can exist between the multipliers implied by the two methods.

We should also point out in passing that an additional set of concerns surround SP model when used directly for forecasting. However, we are not here advocating such use but are concerned primarily with valuation.

Review of evidence

We here provide an account of current understanding regarding multipliers for walk and wait time, service headway and displacement time, interchange, reliability, crowding and information. This is based around existing review material supplemented with evidence from specific studies where appropriate.

At the outset, we recognise that multipliers might vary across countries, although they are inherently more transferable than monetary based valuations. And variations are not restricted to cultural differences, but may stem from different standards and expectations, operating practices, travel conditions and socio-economic composition of the travelling (and sampled) public.

Walk and wait time multipliers

Although somewhat different in nature, these two attributes form part of the OVT associated with public transport and were the first multipliers to receive detailed attention. They can be expected to be valued somewhat more highly than one on the grounds of the inconvenience, effort and frustration they cause. Indeed, the widely used convention of applying a weight of two to walk and wait time is one of the oldest and most common of transport planning practices worldwide and seems to stem from the UK Department of the Environment’s pioneering Mathematical Advisory Unit Note 179 (McIntosh and Quarmby, 1970).

Summary of official walk and wait multipliers

The multipliers recommended as official values in Table 1.1 and used by public transport operators in major cities take on a large spread. On the one hand, some countries treat all types of time the same, as door-to-door time, and implicitly the multipliers are one. This will also be the case for business travel for the vast majority of countries who use the Cost Savings Approach to valuation since all types of travel time are implicitly unproductive and any time saved, of whatever form, is assumed to be transferred into productive effort.

For countries that have explicit multipliers of walk and wait time, even here a large spread can be observed for both walk and wait time; walk varies between 1.2 and 2.0 with 2.5 at transfers whilst wait varies between 1.4 to 2.5, with a lower bound of 1.2 at transfers. Indeed, there seems to be no consensus on which is the larger.

It could be argued that the access time multipliers are lower than for walk time, presumably because access involves modes less strenuous than walking, whilst waiting time at transfer seems relatively high, which might be because here waiting cannot be avoided whereas in other cases wait time might be proxying for headway inconvenience but the effect is dampened insofar as people do not turn up randomly.

Walk and wait multiplier review evidence

There is now a large amount of evidence on walk time and wait time values, not least because they are an essential feature of mode choice models. Although it is common that headway replaces wait time, offsetting this is that wait time is a feature of interchange that sometimes features in such models.

An early review of walk and wait time multipliers (Goodwin, 1975) pointed to multipliers in excess of two. McKnight (1982) reviewed evidence from 17 studies covering the United States, United Kingdom, Australia and France on the relationships between the values of walking, waiting and IVT. The mean walk time multiplier was 1.85 but the wait time values had a larger mean of 2.40. Of the ten disaggregate studies providing walk and wait time values covered in a review of international evidence (TRRL, 1980), walk time was on average valued close to twice IVT and, excepting a study with a very high valuation, wait time was valued around three times IVT. A large scale review of international evidence (Waters, 1992) concludes that “Several studies have shown that time spent waiting is valued more highly than time travelling, of the order of two to one or more” whilst Ortúzar (1994) reviewed 10 mainly revealed preference (RP) Chilean studies conducted between 1983 and 1993 and, on average, walk and wait time were valued at 2.4 and 5.4 times IVT.

Miller (1996) reported what at the time was an extensive review of international evidence on walk time multipliers. It covered 18 from 7 countries yielding 34 multipliers. The mean ratio was 2.28 with a standard error of 0.17. Steer Davies Gleave (1997) in their review of their own and also some European evidence concluded that, “Walking time is usually valued at between 1.8 and 2.4 times in-vehicle time. An average of 2.0 is recommended for simplicity” and “Waiting time is sometimes valued higher than walking time, up to 4.5 times higher than in-vehicle time. A ratio of 3 times is recommended.”

Turning now to more recent evidence, what emerges, both in Britain and elsewhere, is a prima facie challenge to the convention of valuing walk and wait time at twice the rate of IVT which is at odds with the earlier RP based evidence.

Bickel et al. (2005) provided a major review of the state-of-the-practice in transport project appraisal in Europe. It summarises official guidance but it adds no insights on the evidence base over and above that here provided.

A number of large scale reviews of UK evidence, primarily focused on the value of time but with insights into time multipliers, have been provided by Wardman (2001, 2004) and Abrantes and Wardman (2011). For example, the findings of Wardman (2004) were used to increase the UK Department for Transport's recommended value of wait time multiplier to 2.5[5]. Most recently, Wardman et al. (2013) extended the work to cover Europe. The multipliers implied by these studies are reported in Table 1.2

Table 1.2 **Walk and wait time multipliers**

	Wardman (2001)	**Wardman (2004)**	**Abrantes and Wardman (2011)**	**Wardman et al. (2013)**	
				UK	**Non UK**
Walk	1.66:0.06:140	1.68:0.05:183	1.65:0.04:296	1.62:0.05:272	1.93:0.10:68
Wait	1.47:0.09:34	1.76:0.10:62	1.70:0.09:90	1.68:0.10:77	1.93:0.09:59
Transfer Wait				1.72:0.11:11	1.93:0.16:15
Access	1.81:0.10:52	1.77:0.10:60		1.57:0.07:102	1.95:0.14:42
OVT	1.46:0.10 64		1.43:0.09:73		

Note: Mean, standard error of the mean and number of observations reported.

As far as the UK values are concerned, they do not vary greatly across the different data sets. What are noticeable though are that the UK numbers fall short of 2, and sometimes by a considerable margin, and certainly less than the 2.5 for wait time in official recommendations, and the UK values are around 15% lower than the Non UK European values.

The figures in Table 1.2 though mask some important variations. For example, Abrantes and Wardman (2011) report RP multipliers for walk and wait time of 1.84 (0.15) and 2.32 (0.18) in contrast to SP figures of 1.62 (0.04) and 1.43 (0.07) respectively whilst for European wide evidence Wardman *et al.* (2013) report RP multipliers of 2.01 (0.18), 1.88 (0.16), 2.22 (0.14) and 2.03 (0.31) for walk time, access time, wait time and transfer wait time respectively, with the corresponding SP values always being lower at 1.63 (0.04), 1.55 (0.07), 1.60 (0.07) and 1.82 (0.11). It would therefore seem that RP based figures are somewhat higher and not inconsistent with multipliers around 2.

The RP explanation could be behind the divergence between UK and Non UK values, on the grounds that the UK evidence places greater reliance on SP evidence. Wardman (2013) reported a meta-model estimated to a wide range of multipliers, covering 12 attributes and 1389 observations drawn from 244 studies and 18 European countries. The UK walk and wait multipliers were found to be 22% lower even after accounting for RP walk and wait time multipliers being valued 20% more highly.

However, given that the differences are not particularly large, the following discussion is based upon the entire UK and Non UK data set as providing the largest set of multiplier evidence. Furthermore, Table 1.3 splits the values by country, for all the OVT terms combined, and the variation is not large. Noticeably Denmark with a low average multiplier also places more emphasis on SP data.

Table 1.3 **OVT multipliers by country**

Country	
Denmark	1.64:0.07:45
Netherlands	2.02:0.17:14
Norway	1.87:0.15:30
Sweden	2.00:0.13:28
Switzerland	2.14:0.39:11
Spain	2.16:0.19:12
UK	1.62:0.04:468
All Other	2.11:0.13:44

Note: Mean, standard error of the mean and number of observations reported.

Proceeding therefore with the combined European data set, the meta-model reported in Wardman (2013) can be used to 'predict' walk and wait time multipliers. The walk time multiplier varied by mode whilst it and the wait time multiplier varied by purpose and distance, the latter because the money value of time increases with distance at a stronger rate than the money values of walk and wait time. There was also a trend reduction of around 1% per year apparent whilst RP multipliers were larger. The multipliers predicted by the model for 2011 and based on RP evidence are set out in Table 1.4. These figures would suggest multipliers of 2 should be regarded as upper limits.

Table 1.4 **Walk and wait (RP) multipliers implied by Wardman (2013) meta model**

	BUS				TRAIN			
Distance (Km)	5	25	100	250	5	25	100	250
WALK								
Commute	2.05	1.98	1.91	1.87	1.80	1.73	1.68	1.64
Business	1.85	1.79	1.73	1.69	1.62	1.57	1.52	1.48
Other	2.18	2.10	2.03	1.99	1.91	1.84	1.78	1.75
WAIT								
Commute	1.80	1.73	1.68	1.64	1.80	1.73	1.68	1.64
Business	1.62	1.57	1.52	1.48	1.62	1.57	1.52	1.48
Other	1.91	1.84	1.78	1.75	1.91	1.84	1.78	1.75

Note: Transfer Wait and Access have the same multipliers as Wait.

Returning to the raw data, Tables 1.5 and 1.6 sets out the OVT multipliers split by journey purpose and mode for the European wide evidence in Wardman (2013).

We observe that there tends to be relatively little variation by journey purpose, particularly when the sample size is large. If anything the leisure multipliers are largest and the business travel multipliers the lowest, consistent with the meta-model predictions in Table 1.4

Table 1.5 **OVT multipliers by journey purpose**

Attribute	All	Commute	Leisure	Business	Other
Walk Time	1.68:0.04:344	1.69:0.07:119	1.70:0.09:81	1.52:0.25:7	1.65:0.07:137
Access time	1.68:0.07:144	1.68:0.13:34	1.82:0.14:46	1.66:0.17:17	1.55:0.11:47
Wait Time	1.80:0.07:138	1.83:0.11:56	1.76:0.14:37	1.54:0.32:5	1.84:0.11:40
Transfer Wait	1.84:0.10:26	1.59:0.12:11	1.99:0.27:5	1.28:0.0:1	2.12:0.16:9

Note: Mean, standard error of the mean and number of observations reported. Other here includes combinations of purposes.

As for mode, the segmentations are according to whether the multipliers vary by mode used and mode valued. The samples reported are bus users valuing bus OVT, rail users valuing rail OVT and car users valuing any public transport option. Since there are combinations of modes used and valued, the figures cover only a portion of the full data set. The main difference between bus and rail users is that access time is somewhat lower for rail, presumably because rail often involves modes of access that have a lesser disutility than walking which will be typical for bus. Whilst car users might be expected to have higher values of the OVT variables, since they are less accustomed to it and indeed it may be one of the reasons why they choose car, there is no support for this. In general, the modal variations are fairly minor, in line with the findings of the meta-model reported in Table 1.4

Table 1.6 **OVT multipliers by mode**

Attribute	All	Bus	Rail	Car
Walk Time	1.68:0.04:344	1.64:0.12:29	1.65:0.12:17	1.47:0.08:98
Access time	1.68:0.07:144	1.62:0.12:8	1.29:0.14:12	1.45:0.13:21
Wait Time	1.80:0.07:138	1.74:0.13:25	1.49:0.17:17	1.75:0.25:10
Transfer Wait	1.84:0.10:26	1.92:0.20:8	1.83:0.25:5	1.64:0.08:2

Note: Mean, standard error of the mean and number of observations reported.

A review has recently been completed of public transport values of time and other attributes in Australia and New Zealand (Wallis et al., 2013). 21 studies yielded 48 walk time multipliers averaging 1.3, with little variation by time of day. As an average, this seems to be on the low side. However, it was pointed out that:

> *"All but two of the studies were SP surveys and in this regard it is worth mentioning a potential problem in getting respondents to hypothesise a different location for a bus stop or train station they normally use. The exceptions were two Sydney RP studies (Fox et al. 2010; Hague Consulting 1996) in which the value of walk time was estimated cross sectionally based on household travel survey data. These two revealed preference studies estimated a higher valuation of walk time of 1.5".*

Not only does this pattern of results accord with the results presented above, but the explanation is similar to that offered in those studies in terms of the realism of varying walk time.

From 6 Australian studies and 15 multipliers and 1 New Zealand study and 1 multiplier, Wallis *et al.* (2013) found wait time at transfer to average 1.25. Again this seems low and again SP evidence dominates and its inability to represent realistic wait time variations may be a contributory factor. In a resource paper for this Roundtable Lee (2013) reports mode choices models where the OVT multipliers varies between 1.01, 1.05 and 1.7 across three models.

One of the issues discussed in the Roundtable was the level of detail that is provided by the available multiplier evidence, and in particular we might expect multipliers to vary not only according to person type but also according to the conditions in which the walking and waiting time is spent. The weather, the travel environment and facilities, perceived safety, the degree of crowding and the amount of effort involved will impact on these multipliers. Indeed both might be non-linear, so that the unit values depend upon the amount of walking or waiting time. All these possible sources of variation might be why the OVT multipliers have been observed to vary somewhat.

There is not a large amount of evidence on influences on the walk and wait time multipliers. Transport for London's Business Case Development Manual (Transport for London, 2013) provides an unusually high level of detail in its recommended appraisal parameters, although the evidence underpinning it and its strength is not immediately apparent. Nonetheless, some entirely plausible relationships are specified.

For waiting for trains or lifts in acceptable, uncongested conditions a multiplier of 2.5 is used. However, this is increased on crowded platforms. The wait multiplier (WT) is then a function of the congestion factor (CF) as:

$$WT = 2.5 + CF$$

Walking in unimpeded conditions (WK) has a multiplier of 2, but is also allowed to vary with the degree of congestion:

$$WK = 2.0 + \frac{CF}{2}$$

CF is related to passengers per m2 (P) as:

$$CF = 0.667(P - 0.5)^2 \; for \; 0.5 \leq P < 2$$

$$CF = 1.50 \; for \; P \geq 2$$

$$CF = 0 \; for \; P < 0.5$$

Illustrative multipliers for WK and WT are given in Table 1.7 below for vary degrees of congestion (P).

Table 1.7 **Transport for London walk and wait multipliers and congestion**

P	WK	WT
0.5	2.00	2.50
1.0	2.08	2.67
1.5	2.33	3.17
2.0	2.75	4.00
2.5	2.75	4.00

Both multipliers start at UK official recommended values with notable increases with congestion, particularly for waiting time.

In addition, Transport for London has a whole range of additional, entirely sensible, modifiers of:

- Walking upstairs: 4.0
- Walking downstairs unimpeded: 2.5
- Waiting to get to ticket office window or machine: 3.4
- Transaction at ticket office window or machine: 2.5
- Queuing at a PASS agent: 3.0
- Transaction at a PASS agent: 2.0
- Delay at Ticket Gates: 4.0
- Travelling on escalators: 1.5
- Travelling in lifts: 2.0

For bus journeys, the weights used are simply 2.5 for waiting and 2.0 for walking.

As is apparent from Table 1.1, the Japanese CBA manual for rail allows variations in the walking time multiplier according to whether the walking is upstairs, downstairs, on the flat or on an escalator (Kato, 2014). We note though that the recommended Japanese multipliers are relatively low for walk and wait time. This is backed up in the Tokyo rail route choice RP models of Morichi et al. (2001) where across commuting, business and leisure journey purposes the access/egress multipliers vary between 1.18 and 1.35 and the transfer time multipliers vary between 1.19 and 1.46.

Douglas Economics (2006) provides interesting insight into the impact of crowding on platforms and in access areas and entrances on walking and waiting time multipliers. Table 1.8 reports their estimated multipliers for different degrees of crowding defined in terms of passenger per square metre (PM^2). Some very large variations in the multipliers can be observed, somewhat larger than used by Transport for London.

Table 1.8 **Impact of crowding on station walking and waiting times**

Crowding	<0.2 PM^2	0.2-0.5 PM^2	0.5-2 PM^2	>2 PM^2
Wait	1.9	1.5	3.2	5.5
Walk	2.2	2.2	3.5	6.2

A piece of research discussed at the Roundtable is interesting from, amongst other perspectives, the similarity of effects between two somewhat different cities and for casting more light of detailed valuations, particularly interchange which we return to below.

Raveau et al. (2014) used survey data to examine metro users' actual route choices in both London and Santiago. The range of attributes explaining behaviour was very similar in the two locations, with OVT multipliers varying with time of day, purpose and, in the case of walk time, being higher for women. In London the waiting time multiplier ranged between 1.59 and 2.26 whereas for Santiago the range was 1.53 to 1.99. As for the walking time multiplier, it ranged between 1.24 and 2.90 in London and 1.91 and 3.98 in Santiago. Note that these figures would tend to indicate multipliers above the SP based evidence above and notably it was derived from RP data.

Conclusions on walk and wait time

There is now a lot of evidence on walk and wait time multipliers, and indeed there has been for a long time. The evidence seems to be indicating that RP based multipliers are larger than their SP equivalents, and it has been speculated that this might be because of difficulties in conveying realistic valuations in walk and wait times in SP exercises.

It can be seen that the multipliers vary quite a lot. This was noted in the early review of walk and wait time multipliers by Goodwin (1975) and repeated some 30 years later by HEATCO (Bickel et al., 2005). Apart from the RP-SP dimension, this could be because the conditions in which walk and waiting time are experienced vary somewhat, along with possible non-linearities. Having said that, variations by purpose and mode do not seem large.

We have uncovered sensible variations in multipliers according to the degree of crowdedness. These provide an important element of detail. Going forward, it would be informative to add to such level of detail by quantifying other influential factors.

Bearing in mind the heterogeneity within the evidence, there is no doubt that a premium should be attached to walking and waiting time relative to IVT, and one could interpret the results as indicating that multipliers of 2 in normal conditions can be regarded to be upper bounds.

There was limited evidence to suggest the walk and wait time multipliers were falling over time, although it is conceivable that there are confounding effects here.

Departure time convenience

Being able to make a journey essentially without the constraints imposed by timetabled departures is often cited as one of the key features of car convenience. Two attributes are relevant here. One is the service headway and the other is displacement time. As public transport services become more frequent, travellers tend to turn up at random at the station or stop and the inconvenience of not being able to travel at the precise desired time is reflected in waiting time. As services become less frequent, there is the inconvenience not only of departing at increasingly more undesirable times but also the costs involved in obtaining information and planning. In the latter case, displacement time is relevant, indicating the disutility incurred as a result of not departing at the preferred time.

Headway can represent both the wait time and the displacement time effect, and this as we shall see is a cause of some ambiguity in interpretation. Alternatively, it is possible to directly estimate displacement time reflecting the inconvenience of not being able to depart at the desired time.

Headway might also have ‘correlated’ benefits such as providing a degree of flexibility independent of any inconvenience issues whilst more frequent services are likely to be less crowded and be beneficial when there are service disruptions.

Summary of official headway and displacement time multipliers

As is apparent from Table 1.1, we have not identified official values relating to displacement time. Nonetheless, such values are used in practice; for example, the railway industry in Britain constructs its recommended frequency penalties using displacement time multipliers (ATOC, 2013).

Sweden offers official headway multiplier recommendations which have been adopted in Norway whilst in the UK the railway industry has nationally recognised values. What is noticeable about these values is that they fall as headway increases, reflecting the movement from largely random arrivals at high frequencies to largely planned arrivals at low frequencies.

Review of headway and displacement time multiplier evidence

There is less by way of review evidence on the value of headway and departure time shift. The largest conducted, covering UK and European evidence, is reported by Wardman (2013) and Wardman *et al.* (2013).

A feature of the review evidence is that it does not distinguish the random and planned arrival elements surrounding headway. Estimated headway multipliers are invariably constant regardless of the level of headway. Table 1.9 reports European wide headway and displacement time multipliers obtained from Wardman (2013). The headway values are quite variable across countries and this might reflect different balances of planned and random arrivals. The displacement time values largely comes from UK studies, but the vast majority of the other 28 observations are not greatly different.

Table 1.9 **Headway and displacement multipliers by country from Wardman (2013)**

	Headway	**Displacement**
Denmark	0.59:0.07:19	-
Netherlands	**0.36:0.05:6**	**0.52:0.07:18**
Norway	**0.89:0.22:15**	**0.52:0.09:8**
Sweden	**0.45:0.07:13**	**-**
Switzerland	**0.53:0.06:25**	**-**
Spain	**0.53:0.10:18**	**-**
UK	**0.76:0.03:225**	**0.67:0.06:79**
All Other	**0.40:0.09:8**	**0.36:0.21:2**
All	**0.71:0.03:329**	**0.63:0.05:107**

Note: Mean, standard error of the mean and number of observations reported.

Wallis *et al.* (2013) find the headway multiplier to average 0.66 across 22 studies yielding 63 observations but a little lower at 0.48 across 8 New Zealand observations from 5 studies. These are not out of line with the European evidence.

If headway represented purely random arrival effects, then we would expect the value of headway to be half the value of waiting time. A mean headway multiplier of 0.71 is therefore broadly consistent with the waiting time multiplier given that the latter seems to be at most two and headway will not simply represent random arrivals. Indeed, Kroes *et al*. (2006) stated that, “The percentage of passengers aiming for a specific train is strongly related to the scheduled frequency of service: for train services with headways of 15 minutes or longer around 80% of all passengers aim for a specific train, whereas for services with headways of 5 minutes or less only around 20% aim for a specific train”.

If headway represented a pure displacement time effect, then given uniformly distributed desired departure times, a given headway will on average translate into a quarter as much displacement time. Clearly, the mean multipliers for headway and displacement time are not consistent with this. We note that studies rarely give the departure times associated with a given headway do not make the link with displacement time. In any event, the headway, displacement and wait time multipliers can be consistent depending upon the proportion of planned and random arrivals.

Table 1.10 disaggregates the Wardman (2013) displacement and headway multipliers by journey purpose. It also distinguishes between displacement time that involves travelling earlier than desired, later than desired or where no distinction was made.

The headway multipliers are remarkably similar by journey purpose. Displacement time seems to be more highly valued for later than desired departures, although not by much and not for leisure trips. Commuters as might be expected dislike departing later more than departing earlier given arrival time constraints at work whilst leisure travellers might not want to get up sooner to set out on their journey and have fewer arrival time constraints. Confounding factors here though are direction of travel and/or time of day which might be expected to affect relativities but which studies typically do not control for or report on. Given the absence of the latter distinctions, and that the differences are in any event not large, it might be sensible to use a single value for displacement time that does not vary by earlier or later departures. Observing the row for all displacement time multipliers would seem to justify larger values for commuting and lower for leisure, although again purpose effects may confound with other effects.

Table 1.10 **Headway and displacement time multipliers by journey purpose**

Attribute	All	Commute	Leisure	Business	Other
Headway	0.71:0.03:329	0.67:0.05:68	0.71:0.04:95	0.74:0.07:37	0.71:0.05:129
Displace Early	0.56:0.07:44	0.59:0.14:18	0.63:0.22:8	0.50:0.06:7	0.50:0.02:11
Displace Late	0.65:0.08:47	0.74:0.017:19	0.43:0.08:9	0.64:0.14:7	0.67:0.11:12
Displace Both	0.74:0.14:16	1.63:0.87:2	1.00:0.0:1	1.00:0.00:1	0.55:0.08:12
Displace All	0.63:0.05:107	0.72:0.11:39	0.55:0.11:18	0.60:0.08:15	0.58:0.05:35

Note: Mean, standard error of the mean and number of observations reported. Other includes combinations of purposes.

Table 1.11 provides multipliers by mode, where the car multipliers are for motorists but relating to public transport. Very much smaller headway penalties are apparent for rail, presumably due to lower frequencies and hence more trip planning. This might also underpin the larger displacement multipliers for rail than for bus users but it may simply be that it is less of an issue for bus users.

Table 1.11 **Headway and departure time shift multipliers by mode**

Attribute	All	Bus	Rail	Car
Headway	0.71:0.03:329	0.76:0.10:40	0.42:0.03:43	0.80:0.05:92
Displacement	0.56:0.07:44	0.35:0.14:2	0.77:0.09:26	0.60:0.07:14

Note: Mean, standard error of the mean and number of observations reported.

The meta-model reported in Wardman (2013) can be used to provide implied displacement time and headway multipliers. These were found to vary by purpose, distance and mode for headway and whether the journey was inter-urban for displacement time. There is also a slight variation between earlier and later displacement times. Table 1.12 contains illustrative figures.

There is a strong reduction in the headway values with distance, presumably proxying for the different balance of planned and unplanned journeys. Business travellers find headway most important, which is to be expected. The headway multipliers now seems to be more important for train users, and presumably the previous results were being confounded by the strong declining distance effect given that the bus data is almost entirely for urban travel. As for displacement time, this is much more of an issue for inter-urban journeys, thereby explaining the difference between train and bus apparent in Table 1.11 which now disappears[6]. As with Table 1.10, commuters have the largest displacement time multipliers although the variations are relatively small.

Table 1.12 **Multipliers implied by Wardman (2013) meta-model**

	BUS				TRAIN			
	5	25	100	250	5	25	100	250
Headway								
Commute	0.65	0.47	0.35	0.29	0.83	0.60	0.45	0.37
Business	0.76	0.54	0.41	0.34	0.97	0.70	0.52	0.43
Other	0.65	0.47	0.35	0.29	0.83	0.60	0.45	0.37
Displace								
Early	0.48	0.48	0.80	0.80	0.48	0.48	0.80	0.80
Commute	0.37	0.37	0.61	0.61	0.37	0.37	0.61	0.61
Business	0.37	0.37	0.61	0.61	0.37	0.37	0.61	0.61
Other								
Displace								
Late	0.55	0.55	0.92	0.92	0.55	0.55	0.92	0.92
Commute	0.42	0.42	0.70	0.70	0.42	0.42	0.70	0.70
Business	0.42	0.42	0.70	0.70	0.42	0.42	0.70	0.70
Other								

Note: Metro and LRT headway values would be 28% larger. Presumably this reflects the greater degree of random arrivals given the generally higher frequencies involved.

Conclusions on departure time shift and headway

There is a large amount of headway multiplier evidence, which at an aggregate level is consistent with the wait time multipliers reviewed in the previous section. There are only slight variations by journey purpose but, as expected, headway becomes less important for longer journeys. The headway multiplier is larger for train. Displacement time seems to be more of an issue for inter-urban travel, where planning is commonplace.

It is noticeable that the multivariate analysis provides different results to the simple tabulations with regard to how the multipliers vary mode, and this is presumably because the latter are confounded with the distance effects.

Whilst service frequencies can be readily observed and hence their use in GC based applications is straightforward, this is not the case for displacement time where surveys are needed on desired departure times to convert timetabled departures into displacement time.

Two words of caution. There is an element of ambiguity in the headway multipliers. We might expect them to fall as the balance between planned and random arrivals moves in favour of the former as headways increase. The evidence does not distinguish direction of travel or time of day, although we suspect the outward journey will have dominated, and we might expect displacement time multipliers to depend upon these. The differences between earlier and later displacement times would seem to relate to the outward journey but are in any event slight enough to be ignored.

Railways in the UK get around the problem of the headway value representing two different effects. They use a displacement time value for those who plan their journey, with a greater proportion planning as headways increase. This indicates the inconvenience of not being able to travel at the desired time. For those who arrive at random, which is more likely at more frequent services, headway is converted into waiting time and a wait time multiplier used to represent the inconvenience. However, there is little evidence of how travellers choose between planned and random arrivals.

Interchange

We have already covered the wait and walk time involved in interchange. Here we consider the fixed penalty involved in having to transfer between vehicles. This arises because of the hassle and risks involved independent of any walking and waiting time. Thus there is a risk that the next service is missed whilst any activities being undertaken will have to be interrupted.

Summary of official interchange penalties

Official values are comparatively rare for transfer penalties. They are 10 minutes or less with variation by type of interchange. The penalties used in New York City and Toronto fit with this range whilst Transport for London (Transport for London, 2013) uses a 3½ minute penalty for transfer between underground services and 5 minutes for transfer between underground and rail.

Review of interchange penalty evidence

There are three components to an interchange; walking between services, an amount of waiting and a fixed penalty for the inconvenience and risks involved. Wallis *et al*. (2013) stated that, "Many studies on transfers do not clearly distinguish between these three transfer components" which limits the amount of usable information available.

Wardman (2001) also recognised this problem in the literature. He distinguished between studies which estimated a pure interchange penalty independent of time effects, those that simply estimated an interchange variable without any separate connection time and those that estimated an interchange penalty and allowed for connection time but without any additional weighting of the latter. The latter two were, as expected, larger than the pure penalty and averaged around 30 minutes whereas the 8 observations relating to pure penalties were found to average 17.6 minutes. A meta-model was developed on 1116 money values of a range of variables, including 47 interchange values. It found interchange values to vary with purpose and region. The implied pure transfer penalties are set out in Table 1.13

Table 1.13 **Implied transfer penalties (Wardman, 2001)**

Kilometres	5	25	100	250
Commute	6.9	5.8	5.0	4.5
Commute SE	5.0	4.2	3.6	3.3
Other	13.7	11.5	9.9	9.0
Other SE	10.0	8.4	7.2	6.5

The time multipliers fall since the money value of time increased with distance but the money values of the pure interchange penalty did not. Those in the South East (SE) have lower values, presumably due to a greater familiarity with the rail network as a result of greater usage whereupon the risks and uncertainties involved in interchange will be less whilst the more frequent onward

Wallis *et al*. (2013) cover 17 Australian studies and 63 values but only one New Zealand study yielding one value. Most studies estimated an interchange 'effect' containing the wait time and this was removed to leave a pure penalty. However, the approximations involved in this should be borne in mind.

The peak interchange penalties were 4 minutes for the same mode and 9 minutes between modes. The corresponding off-peak figures were 12.5 for the same mode and 17 minutes for different modes. It is plausible that the penalty is higher between modes. As for the high off-peak values, this might be because travel time in the peak has a higher disutility, passengers in the peak are frequent users and hence interchange will be more familiar, and the higher frequencies in the peak mean the risks associated with interchange are less.

Douglas and Jones (2013) review 17 interchange studies covering Australia and the UK. These largely overlap the Wallis *et al*. (2013) and Wardman (2001) reviews. What is particularly noteworthy about this study is providing more detail of how the interchange penalty might vary. The reported penalties are contained in Table 1.14 for bus users and train users. The penalties tend to be larger for longer distance. As expected, rail users find a cross platform interchange to be less onerous than an 'up and down' transfer to another platform. Bus users are more averse to rail interchange, perhaps due to unfamiliarity. Similarly, rail users have a larger dislike of bus interchange than do bus users. However, even bus users have quite large bus interchange penalties perhaps because transfer is relative uncommon by bus.

Table 1.14 **Transfer penalty variations (Douglas and Jones, 2013)**

Transfer	Bus Short	Bus Medium	Bus All	Rail Short	Rail Medium	Rail All
Rail Cross Platform	9.0	13.7	12.5	6.8	7.2	6.9
Rail 'Up and Down'	11.3	13.6	12.9	9.5	9.3	9.3
Bus to Rail	11.1	16.6	15.1	15.8	19.3	17.5
Bus to Bus	14.8	14.6	14.5	18.1	28.6	23.3

Wardman and Shires (2000) report a joint RP-SP model to explain the three components of interchange. The penalty was found to vary with journey duration, flow type and whether it was the first or second transfer. The second transfer had a smaller effect than the first. However, there was no difference according to whether the connecting train was on the same platform or another. Noticeably, they found some evidence that SP based transfer penalties were larger than those obtained from RP data. The interchange penalties implied by their model are reported in Table 1.15. Unsurprisingly, penalties are lower in the dense South East network, where frequencies and familiarity are high. For suburban journeys, the penalties are in line with other evidence.

Table 1.15 **Implied transfer penalties (Wardman and Shires, 2000)**

Journey Duration	Inter Urban 1st change	South East 1st change	Inter Urban 2nd change
30 minutes	9.1	7.5	5.8
60 minutes	11.1	9.1	7.0
120 minutes	15.1	12.3	9.4
180 minutes	19.1	n/a	11.9
240 minutes	23.1	n/a	14.3
300 minutes	27.1	n/a	16.8

The Raveau *et al*. (2014) metro route choice models for London and Santiago discussed at the Roundtable provide interesting insights into variations in transfer penalties. Even though in principle these penalties are independent of the amount of transfer time, there does seem to be variation with the amount of effort involved. Nonetheless, the variations with effort are slight; we would be surprised if they were large. The penalties for peak travel fit with other evidence and again off-peak travellers are found to have higher values. Similar results were found by Navarrete and Ortúzar (2013) for the multi-modal transit system in Santiago.

Table 1.16 **Metro transfer penalties**
(Raveau *et al.*, 2014)

	London		**Santiago**	
	AM Peak Commute	**Off Peak Non Commute**	**AM Peak Commute**	**Off Peak Non Commute**
Ascending Assisted	6.08	12.36	8.72	13.49
Ascending Semi-Assisted	7.11	14.46	n.a.	n.a.
Ascending Unassisted	7.70	15.66	10.30	15.95
Descending Assisted	5.24	10.65	5.84	9.05
Descending Semi-Assisted	6.28	12.76	n.a.	n.a.
Descending Unassisted	6.86	13.95	7.43	11.51

Note: Assisted means that an escalator or elevator can be used for all changes of level whereas they can only be used for part of the change of level under semi-assisted.

Conclusions on interchange penalties

Litman (2014) states that "transfers are estimated to impose penalties equivalent to 5-15 minutes of in-vehicle time". This is expected to be at the lower end where good information and comfortable waiting conditions are provided and there is a minimum of insecurity, stress and effort. We concur with this statement in the light of the evidence covered here and note the consistency between the evidence based and official and used transfer penalties.

There is evidence that commuters have lower transfer penalties than other travellers and this might be through a familiarity effect which was apparent in other findings. The evidence on the distance effect is not consistent, but it is very limited. There is evidence that shows worse transfers have larger penalties, as is the case for between modes.

Reliability

Reliability is, unlike the other convenience factors covered here, as much an issue for car travel as it is for public transport. As such, a considerable amount of evidence relates to car. Nonetheless, this is an area where there is a relatively large amount of public transport evidence, and much of it is comparatively recent.

Another aspect in which reliability is different to the other convenience attributes is that it has been measured and valued in a number of different ways. These are:

- Mean lateness on schedule, which was the first measured employed. Rather than offer a range of times, as is now customary, this method typically stated that the service would be X minutes late one in Y times.
- Schedule delay early (SDE) and schedule delay late (SDL). These are, across n arrival times, the mean level of earliness and lateness relative to the preferred arrival time.
- The standard deviation of travel time (SD), expressed across n arrival times. The ratio of the value of the standard deviation of travel time and the value of mean travel time is termed the Reliability Ratio (RR)[7].

Summary of official reliability values

Official values for public transport are either based around mean lateness or the RR. The former exhibits a large range, from 1.5 to 6 but is generally between 2 and 4. The RR tends to be in the range 0.4 to 0.7, but with the 1.4 for the UK an exception.

Review of reliability multiplier evidence

Wardman (2013) reports evidence on reliability related values covering Europe. An immediate issue with the scheduling (SDE and SDL) and mean-variance (RR) terms, originally pointed out by Tseng (2008), is that some models specify either the scheduling variables or the standard deviation of travel time whilst others include both. In the latter case, the effect attributed to the scheduling variables and to the variance will obviously be less than in the former case where the effect is not 'shared out'. The issue does not arise with the late time variable.

Table 1.17 provides multipliers for SDE, SDL and RR when the scheduling variables and the spread variables are specified on their own (Alone) and also when both term are specified (Both). Since we simply cannot report the average values across the Alone and Both model specifications, because this is neither one thing nor the other, the subsequent tabulations provided here are therefore for models which specified either the scheduling terms or the spread (Alone). This would be most appropriate for practical forecasting where accommodating just one reliability variable provides enough challenges let alone two!

It can be seen that, as expected, the multipliers for the both observations are somewhat less than for the Alone observations

Table 1.17 **Reliability multipliers by model specification**

Attribute	Alone	Both	All
SDE	0.86:0.07:48	0.35:0.04:6	0.81:0.07:54
SDL	1.94:0.14:54	1.31:0.16:16	1.80:0.12:70
RR	1.02:0.13:31	0.66:0.14:14	0.91:0.10:45

Note: Mean, standard error of the mean and number of observations reported.

Bates (2001) demonstrated the following relationship between the RR and the parameters of the scheduling approach:

$$RR = \frac{\beta}{\alpha} ln\left(1 + \frac{\gamma}{\beta}\right)$$

α relates to mean travel time, β to SDE and γ to SDL. Although strictly speaking this relationship is only applicable where the traveller has a continuous choice of departure times, it is nonetheless illuminating to consider whether this theoretical relationship between the mean-variance approach and scheduling approaches holds in practice.

Taking α to be one and with average values for β and μ of 0.86 and 1.94 from Table 1.17, the implied RR is 1.02. This is exactly the figure reported in Table. 1.17 for the mean value for RR of 1.02.

Table 1.18 illustrates how the reliability multipliers vary across the European countries covered. We have combined the SDL and late multipliers on the grounds of sample size. There is considerable variation across countries, much more than for the other convenience variables, and this might be because of the inherently greater challenges involved in valuing reliability. In particular, the UK seems to be an outlier with the irrational mean SDE value and the very large SDL/Late values which may well be due to the dominance of mean lateness in the latter sample. We note that the late values were often obtained from SP exercises that specified one service X minutes late one in Y times. However, uncertainties surrounding how respondents interpreted lateness for the (Y-1)/Y occasions could well have led to inflated valuation estimates.

Table 1.18 **Reliability multipliers by country**

	SDE	SDL/Late	RR
Denmark	-	2.02:0.10:8	-
Netherlands	0.97:0.09:26	1.52:0.19:23	0.85:0.26:2
Norway	0.72:0.29:4	2.43:0.30:13	0.20:0.06:3
Sweden	0.77:0.19:5	2.88:0.56:10	0.59:0.19:3
UK	1.20:0.46:4	3.70:0.44:19	1.21:0.16:22
All Other	0.52:0.07:9	1.28:0.17:8	0.98:0.0:1

Note: For SDE, SDL and RR valuations estimated ‘Alone’. Mean, standard error of the mean and number of observations reported.

Table 1.19 demonstrates some large but not entirely consistent variations by journey purpose. For mean lateness, leisure travellers have the highest values which is also the case for RR whereas commuters have the largest value of SDL and business travellers are particularly averse to arriving early.

Table 1.19 **Reliability multipliers by journey purpose**

Attribute	All	Commute	Leisure	Business	Other
Late	3.24:0.39:27	3.53:0.75:6	4.95:0.97:7	2.33:0.58:3	2.23:0.32:11
SDE	0.86:0.07:48	0.82:0.09:26	0.68:0.11:8	1.18:0.22:9	0.77:0.23:5
SDL	1.94:0.14:54	1.91:0.10:25	1.83:0.39:11	1.49:0.30:9	2.61:0.27:9
RR	1.02:0.13:31	1.27:0.25:6	1.34:0.28:10	0.67:0.35:2	0.71:0.15:13

Note: For SDE, SDL and RR valuations estimated ‘Alone’. Mean, standard error of the mean and number of observations reported. Other covers a mix of purposes.

Table 1.20 is based on mode users valuing the mode they used. It reveals that the values do not vary greatly between rail and bus, with the possible exception of SDL, but the limited sample sizes should be borne in mind.

Table 1.20 **Multipliers by mode**

Attribute	All	Bus	Train
Late	4.10:0.44:37	3.63:0.09:3	3.88:1.05:7
SDE	0.86:0.07:48	0.59:0.41:2	0.53:0.10:7
SDL	1.94:0.14:54	3.03:0.44:6	2.17:0.28:9
RR	1.02:0.13:31	0.96:0.30:5	0.77:0.16:3

Note: For SDE, SDL and RR valuations estimated ‘Alone’. Mean, standard error of the mean and number of observations reported.

The meta-model reported in Wardman (2013) estimated to a very large data set of multipliers contained around 200 reliability observations. It took account of the ‘Alone’ and ‘Both’ effects discussed above. It found the reliability values to fall with distance, and we can well understand that unreliability is expected, accepted and allowed for more for longer distance journeys. A strong positive effect was found for the late multiplier for leisure travel. Although reported in Table 1.21, we would be inclined to ignore this quite extreme effect, possibly attributable to the lack of clarity on arrival times for the (Y-1)/Y times the service is not late. Otherwise the multipliers seem sensible.

Table 1.21 **implied reliability multipliers for train and bus (Wardman, 2013)**

Distance	5	25	100	250
LATE				
Non Leisure	3.59	2.82	2.30	2.00
Leisure	6.71	5.28	4.30	3.75
RR				
All	0.80	0.63	0.51	0.45
SDE				
All	1.02	0.80	0.65	0.57
SDL				
All	2.17	1.71	1.39	1.21

Note: For SDE, SDL and RR valuations estimated ‘Alone’.

The values so far cover European experience, but there have been a number of reviews that cover broader international evidence.

The Wallis et al. (2013) review covered 4 New Zealand studies yielding 4 values of mean lateness and 6 Australian studies yielding 6 values. No distinction is made between bus and train, or between lateness at the stop or final destination, although the authors point out that there is some uncertainty as to whether the late time relates to the origin or destination arrival. The mean lateness figures were 2.7 for New Zealand and 3.6 for Australia.

With regard to the reliability ratio, Bates et al. (2001) stated that, “values around 1.3 appear plausible for car travel; somewhat higher may be appropriate for scheduled public transport but values above 2 are unlikely”.

Carrion and Levinson (2012) conducted a worldwide review of reliability evidence. This is based on the RR, covering 17 studies and yielding 68 observations that were entered into a meta-analysis, although it is not restricted solely to public transport. The RR averages 1.2 across studies, although this varies enormously from 0.10 to 3.29. The meta-analysis specified variables to represent time of day, data type, choice dimension, region and whether the reliability values was from a model that allowed for unobserved heterogeneity. No significant effects of note were obtained.

Tseng (2008) also conducted a worldwide review of reliability evidence covering 16 studies. This study and the Carrion and Levinson (2012) review have 9 studies in common, although this study additionally covers values of SDE and SDL.

The RR was found to average 1.33 with a standard deviation of 0.68 across 74 observations. This varies between 1.46 in the 59 cases where no scheduling terms were specified in the estimated model to 0.81 in the 15 cases where they were. The former figure of 1.46 is higher than the 1.02 of Table 1.17 although the pattern of results is similar.

The mean value of SDL was 1.65 with a standard deviation of 1.39 across 67 observations, with the corresponding figures for SDE being 0.75, 0.40 and 69. SDE varied little between commuting and other trips and between public and private transport. For SDL, we find the commuting value to be somewhat larger at 1.99 from 44 observations than the 1.01 from 23 observations for other trips. This is not surprising although not apparent in the European evidence reviewed above. Similarly, private transport had a mean

SDL value of 1.83 from 48 observations somewhat larger than the 1.20 from the 19 public transport observations.

It was also found that the figures depended upon whether the estimated model contained another reliability variable. Where SDE and SDL were specified on their own, their mean values were 0.81 from 54 SDE observations and 1.77 from 55 SDL observations. These fall to 0.53 from 15 SDE observations and 1.13 from 12 SDL observations when other reliability terms entered the model. This pattern of results, and particularly the multipliers where there is no standard deviation term, are highly consistent with the European evidence discussed above.

Meta-models were estimated to the RR, SDE and SDL observations. Explanatory variables were data type, choice type, mode, purpose, utility specification, and travel time measurement. The models were somewhat more successful than those of Carrion and Levinson (2012) in recovering significant effects. The values implied by the model exhibited considerable variations.

Based on RR or SDE/SDL being the only variables specified, RR was 1.71 for all trips and purposes (where the model did not specify terms for purpose and mode). This is very much larger than the implied RR multipliers in Table 1.21 based on the Wardman (2013) meta-analysis.

The implied values of SDE and SDL for public transport commuting were 0.51 and 3.37. These fell to 0.41 and 2.41 respectively for other trips. Again, these are not entirely consistent with the implied SDE and SDL multipliers in Table 1.21 based entirely on European evidence.

Wardman and Batley (2014) review British evidence on the late time multiplier. Whilst it covers much of the material considered in Wardman (2013) the two are not identical in terms of British evidence. The meta-model estimated to 41 late time multipliers implied values of 3.42 for inter-urban non-commuting, 3.92 for suburban commuting and 2.26 for suburban non-commuting.

Finally, we cover recent work conducted in the Netherlands which had a strong emphasis on the valuation of reliability. Table 66 of their report (Significance et al., 2012) provides an interesting comparison of their RR estimates against other evidence. Much of the latter is covered in other reviews here so we report their new evidence along with the ‘expert workshop of 2004’ evidence they cite. The results are reported in Table 1.22.

The expert opinion multipliers are probably heavily influenced by UK evidence, and we noted in Table 1.18 above that the UK RR evidence is somewhat out of line with other evidence. If we take the implied multipliers of Table 1.21 for the shorter journeys as more appropriate for comparison, then these new Dutch values, at least for commuting and other, would seem consistent with the European meta-analysis evidence.

Table 1.22 **New Netherlands reliability ratio evidence**

	Train	Bus/Tram	Car
New Study			
Commuting	0.4	0.4	0.4
Business	1.1	1.1	1.1
Other	0.6	0.6	0.6
Expert Opinion	1.4	1.4	0.8

Conclusions on Reliability Evidence

There have been three measures of reliability used in valuation. The one that is the most straightforward to apply is the multiplier for mean lateness on schedule. This has been widely used in the UK and underpins the regulatory mechanism, driving fines and compensation payments on operator and infrastructure providers. The issue here though is that it does not allow for different distributions of lateness or the fact that regularly late trains can to some extent be anticipated and hence the consequences are less.

The standard deviation of travel times or the standard deviation of lateness on schedule can be objectively measured so they too could be readily incorporated in policy and planning decision making. Indeed, both late time multipliers and RR form the basis of official valuations.

However, approaches based around SDE and SDL are less easily implemented given that they require information on preferred arrival times which cannot be readily measured and instead requires survey based evidence.

It seems that the reliability evidence is more diverse than for other attributes, even though there is quite a lot of it, and we attribute this to the inherently greater difficulties in estimating values of reliability terms and perhaps also because it can be a contentious issue which might attract protest responses in survey based evidence. We note that empirical evidence relating to reliability is almost entirely SP based.

Nonetheless, it is clear that late arrivals are important, and are most likely the largest multipliers of all the convenience terms. Litman (2014) recommends that, “each minute of delay beyond the published schedule should be valued at 3-5 times the standard in-vehicle time”. This perhaps extends to too high values but it would seem the late time multiplier exceeds the walk and wait time multipliers of 2 and the crowding multipliers discussed in the next section, even if they contain an element of protest. We should also point out that we would expect mean lateness to be less than the value of SDL, on the grounds that SDL is always lateness whilst, as a result of scheduling constraints, lateness on schedule could actually move some people nearer to their desired arrival time!

It is encouraging to have found a high degree of consistency amongst the mean estimated RR and that implied by the SDL and SDE values. Whilst the evidence on the RR across studies is quite variable, it does seem to be less than the figure attributed to it by ‘expert opinion’.

Finally, we point out that much of the empirical work relates to late arrivals at the destination. The official Australian and New Zealand values distinguish between lateness at the destination and lateness at the point where public transport is accessed but this is a neglected aspect.

Crowding Convenience[8]

Crowding is a feature of public transport commuting journeys the world over, whether by train or bus. In some cases, particularly major metropolis and also in regional centres, standing is a common occurrence on buses but especially trains and metros. Whilst the inconvenience of standing can be readily appreciated, and can be expected to increase the value of travel time appreciably, crowding will also impact on those seated to the extent they will also incur an increased inconvenience and discomfort which will lead to higher values of time.

Traditionally, the measure used to represent crowding was load factor. This is fine for the inconvenience incurred by seated passengers as occupancy increases. However, a superior means of representing crowded conditions for those having to stand is in terms of passengers per metre squared. Trains can have high load factors but, because of a small amount of seating and ample standing space, the crowding conditions are not as bad as the high load factor might imply.

The common convention in this area is that although penalties on seated passengers can occur before a train is full, and a figure of 70% seems to be when the inconvenience is felt to start, standing penalties are not relevant at load factors less than 100% since if anyone chooses to stand when there are seats free then they are not particularly averse to standing.

Summary of Official Crowding Multipliers

There are some small multipliers for seated time between around 70% and 100% load factor. However, when seated there seem to be two different views of the world. In some countries, even in very crowded conditions, the multiplier for crowding when seated would be less than 1.5. In the UK, it could be over 2. As far as standing multipliers are concerned, there is a wide range, from around 1.4 to over 2.5 in crush conditions. As with reliability, this is an area where there is a wide range of multipliers.

Review of Crowding Multiplier Evidence

Wardman and Whelan (2011) report the most extensive review of crowding multipliers, albeit exclusively based around British evidence. They covered 17 UK studies spanning 20 years and yielding 208 valuations. From the meta-analysis model estimated, the crowding multipliers were found to vary with load factor and journey purpose. The implied multipliers are set out in Table 1.23 and can be very large. Presumably the multipliers are lower for commuters since they are more resigned to crowding!

Table 1.23 **Implied crowding multipliers (Wardman and Whelan, 2011)**

Seated Multiplier			**Standing Multipliers**		
LF	Commute	Leisure	LF	Commute	Leisure
50%	0.86	1.04			
75%	0.95	1.14			
100%	1.05	1.26	100%	1.62	1.94
125%	1.16	1.39	125%	1.79	2.15
150%	1.27	1.53	150%	1.99	2.39
175%	1.40	1.69	175%	2.20	2.64
200%	1.55	1.86	200%	2.44	2.93

The railways in Britain have now moved to the superior means of representing crowding conditions in terms of passengers per metre squared. The PDFH values (ATOC, 2013) for standing are largely driven by the work of MVA (2008) and Whelan and Crockett (2009) who conducted an innovative SP exercise involving trade-offs between time and crowding where crowding levels were clearly set out graphically and in written explanation. They recommended the crowding penalties set out in Table 1.24. Values did not vary by purposes but did vary by flow type. It is commonly argued that those in London and the South East are more accustomed to crowding and hence their values are lower whilst for the generally somewhat longer inter-urban journeys crowding will be more unpalatable. It can be seen that some large multipliers are implied even for sitting when there are high levels of crowding.

Table 1.24 **Estimated crowding multipliers**

Pass/m^2	London and SE		Regional		Inter Urban	
	Sit	Stand	Sit	Stand	Sit	Stand
0.0	1.00	1.43	1.00	1.34	1.00	1.77
0.5	1.05	1.50	1.12	1.48	1.06	1.79
1.0	1.09	1.56	1.24	1.61	1.11	1.81
1.5	1.14	1.63	1.36	1.75	1.17	1.83
2.0	1.18	1.69	1.48	1.88	1.23	1.85
2.5	1.23	1.76	1.60	2.02	1.29	1.87
3.0	1.27	1.82	1.72	2.16	1.34	1.89
3.5	1.32	1.89	1.84	2.30	1.40	1.91
4.0	1.36	1.95	1.96	2.43	1.46	1.92
4.5	1.41	2.02	2.08	2.57	1.52	1.94
5.0	1.45	2.08	2.20	2.70	1.57	1.96
6.0	1.54	2.21	2.44	2.97	1.69	2.00

Wallis et al. (2013) found only a limited amount of Australian and New Zealand evidence. They report 2 Australian observations from seated in crowded conditions with a mean multiplier of 1.23. This increases to 1.62 for 6 Australian observations for standing in crowded conditions, with the corresponding figure of 1.49 across 4 New Zealand observations, with a mean multiplier of 2.0 for 3 observations relating to standing in crush conditions.

Haywood and Koning (2013) report on a contingent valuation exercise, discussed at the Roundtable meeting, where travellers on the Paris metro could forego travel time in return for less crowding. Seven levels of crowding were presented. The multipliers for the different levels of crowding are presented in Table 1.25.

Table 1.25 **Time multipliers on Paris metro**

Pass/m^2	Multiplier	Multiplier Morning Peak	Multiplier Evening Peak
0	1.00 (0.91-1.08)	1.02 (0.93-1.12)	0.93 (0.78-1.08)
1	1.00	1.00	1.00
2	1.05 (0.97-1.13)	1.06 (0.96-1.15)	1.06 (0.91-1.21)
2.5	1.18 (1.07-1.28)	1.19 (1.07-1.31)	1.18 (0.99-1.36)
3	1.26 (1.13-1.39)	1.24 (1.10-1.38)	1.29 (1.05-1.53)
4	1.40 (1.25-1.56)	1.52 (1.33-1.71)	1.31 (1.06-1.56)
6	1.57 (1.35-1.80)	1.46 (1.20-1.73)	1.67 (1.27-2.06)

Note: 95% confidence intervals in brackets. The 2-6 pass/m^2 figures relate to standing and the 0-1pass/m^2 relates to seating.

There are some, but generally slight, differences between the time multiplier in the morning and evening peaks. The figures are somewhat lower than those so far discussed.

Kroes et al. (2013) provided a resource paper as part of this Roundtable, reporting the findings of an extensive study of crowding in Paris. This covered rail, metro, tramway and bus. Two SP exercises were used; one based around the idea of catching the first but crowded arrival or waiting for a less crowded train, and the other offering a trade-off between two options with different travel times and crowding levels. In addition, there was experimentation with SP methods.

Although the best model was one that specified a fixed effect per trip rather than a time multiplier, for practical reasons a model with crowding multipliers was developed. The multipliers split by mode are reported in Table 1.26.

The multipliers for seated, which here largely relate to commuters, bear a reasonable resemblance to those in Table 1.23. However, the standing multipliers are somewhat lower and very much in line with the other Paris values in Table 1.25.

Table 1.26 **Paris Crowding Penalties (Kroes et al., 2013)**

Load	**ALL**		**METRO**		**TRAIN+RER**		**BUS+TRAM**	
	Seat	Stand	Seat	Stand	Seat	Stand	Seat	Stand
25%	1.000		1.000		1.000		1.000	
50%	1.000		1.000		1.000		1.000	
75%	1.000		1.000		1.000		1.000	
100%	1.083		1.077		1.073		1.102	
125%	1.165	1.289	1.155	1.270	1.145	1.261	1.204	1.342
150%	1.248	1.394	1.232	1.362	1.218	1.358	1.307	1.467
200%	1.330	1.499	1.309	1.453	1.290	1.456	1.409	1.593
250%	1.413	1.604	1.386	1.545	1.363	1.553	1.511	1.718

Li and Hensher (2011) provide a review of willingness to pay evidence relating to crowding but it does not add to what is covered elsewhere here.

Finally, we are aware of evidence from a country famous for its sometimes very high degree of rail overcrowding. Valuations from the Japanese CBA Manual for Rail, as discussed in the resource paper by Kato (2014), and a rail route choice RP model for commuting trips (Morichi et al. 2001) are presented in Table 1.27. The values from these two Japanese sources are not only very similar but are broadly in line with the Paris evidence.

Table 1.27 **Japanese Crowding Multipliers**

	Multiplier	
Load Factor	CBA Manual	Morichi et al. (2001)
110%	1.04	1.11
140%	1.06	1.13
170%	1.10	1.27
200%	1.16	1.37
230%	1.37	1.49
260%	1.62	1.62

Note: The load factors are defined with regard to seating and standing capacity and so will be lower than the more usual definition relative to seating capacity.

Conclusions on Crowding Multipliers

The evidence on crowding values in line with the official values is bimodal. Some evidence points to crowding multipliers that would imply that standing rivals late time in terms of inconvenience whilst other evidence points to lower multipliers somewhat less than the value of 2 commonly ascribed to walk and wait time. From a theoretical perspective, we could argue that crowding multipliers ought to be high, on the grounds it can reasonably be expected to be worse than walking and waiting, but we could also argue that we travellers are observed to stand even when seats are available. One thing is for sure though; the crowding multipliers unequivocally increase with the degree of crowding!

Litman (2014) concludes that the value of transit travel time is doubled when standing and further doubled when standing in a crowded bus or train. Our view is that this is not supported by the evidence.

Kroes et al. (2013) concluded in their study of crowding penalties in Paris:

> *"It is clear that more value of crowding studies, conducted in similar and different contexts, are needed before more definitive and more general conclusions can be drawn with respect to the value of crowding in public transport"*

It would be hard to argue with this. Well focused and large scale RP exercises and observations of actual behaviour might be able to cast more light on the issue. In this regard, we note the Japanese RP based crowding penalties are relatively low.

The Convenience of Information

The presence (absence) of information adds to (diminishes from) public transport convenience in several respects. Travellers do not like uncertainties surrounding how to use and pay for public transport, what to do when there are alternative possibilities or when things go wrong, and not knowing the causes of any irregularities in service. Information can reduce the stress of waiting or interchanging and allow travellers to make better use of their time. There might be a value for the existence of information, even if it is not used, since it provides reassurance in the event it is needed. In the extreme, lack of information about a public transport product inevitably means it will not be purchased[9].

Those who are unfamiliar with public transport, or at least with the particular journey being made, can be expected to benefit most from the availability of suitable reliable information, as might those who are making complex inter-modal journeys, whilst in this digital age there are ever increasing expectations that information is not only of a high standard but is easily accessed. In recent years, there has been considerable investment in improving the information available to public transport users (Litman, 2014), in large part due to technological developments.

There are different means by which public transport users can obtain information. Some has to be actively sought, such as that available via the internet and mobile phones, from travel information centres and phone hotlines, and email and text alerts, either prior to starting a journey or during it, whilst other information is routinely present in the course of a journey, such as real time information displays, signage, information points, staff, posters, announcements, departure boards and printed matter. The information can relate to a range of different aspects of a journey, such as how to access and egress public transport and system navigation, timetable details, prices and how to pay, what facilities are present during the journey and what to do when things go wrong.

There might well be interactions between the valuations of different information sources. For example, the presence of mobile information may well reduce the value of information from station staff, signs and displays, whilst providing information on-vehicle may reduce the value of information provided at stations and stops.

Summary of Official Information Values

Table 1.1 contains the official multiplier evidence we have identified for the time related aspects of convenience. We are not aware of official guidance in the context of information convenience. This is partly because of the diverse nature of information and partly because it is not a prominent feature of scheme appraisal. However, what is in our understanding the most extensive set of information values in use in transport scheme appraisal, as recommended by Transport for London, is considered below.

Review of Information Valuation Evidence

There have been a large number of SP studies which have covered some aspect of information provision. We have inevitably made extensive use in this document of review material, but we are not aware of a comprehensive review of the valuation of information provision. To some extent this is because of the more diverse nature of the improvements being valued, although the fact that some developments in information provision are quite recent and will form a more modest proportion of generalised cost than other aspects of convenience are also contributory factors. Litman (2014) discusses a variety of real-world improvements in information provision and travellers' favourable responses to them.

There is little evidence on valuations of some aspects of information, such as on how to pay and what to do when journeys are disrupted. The evidence tends to relate to the valuation of real time arrival information and timetable information.

Information is different to the other attributes we have here covered. Whilst it undoubtedly influences the convenience of using public transport, it does not always operate as a multiplier on the value of time in the same way as an interchange penalty. In many circumstances it is more of a fixed benefit, although not necessarily independent of journey length, such as might be expected of information on departure times, routes and fares, but it can interact with other valuations in a multiplier fashion, such as when arrival or performance information reduces the stress of waiting time and anxieties of travel time.

Of particular relevance here is the possible presence of a 'package' effect. It is not uncommon that the information is considered alongside a wide range of other 'soft factors' and that the sum of the valuations of the separate attributes exceeds the valuation of all attributes estimated as a package (Jones, 1997). This might be because of: interactions, as mentioned above; halo effects, whereby improvements in one attribute are taken to imply improvements in another; budget effects, where travellers are prepared to pay for improvements to some attributes but not all to the same pro-rata extent; or simply an artefact of the artificial nature of SP experiments in what is a challenging valuation context and one that might attract strategic responses.

Given the absence of review material, and because values have often been obtained in money units which are less transferable than the time multipliers considered previously, we here consider a selection of illustrative empirical evidence from the wide range available before turning to Transport for London's extensive set of recommendations which seem to be the most comprehensive of any transport authority in the world.

Hensher and Prioni (2002) developed a service quality index for use in evaluating the overall performance of bus operators. In the SP exercise undertaken to create parameters to populate the index, 13 variables were simultaneously covered in each of three bus options offered. The attributes ranged from time and cost through to on-board safety and the friendliness of drivers. One of the attributes covered related to information; whether there was timetable information or timetable information and a map at the bus stop. The results obtained were counter-intuitive, with the former valued at 9.25 minutes and the latter at 6.15 minutes relative to no information. Whilst this might have been due to what appears to be a highly complicated SP exercise, nonetheless even the lower of these two valuations seems implausibly large.

Laird and Whelan (2007) report valuations of information for bus journeys after a package effect had been estimated. The implied valuation of up-to-the-minute bus arrival time information was 3.97 minutes per journey for leisure travellers and 1.97 minutes for commuters. Again such values seem rather large.

The UK rail industry's Passenger Demand Forecasting Handbook's (PDFH) recommendations distinguish between on-train and at-station facilities, which includes information. Unfortunately, the recommendations for at-station facilities come in the form of demand uplifts. Matters are little better for on-train information. Although expressed as value of time multipliers, they only cover audibility of announcements and electronic displays and a number of assumptions are made in converting monetary values into time units, particularly given that the value of time depends upon distance.

Given the qualitative nature of many bus quality attributes, Douglas Economics (2014) conducted an SP exercise in New Zealand that offered trade-offs between two bus options described in terms of time, cost, service headway, bus vehicle quality and bus stop quality. The latter two were characterised by a 5 star system (similar to that used to rate films and restaurants) which included verbal descriptions of quality. The respondents' ratings of their current bus vehicle and bus stop quality were regressed on various relevant factors to determine what influenced them. Thus the valuations of the ratings in the SP model could be decomposed into the various influential factors. Whether the bus stop had a shelter, seating, real Source: Transport for London (2013time information and a timetable influenced the ratings. The benefits of providing real time information and a timetable were found to be worth 1.7 minutes or 6% of fare. This increases to 4.3 minutes or 16% of fare when seating and shelter are provided.

This work built upon a previous study in Australia (Douglas Economics, 2006) which involved nine point scales for each of 46 rail service attributes. This was converted into a % scale and the ratings were linked to the rating of time variation, thereby allowing values to be obtained in time units. Table 1.28 reports time valuations for a range of train improvements. Information is not the most important factor but nor is it the least.

Table 1.28 **Value of Train Improvements from 60%-70% (minutes per journey)**

Improvement	Value
Train Outside Appearance	0.15
Ease of Train Boarding	0.22
Seat Comfort	0.07
Smoothness of Ride	0.10
Quietness	0.22
Heating and Air Conditioning	0.15
Lighting	0.13
Cleanliness	0.26
Graffiti	0.08
On-train Announcements	0.16
Layout and Design	0.38

Source: Transport for London (2013)

The valuations of station improvements reported in Table 1.29 are far less than for train improvements, which is unsurprising given train travellers generally spend far longer on a train than at the station. Taking the three information related terms together, they are joint second in importance behind ticketing.

Table 1.29 **Value of Station Improvements from 50%-60% (minute per journey)**

Improvement	Value	Improvement	Value
Ease of Train On and Off	0.08	Graffiti	0.05
Platform Weather Protection	0.004	Toilets	0.01
Platform Seating	0.04	Safety	0.06
Platform Surface	0.07	Staff	0.09
Subway/Overbridged	0.01	Car Park	0.01
Station Building	0.10	Car Park Drop Off	0.01
Lifts/Escalators	0.03	Taxi	0.01
Signing	0.05	Bus	0.02
Station Announcements	0.05	Bike	0.02
Information	0.03	Telephone	0.01
Station Lighting	0.03	Retail	0.05
Cleaning	0.13	Tickets	0.16

Source: Transport for London (2013)

This ratings based approach has attractions since otherwise diverse and categorical attributes not easily measured or defined cannot be valued within an SP exercise. Real life application requires that for an improvements that are planned then ratings of the before and after situation are required.

What seems to us to be the most extensive set of recommended valuations relating to information provision, and indeed to a wide range of other 'soft factors', is provided by Transport for London's Business Case Development Manual (Transport for London, 2013). This document "summarises the values which passengers place on a comprehensive list of key service attributes". Valuations of information are recommended for the underground, bus and train and for information provided on-vehicle and at stations/stops. In some cases, the valuations are based on ratings of information attributes whilst in other cases categorical information levels are specified.

We set out below the wide range of information related valuations recommended, partly as inspiration that valuations can be provided for a wide range of information attributes and indeed other soft, comfort-related, factors.

The valuations recommended in the Business Case Development Manual are in money units. To convert to time units, the recommended values of time are 14.7 pence per minute for the underground, 15.8 pence per minute for rail and 12.8 pence per minute for bus.

Values relating to the ticket hall are not time dependent. Those for on-train are based on a typical 15 minute journey whilst the average platform wait time is 3½ minutes with one minute on average of access time. These time dependent valuations should be amended where the average durations of these variables is different.

Some valuations are linked to the scores obtained from Mystery Shopper Surveys (MSS) or Staff and Information Surveys (SIS). These are reported in Table 1.30 for information provided to underground users in the station ticket hall, station access, station platform and on-train.

Thus an improvement in electronic displays in carriages that led the ratings to improve from 20% to 50% would be worth 1.641 pence. The valuations relating to on-train provision tend to be somewhat larger, as is to be expected given the relative amount of time spent on the train. Noticeably, information related to the next train and particularly to service disruption are highly valued.

Table 1.31 presents the recommended values for underground users for information provision represented in categorical form. Again, the benefits of providing information on service disruption and next trains are the largest. Definitions of each level for each type of information are given in the Business Case Development Manual Section E4.3

Table 1.30 **Underground information provision benefits using MIS/SIS scores** (pence per passenger September 2013 prices)

	Score	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Station Ticket Hall												
Clarity of the PA announcer's delivery	SIS	0.351	0.340	0.308	0.263	0.213	0.171	0.131	0.094	0.059	0.027	0
Usefulness of the PA messages	SIS	0.325	0.278	0.235	0.196	0.160	0.127	0.096	0.069	0.044	0.021	0
Directional signing	MSS	0.433	0.395	0.363	0.334	0.298	0.244	0.191	0.140	0.091	0.046	0
Clocks	MSS	0.241	0.234	0.215	0.189	0.160	0.130	0.100	0.072	0.045	0.021	0
System disruption information	MSS	3.610	3.551	3.311	2.934	2.465	1.953	1.447	0.962	0.547	0.229	0
Next train information	MSS	3.097	2.734	2.368	2.010	1.665	1.337	0.933	0.605	0.349	0.152	0
LUL information leaflets	MSS	0.380	0.372	0.344	0.305	0.260	0.211	0.163	0.117	0.074	0.035	0
Station Access												
Clarity of the PA announcer's delivery	SIS	0.384	0.372	0.338	0.288	0.233	0.187	0.143	0.102	0.064	0.030	0
Usefulness of the PA messages	SIS	0.356	0.305	0.258	0.214	0.175	0.139	0.105	0.075	0.048	0.023	0
Directional signing	MSS	0.474	0.433	0.398	0.365	0.326	0.268	0.209	0.153	0.100	0.051	0
Station Platform												
Clarity of the PA announcer's delivery	SIS	0.482	0.467	0.424	0.362	0.292	0.235	0.180	0.129	0.081	0.037	0
Usefulness of the PA messages	SIS	0.446	0.382	0.323	0.269	0.219	0.174	0.132	0.095	0.060	0.029	0
Directional signing	MSS	0.595	0.543	0.499	0.459	0.410	0.336	0.262	0.192	0.125	0.064	0
Clocks	MSS	0.266	0.261	0.242	0.215	0.183	0.150	0.116	0.084	0.053	0.025	0
Next train information	MSS	1.372	1.314	1.238	1.144	1.022	0.880	0.726	0.558	0.377	0.190	0
System disruption information	MSS	2.954	2.545	2.135	1.752	1.405	1.027	0.718	0.474	0.279	0.124	0
Train												
Clarity of driver's delivery over PA	SIS	3.478	3.396	3.274	3.120	2.938	2.731	2.503	2.173	1.491	0.765	0
Usefulness of PA messages on train	SIS	3.261	3.090	2.787	2.367	1.521	0.821	0.402	0.213	0.115	0.051	0
Interchange and next station information over train PA	SIS	3.261	3.090	2.787	2.367	1.521	0.821	0.402	0.213	0.115	0.051	0
Electronic displays in the carriages	MSS	5.175	5.050	4.809	4.398	3.830	3.168	2.538	1.974	1.376	0.697	0
Time of first PA announcement when a delay occurs	MSS	3.158	2.978	2.740	2.477	2.185	1.761	1.373	1.003	0.656	0.317	0
Frequency of PA announcements when a delay occurs	MSS	2.721	2.449	2.177	1.905	1.633	1.361	1.088	0.816	0.544	0.272	0

Source: Transport for London (2013)

Table 1.31 **Underground benefits**
(pence per passenger September 2013 prices)

	1	**2**	**3**	**4**
Station Ticket Hall				
Audibility of the PA system	0.351	0.035	0.000	0
Ease of seeing signs	0.326	0.160	0.000	0
Information available via the help points	0.461	0.000	0.000	0
Service disruption notices in the ticket hall	5.781	1.823	0.527	0
Information on planned station and line closures	6.193	2.451	0.321	0
Information button in help points – speed of response	0.361	0.000	0.000	0
Station Access				
Audibility of the PA system	0.384	0.038	0.000	0
Information available via the help points	0.634	0.133	0.008	0
Ease of seeing signs	0.440	0.305	0.000	0
Information button in help points	0.361	0.000	0.000	0
Station Platform				
Audibility of the PA system	0.446	0.104	0.000	0
Information available via the help points	0.959	0.335	0.020	0
Information on the outside of the train	0.613	0.000	0.000	0
Next train information on platform displays	5.948	0.456	0.000	0
Disruption information on platform displays	0.482	0.000	0.000	0
Ease of seeing signs	0.552	0.382	0.000	0
Information button in help points	0.361	0.000	0.000	0
Train				
Announcements of disruption on connecting lines	8.561	5.328	1.976	0

The recommended values for improvements to train, as opposed to underground, information are reproduced in Table 1.32. These largely relate to information on the next train and on service disruptions and as for the other modes these are quite highly valued.

Table 1.32 **Rail improvements**
(pence per journey September 2013 prices)

Ticket Hall		
Information about Service Disruptions	No information in the ticket hall about service disruptions	0
	Hand-written notices in the ticket hall showing service disruptions	14.31
	Electronic display in the ticket hall showing service disruptions	17.31
Platform Facilities		
Next Train Information	No information about next train on the platform	0
	Electronic information about next train arrival time, destination and all stations where the train is stopping	14.83
Train Information		
Electronic Display	No electronic display in carriages	0
	Flat screen style display showing next station, final destination information and relevant service disruption information	11.71
PA Announcements	Public announcement impossible to hear, muffled or echoing	0
	Public announcement message able to be heard	11.32

Source: Transport for London (2013

Turning to bus users, Table 1.33 reports the wide range of recommendations for improvements to information provided at bus stops, bus stations, on buses and at bus-underground interchanges. These are all for discrete levels of information. The values of the improvements tend to be clustered in a fairly narrow range.

Table 1.33 **Bus improvements**
(Pence per Journey September 2013 Prices)

Bus Stop Information		
Countdown signs	No Countdown sign	0
	Countdown displays up to the minute bus arrival times	3.35
	Countdown displays up to the minute bus arrival times, diversions and delays	4.11
Mobile phone real-time information	No information on phone about time of next bus or disruptions	0
	By typing in code shown on bus stop, receive information sent to phone about time of next bus	0.83
	By typing in code shown on bus stop, receive information sent to phone about time of next bus and any service delays	1.39
Spider Map	No diagrammatic map of bus routes serving the stop	0
	Stop with diagrammatic map of bus routes serving the stop	4.63
Local Map	No map of local information / services	0
	Stop with map of local information / services	4.52
Bus Station Information		
Public Announcement	No public announcements	0
	Public announcements that can clearly be heard	1.12
Staff providing bus service information	No staff at the station	0
	Member of staff walking around bus station	0.92
	Member of staff at information desk	1.25
Bus Service Information Displayed on Screen	No countdown sign	0
	Countdown displays up to the minute bus departure times	2.88
Finding way round bus station: signs	Unclear of badly located signing, difficult to find your way around the bus station	0
	Good signing, easy to find your way around the bus station	2.62
Finding way round bus station: maps	No display	0
	Displays showing location of the stop for your bus	6.08
Bus Environment		
Information provided inside bus	No electronic information inside the bus about the next stop	0
	Electronic sign and voice announcement of the next stop	2.34
	Electronic sign and voice announcement of the next stop and also connections that can be made with other transport services, plus nearby attractions that can be reached from that stop	2.54
Bus-Underground Interchange		
Visual information on bus service disruption	No service disruption information in Underground station for bus services	0
	Hand-written notices in Underground station about bus disruptions	6.55
	Electronic information in the Underground station about disruptions to bus services	8.62
Signage at Interchange	No signs to bus and Underground services	0
	Generally good signs between bus and Underground services, but additional signs would make it easier to find the way	3.52
	Excellent signs giving a direct route between bus and Underground services	6.92

Source: Transport for London (2013

Conclusions on Information Values

Although evidence relating to information levels is much more diverse than for other aspects of convenience, a large amount of evidence exists, although no review study as far as we are aware, and we have here considered some of the available evidence.

We feel it right to issue a word of warning in this context, since it is not unknown that values can be implausibly large. Whether this is due to unaccounted for package effects or simply strategic bias when the purpose of the relevant SP exercise is quite transparently to value information, care should be taken in estimation, interpretation and application. Care also needs to be taken to account for interaction effects[10].

Having said that, credible results do exist and approaches based around rating scales have proved popular because they allow transferability of results for variables which have no natural units of measurement.

The findings suggest, as would be expected, that on-vehicle information is more important than at-station or stop information. The relatively new area of real-time information on services available on-line before leaving home/office appears particularly important, although empirical studies were not found to have been undertaken. Information relating to disruptions seems particularly important, as does information on next services. We should point out though that large sums of money are being spent on real-time information on platforms and some bus stops, but increasingly less on more traditional information such as paper maps posted on stations and bus stops. Evidence is required to ensure that the appropriate policies are being followed.

The extensive recommendations provided by Transport for London, not only for information but a wide range of ‘soft factors’, should serve as an achievable aspiration more generally for practical transport appraisal and helping to ensure that authorities deliver best value to the travelling population and taxpayer alike.

Summary

We have above considered each convenience attribute in isolation. Whilst we return to the issue of interactions between valuations below, it is informative to summarise this individual evidence to determine what really matters most with regard to public transport convenience of use, not least because this is where operators and funders can focus attention on improvement.

Clearly, what matters most to individuals will depend on specific circumstances, such as the current levels of attributes, the type of journey being undertaken and the travel conditions, and of course cultural factors. Therefore in generalising the results, it seems that the most important convenience issues for public transport users are:

- waiting in crowded conditions;
- walking in crowded conditions;
- walking that involves more than normal levels of effort;
- travel time reliability.

Poor performance on these can be a significant deterrent to public transport use where choices are available or else will impact appreciably users’ wellbeing. The next most important aspects of convenience are:

- walking and waiting in normal conditions
- having to stand while travelling, although its inconvenience might be expected to exceed normal walking and waiting when there is severe overcrowding.
- displacement time and headway, with displacement time being more of an issue for longer journeys where planning is more commonplace and headway being more important for shorter journeys where there is less planning and perhaps an expectation of better frequencies.

The two variables that generally make the least contribution to convenience are:

- the penalty involved in having to interchange
- information provision at stations and stops

Our summary of the empirical evidence on the relative importance of the different convenience multipliers is set out in Table 1.34.

Table 1.34 **Summary of importance of convenience multipliers**

CONVENIENCE TERM	INDICATIVE MULTIPLIER
Late Time	3.0-5.0
Walking with more than normal effort	4.0
Waiting in Crowded Conditions	2.5-4.0
Walking in Crowded Conditions	2.0-3.5
Walking and Waiting in Normal Conditions	1.75-2.0
Standing (depending on conditions)	1.50-2.0
Headway	0.5-0.8
Displacement Time	0.4-0.6
Interchange Penalties	5-15 mins
On-Vehicle Information	<< 1 min
Off-Vehicle Information	<< 1 min

The research agenda

There seem to be two aspects to a forward research agenda in the area of valuing public transport convenience

- Consolidating and particularly adding to the evidence base on convenience multipliers
- Monitoring, validating and ex-post analysis of the use of the convenience multipliers[11]

Adding to the Evidence Base

The Roundtable was of the view that there is insufficient use worldwide of convenience multipliers to understand and appraise public transport. In part this is because even in developed countries the cost-benefit analysis to evaluate transport investments, planning and policies is not always routine, but the absence or unawareness of relevant information cannot help matters.

The Roundtable also recognised that even where formal cost-benefit analysis procedures are in use, there is a need to add further detail. We might expect the walk and wait time multipliers to depend upon the conditions in which they are incurred. Whilst there are some notable examples of allowing for this, considerably more insight could be obtained here. So how do the various multiplier values covered here vary with the levels of the variables, with the degree of crowding, with the travel environment, with the length of the journey, with journey purpose and the like? The emphasis though must be on generating new evidence that can be readily applied rather than providing insights into influential variables, such as personal characteristics, that would be difficult or impossible to use in real world appraisal.

This research into conditions is important since it demonstrates how the 'time costs' of travel can be reduced by reducing the time weight rather than the amount of time and, as some studies have indicated, it might in some circumstances be more cost effective to reduce the time cost to achieve and effective time saving.

Another neglected area of research, although by no means confined to convenience related variables, is that of examining thresholds, non-linearities and interactions. It may be that target levels of convenience need to be achieved before, say, car users will entertain using public transport, or that there is little point in improving convenience if fares are unacceptably high. So convenience multipliers for one attribute might depend upon the levels of another attribute or in some way or another its own levels. Although probably more of an issue for comfort related variables, package effects might be present, whereupon the introduction of various improvements has a larger impact than the sum of each introduced separately. The roundtable had the view that we can sometimes spend too much time looking at separate parts and not the whole. Evidence on these matters is scant, which is of concern if public transport 'retailers' have to get all aspects of their offering right.

There are some particular valuation related issues that need further attention. Headway values have typically not distinguished properly between the dominance of wait time at high frequencies and the dominance of displacement time at low frequencies. Late time values either explicitly relate to destination arrivals or else there is a degree of indeterminacy as to what they represent. The latter ambiguity does need to be removed in future work but in any event there is a need to distinguish between and value of late arrivals at the destination and the value of late arrivals at the departure point. Crowding values need to be grounded in occupancy rates up to 100% load factor and then passengers per square metre beyond that whilst displacement time multipliers must distinguish direction of travel and time of day. New research could usefully examine convenience aspects such as integration between modes, the acquisition of tickets and obtaining relevant information, and Lee (2013) demonstrates such issues to be able to influence public transport demand favourably. We have not covered these latter aspects of convenience here but our impression is that the evidence base is not large.

To these 'lists' we can add that there may be temporal variations in multipliers whilst concerns will remain regarding cultural transferability and there are clearly differences between 'users' and 'non-users' about which we do not know as much as we should. Changing expectations over time and an ageing population could lead to different multipliers over time whilst multipliers might be tempered by conditions, so for example, commuters in Tokyo might have somewhat greater tolerance to crowding than commuters in many other metro systems.

Conditional upon more widespread adoption of formal procedures to evaluate convenience improvements, and we have argued that the treatment of convenience really does matter, our review of evidence and in any event general impressions and expectations would suggest that it make sense to derive local values where possible. Of course, these can be benchmarked against broader review based material.

SP methods are traditionally used in a very detailed manner, to derive parameters that can then be used to populate a 'bottom-up' cost-benefit appraisal. A novel alternative, which could be regarded as 'top-down', would be to use SP in a more strategic fashion, as a sophisticated voting system, to determine the sort of public transport system and policies that people really want.

In addition to addressing research themes, there is also a need to embrace and exploit new and emerging sources of data and information that reveal people's choices, preferences, implied valuations and indeed deterrents. For example, mobile phone data for the Paris underground has recently been exploited to provide reliable insights into passenger behaviour (Aguiléra et al., 2013). The Roundtable identified promising new behavioural data sources as:

- check-in and check-out data can provide considerable insights into urban travel patterns and choices;
- mobile phone data contains a wealth of information from ultimate origin and destination details[12,] through route choices down to even which carriages are boarded;
- CCTV data informs on train arrival and departure times, on escalator-stairs choice, on platform crowding, choice of seat and whether to stand and a range of other behavioural issues;
- mobile phone apps can be used to contact travellers during the course of their journeys regarding their ongoing experiences and also to undertake post-journey market research

These data could be particularly useful for the access and egress components of convenience, where operators have little control, and for inter-modal integration.

Finally, our view is that there are significant economies in pooling research efforts. In Britain, the 24 train operating companies and other organisations with railway responsibilities have voluntarily formed a 'research club' to pursue common research interests which is funded through subscription. At the other extreme, there is 'pan-country' funding of research, such as by the European Commission. We feel that opportunities are being missed for conducting more meaningful, significant and path-breaking research by transport operators and regional authorities through collaborative, well-focussed research to address the sort of common challenges that this document is concerned with. Opportunities to share knowledge, expertise and research findings should be fully exploited.

The view of the roundtable was that this is an area of considerable interest to many researchers and practitioners, so we can expect a considerable amount of further research (both published and unpublished) on this subject going forward. It would therefore be useful if some organisation established a central repository for travel time valuation (and also elasticity research), organised and categorised by subject area, similar to but expanded on the Bureau of Transport Economics Transport Elasticities Database Online (www.bitre.gov.au/tedb), perhaps along the lines of the resource provided by the Victoria Transport Planning Institute (eg, www.vtpi.org/elasticities.pdf) or indeed the UK railway's Passenger Demand Forecasting Handbook (PDFH) but with access to source material. This would require ongoing funding, and ideally would be housed and supported in a governmental agency much along the lines of maintaining physical libraries.

The PDFH provides a good example of how different parties, such as operators, government, infrastructure providers and other bodies, can work together to develop and agree a common, and evolving, evidence base in these issues, considering all the attributes together rather than each in isolation. It would make sense to take forward such an initiative on a much wider basis than just the UK, and indeed extended to cover not just the convenience issues here discussed but also cost, comfort and time.

There are also three highly complementary research themes that should be pursued, each of which could itself be the subject of a Roundtable. These are:

- The marketing of public transport convenience, and in particular what are the perceptions of the current situation and of changes and how can these be improved and what promotional measures can be taken to increase public transport use?
- What is the most appropriate means of forecasting how changes in convenience impact on public transport demand?
- Measuring changes in convenience and monitoring their effects.

The former two issues are somewhat outside the remit of this study. The latter we cover amongst other issues in the next section.

Monitoring, Validating and Ex-Post Analysis

Whilst we have pointed out there is now a significant evidence base relating to convenience multipliers, there is also a need to appraise the methodologies used to obtained the valuation evidence and the findings themselves.

The Roundtable was of the view that a 'research protocol' needs to be established for monitoring and ex-post analysis of improvements to convenience. In this regard, Litman (2014) makes the following important points:

- "*Survey transit operators who have implemented various service quality improvements, such as reduced crowding and real-time information signs, to better understand their experience. In particular this research should attempt to identify:*

  The impacts of these improvements on patron satisfaction and transit ridership.

  How individual improvements are coordinated to maximize their effectiveness.

  How to avoid potential pitfalls."

Learning from the experiences of operators is often a neglected aspect of monitoring. In addition though there is a need for the more conventional form of behavioural monitoring. Litman (2014) adds:

- *"Perform detailed before-and-after studies of any transit service improvements. For example, before implementing service improvements collect appropriate baseline data through surveys and traffic counts as a basis for evaluating how they affect patron satisfaction, travel and operations"*

We might usefully add to this that operators can monitor changes in demand as represented in their sales of tickets and surveys must be conducted post-improvement to identify the reasons for behavioural change.

There is another, but indeed related, issue of validation that also needs to be addressed. This relates to the use of hypothetical questions to derive values and drive policy. The SP method has, for around 30 years, been a key part of the tool-kit available to transport planners and analysts. It has provided an enormous amount of evidence worldwide on parameters used in transport forecasting and appraisal, as is clear from our review. Despite this, there still remains an underlying unease about the SP approach, and not just amongst economists who traditionally favour methods based around individuals' actual behaviour. Indeed, we have reported what we regard to be convincing evidence that SP based multiplier values for walk and wait time seem to be too low. This appears to be on the grounds of realism rather than protest response. We are also aware that SP methods can provide what can be regarded to be inflated values for contentious issues such as late time and crowding, as well as comfort related factors, where exaggerated responses might influence policy.

We would therefore recommend, wherever possible, that SP values are given a firm basis in RP behaviour and that convincing evidence is provided that SP evidence is reliable. Of course, poor RP data and models serve no useful purpose in validating SP methods. But it is not beyond the bounds of reasonableness and ingenuity to identify RP choice contexts where we can obtain large samples of travellers with real and familiar trade-off choices between convenience attributes. Although there are those who are sceptical about building reliable RP models, we note the plausible and generally robust Raveau et al. (2014) RP results discussed at the Roundtable even without the benefit of very large sample sizes. Moreover, the resource paper by Kato (2014) reveals the emphasis on robust RP data in Japanese studies, often based around the choices presented amongst rival train companies and routes, although the unexploited potential of SP methods in that country is also pointed out. Concerted efforts to build robust RP models will, in our view, yield reliable parameters that can be used to evaluate comparable SP evidence.

Policy implications

The view of the Roundtable was that convenience is not generally covered as well as it should be in policy and project assessment, either because of the absence of official economic appraisal procedures or else because of limitations in coverage of existing appraisal methods. This is disappointing given the importance of convenience terms in the overall attractiveness of public transport.

Current transport evaluation methods tend to focus on speed and price and undervalue comfort, convenience and reliability. This skews planning and investment decisions. Some cost-effective transit improvement strategies are overlooked and undervalued, resulting in underinvestment in transit service quality makes transit less attractive relative to automobile travel. Opportunities for modal integration are overlooked, since many transit quality improvements involve improving walking and cycling conditions, or improving connections with other modes. This reduces the attractiveness of public transport in relation to use of the private car contributing to a cycle of increased automobile dependency and sprawl and reduced transit ridership and revenue.

The review findings should be a valuable resource to planners and policy makers, operators and funding bodies, facilitating access to a significant body of empirical evidence on travel quality attributes often overlooked. The findings also yield insights into methodological issues and provide a means by which the results of specific empirical studies can be interpreted in relation to a large amount of accumulated evidence.

By providing evidence on convenience multipliers and demonstrating the importance of convenience, this report aims to support the identification and evaluation of schemes that improve convenience to achieve broader transport policy and mobility objectives.

We have seen that factors related to convenience can form a significant proportion of the generalised cost of public transport. Addressing convenience is therefore an important part of improving wellbeing of public transport users, and attracting non-users to use public transport, and more generally a significant route to increasing welfare by reducing the costs of transport.

Litman (2008), reports that inconvenience and discomfort often double or triple average travel time costs. This underlines the need to take convenience seriously in project appraisal and planning and for planners and policy makers, operators and funding bodies to identify means of improving convenience.

The previous section sets out suggestions for further research into convenience multipliers. However, there is little point in authorities, planners and operators conducting further empirical research if there is no appraisal system in place to make use of the values.

Existing appraisal methods should be extended where necessary to appraise the full set of convenience measures. Incorporating convenience can clearly alter the outcome of cost-benefit assessments of projects and policies. For example, the Paris experience (Kroes et al., 2013) demonstrates that counting the benefits of reducing crowding added around 6% to the total benefits of the investment to extend RER line E[13].

Policy makers must also recognise that there is more to improving convenience than schemes to reduce walking times, reduce headways or improve crowding levels. A cost effective way forward might in some circumstances be to achieve an effective convenience improvement by reducing the penalty attached to the variables walk time and crowding. Thus reductions in generalised cost might be achieved more cost effectively by designing public transport interiors to facilitate standing safely and comfortably rather than by generally expensive increases in capacity. Similarly, improving facilities at bus stops, stations and at transfer points can reduce the cost attached to wait time and hence again effectively serve as a reduced waiting time.

Apart from the valuations themselves, there are issues of measurement and implementation. Quality measured is not always quality delivered nor quality perceived. There are significant challenges in measuring reliability and crowding, although possibilities are improving here with technology, noting that these vary across, for example, different departures and indeed within any given departure through the course of a journey. Different market segments will have different convenience multipliers, and the ability to more closely tailor provision with what people want and are willing to pay for requires more information than is currently available. Implementing improvements in the appraisal of convenience will place significant demands on measurement abilities. Measurement and valuation of convenience is important not just for the appraisal of schemes but also management and regulation and improvement of operations. Indeed, measurement of convenience is a pre-requisite to its good management, regulation and delivery.

The sorts of interventions that the valuations reported here could be used to evaluate investment, planning, pricing and policy options that cover:

- Measures such as longer and higher capacity trains, improved service frequencies and appropriate pricing incentives that reduce the degree of crowding, particularly on peak services;

- Providing more through services and where possible improving conditions and time transferring at interchange locations;
- Improving access to and from public transport and integration between modes;
- Pricing measures to encourage travellers to change their time of travel to off-peak periods;
- Operational and infrastructure measures to improve on-time performance and to provide reliable information to travellers on how trains and buses are running;
- Higher service frequencies, in terms of the impact of waiting time as well as the convenience effect;
- Providing better passenger information, both on-vehicle and at-stations/stops, on a wide range of issues such as service performance, next departure, disruptions, directions and obtaining assistance.

Concluding remarks

The outcome of this roundtable has been, we would argue, the most extensive review so far conducted of valuations of public transport convenience, covering appraisal practice, the now extensive empirical evidence base and identifying policy implications and future research needs and directions. Valuations of in-vehicle time have dominated transport appraisal and a review of evidence on attributes that influence public transport convenience is timely, not least given the serious transport-related challenges that increased investment in and better planning of public transport is well suited to address.

Our hope is that this document will facilitate greater use of convenience valuations in the appraisal of transport investments and policies worldwide. There is no reason why, in principle, the ‘best practice’ adopted in some countries and by certain organisations cannot be adopted more widely. Whilst the valuations summarised here provide a valuable resource, ideally appraisal should be informed by local parameters and we would encourage their estimation as well as a greater level of detail as to how and to what extent the convenience multipliers vary across different circumstances.

And finally, we recognise that there are a wide range of comfort related variables which are also of importance in public transport provision and increasing its attractiveness. A similar assessment of their valuations is also long overdue.

Notes

1. However, we note that highway scheme appraisals rarely include ‘analogous multipliers’, such as might account for time spent in congested as opposed to free flow traffic or represent different qualities of road surface.
2. Factors not included in convenience are: safety, security, comfort, scheduled journey time and speed.
3. It is elsewhere in the report stated “In Germany only in-vehicle time is included within an appraisal - thus interchange time and time spent waiting for a public transport service is excluded
4. Values might be derived as a willingness to pay to save time, a willingness to pay to avoid a time loss, the willingness to accept compensation in place of a time saving and the willingness to accept compensation in the event of a time loss.
5. This was based on the RP element of the evidence.
6. This is an advantage of the multivariate approach of meta-analysis rather than the simple tabulations that are common in more conventional literature reviews.
7. To add confusion, this approach has traditionally been referred to as the mean-variance approach.
8. Some might regard crowding to be more a comfort than a convenience factor. We do not wish to get into semantics here, and indeed crowding does impact on the comfort dimension. However, the view of the Roundtable was that it is clearly inconvenient to have to stand; it was extensively discussed at the Roundtable and hence is covered here. Crowded conditions also extend walking times, in-vehicle times and make waiting time more onerous.
9. In some cases there are benefits (to operators) from the absence of information. For example, price discrimination is more effective if, say, low cost sensitivity business travelers are not fully aware of the presence of tickets targeted at more price sensitive segments of the market.
10. It is conceivable that some of the Transport for London valuations might interact with the provision of information by other means. For example, the value of next train information in ticket halls (on-platforms) might well depend upon whether the information provided on platforms (in ticket halls).
11. Whilst this takes us into the world of forecasting, which was not the primary concern of this Roundtable, values are used in forecasting and hence this process might inform on the reliability of the multipliers.
12. This is important given that the public transport operator provides only a proportion of the journey product and particularly because access and egress are important aspects of convenience.

13. This scheme also involves some direct travel time benefits because of a shorter route for some travelers. In other schemes without travel time benefits, the importance of incorporating the crowding benefits might be much higher.

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Chapter 2

Measuring and valuing convenience
A review of global practices and challenges from the public transport sector

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The term "convenience" is often used in relation to transport; the assumption being that a "convenient" service will be more attractive. Hence those responsible for the specification and supply of public transport have an interest in optimising the level of convenience provided to passengers. However, what makes a service convenient is generally neither well defined, nor understood. Basic attributes such as network size, service frequency, journey time and pricing alone cannot explain passenger demand for public transport modes. Other factors of convenience play a key role in influencing demand and mode choice but they are often more complex and harder to define, measure and value. In this paper we first consider the meaning of the term convenience in transport, and urban public transport in particular, including the attributes which it encompasses.

We argue that the good measurement of public transport convenience and service quality is a pre-requisite to its valuation and ensuring more optimal policy decisions and management actions to maximise convenience and hence demand. We focus on the urban public transport operator and its measurement of convenience by reviewing the practical experience gained from over 20 years of international benchmarking with more than 50 metro, bus and suburban rail operators in large cities around the world. Specifically, we review the current standards and practices from the urban railway industry in measuring convenience and provide examples of how such performance in metro operations varies globally. It is demonstrated that current practice in many cities remains too operationally based, despite there being an opportunity for much more customer focused measures using the greatly increased data availability from new technologies.

The experience of the UK railway industry in valuing convenience related attributes is discussed. Here, a common framework for demand forecasting has been developed combining service quality and convenience measures with other service attributes to effectively measure the "attractiveness" of the service to customers. The paper concludes by considering the implications and opportunities for public transport operators, authorities and regulators worldwide in better measuring, valuing and managing public transport convenience in order to better meet mobility needs.

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Introduction

In this discussion paper we review the practical experience of measuring and valuing convenience in two transport sectors: the operators of public transport systems in urban areas, and the railway industry in Great Britain.

In this section we firstly define convenience and service quality in the context of the roundtable. Section "Measuring convenience" of the paper then explores the practices that metro, bus and rail operators from around the world have adopted to measure the service they provide from a customer focused perspective. We draw on the practical experience of over 50 metro, bus and suburban rail operators in large cities. These operators participate in an international benchmarking programme which has been led by Imperial College for nearly 20 years and which measures and evaluates the comparative performance of public transport. International standards that define the attributes of convenience and service quality are reviewed, and we present the most common and innovative measures used by metro operators in particular. It should be emphasised that our experience is mainly based on observations from public transport operators, rather than their authorities.

The challenges and outcomes of benchmarking convenience between metro operators are also discussed in Section " Measuring convenience ", with some recent empirical research that has sought to quantify the responsiveness of demand to service quality and in turn, some the factors which also affect convenience in metros. We explain how metros and their authorities might better measure some convenience attributes, giving examples from London, Hong Kong and Paris. In recent years, public transport operators have been gifted with significantly better data, for example from ticketing and signalling systems that offer opportunities for better service quality measurement.

In Section "Valuing convenience" we examine the specific experience of the rail industry in Great Britain in attempting to value convenience related attributes and consider whether any of the approaches could be better adopted by urban transport operators. This framework is based on a variation of standard transport planning principles and economic theory, but has been specifically adapted and calibrated for the industry through an on-going research programme conducted over more than three decades. In addition to measuring and valuing the core variables such as journey time, frequency, interchange and fares, "softer" factors such as the provision of information, rolling stock quality and passenger information are also captured within a common metric. All major industry parties, including operators, government, transport authorities and the regulator sign up to this common framework and set of values, meaning the business cases can be developed using mutually agreed parameters.

Finally, in Section "Conclusions", we draw conclusions based on lessons from the experience of the two sectors studied on why convenience matters for public transport and how it might be better measured and valued.

Defining Convenience in Public Transport

The term "convenience" is often used in relation to transport: It is generally assumed that a *convenient* service is more desirable and may therefore lead to increased demand, both by attracting additional customers away from alternatives and generating new trips. Hence convenience matters for public transport; to be attractive it must meet the needs of users, catering for ever rising expectations in an environment of increasing competition. This makes convenience vital in helping to ensure long term viability of public transport, through increases in demand, revenue, public support and acceptability.

Therefore '*convenient public transport'* is important to define and understand, particularly when devising strategies and policies to encourage mode shift. However, what makes a service convenient is not always well understood, nor is there a universal definition of which attributes come under the definition of convenience. Crockett and Hounsell (2005) noted that convenience is an ambiguous concept in public transport, often showing a high degree of overlap with other service attributes.

The Oxford English Dictionary defines **convenience** and **convenient** as:

"convenience [noun].. the state of being able *to proceed with something without difficulty*…the quality of being *useful, easy*, or *suitable* for someone…a thing that contributes to an easy and *effortless* way of life.."

"**convenient** [adjective]…*fitting in* well with a person's *needs*, *activities*, and *plans*.. involving *little trouble or effort*…*helpfully placed* or *occurring*.."

Thereby to be *useful and suitable,* the public transport service needs to be available to take passengers where they want to go at the time they wish to travel. This is facilitated by access and egress via *helpfully placed and available* (occurring) boarding and alighting points, and a network, timetable and operating hours *fitting* with *activities* which give rise to travel demand. A *suitable* service must also be reliable, punctual, and provide an appropriate level of comfort.

For many, the car, offering door-to-door mobility, symbolises the very essence of convenient travel, allowing the traveller to *proceed without difficulty*. Huey and Everett (1996) found convenience to be the greatest benefit of car use. Yet most public transport trips involve multiple journey stages or intermodal changes (Wardman et al, 1997). To be *easy* to use, a public transport service needs to offer effective integration as well as features including suitable information and appropriate ticketing.

Fundamentally, in transport terms *proceeding without difficulty, or with little effort* can be assumed to be synonymous with attributes of generalised cost and time, encompassing all dimensions of access (Brons et al. 2009), egress (Wardman et al, 2007), travel time (Wardman, 2011), wait time, congestion, as well as service-specific factors including measurable and more subjective (Eboli and Mazzulla, 2011) service quality attributes (Whelan and Johnson, 2004; Litman, 2008).

Convenience can be related to all stages of the trip, from initial planning to arrival at the destination. Berry *et al.* (2002) conceptualise service convenience as consumers' *time* and *effort* perceptions relating to the purchase or use of a service and defined five types of convenience – decision, access, transaction, benefit and post-benefit. They explain how benefits of convenience and burdens of inconvenience relate to saving or wasting time and/or effort and argue that "A firm's […] operations can dramatically influence consumers' perceptions of service convenience." Poor public transport service quality like crowding (Waldman and Whelan, 2011) might therefore be assumed to impact negatively on the perception of convenience.

Crockett *et al.* found that "it is possible to consider convenience in rail travel as an embodiment of four themes: access/egress, station facilities/environment, frequency of service/scheduling and interchange between train services". They also note that there is a considerable overlap between a broader definition of convenience and other travel factors including reliability, which they sought to differentiate in the context of rail travel.

Others have considered a narrower view of convenience as independent of time, reliability and comfort (Noland and Kunreuther, 1995), yet analogous with the door to door convenience of car travel. Earlier research considered convenience solely as a function of the number of stages within a trip (Watson, 1972). Litman (2008) refers to 'Comfort and Convenience' as more qualitative factors, possibly implying that these are separate from journey time components.

For the purpose of this paper we assume that convenience relates to the whole journey, including access and egress, and also other subjective factors such as perceived value (Lai and Chen, 2011, and de Ona et al, 2013). Therefore, all dimensions of public transport users' generalised travel time equation are considered, including but not restricted to, time, interchange and "softer" quality attributes. Monetary cost (fare) is excluded.

Public Transport Convenience and Service Quality

Although convenience is not necessarily synonymous with service quality, for simplicity, we use the term "convenience" in this paper to encapsulate both the wider scope of convenience as well as attributes of service quality. This is consistent with the scope of service quality defined in the two European Standards created to help define (EN13816, 2002) and measure (EN15140) service quality, which cover all attributes of the public transport service, as detailed in Table 2.1 and discussed further in section "Measuring convenience".

Table 2.1 **Eight attributes of service quality as defined by EN 13816 (adapted)**

Availability	Extent of the service offered in terms of geography, time (operating hours) frequency and transport mode
Accessibility	Access and egress to/from the public transport system including interface with other transport modes
Information	Systematic provision of knowledge about the system to assist the planning and execution journeys
Time	Aspects of time relevant to the planning and execution of passenger and train journeys, including journey time, punctuality and reliability
Customer Care	Service elements introduced to match the requirements of any individual customer, including staff reaction to customer complaints and kindness of staff
Comfort	Including crowding, cleanliness and service elements introduced for the purpose of making public transport journeys as comfortable as is reasonably possible.
Security	Offering safety and security to customers for the whole journey
Environmental Impact	Effect on the environment resulting from the provision of a public transport service (pollution and noise)

Source: Adapted from: European Committee for Standardisation, 2002

Measuring convenience

Service quality and convenience is of increasing importance to all businesses, including public transport organisations. It influences customer satisfaction, passenger demand, investment decisions and revenue. As described above, convenience is difficult to define and encapsulates a broad range of attributes.

However, to deliver an appropriate level of convenience, and hence to make the service attractive to passengers, operators and authorities must ensure that the quality delivered meets the needs and expectations of both existing and potential users. To achieve this, a clear understanding of travel behaviour and consumer needs and expectations is required, together with an accurate quantification of the strengths and weaknesses of the service. Therefore, it is essential to measure the quality of the service provided so that improvements aimed at enhancing user satisfaction and increasing market share can be most effectively targeted. However, developing accurate measures is a complex task, since it involves understanding perceptions and attitudes.

Availability of the service and the provision of adequate capacity are at the forefront of convenience, particularly in large, dense urban areas. High level measures can include frequency, operating hours, network structure, reliability (ensuring that passengers arrive at their destination on time) and comfort (including crowding). Ensuring that public transport is accessible to all, especially for people with special needs is vital to encouraging public transport use. Accessibility can be measured in terms of ease of getting to and from stops, ease of boarding and alighting and of obtaining a ticket.

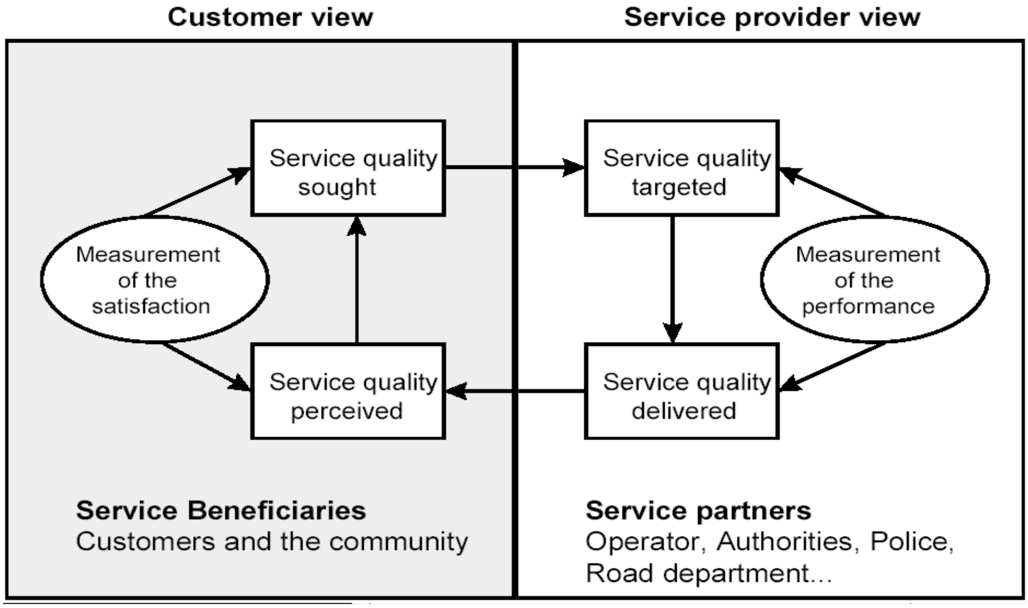
In this section of the paper we firstly review the European Standards for public passenger transport service quality, EN13816 and EN15140, in the context of the framework they provide to measure convenience in public transport. We then summarise the different convenience and service quality measures adopted by metro, bus and rail operators from around the world, and assess these against the criteria in the European Standards.

European Standards EN13816 and EN15140

The European Standard EN13816 provides a useful theoretical and practical framework for organisations to define and set convenience targets. It offers guidance on methodology for setting targets and measuring quality, and provides a comprehensive list of areas that together make up the service quality delivered to customers. The list of areas can help organisations ensure that they are considering the whole customer experience. For example, whilst aspects of journey time may be the most obvious aspects of convenience, customers are also affected by issues such as ease of obtaining information, and operating hours. The eight aspects of customer service quality as defined by EN13816 were presented previously in Table 2.1.The EN13816 Quality Loop

The diagram below illustrates the Quality Loop set out in EN13816, which defines a clear process to ensure that the service provided can meet the needs of existing and potential users most effectively, and therefore be as convenient as possible.

Figure 2.1 **EN13816 service quality loop**



Source: European Committee for Standardisation, 2002

The Quality Loop links the perspective of the users ("Service Beneficiaries"[1]) with that of the operators and authorities ("Service Partners") by setting out the steps by which the latter can most effectively meet the needs of the former, thus maximising the convenience of the service. The aim of the public transport provider should be to 'minimise the gap' between the service quality sought, targeted, delivered and perceived.

The first stage, "service quality sought" represents the ideal service to meet the needs of users – this could be considered as the "convenience maximising" service. It is vital that transport providers understand the needs of users and, ideally, attempt to deliver a service which best matches these needs – therefore the "service quality targeted" should be as close as possible to the "service quality sought".

Of course the service delivered will not normally fully match the level targeted – e.g. there will be delays. To understand how well the service actually delivered matches the targeted level, a comprehensive process for the measurement of performance is required. These must be objective measures; they are not equivalent to satisfaction.

Service quality perceived by customers will tend to reflect the service actually delivered, hence satisfaction measurement relates the level of service perceived with the level of quality sought, the final link in the Quality Loop – this measures how well the service meets customers' expectations. Since satisfaction relates quality perceived with quality *sought*, there is no direct link between satisfaction and the planned service (targeted quality). Therefore it is possible to have low satisfaction scores even where the level of service provided exactly matches that targeted – i.e. everything works according to plan.

Hence the quality loop illustrates the distinction between customer satisfaction which is a subjective measure of success, and performance measurement, which is an objective measure of success. Both types of measurement are required to understand how well the organisation is serving the customer.

EN13816 and EN15140 Guidance on Measuring Convenience

According to EN13816, any good service quality definition should be relevant, specific, and customer focused. Decisions about what to monitor should be based on customer priorities: each measurement should have a specific purpose. Measurements must be relevant to the goal of improving service quality as measuring for measurement's sake is a waste of resources. Definitions of success are needed; these should be grounded in intelligence about what level of service will please customers.

The related European Standard, EN15140 (Public passenger transport - Basic requirements and recommendations for systems that measure delivered service quality) provides recommendations on service quality measurement in the framework of EN13816. The focus is on advising operators and authorities how to set measurement processes, formulate specific indicators and set clearly defined targets.

Public transport providers must understand what is important to the customer. For example, EN15140 recommends that customer expectation surveys are conducted in order to determine and weight attributes to reflect what is most relevant to customers. It advises that the design of measurement systems should balance the customers' view with the use of the system as an internal management tool to achieve quality targets.

Crucially, a key instruction of EN15140 is that "the level of achievement shall be expressed, where appropriate, as a ratio of passengers affected". The standard recommends that operators split peak and off-peak measurements, giving greater weight of importance to services in the peak period (where more passengers are affected).

EN15140 advises that when quality indicators are used in a contractual relationship between a transport authority and an operator, the measurement processes should be understood and agreed on by the contractual partners with clear allocations of responsibility in the contract.

Recent Experiences and Practices from the Urban Rail Industry

The purpose of this section of the paper is to summarise the convenience measures adopted by metro, bus and rail operators from around the world. Benchmarking research by Imperial College London for the CoMET and Nova benchmarking groups shows that metro operators have adopted a broad range of attributes to measure and understand the service they provide to customers. This allows operators and authorities to evaluate the service from a more customer focused perspective, although as we shall see, many are more customer-oriented than others. Since the data comes under a strict confidentially agreement for the groups, graphs and figures shown are anonymised as follows:

- Am – North and South America
- Eu – Europe
- As - Asia

We necessarily focus on the experience of the urban metro groups who have agreed to share knowledge with OECD. At the time of this paper, the CoMET and Nova groups comprised 31 metros from North and South America, Europe and Asia (See Appendix A). The groups were initiated in 1994 and are focused on using benchmarking to identify and share best practices in operations and management. In 2012, CoMET and Nova metros combined carried over 22 billion passengers, therefore their contribution to the economies of major world cities is considerable and optimising the generalised cost of travel is essential. Interest in understanding the measurement of convenience is understandably high and the delivery of higher levels of quality is increasingly being seen as a key to an operator's effort to position themselves more effectively in the market.

As part of the CoMET and Nova process and using publicly available data, twenty-one metros responded to a survey in which they were asked to report the specific Service Quality and Customer Satisfaction measures used in their metro. The most common performance measures reported are shown in Table 2.2 below.

Table 2.2 **Top 10 service quality indicators measured by CoMET and Nova metros**

Top 10 Most Frequently Measured Service Quality Indicators	Proportion of (%) Metros
Escalator And Lift Availability	76%
Train Delay: Measured At 2 And 5 Minute Delay Thresholds	48%
Ticketing Service Availabiltiy/Failure Rate/Time Taken	48%
Level Of Crowding	43%
Cleanliness Of Stations/Trains	43%
AFC Gate Availability/Failure Rate	43%
Availability/Quality Of Staff	43%
Passenger Journeys On Time: Measured At 2 And 5 Minutes Delay Thresholds	38%
Information At Stations	38%
Waiting Time	33%

Source: Community of Metros /Nova Group of Metros /Imperial College London

Escalator and lift availability, train punctuality, ticketing service availability and crowding are the most frequently measured indicators. The most common indicators are broadly speaking very operationally focused, with only 38% of metros reporting that they measure the reliability of the service as perceived by passengers.

Indicators relating key measures of convenience, such as in-vehicle travel time, access and egress and interchange are less common, we expect because they are less easy to vary in an operational context (the planning authority rather than the operator may measure such attributes instead). Waiting time and the level of crowding are important sources of customer inconvenience, yet are measured by only a minority of operators. Provision of capacity is a key element of convenience although many very busy metros in large cities did not report that they measure any crowding or capacity indicators.

Examples of specific indicators used in CoMET and Nova metros are shown in Table 2.3 below. The most common indicators are shown in addition to some more innovative or good practice measures in each Service Quality area as defined by the EN13816.

Common measures used by metros include many indicators that relate to the management of the system to achieve targeted service quality, such as trains on time, frequency, proportion of scheduled headways achieved, and the proportion of scheduled kilometres achieved. More customer focused indicators, but less common, include the proportion of passenger journeys arriving on time, 'Lost Customer Hours' and 'Excess Wait time', which we discuss in the sections below.

Table 2.3 **Top 10 service quality indicators measured by CoMET and Nova metros**

	Most Common Indicators Used by Metros	**Innovative / Good Practice Measures by Metros (Eu=European Metro, Am=American, As=Asian)**
Availability	% of rolling stock available for service in the peak period % of actual service delivered that meets scheduled service Car kilometres between train failure causing delays ≥ 5mins	Number of unplanned full station closures - measured each service day (Eu) Occasions when passengers exceed the maximum capacity of a station (Am) Peak headway targets by line (minimum interval between two trains) (As)
Accessibility	% of escalators and elevators available for service % of Ticket Vending Machines available across the network	% of customers affected by the unavailability of escalators (Eu) Target: 96% passengers should not get stuck in lift for +15mins (Eu)
Information	Availability of dynamic passenger information in stations and trains (for service disruptions) Mystery Shopper Survey to evaluate quality of passenger information	% of passengers that have access to real time travel information during service interruptions (Eu) % of staff interactions that offer correct ticketing and route information (Eu)
Time	% of trains operated on time (2,3 and 5 minutes delay threshold) % of passenger journeys on time (2,3 and 5 minutes delay threshold)	Excess Journey Time (EJT) (Eu) Lost Customer Hours (LCH) (Eu) Excess Wait Time (EWT) (Eu) Passenger affected ratio (% passengers delayed by 5 minutes or more) (As) % of passengers that waited less than the reference headway (non-peak hours) (Eu)
Customer Care	Ratio of complaints / passenger Passenger enquiry response time - X% of customer complaints addressed within X number of days Overall Customer Satisfaction Score	General Perceived Quality Index: overall index is calculated weighting the rating of each aspect according to its importance (Eu) Monitoring and evaluation: % of satisfaction (rating 3 and above) in Supervisors' monitoring/evaluation at Customer Service Officers' call handling (As)
Comfort	Crowding density: average number of passengers standing per m^2 trains in most heavily loaded section in peak period Temperature on trains and in station must not exceed pre-set standards Perceived cleanliness rating in stations and trains (survey)	Maximum crowding on the train in peak hour, line by line, peak direction: must not exceed 100% of planning standard (As) % of Peak Services at above 135% seat capacity (As) Agreed standard between operator and regulator that there should be no more than 4 passengers per m^2 in the train (Eu)
Security	Incidence of fatalities to staff and passengers Rate of passenger accidents (per passenger) Incidence of crime in trains and stations	Criminal cases that result in system interruption, influencing passengers' safety and property security in every 1 million passenger kilometres (As) Perceived security rating (regarding assault and robbery) (Eu) Area of graffiti removed (as m^2) (As)
Environmental Impact	*No indicators reported*	*No indicators reported*

Source: Community of Metros /Nova Group of Metros /Imperial College London

Table 2.4 below presents the proportion of Service Quality indicators measured by CoMET and Nova metros, split for European, Asian and American (North and South) metros. The eight categories represent the areas outlined in EN13816 (as described above).

Table 2.4 **Service quality measurement areas measured by CoMET and Nova metros**

	% of Asian Metros Which Measure This Category	**% of European Metros Which Measure This Category**	**% of American (North/South) Metros Which Measure This Category**
Availability	75%	**100%**	75%
Customer Care	63%	**100%**	75%
Accessibility	50%	67%	75%
Time	63%	89%	**100%**
Comfort	75%	**100%**	75%
Safety and Security	63%	89%	75%
Information	63%	89%	75%
Environmental impact	0%	0%	0%

(Source: Community of Metros /Nova Group of Metros /Imperial College London)

Availability (e.g. minimum frequency of service achieved), customer care (e.g. standard timescales for staff response time to passenger queries or complaints), Accessibility (e.g. availability of lifts/ escalators) and time (e.g. Excess Journey Time / Excess Waiting Time) are the most commonly measured service quality areas within CoMET and Nova, with 81% - 86% of all metros having some service quality measurement in these categories. Environmental impact was the only area not measured by any metro.

It is clear that there is more service quality measurement in European metros where there is often a greater contractual or regulatory relationship between the operator and the authority. For example, some of the more novel measurement practices in London Underground stem from regulatory standards set up as part of the Public Private Partnership (PPP) contracts. In general, Asian metros have far less comprehensive measures, although there is a strong focus on operationally focused, time-based indicators (such as punctuality, reliability and the percentage of trains operated).

In many cities, there are limited alternatives to the fast service provided by the metro so a decline in service quality may cause passenger dissatisfaction and/or political discomfort, rather than any significant drop in demand (at least in the short term). Therefore, an independent regulator is sometimes needed to monitor service quality, which is then linked to financial rewards and/or penalties. Although incentive regulation is a relatively recent mechanism in metro operations, it is becoming more prevalent in the bus sector and is very common in regulated utility sectors.

Setting clear targets is an effective management tool for reaching targeted quality levels. EN13816 recommends that operators should adopt specific targets for each indicator, with clearly defined measurement processes. This is important to highlight, because not all CoMET, Nova or IBBG members reported both these elements in their service quality measures. Indeed, some urban transport operators only use customer satisfaction surveys, so have no defined objective quality indicators.

Setting a specific target to reach may provide a better incentive for improvement, which is often stipulated in operating performance contracts. Paris RATP has a strict set of key performance indicators and service quality targets written into their operating contract with the Transport Authority (STIF). These targets, which are set annually over a three year period, lead to a financial bonus or penalty depending on whether their overall performance is above or below the stated threshold (RATP Activity Report, 2012).

Leading CoMET and Nova metros such as Metro de Santiago and Hong Kong MTR have implemented a continuous improvement processes and culture in their organisations. Each month performance is compared against previous levels.

Case Studies of Worldwide Practice in Measuring Convenience and Service Quality

We next look at some of the more innovative measures of convenience and service quality in more detail, with examples from the United Kingdom, other European countries, North America and Asia.

The UK Experience: Transport for London / London Underground / London Buses

The impact of service quality on the potential to generate passenger growth (revenue) remains a strong focus in London. Contracting out of bus services by Transport for London (TfL) and the now-defunct London Underground (LU) Public Private Partnerships (PPPs) have both been catalysts for new and more inventive measures of convenience.

The strong focus on measuring and valuing performance in the UK is based around detailed appraisal requirements for government funding. Detailed measurements include the Journey Time Metric (JTM) and Lost Customer Hours (LCH) used by LU and Excess Wait Time (EWT) used by London Buses.

LU measures ‘excess journey time’ through their Journey Time Metric (JTM) (London Transport, 1999). The JTM was developed to measure customers’ overall journey time on the network. Each journey is broken down into constituent parts; access from entrance to platform, ticket queuing & purchase, platform wait time, on train time, platform to platform interchange and egress from platform to exit. Times for these elements can be disaggregated by line and time band. Using information from the Passenger Origin & Destination Survey, LU is able to derive a passenger demand matrix; thereby estimating how many passengers travel on a particular line section or along a certain station passageway. Hence they can calculate the average time for any given journey stage. Each JTM also has a Value of Time weight associated with it dependent on how the customer perceives the activity. Changes in the scheduled values for components of the JTM can reflect capital improvements, for example by re-designing stations to shorten walk links or the use of faster trains. Non-capital initiatives, for example better management of station dwell times or the provision of station assistants to reduce ticket queues, can have an immediate impact on excess time and even scheduled time in the longer term.

Lost Customer Hours (LCH) measures the total additional time (summed for all customers) resulting from all service disruptions of two minutes or more, due any cause. For example, a two minute delay at a busy central station in the morning peak costs significantly more LCH than a two minute delay on a Sunday evening in the suburbs, as more passengers are affected. The measure takes into account the duration, location and time of the disruption to estimate the total “cost” in terms of customer time, directly measuring the impact on passengers. It reflects whether or not metro assets are available and was the primary measure used for assessing the PPP Infrastructure Company’s performance in improving the day-to-day availability.

Excess Wait Time (EWT) is a measure of regularity used by London Buses. EWT is defined as the difference between the actual wait time (AWT) and scheduled wait time (SWT). The lower the EWT, the more likely it is that passengers will not wait more than the scheduled time and will perceive the service as regular, hence it is a measure of perceived regularity. It is objective, relatively easy to communicate to passengers, represents all customers and penalises very long headways (bad for customer convenience). However, this is only valid for regular scheduled headways.

Of four regularity measures tested in the International Bus Benchmarking Group (IBBG) by Imperial College London, EWT was considered the most statistically robust and the only method that fully incorporates the customer perspective (Trompet et al, 2011). Other service regularity indicators tested included wait assessment, service regularity and standard deviation of the difference between the actual and scheduled headways, a measure related to headway adherence, but with the output expressed in minutes.

The Contemporary European Experience

In general, European Metros have a more comprehensive approach to measuring convenience and service quality, with many following the EN13816 standard closely.

Many European metros in CoMET and Nova have an inclusive approach to setting Service Quality benchmarks, to ensure the service standards are upheld. Service Quality standards are often dictated by transport authorities and governments through an operating contract. Several metros used a range of measures based around EN13816, aiming to provide internal incentives and to pledge a high quality service to customers. For example, all lines in Metro de Madrid are individually certified by AENOR (Spanish Standards / Certification Authority), in accordance with EN13816.

There is a strong Service Quality commitment in the new (2012-2015) operating contract between Paris RATP and the transport authority (STIF). Financial incentives are enforced based on a range of indicators which broadly conform to EN13816. Specific targets are set for each indicator, including a minimum standard. If RATP exceeds this minimum, a progressive bonus is applied. However, if the specified target is not met on any measure, a penalty is applied. The focus on service quality within the contract ensures that standards are upheld and Metro, RER and bus services meet the needs of their (growing) customer base. RATP sometimes uses higher targets than those set by the authority for internal management (RATP Activity Report, 2012).

The new contract between STIF and RATP includes more performance indicators than the previous one; 141 performance indicators compared to 79. More weight is given to punctuality and regularity (43% of service quality indicators based on punctuality, compared to 29% previously) and customer satisfaction now also has a higher weight (RATP Activity Report, 2012). Crucially, the contract includes indicators that measure the impact of the service on the passenger. For example, a target or minimum threshold is set for passenger waiting time (% of passengers who waited less than the reference headway) in the off peak period. Similarly, a ticketing (Automatic Ticket Machine) availability threshold has been set to measure convenience of ticket purchase.

The Contemporary Asian Experience: Hong Kong MTR

Some Asian metros are improving their service quality measures in response to changing regulatory environments and a need to be continuously customer facing. Best practice metros measure both operational and customer focussed indicators. Hong Kong MTR measure a ‘Passengers Affected Ratio’, representing the number of passengers on trains delayed by five minutes or more. Passenger numbers are based on fifteen-minute average loading figures per line from the Automatic Fare Collection system (AFC). Train delay is measured directly from the signalling system and collated by the control centre.

While operational and technical indicators are useful, they can misrepresent the customer perspective, hence there is often a mismatch between public perception and punctuality indicators. Service reliability measures such as mean distance between failures (MDBF) typically focus on the frequency with which incidents or delays occur. However, to truly understand reliability, measures that capture the total impact of incidents to trains and ultimately to customers, such as train hours delay and passenger hours delay, are needed (Barron et al, 2013). This is important because the impact of incidents increases exponentially with the duration. Furthermore, the context of incidents is critical; incidents that occur during peak times or at busy locations have much greater impacts than those at the outer end of a long metro line late on a Sunday night.

Metros such as Hong Kong MTR exhibit a balanced and detailed approach to measuring time and reliability based indicators, considering both customer and operationally focused measures. As well as the 'passenger affected ratio,' there is strong focus on measuring punctuality (the proportion of trains that run on time) and reliability (the mean distance between incidents causing delay to service) at two and five minute thresholds, which are more useful for measuring the technical performance of assets.

Frequency, Capacity and Crowding

Passengers in Excess of Capacity (PiXC) is an aggregate metric used to measure crowding levels for Train Operating Companies (TOCs) in Great Britain. PiXC is derived from the number of passengers travelling in excess of capacity on all services passing a critical load point (above a critical threshold) divided by the total number of people travelling, expressed as a percentage. The critical load points aim to represent the most crowed section of the journey, normally the approach to – or departure from, major termini, and cover only the three hour morning and evening peaks (Department for Transport (DfT), United Kingdom, 2012).

In a metro context in large and dense cities, capacity provision and crowding can be key measures of how convenient the public transport service is for potential customers as they can significantly affect the total generalised costs of trips. Surprisingly, specific crowding and capacity measures do not feature prominently in most CoMET and Nova metros' indicators. Only seven out of twenty-one CoMET and Nova metros measure capacity or crowding. A further two metros include crowding in their Customer Satisfaction scores. An example is a Chinese metro which measures the degree of crowding on trains in the peak period by relating real time passenger demand by line with the maximum capacity of the line in the peak hour in the peak direction. If the degree of crowding exceeds the threshold, they use this indicator to identify overcrowded trains and hence determine where capacity increases are needed. Sydney Trains measures the proportion of peak services above 135% of seated capacity. Some European metros have a standard to limit crowding to four passengers per m^2 during the peak period.

Previous work by Imperial College (Graham et al, 2009) used a dynamic panel model to estimate the effect of fares, income and quality (capacity and frequency) on demand for a sample of 22 metros, using time series data from a 13 year period. The key results are summarised in Table 2.5, below:

Table 2.5 **Metro elasticities of demand**

Demand with respect to:	**Elasticity (short-run)**	**Elasticity (long-run)**
Income	0.026	+0.183
Fares	-0.047	-0.331
Quality of service (using car km / route km)	0.072	0.507

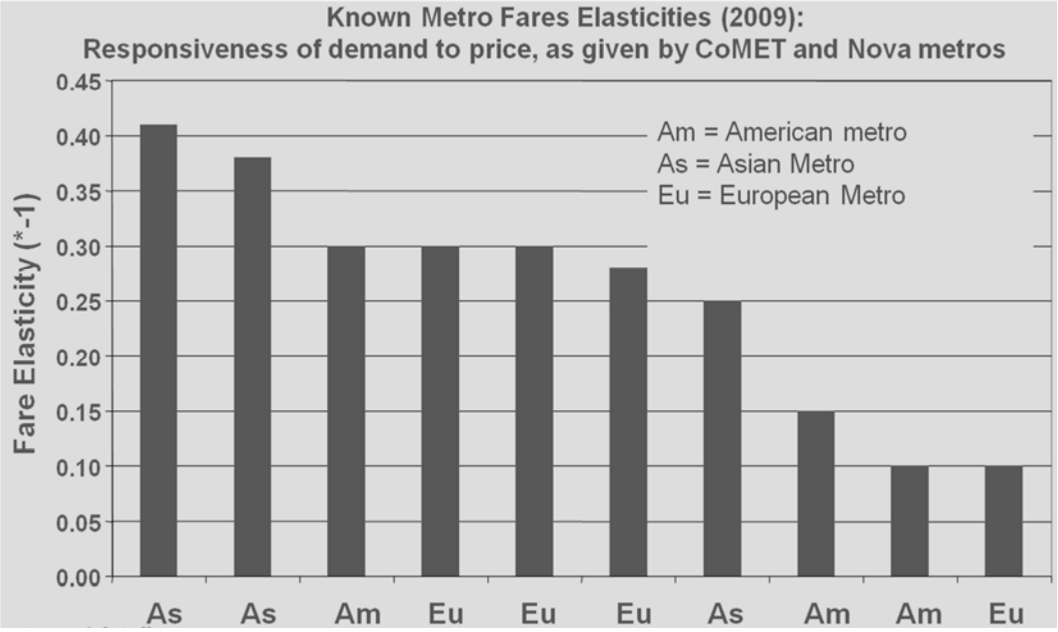
Source: Graham et al, 2009

The estimated long run income elasticity was small but positive (0.18), indicating that metros are perceived as normal goods (demand increases as incomes rise). Long-run quality of service elasticities (here, +0.51 using capacity: car km per route km) were positive and substantially higher than the absolute value of fare elasticities (-0.33). However, increasing speed appeared to have little effect on demand. The implication was that increasing capacity, rather than fare reductions or reducing in-vehicle time, may be most effective in increasing patronage. Of course, an average elasticity of demand to service quality of 0.51 across all metros, for all time periods might suggest a much higher elasticity for busy metros during peak periods and may imply that passenger demand is highly sensitive to crowding factors in terms of their generalised cost.

Sensitivity tests on Chinese metro costs and revenues, using these elasticities (Anderson et al, 2012), demonstrated that operating cost recovery from fares would be increased significantly by maximising use of fixed capacity by increases in train frequency and capacity.

It is notable that only 50% of CoMET and Nova metros, when surveyed in 2009, knew their own elasticities of demand to price (values received are shown in Figure 2.2). It is probable that such information is better known by transport authorities, but this may indicate that key policy and service decisions, and the case for investment, could be made better by operators if a greater understanding of passenger demand and revenue was known.

Figure 2.2 **Known metro fare elasticities (2009): responsiveness of demand to price, as given by CoMET and Nova metros.**



Source: Anderson et al, 2010 / CoMET and Nova Benchmarking Groups

Benchmarking Public Transport Convenience and Service Quality

The CoMET, Nova, ISBeRG and IBBG groups include metros, suburban railways and bus systems of many different characteristics, but many share fundamentally the same challenges and issues which provides for a wealth of experience and knowledge that operators can share with each other.

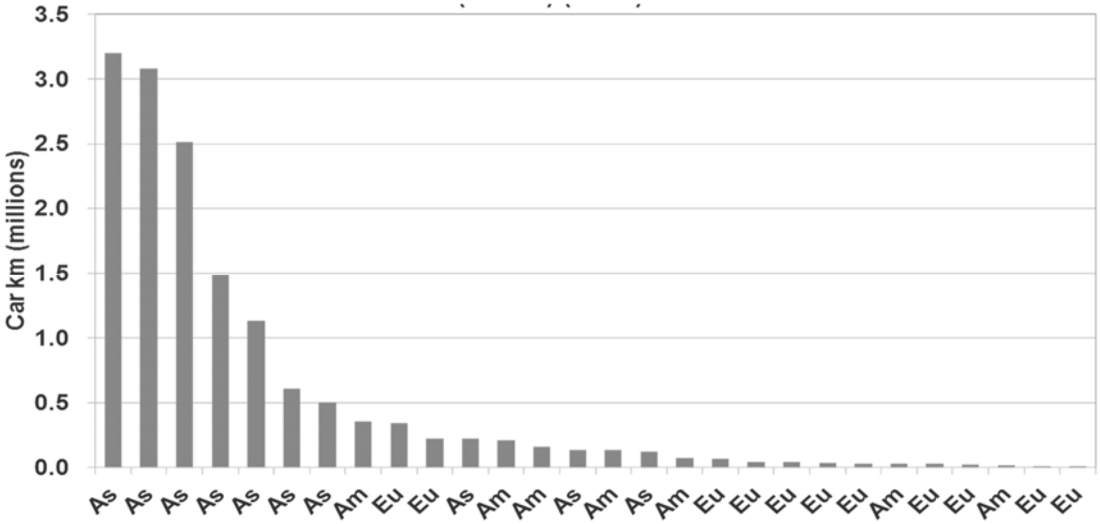
The benchmarking process, facilitated by Imperial College London, is centred on a Key Performance Indicator (KPI) system, which enables universally consistent and understandable comparisons between different organisations. However, it involves not only the comparison of performance, but also the identification of best practices, helping support decision making and improve internal management. This leads to a better understanding of the differences between operators, to improve internal motivation, set targets for better performance and identify high priority problems, strengths or weaknesses. All areas of the business are covered, including finance, operations and safety as well as aspects related to convenience.

Benchmarking convenience involves many challenges. Firstly, the subjective dimension of many convenience attributes implies that it is not always clearly defined or the definitions of individual organisations may present significant differences. People from different cities or countries may have different habits, customs and expectations regarding convenience. Having different understandings of the concepts also compromises the direct comparability of data between organisations. Moreover, convenience is a dynamic dimension as the expectations of the customers are not fixed and may become more demanding depending on the progress in other sectors (for example, with the introduction of new technology, air conditioning and increasing comfort standards).

Despite these challenges, the CoMET and Nova KPIs provide a number of measures that can help us define objective levels of convenience. We present a selection of examples below. These have been anonymised to maintain confidentiality, using the codes defined in "Recent Experiences and Practices from the Urban Rail Industry".

The first example, car km between incidents causing a delay of 5 minutes or more, is shown in Figure 2.3. A key determinant of metro quality and customer satisfaction is the extent to which trains and therefore passengers are delayed. This KPI measures reliability in terms of incident frequency, regardless of delay duration (provided the delay was 5 minutes or more). Total reliability should also consider the length of delays and how many passengers are affected. This is an important KPI in CoMET and Nova due to the huge disparities in performance observed, and the significant year-on-year improvements in several metros.

Figure 2.3 **Car kilometres between incidents causing delay of equal to or more than 5 minutes. also known as mean distance between failures (MDBF) 2012.**



Source: Community of Metros /Nova Group of Metros /Imperial College London

However, car km between incidents not a true measure of convenience to passengers as it is operationally focused and does not necessarily reflect the service experienced by customers. It is therefore important to measure the impact of train delays on passengers. The table below demonstrates the hierarchy of time based delay indicators considered by the CoMET and Nova KPI system, in increasing order of customer focus:

Table 2.6 **Measuring train and passenger focussed delay incidents**

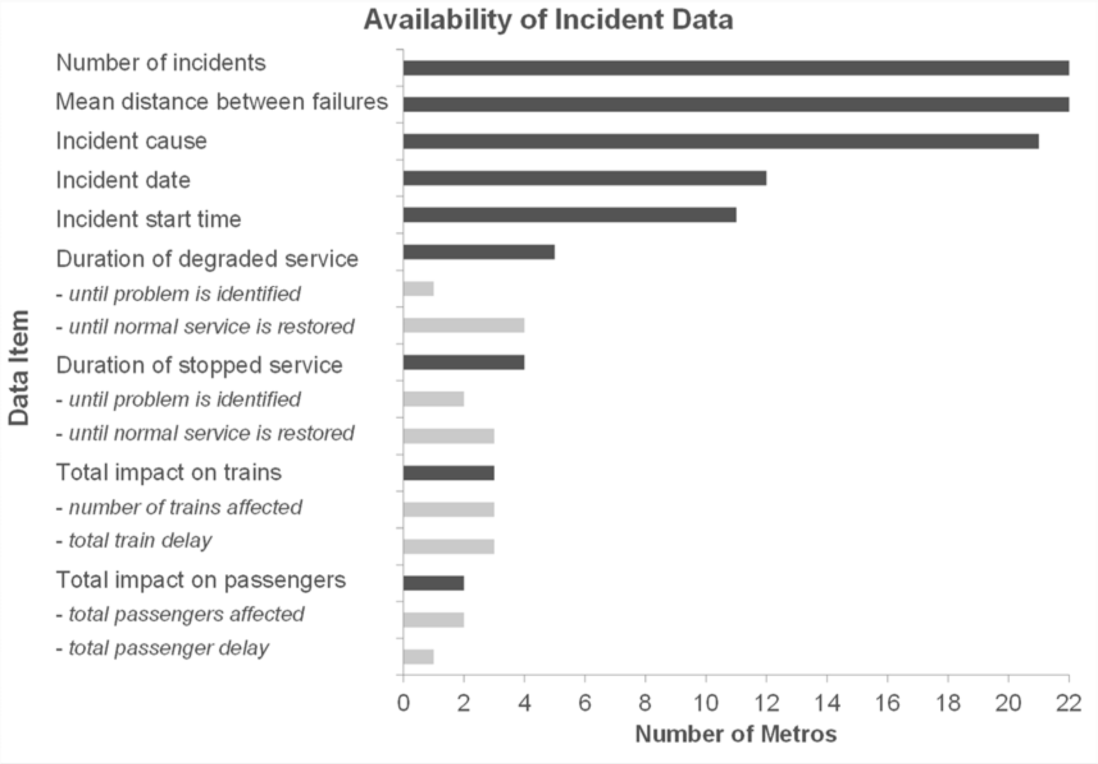
On Time Arrival at Final Destination	Trains On Time / Total Number Trains (Terminal Station Only)
On Time Arrival at En-Route	Trains On Time / Total Number Trains (at any point En-Route)
Average Delay per Train	Number of Minutes of Train Delay Versus Number of Trains Affected by Delay Train Hours Operated / Hours of Train Delay
Passengers Affected Passenger OTP	Average Number of Passengers per Train (Loading) and Time and Location of Train Delay
Passenger Hours Delay	Passenger Hours' Delay / Passenger Journey Passenger Journeys On Time / Passenger Journey

Increasing Customer Focus

Source: Community of Metros /Nova Group of Metros /Imperial College London/ (Barron et al., 2013).

To measure delays from a more customer focused perspective appropriate data needs to be collected in a sufficient level of detail. Figure 2.4 presents an overview of incident and delay data that 22 metros provided for a recent survey (Barron et al, 2013). Of the metros that responded, all were able to provide the most basic data such as the number of delay incidents, but very few could provide detailed data on the impact of delays on trains and passengers.

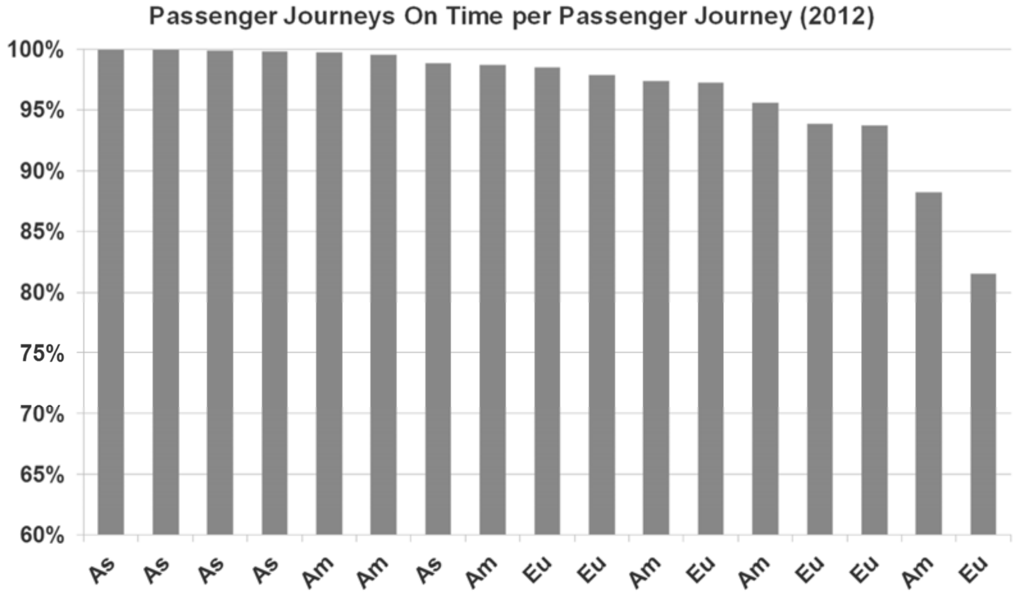
Figure 2.4 **Overview of availability of incident data: CoMET and Nova survey,** 2012 (Barron et al, 2013)



Source: Community of Metros /Nova Group of Metros /Imperial College London/ (Barron et al., 2013).

Despite difficulties of data collection limiting its availability for many metros, the current benchmarking methods enable us to estimate the impact of incidents on delay to passengers. Figure 2.5 shows the proportion of passenger journeys on time for CoMET and Nova metros in 2012. It is notable that this is estimated by metros for the benchmarking groups, yet not often used as an internal performance measure. In this case, those operators with incidents concentrated in the peak hours (affecting more customers), will have a significantly lower proportion of passenger journeys on time. The data shows that the average daily commuter in a high reliability metros such as Hong Kong is delayed by 5 minutes or more only every two years, yet once every 2 weeks in a typical European metro. However, current measurement methodologies exclude delays caused by congestion in stations; further research and more precise measurement from ticketing systems might reveal a higher level of passenger delay than currently recorded.

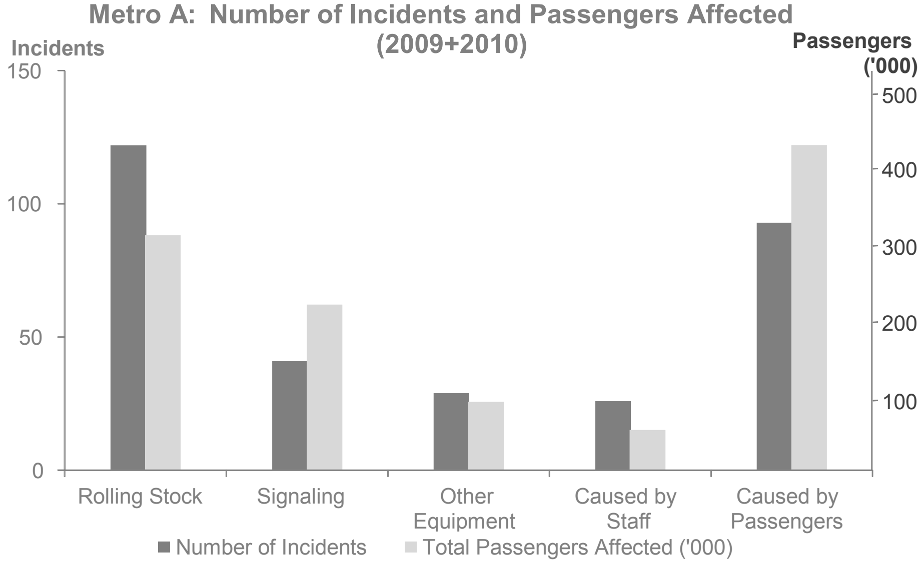
Figure 2.5 **Metro passenger delay: passenger journeys on time per passenger journey**



Source: Community of Metros /Nova Group of Metros /Imperial College London

The importance of measuring delays from a passenger perspective is often poorly understood by operators, which can lead to incorrect management decisions and focus. As shown by Figure 2.6, if 'Metro A' managed it service based on the number of incidents, as opposed to their impact on customers, they would see the biggest challenge as rolling stock, yet delays caused by passengers have a greater impact on customer delay. Barron et al (2012) state that "this supports the hypothesis that number of incidents is not an accurate proxy for effect on passengers. Therefore, use of a performance indicator that specifically addresses passengers is indeed a necessary pre-requisite for passenger-focused management of incidents".

Figure 2.6 **Number of metro delay incidents and passengers affected by delays – sample from an anonymous metro**

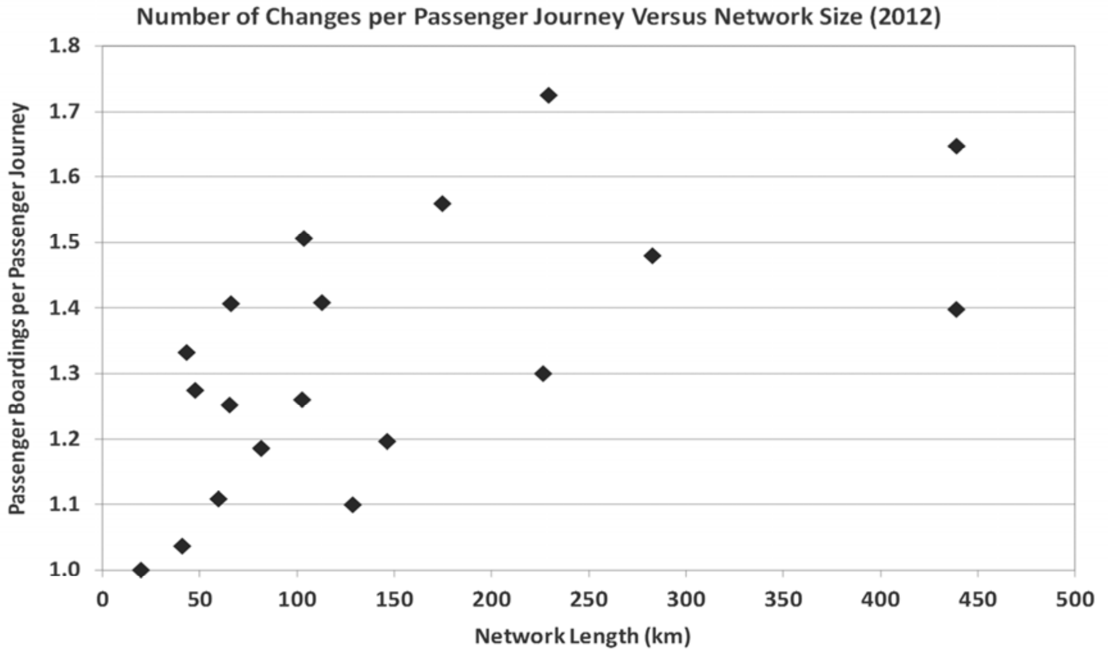


Source: Community of Metros /Nova Group of Metros /Imperial College London

Another aspect of importance for customer convenience is the generalised cost components of interchange penalties and waiting times, as discussed in

Section “ Introduction ”. Using the benchmarking data we can compute the average number of interchanges for each journey on the metro. As networks expand, as they are doing so rapidly in China and India, increasing reach offers greater access to the metro, but the complexity of the network can result in more interchanges on each trip. A poorly designed network can add additional generalised cost to passengers, as well as increasing unit costs to the operator. More widely, the transport authority must consider improving the total journey, including all access and egress modes. Figure 2.7 shows the number of interchanges (between lines) per passenger journey and how it relates to network length; we observe a positive correlation.

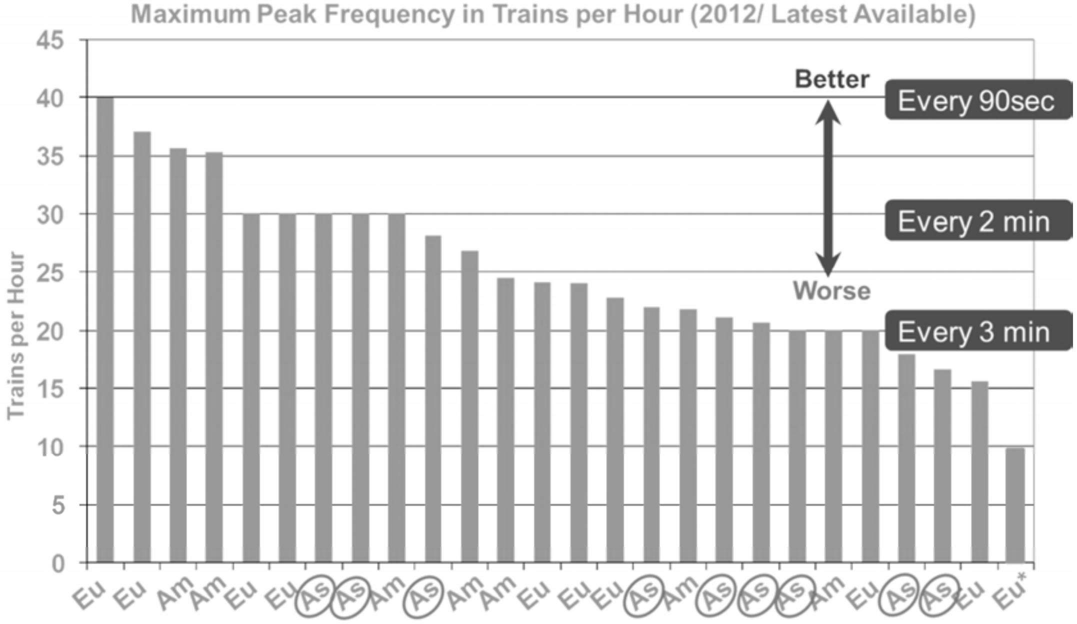
Figure 2.7 **Number of interchanges per metro passenger journey and network size**



Source: Community of Metros /Nova Group of Metros /Imperial College London

Finally, Figure 2.8 demonstrates a further element from the benchmarking which represents a common problem for emerging metros in Asia: delivering sufficient peak period frequency to maximise capacity and minimise crowding (where many new metros are not exceeding 24 trains per hour). European and South American metros have generally better optimised design and operating practices to take full advantage of modern signalling technology and maximise the frequency of trains during the peak hour. This can be seen clearly in Figure 2.8 where twelve of the fifteen metros with the highest service frequencies are in Europe and South America; for example, 33 trains per hour are operated on London’s upgraded Victoria line. Maximising frequencies is important because metros exhibit ‘strong returns to density’ (Graham et al, 2003): maximising capacity can increase efficiency and reduce subsidy requirements for metros in large cities with very high levels of passenger demand.

Figure 2.8 **Maximum peak hour train frequency (CoMET and Nova metros, 2012).**



Source: Community of Metros /Nova Group of Metros /Imperial College London

However, when attempting to maximise train frequencies it is important to understand the relationship between capacity utilisation and delays. Research (Melo et al, 2011) confirms that increasing available line capacity (e.g. with new signalling), so as to provide some slack, limits the impact of delays and increases reliability. Conversely, running more trains without any increase in line capacity leads to more delays. Table 2.7, below, shows the results of recent statistical analysis of delays by metro line, taking into account a number of operating and demand characteristics. The results also demonstrate that technology has a significant influence on the number of delays. Crucially, however, from a generalised cost point of view, maximising utilisation of line capacity (frequency) increases delays yet investing to add the same change in available capacity reduces delays by a greater degree.

Table 2.7 **The sensitivity of metro delay incidents to technology and demand factors**

Parameter	**% Change in Delay Incidents (Mean distances between failures causing a delay > 5 minutes)**
+1 Year of Rolling Stock Age	0.7% - 2% depending on model
+1 train per hour in the peak period	+3.5%
+1 train per hour practical capacity	-5.0%
Moving from manual to automatic train operation (ATO)	-26%
+10% passengers	+3.0%

Source: Melo et al, 2011 / Subsequent analysis by Imperial College London using CoMET and Nova data

These benchmarking examples have shown that trading off the value and demand impact of delays against crowding and increased waiting times is a process that only a few metros undertake. Metros naturally focus on the objective measures of service quality against which they are regulated or managed by their authorities, commonly measures of train delay. Although we have not surveyed metros to identify their decision making process, other research shown above (e.g. in Table 2.4) demonstrates that metros, particularly in Asia, are not measuring the impact of delays and crowding on passengers well.

If good measurement is the pre-requisite to good valuation of such convenience measures, we argue that insufficient attention is given to minimising generalised cost / journey time. Good practice is nonetheless observed in cities such as Paris and London: Transport for London uses its Business Case Development Manual (described in Section "Valuing convenience") to give guidance on values to attribute to changes in passenger generalised costs for investments improvements. In summary, we argue that greater management attention by operators to the measurement and valuation of attributes of most important for passenger convenience is required in many cities and that such analysis should not be left only to the authority to undertake. In Section "Valuing convenience" we look at how convenience attributes can be valued, taking the specific example of the rail industry in Great Britain.

Valuing convenience

In Section " Measuring convenience " we looked at how convenience can be measured for public transport. In this section, we show how similar attributes of the service can be valued through the quantification of the effects on passenger demand. Taking the example of the extensive demand forecasting framework used by the British rail industry, we demonstrate how these impacts can be quantified and describe some of the evidence.

Measuring Convenience by Looking at the Impacts on Demand

One means of measuring how well public transport meets the needs of existing and potential customers is to look the level of demand for the service. All else being equal, we would expect more people to use a convenient service than an inconvenient one.

This relationship between convenience and demand means that transport providers have a direct commercial interest in the level of service they offer to customers. The railway sector in Great Britain has invested considerable effort to understand this relationship. They need to know how best to target investment to maximise the impact on demand, and hence revenue from passengers. This was as important for the nationalised British Rail in the 1970s and 80s as it is for the private sector operators today; funding pressures from government can provide as strong an incentive as the need to maximise commercial profits.

Specifically, this evidence helps us understand convenience from two perspectives. Firstly, it demonstrates that improving the level of convenience attracts more people to the service, proving that investment to make the transport system more convenient can help increase the overall use of public transport, helping to meet wider social, environmental and economic objectives. Secondly, it provides quantified evidence of what customers find most important when making travel decisions and the relative importance they place on different attributes of the service.

Although the demand forecasting experience from the British railway sector can only provide high level guidance on the convenience of public transport more broadly, we consider that the approach, and much of the evidence is likely to be transferable in general terms, and the wealth of quantified evidence available makes it especially valuable.

The British Rail Industry Passenger Demand Forecasting Framework

A substantial volume of quantitative and qualitative research has been undertaken over several decades to understand the impact of a broad range of service attributes on demand. Attributes include aspects of the service which may be classed as convenience, including frequency, reliability, quality and crowding. The evidence is collated in the Passenger Demand Forecasting Handbook (PDFH). The document is updated on a regular basis with new and revised evidence; the latest edition contains 500 pages.

Transport for London (TfL) use a similar body of evidence to understand demand impacts of service changes and quality enhancements on the London Underground, buses and the other modes for which they are responsible. This is contained in TfL's Business Case Development Manual (BCDM).

All major industry bodies participate in the PDFH including train operators (TOCs), the infrastructure provider (Network Rail), government (Department for Transport and Transport Scotland) and the regulator (ORR). The broad participation helps ensure that the evidence is accurate and unbiased. Participants jointly fund a research programme to develop the evidence and keep it up to date. PDFH also takes input from other academic work and research undertaken independently by the participating organisations.

The research underpinning the PDFH includes both stated preference and revealed preference work with passengers, as well as substantial econometric and similar analysis. The substantial volume of research on which the PDFH is based means that most attributes have been the subject of a number of different studies, increasing robustness. The high level of use of the evidence across the industry also means that significant practical validation of the findings is carried out.

The PDFH is a confidential document; hence the evidence is described here in general terms only. It is not possible to quote specific values, however, as noted above these would not generally be directly transferable. Third parties can however apply for licenced access.

PDFH Methodology

The primary methodology used in the PDFH is based on elasticity to time and cost (fare). Most evidence is expressed in units of time. Each variable, including those related to convenience, is converted into an equivalent amount of travel time (expressed as "Generalised Journey Time"), weighted to reflect relative importance. Elasticities to time are then applied to estimate changes in demand, based on the principle that reductions in journey time lead to increases in demand, as follows:

$I_j = (GJT_{new}/GJT_{base})^e$

Where:

- I is the index for change in demand,
- GJT_{new} is the weighted Generalised Journey Time after a change to the service,
- GJT_{base} is the weighted Generalised Journey Time before the change to the service,
- and e is the elasticity to time

Generalised Journey Time (GJT) has specific definition in PDFH, different to that often used in conventional transport planning theory. The concept is analogous to Utility theory in economics (but of reverse sign). Basically GJT is a measure of the "attractiveness" of the service to customers. The lower the GJT the more attractive the service is to customers. E.g. a shorter journey time, higher frequency, more comfortable, or cheaper service will have a lower GJT. The use of common units (time) means that it is also possible to compare the relative importance of different variables in terms of their impact on demand.

PDFH evidence (elasticities and weightings for specific service attributes) is disaggregated according to market segment: journey purpose (business, leisure and commuting), journey length and geography (e.g. typically passengers around major cities respond differently to those in rural areas).

There are separate elasticities to price (fare), used to estimate the impact of changes in ticket price. This is assessed separately from the time based attributes – i.e. values of time are not used to combine cost and time-based elements. Here we focus on the time based elements only.

Examples from the PDFH

The key areas in the PDFH relating to convenience are:

- (Station to Station) Journey time
- Frequency
- Interchange
- Punctuality and Reliability
- Crowding
- Rolling stock and station quality

The evidence on each of these areas is considered below.

Journey time, frequency and interchange

In-vehicle time (effectively travel time), waiting time (a function of service frequency) and interchange are combined in the PDFH framework as a single measure of Generalised Journey Time (GJT) which can be calculated for each origin destination flow. Individual GJT elements can also be weighed to account for further quality attributes, including crowding levels and rolling stock quality, as described below.

The evidence shows that passengers are very sensitive to GJT, as might be expected. Elasticities of demand to GJT have typically been found to be in the range of around -0.7 to -1.1, depending on market segment. An elasticity of -1.0 means that the increase in demand for the service is directly proportional to the reduction in GJT – i.e. a 10% reduction in GJT would lead to a 10% increase in demand for the service.

For short distance services, such as in urban areas, the evidence shows that the impact of changes frequency can be very significant. Often it may be easier, and cheaper, to improve the attractiveness of the service by means of frequency enhancement than though reduction in actual travel time, consistent with our findings from research on metros describes in Section "Frequency, Capacity and Crowding". This is in addition to any further impacts resulting from the increased capacity usually associated with higher frequencies.

The example shown in Table 2.8, based on PDFH evidence[2], illustrates the relative changes in journey time and frequency required to achieve the same impact on demand, assuming an elasticity to GJT of -1.0. This involves a base scenario with of a service operating every 10 minutes, and a travel time of 15 minutes. The evidence suggests that the impact on demand due to doubling the frequency to every 5 minutes will be the same as reducing the travel time from 15 to 10 minutes (excluding capacity impacts). This demonstrates that frequency has a very large impact on demand, and therefore convenience. This is particularly important when considering off-peak service levels. During off peak periods many trips may be more discretionary (compared to trips to/from work).

Table 2.8 **Relative changes in journey time and frequency required to achieve the same impact on demand**

	Travel Time	Frequency	Generalised Journey Time (GJT)	% Change in GJT	Demand
Base Scenario	15 min	Every 10 min	25 min	N/A	(Existing)
Doubling Frequency	15 min	Every 5 min	20 min	-20%	+20%
Journey 5 minutes (50% faster)	10 min	Every 10 min	20 min	-20%	+20%

Source: Imperial College London, based on UK rail industry experience/PDFH

The PDFH evidence also shows that the need to interchange can have a major negative impact on demand, suggesting that passengers find this especially inconvenient. Each change of trains is equivalent to an absolute minimum of 10 minutes additional journey time, over and above the actual connection time between trains. For most journeys the impact is even greater. For regular travellers using high frequency urban public transport we would expect the negative impact to be less, although as we saw previously (Figure 2.7) journeys on some urban networks can involve a high number of interchanges.

As an example, consider a journey from A to C which involves a 10 minute journey from A to B, with a 5 minute wait at B for the next service, and a journey time of 15 minutes from B to C. The total elapsed time from A to C would be 10 + 5 + 15 = 30 minutes. However, with an interchange penalty of 10 minutes, applied in addition to this, the total GJT would be 40 minutes – i.e. the service from A to C including the interchange could be expected to be as attractive to passengers as a direct service from A to C taking 40 minutes (and therefore attract a similar level or demand).

Crowding

Impacts of changes in crowding are estimated using a weighting factor applied to the in-vehicle component of GJT. Larger weighting factors represent higher levels of crowding. In a crowded vehicle with 4 to 6 passengers standing per m^2, the impact for those passengers standing is equivalent to a 2 to 3 times increase in in-vehicle time. This means that the negative impact on demand from crowding can be equivalent to a 2 to 3 times increase in travel time for affected passengers; crowded services are, as we would expect, significantly less attractive.

The negative impacts of crowding for rail services start even when there is still plenty space on board trains. Evidence shows that there are marginal detrimental impacts on demand once around 75% of seats are taken. All else being equal, passengers are more likely to travel if they have a choice of seat.

For urban transport such as metros, we might expect the negative impacts of crowding to be lower, since journeys are normally shorter than on mainline railways, but the effect is still likely to be significant. In Section " Benchmarking Public Transport Convenience and Service Quality " we saw that the demand impact of capacity provision on metros can be substantial. One of the implications of this evidence is that as well as making the service more comfortable for existing users, reducing crowding levels (e.g. by running longer trains) will make the service more attractive, leading to an increase in demand. Therefore there is a degree of feedback, where a proportion of any new capacity provided is filled with new passengers attracted to the (now) less crowded service. Providing additional capacity by means of shorter headways, rather than higher capacity vehicles, will increase this effect further as new demand is attracted by increased frequencies as well as the less crowded conditions on board.

As explained in section " Measuring convenience ", above, analysis of CoMET and Nova data (Graham *et al*, 2009) revealed an average elasticity of demand with respect to capacity of +0.51, with far higher elasticities expected for busier metros during peak periods. The economics and efficiency of metros improves significantly the greater the extent to which fixed costs are met with increasing levels of capacity and revenue (Graham *et al,* 2003).

Punctuality and Reliability

Punctuality and reliability are addressed in the PDFH by adding a weighted value of "average lateness" to the in-vehicle time component of GJT. Average lateness is the mean magnitude of delay to a service. As an example, a delay of 10 minutes every 5 days would equate to an average lateness of 2 minutes (10/5 = 2). The evidence shows that each additional minute of average lateness is equivalent to several times that of an additional minute of scheduled journey time, which is reflected in the weighting factors. Therefore the negative impact on demand of 2 minutes average lateness would be equivalent to adding much more than 2 minutes to the scheduled journey time every day if the service were never delayed.

Rolling Stock Quality and Station Facilities

The PDFH also contains evidence on the "softer" quality attributes of both trains and stations, including cleanliness, comfort and information. The impacts of these attributes have been found to be very small relative those for journey time, frequency, interchange and crowding. Typically they are equivalent to a reduction in travel time of a few percentage points, with a similar level of impact on demand. However, some of these attributes may be relatively easy to improve, and may often be less costly than – for example – increasing average speeds to obtain faster journey times. High quality passenger information in particular has been shown to have a relatively significant impact on attractiveness of the service.

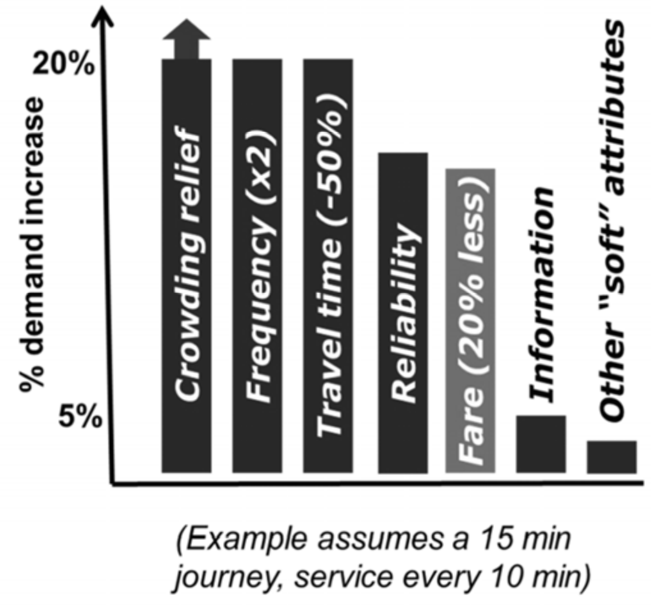
Understanding the Relative Impact of Convenience Attributes

Since the majority of convenience related attributes are converted into common units of time in the PDFH, it is possible to compare their impacts on a common basis, effectively providing an indication of their relative importance to customers.

Figure 2.9 provides an illustration of this, based on an example service operating every 10 minutes with and end-to-end travel time of 15 minutes, as in Table 2.8. The y-axis represents the expected percentage change in demand as a result of each of the individual service enhancements. Although based on sample PDFH evidence, this example is included for illustrative purposes only. Actual impacts will depend on the existing level of service, the changes being made and specific local circumstances. However, it is clear from the graph that a unified approach to valuing service attributes using common units can provide a powerful management tool for assessing the relative benefits of different enhancement options.

In the specific example given, a relatively high level of crowding (around 4 passengers per m^2) was assumed, leading to significant benefits from crowding reduction by means of extra capacity. Reliability improvements (assumed here as a 2 minute reduction in average delay) and price (20% reduction assumed), are shown to have a smaller impact on demand than the core attributes of capacity, frequency and journey time. Similarly, the figure shows that for a typical service, relative impacts of attributes such as information and other soft factors including comfort and cleanliness are relatively small. However, these can often be cost effective to address and may be easier to improve in the short term; they are still important for convenience.

Figure 2.9 **Example illustration of the relative impact of selected convenience attributes on demand**



Source: Imperial College London, based on UK rail industry experience/PDFH

Applicability of the PDFH Methodology to Other Public Transport Systems

The PDFH methodology and evidence has been developed specifically for the rail industry in Great Britain, with values calibrated to this sector based on substantial evidence. Rail users in Great Britain may not be typical of public transport users more broadly and there are also specific factors relating to the service and areas within which it operates. For this reason, we would not expect all PDFH evidence to be directly applicable elsewhere. However, we have demonstrated that in areas such as journey time, frequency and crowding, the evidence appears similar to our findings from research on metros (e.g. Graham *et al*, 2009).

However, the basic principle of valuing service attributes in common units of time, with specific weightings applied, should be broadly applicable. In fact this method is consistent with conventional transport planning theory and demand modelling. It should be feasible to determine equivalent valuation of individual service attributes for other public transport systems, although the research required should not be under estimated.

A potential issue in attempting to value convenience based on observed impacts on demand is that some users may be captive to public transport, with no choice about whether to use it, even if it is not convenient. This may be a greater issue where there are limited alternatives available (demand for rail in Great Britain is relatively elastic). In these circumstances, demand related impacts may be small and therefore difficult to measure. However, even where existing users are fully captive to public transport the evidence from those places where they do have a choice helps us understand what is important. In general, we could expect all public transport users to have a similar view of convenience, even if local conditions and the range of alternatives available mean that they have limited opportunity to change their travel behaviour in the short term.

Also, although public transport users may be captive to the mode in the short term, and may have little choice other than to use the service provided – even if not convenient –there is often a large turnover in passengers over time. Recent research in the UK (Mason, Segal and Condry, 2011) found a "churn rate" of close to 25% over two years in the commuter marker. I.e. over a two year period, one-quarter of rail commuters stopped using the service and were replaced by a similar number of new users. In the longer term, people make choices on work and home location, as well as car ownership, which impact on their use of public transport. Often these locational decisions are heavily influenced by the availability, and especially the convenience of transport. Since the availability and convenience of public transport can influence lifestyle decisions, it is clear that a more convenient service will tend to attract more passengers in the longer term. Increasing wealth in many countries, and greater competition in the transport market, means the ability of users to change travel patterns and modes is likely to increase in future. Customers may have little choice today, but if the service is not convenient they may cease to use it as soon as more attractive alternatives become available to them.

Another potential issue is that some convenience attributes may not have a significant impact on demand, but may still be important for other reasons. Certainly there may be some attributes that will make the service more attractive for passengers, but not influence their behaviour. However, if an attribute of the service has no effect on the decisions of even the most discretionary travellers, with little observable impact on demand, then it may be reasonable to conclude that this has no relevance to passengers. Understanding the relative impact of different measure will help those responsible for specification and provision to focus efforts on the aspects with greatest impact.

Conclusions

It is generally assumed that a convenient service is more desirable and will therefore lead to increased demand. This is supported by empirical research including evidence from the railway industry in Great Britain. Rising customer expectations and increasing competition make optimising convenience important to help ensure long term viability of public transport, through increases in demand, revenue, public support and acceptability. It is important to understand the relative impact of changes to the different attributes of convenience (what is more or less important) so that both transport operators and authorities can focus on defined areas within constrained resources.

However, what makes a service convenient is not always well understood, nor is there a universal definition of which attributes come under the definition of convenience. We define convenience as encompassing all attributes which influence the attractiveness of the service to customers; thus covering all elements of the conventional generalised cost equation, including access, egress, frequency and crowding, as well as "softer" factors such as comfort and information.

We argue that it is a pre-requisite that convenience must be measured before it can be valued and managed optimally. Using the case of the metro industry, we have shown that to date, public transport operators are is still, relatively too operationally focused in terms of the attributes of service which they are measuring and acting on. There are several reasons for this; firstly, historically metrics such as on-time performance at terminals have been easy to measure by operators and regulate by authorities: better technology was required to better measure the customer experience. Secondly, incentives within the industry have not been perfectly aligned towards the customer.

These constraints, however, are changing rapidly and operators in Europe in particular, and no doubt elsewhere in the world, are exhibiting innovative approaches to the measurement and valuation of convenience. The key catalysts have been: improved and better specified regulation and contracting regimes (such as in Paris and, earlier, for bus services in London), technology (particularly ticketing, signalling and remote monitoring systems) and the development of European standards such as EN13816. It is arguably important that financial incentives are present and strong enough to encourage operators and authorities to become more customer-focused, whether through either body taking revenue risk and/or or bonus/malus regimes for the operator.

It is important that strategic transport planning decisions concerning passengers' generalised cost are not simply left for the transport authority to decide; for example metros carrying revenue risk would benefit significantly from a better understanding of the impacts of frequency and capacity on demand. It is necessary for the design of performance measurement systems to consider the objectives, aims and desired outcomes and then develop a measurement system around that: to measure attributes that are important to (potential) customers. The operator must still have operational measures of performance (to see if the operator is delivering what it plans to); 'operational excellence' is still very much required. There can be unintended consequences of operators 'gaming' a contractual performance measurement system in order to maximise performance only in regulated or contractual areas, to the exclusion and detriment of unmeasured service quality attributes; it is our professional judgement such a situation is arising in some cities, particularly for newer metros.

We have shown that there are regional differences in the scope of convenience measurement between metro operators and that a more comprehensive and customer oriented approach tends to be present in Europe. However, such metros have had time to develop their management systems.

Crowding can be chronic in the metros of many large cities and research for the railway industry in Britain shows that this is a large component of the generalised cost of peak travel. The experience of metro operators suggests that this attribute is rarely well measured and specified by operators and authorities in terms of its demand and generalised cost impact. Measurement of train delay at terminals, without measuring its impact on passengers is common but not good practice, yet today's technology is available to measure and mange such an important element of service quality. For metros, data from ticketing systems should now permit a greater understanding of journey times from gate to gate (origin station to destination) yet such information is not currently well reported or used by metro operators (we do not know the extent of such analysis at an authority level, however). We conclude from our evidence from metros' measurement of convenience and service quality that operators worldwide could do much more to measure (and later value and act on) the variability and reliability of journey times, using new ticketing and gate data. This appears to be a significant opportunity for future analysis and research. The urban bus industry, however, is using GPS data and technology to better manage and measure wait times.

Newer Asian metros are expanding rapidly, therefore their focus is necessarily to stabilize operational performance; in future years we may see a more comprehensive attention and measurement of more customer-facing attributes. Sharing experience from more established metros in Europe (London, Paris) and elsewhere in Asia (e.g. Hong Kong) will be beneficial to both new metros and their authorities in ensuring that the economic potential of mass transit in large cities is optimised.

Even where the measurement of convenience is better, what is less common still is the valuation of the related service quality attributes. The experience of the UK railway industry's Passenger Demand Forecasting Handbook (PDFH) shows what can be achieved with sufficient data and analysis. Transport for London's relatively comprehensive 'Business Case Development Manual' is good practice worth emulating elsewhere, although extensive research on the demand response to the generalised cost components of trips is required.

The valuation of the individual components of convenience enables transport providers to focus improvements on the aspects which have the greatest impacts. Even well-defined service specifications and quality measurement processes can lead to the wrong areas being targeted from improvements if the real long term effects are not sufficiently understood.

Nonetheless, many metros are instinctively and increasingly customer facing in their management actions notwithstanding shortcomings in the measurement and valuations of passengers' convenience. For example there is a significant trend towards optimising available information where operators understand that that the service starts when the passenger plans to use the metro service. Finding ways to estimate the value of such attributes is not easy, yet their effect on demand has been shown to be significant. It could be argued that customer expectations of convenience and service quality are always changing and therefore operators and authorities need to be receptive to changing circumstances and available technologies in their measurement and valuation.

Acknowledgements

The authors wish to thank the CoMET and Nova metro benchmarking groups for participating in the data collection process and for agreeing to share knowledge for this discussion paper.

Annex A - List of CoMET and Nova metros that participate in the Benchmarking facilitated by Imperial College London

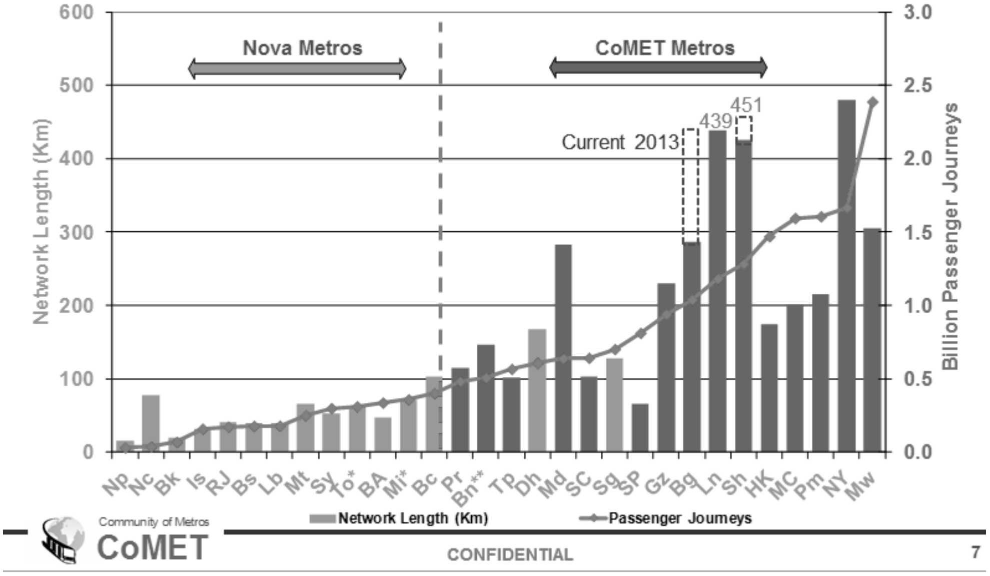
CoMET:

Bg – BMTROC, Beijing
Bn – BVG, Berlin
Gz – Guangzhou Metro Corporation
HK – MTRC, Hong Kong
Ln – LUL, London
MC – STC, Mexico City
Md – Metro de Madrid, Madrid
Mw – MoM, Moscow
NY – NYCT, New York
Pm – RATP Metro, Paris
Pr – RATP RER, Paris
SC – Metro de Santiago
Sh – SSMG, Shanghai
SP – MSP, São Paulo
Tp – Taipei TRTC

Nova:

BA – Buenos Aires Metrovías
Bc – Barcelona TMB
Bs – Brussels STIB
Bk – Bangkok BMCL
Dh – Delhi Metro Rail Corporation
Do – London DLR
Is – Istanbul Ulasim
KL – Kuala Lumpur RapidKL / Prasarana
Lb – Lisbon Metropolitano de Lisboa
Mt – Montréal STM
Nc – Newcastle Nexus
Nj – Nanjing Metro
Np – Naples Metronapoli
RJ – Metro Rio
Sg – Singapore SMRT
Sy – Sydney City Rail
To – Toronto TTC

Figure 2.10 **Network size and passenger journeys (2011)**



Source: CoMET, Community of Metros and Imperial College London.

Notes

1. It should be noted that “Service Beneficiaries” in the quality loop includes the community as well as customers – the ideal service needs to balance the needs of both, including in relation to aspects such as environmental impacts and cost.
2. Due to the confidentiality of PDFH, only approximate values have been used for this example. These are intended to represent a “typical” service; PDFH includes specific values for individual market segments.

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Chapter 3

Valuation of Urban Rail Service
Experiences from Tokyo, Japan

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Promoting public transportation, which includes rail, metro, bus rapid transit, and bus services is one of the most popular urban transportation policies among transportation authorities in many countries. This popularity may reflect the social requirement to pursue a sustainable transportation system by motivating people to use an environmentally friendly transportation mode. As most public transportation services are provided directly by public authorities or are financially supported by government/public-sector entities, an investment in public transportation is typically evaluated within a cost-benefit analysis framework. However, since public transportation service consists of many different components, including accessing public transit stops, waiting for the service, riding trains, transferring from one train to another, and exiting to a final destination, it is necessary to evaluate each component in detail. Thus, there is a strong need to develop a clear methodology by which to value the expected benefits stemming from a public transportation service change in monetary terms according to each service component.

This paper aims to describe the government's manual and report the recent practices of valuing urban rail transportation services in Japan.

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Introduction

This is also the case for Japan's urban rail service. Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) introduced the Cost-Benefit Analysis (CBA) Manual for rail projects in 1998 to provide a standard methodology for valuing rail service in Japan. This methodology has been applied to a number of rail projects in Japan that were subsidized by the central government. The Manual contains detailed methods for valuing the improvement of rail transportation services by the components of service as well as by their multipliers and parameters. Some parts of the CBA Manual may be highly dependent on the uniqueness of the Japanese urban rail market; however, it may be worthwhile for Japan to share its experiences with other OECD member countries. Additionally, although a number of studies have examined valuations of travel time for road traffic in Japan (for example, Kato *et al*., 2010b; 2011), valuations for public transit services have been rarely reported (an exception is Kato, 2007).

This paper aims to describe the government's manual and report the recent practices of valuing urban rail transportation services in Japan. The remainder of this paper is organized as follows. First, the CBA Manual for rail projects in Japan will be introduced. The detailed methods for valuing rail transportation services are described. Next, the latest master plan for urban rail development in the Tokyo metropolitan area is presented, including the policy targets set in the plan. The characteristics of the urban rail market in Japan are also discussed. Then, the rail service values are computed with the travel demand model used in the master plan are presented. Finally, further issues are discussed with a summary of the paper.

The government's cost-benefit analysis manual for rail projects in Japan

Cost-benefit analysis manuals in Japan

The Government of Japan officially introduced the CBA to the evaluation of public-funded projects in 1998. The introduction of formal CBA Manuals reflected a political statement made by then-prime minister Ryuichiro Hashimoto, who requested the improvement of the effectiveness of public investment. (Note that various approaches, such as regional econometric models, hedonic models, and general equilibrium models, were informally used in an ad-hoc manner for project evaluation even before the official introduction of CBA in Japan.)

In Japan, various CBA Manuals have been made for different types of public infrastructure projects such as airports, railways, roads, seaports, agriculture, urban development, natural parks, rivers, and coastal projects. These CBA Manuals are developed independently by different bureaus under Japan's MLIT. Although the MLIT provides general guidelines (MLIT, 2009) that cover all transportation-related projects under them, the details of CBA Manuals vary among project types. Table 3.1 shows the latest CBA Manuals for transportation investment in Japan. The first CBA Manual for rail projects was published in 1998 (MLIT, 1998) by the Railway Bureau under the MLIT. It was established with support from advisory committees including experts in economics and transportation research. It has been revised three times: in 2000, 2005, and 2012 (MLIT, 2000; 2005; 2012). These revisions addressed additional policy requirements such as sophisticated methods of re-evaluation and post-evaluation, new evaluation methods for anti-disaster projects, the consideration of additional benefits from environmental impacts, and the introduction of updated techniques for benefit estimation. Although the CBA Manuals are available publicly online, they are exclusively in Japanese.

Table 3.1 **Latest CBA manuals of transportation investment in Japan**

Type of project	Title	Latest updated
Airport	Cost-effectiveness Analysis Manual of Airport Development Projects Version 4	March 2008
Rail	Cost-effective Analysis Manual of Rail Projects 2012	July 2012
Road	Cost-benefit Analysis Manual	November 2010
Seaport	Cost-effectiveness Analysis Manual of Port Development Projects	June 2011

Source: Author

CBA manual for rail projects

The CBA Manual for rail projects provides methods and examples of rail project evaluation. It covers not only urban rail service, but also inter-urban and rural rail services. The projects included in the Manual consist of new construction of rail lines, the improvement of existing rail lines, the improvement of rail stations, the installation of barrier-free rail service facilities, and anti-disaster rail investment, all of which are financed in full or in part by the national government. The Manual contains three types of project evaluations: pre-evaluation, re-evaluation, and post-evaluation. Pre-evaluation is implemented to analyse the feasibility of a new project; re-evaluation is implemented to examine the feasibility of the continuation of on-going projects of five years or more; post-evaluation is implemented to study the impacts of completed projects five years after project completion.

Conventional cost-benefit analysis theory (Small and Verhoef, 2007) is applied in the CBA Manual, where three indexes are produced from the economic analysis: the net present value, cost-benefit ratio, and economic internal rate of return. Periods of project evaluation are construction years plus 30 and 50 years. The social discount rate is four percent, which is assumed to be constant throughout the project period. Sensitivity analysis is required with respect to total travel demand, total project cost, and construction years. The benefit and cost stemming from a transportation project are computed assuming two scenarios: a without-project scenario and a with-project scenario. The benefit is classified into user's benefit, supplier's benefit, and other benefit. The user's benefit is estimated with the consumer surplus approach based on travel demand analysis. The supplier's benefit is computed with the net profit of rail operators. Other benefit includes environmental (dis)benefits such as the reduction of the emission of carbon dioxide from automobiles, changes in noise damage emitted from the rail service, and the existence benefit.

Although the CBA Manual does not explicitly provide a methodology for forecasting travel demand, it expects travel demand to be analysed with a discrete-choice modelling approach (for example, Ben-

Akiva and Lerman, 1985) for rail route choice analysis, particularly for urban rail projects. Note that for three major metropolitan areas in Japan, Tokyo, Osaka, and Nagoya, revealed preference (RP) about rail route choice data for rail users is available. The MLIT has implemented the Metropolitan Transport Census every five years since 1960, in which large-scale paper-based questionnaire surveys are administered with support from local public transportation operators, including rail companies and bus operators (ITPS, 2008). Respondents are requested to describe their daily travel using the public transportation service such as origin, destination, mode of travel to rail stations, chosen rail routes, departure time, and ticket type. Rail route demand analysis in the Tokyo metropolitan area typically uses multinomial logit or probit models with data from the Metropolitan Transport Census. The CBA Manual then uses the expected consumer surplus to estimate the user's benefit when the discrete-choice approach is used for route demand modelling.

Estimation of user's benefit in rail projects

The CBA Manual shows the method for estimating the user's benefit based on the concept of generalized cost. It assumes the origin-destination (OD)-based generalized cost. The benefit is computed using the "rule-of-half" formula, which is shown as

$$UB = \sum_{ij} \frac{1}{2}\left(GC_{ij}^{o} - GC_{ij}^{w}\right)\left(X_{ij}^{o} + X_{ij}^{w}\right) \tag{1}$$

where UB is the user's benefit, GC_{ij}^{o} is the generalized cost from zone i to zone j in the without-project scenario, GC_{ij}^{w} is the generalized cost from zone i to zone j in the with-project scenario, X_{ij}^{o} is the travel demand from zone i to zone j in the without-project scenario, and X_{ij}^{w} is the travel demand from zone i to zone j in the with-project scenario.

Definitions of Generalized Cost

The CBA Manual presents two approaches to define the generalized cost. The first approach uses a log-sum index, while the second approach does not. The log-sum index is the expected maximum utility or expected indirect utility computed from the multinomial logit (MNL) model (Williams, 1977).

Log-sum approach

This approach assumes that the MNL model is used for travel demand analysis in the context of travel modal choice or rail route choice. The generalized cost is computed with a utility function in the MNL as

$$GC_{ij} = \frac{1}{\partial V_{k,ij} / \partial F_{k,ij}} \ln \sum_{k} V_{k,ij} \tag{2}$$

where

$V_{k,ij}$ is the (indirect) utility function under the condition that an option (travel mode or rail route) k is chosen for travel from zone i to zone j and

$F_{k,ij}$ is the travel cost or fare in the utility function under the condition that an option (travel mode or rail route) k is chosen for travel from zone i to zone j.

As the utility function is typically assumed to be linear with a generic coefficient with respect to travel cost, the marginal utility with respect to income is constant. Thus, the following formula of the generalized cost is presented in the Manual:

$$GC_{ij} = \frac{1}{\hat{\theta}} \ln \sum_{k} V_{k,ij} \tag{3}$$

where $\hat{\theta}$ is the estimated coefficient with respect to travel cost in the utility function.

When the discrete-choice modelling approach is used, public transportation service values such as the value of travel time, value of service frequency, and value of crowding can be estimated with the empirical data in the travel demand analysis. However, they are not used to estimate the total user's benefit because they are implicitly incorporated into the utility function. Rather, they are often used to compute the shares of different benefit components of the total user's benefit.

Non-log-sum approach

This approach first assumes a route-based generalized cost. The Manual shows that the formula of the generalized cost of a rail route is as follows:

$$GC_{k,ij} = F_{k,ij} + \sum_{a} \left(\omega_a \cdot \sum_{pq} \delta_{k,ij,pq} \cdot T_{a,k,ij,pq} \right) + \sum_{b} \left(\omega_b \cdot \sum_{pq} \delta_{k,ij,pq} \cdot comf_{b,k,ij,pq} \right) \tag{4}$$

where

$GC_{k,ij}$ is a generalized cost of rail route k from zone i to zone j;

$T_{a,k,ij,pq}$ is the travel time of link type a in a link from p to q of rail route k from zone i to zone j;

$comf_{a,k,ij,pq}$ is a comfort level of link type b in the link from p to q of rail route k from zone i to zone j;

$\delta_{k,ij,pq}$ is equal to 1 if the link from p to q is included in the rail route k from zone i to zone j and 0 otherwise;

ω_a is a value of travel time of link type a; and

ω_b is a value of comfort level of link type b.

The Manual cites in-vehicle travel, rail station access, rail station egress, and transfers at stations as examples of type-a links, whereas it cites in-vehicle comfort, convenience of transfer at stations, and service frequency as examples of type-b links.

Finally, the OD-based generalized cost is computed using the route-based generalized cost. The Manual proposes a weighted average method to estimate the OD-based generalized cost with the route shares of travel demand and the route-based generalized costs, although this method is not theoretically supported (Kidokoro, 2004; Kato *et al.*, 2003a).

Methods of valuing rail service components

The Manual also presents methods for valuing each rail service component. These are primarily aimed at estimating the generalized cost in the non-log-sum approach, but are also used to compute the shares of different benefit components out of the total user's benefit even when the log-sum approach is applied.

In-vehicle travel time

User's welfare with respect to in-vehicle travel time is computed with a value of in-vehicle travel time as

$$\omega_{in-vehicle} \cdot \sum_{pq} \delta_{k,ij,pq} \cdot T_{in-vehicle,k,ij,pq} \tag{5}$$

where

$\omega_{in-vehicle}$ is the value of in-vehicle travel time;

$\delta_{k,ij,pq}$ is equal to 1 if a link from p to q is included in the rail route k from zone i to zone j and 0 otherwise; and

$T_{in-vehicle,k,ij,pq}$ is the in-vehicle travel time of the link from p to q in rail route k from zone i to zone j.

The Manual recommends that the value of travel time be estimated empirically with travel data because it may vary among regions and individuals' attributes. However, if the data is not available to estimate the value of travel time, the Manual requests that the analysts show the reason for it, and it allows them to use a standard value. The Manual presents the standard values in 2010, which are estimated with the government's statistics for the entire nation of Japan, Tokyo, and Osaka, as shown in Table 3.2.

Table 3.2 **Standard values of time in 2010 estimated from monthly work statistics survey**

	Japan	Tokyo	Osaka
Value of time (JPY/min)	36.2	47.0	39.2

Source: 2010 Annual Report of Monthly Work Statistics Survey: Local Survey, Ministry of Health, Labour and Welfare, Japan.

Note 1: Values of time are computed by dividing the monthly average cash income of permanent workers working at workplaces with over four workers by the monthly average work hours of permanent workers.

Note 2: Table 3.2 shows the value of time in 2010. The latest statistics should be used when the data is available in the same manner as that shown in Note 1.

The Manual notes that the time values of children and elderly people who do not work should be equal to the standard value because another family member may have the willingness to pay to save travel time as an opportunity cost assuming the case where no rail service is available.

Rail station transfers

The Manual identifies two approaches to valuing the convenience of rail station transfers: a multiplier approach and a constant-parameter approach.

First, the multiplier approach assumes the following formula:

$$\alpha_{transfer} \cdot \omega_{in-vehicle} \cdot \sum_{pq} \delta_{k,ij,pq} \cdot T_{transfer,k,ij,pq} \tag{6}$$

where

$\alpha_{transfer}$ is a multiplier with respect to transfer time (= 2);

$\omega_{in-vehicle}$ is the value of in-vehicle travel time;

$\delta_{k,ij,pq}$ is equal to 1 if the link from p to q is included in the rail route k from zone i to zone j and 0 otherwise; and

$T_{transfer,k,ij,pq}$ is the transfer travel time of the link from p to q of rail route k from zone i to zone j.

This multiplier refers to past studies of rail route choice in Tokyo such as Yai *et al*. (1998). It should be noted that the above multiplier is higher with respect to transfer time (=2) than the multipliers with respect to transfer time by transfer type (= 0.89 to 1.65), which will be shown later in Table 3.4. This is probably because the above multiplier includes the psychological effect of transferring. It means that the above multiplier contains both the variable component that is in proportion to transfer minutes and the fixed component.

On the other hand, the constant-parameter approach assumes the following formula:

$$\omega_{in-vehicle} \left(10 \cdot \lambda_{transfer,k,ij} \right) \tag{7}$$

where

$\omega_{in-vehicle}$ is the value of in-vehicle travel time; and

$\lambda_{transfer,c,k,ij}$ is the number or frequency of transfers of rail route k from zone i to zone j.

This means that the constant-parameter approach assumes that the value of a unit transfer equals the value of 10-minute in-vehicle travel time.

In-vehicle crowding

The (dis)comfort of in-vehicle crowding is computed with the following formula:

$$\omega_{in-vehicle}\sum_{pq}\delta_{k,ij,pq}\cdot T_{in-vehicle,k,ij,pq}\cdot f\left(x_{pq},cap_{pq}\right) \tag{8}$$

where

$\omega_{in-vehicle}$ is the value of in-vehicle travel time;

$\delta_{k,ij,pq}$ is equal to 1 if the link from p to q is included in the rail route k from zone i to zone j and 0 otherwise;

$T_{in-vehicle,k,ij,pq}$ is the in-vehicle travel time of the link from p to q in rail route k from zone i to zone j;

$f(\cdot)$ is an in-vehicle congestion function;

x_{pq} is the traffic flow in the link from p to q; and

cap_{pq} is the traffic capacity in the link from p to q.

The Manual shows the in-vehicle congestion function as presented in Table 3.3.

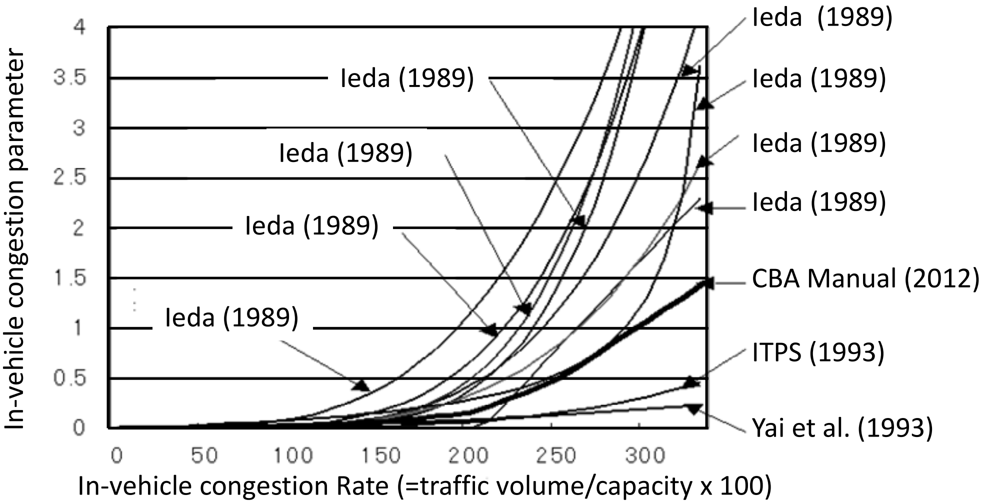
Table 3.3 **In-vehicle congestion functions proposed by the CBA manual**

In-vehicle congestion rate	In-vehicle congestion function
Less than 100 percent	$f = 0.0270R$
100 to 150 percent	$f = 0.0828R - 0.0558$
150 to 200 percent	$f = 0.179R - 0.200$
200 to 250 percent	$f = 0.690R - 1.22$
250 percent or more	$f = 1.15R - 2.37$

Note: R is the in-vehicle congestion rate, which is defined as the traffic flow over the traffic capacity, that is, $R_{pq} = x_{pq}/cap_{pq}$.

Figure 3.1 depicts the curves of the in-vehicle congestion functions, including the function shown in Table 3.3 and other estimates in Japan.

Figure 3.1 **In-vehicle congestion functions**



Source: Slightly changed from MLIT (2012)

It should be noted that the in-vehicle congestion function is not equal to the multiplier with respect to in-vehicle congestion and in-vehicle travel time. The multiplier with respect to in-vehicle congestion is given as

$$\alpha_{cong} = 1 + f\left(x_{pq}, cap_{pq}\right) \tag{9}$$

The traffic capacity of rail service is typically defined in terms of hourly capacity. It is estimated using the passenger capacity of cars, the number of cars per rolling stock, and hourly service frequency. The passenger capacity of cars is defined by the Japanese Industrial Standards (JIS). Rolling Stock−General Requirements of Car Bodies for Passenger Cars (JIS E 7103, 2006) defines the passenger capacity as follows:

a) Passenger capacity: the passenger capacity is the sum total of seat capacity and standing capacity.

1) *Seat capacity: seat capacity is calculated by dividing the total width of all seats in a car body by the width of a seat occupied by a unit passenger, and it is rounded down to the nearest decimal. When there is no specific agreement about the seat capacity between the rolling-stock producer and the client, the width of the seat capacity occupied by a unit passenger is given to be 430 mm.*

2) *Standing capacity: standing capacity is calculated by dividing the available floor space by the space occupied by a unit passenger, and is rounded down to the nearest decimal. The available floor space is calculated by eliminating the seat area and the floor space within 250 mm of the front edge of seats from the total passenger space that has an effective width of 550 mm or more and an effective height of 1,900 mm or more. When there is no agreement about the standing capacity between the rolling-stock producer and the client, the space occupied by a unit passenger is given to be 0.3 m^2.*

Complementary method of valuing transfer improvement in rail stations

The Manual also presents complementary guidance for evaluating rail projects to improve transfers. This is because the government has recently called attention to rail station improvement projects in its goal of developing a seamless rail network. The Manual includes projects in rail stations for decreasing transfer time, lowering transfer barriers, reducing in-station congestion, and decreasing waiting time.

Multipliers of transfer time by transfer type

The Manual recommends that transportation planners primarily use travel demand models to value station transfers. The coefficients estimated in the travel demand model can be used to value transfers by transfer type when the travel demand model contains the variables with respect to the service level of going upstairs, going downstairs, using escalators, etc. The Manual presents a method to value transfers in stations by transfer type when such travel demand models are not available.

The following formula is presented for valuing transfers in stations:

$$\alpha_r \cdot \omega_{in-vehicle} \cdot T_{transfer,r} \tag{10}$$

where

α_r is a multiplier with respect to transfer type r ;

$\omega_{in-vehicle}$ is the value of in-vehicle travel time; and

$T_{transfer,r}$ is the travel time of transfer type r .

The transfer types are walking upstairs, walking downstairs, walking on a flat floor, and using escalators. The Manual shows the multipliers as presented in Table 3.4.

Table 3.4 **Multipliers with respect to transfer time by transfer type**

Transfer type	Walking upstairs	Walking downstairs	Walking on a flat floor	Using escalator
Multiplier	1.65	1.53	1.25	0.89

Source: Institution of Transport Policy Studies (2000)

Note that Kato *et al.* (2003b) also report the estimation processes and results of valuing transfer time by transfer type, which is the original source of Institution of Transport Policy Studies (2000).

Multiplier of waiting time in stations

The Manual identifies two types of waiting times in stations: waiting time in front of stairs for passengers and waiting time at station gates for passengers who want to pass through the gates. It is assumed that benefits in this area stem from expanding the width of existing stairs in stations and installing new station gates.

The generalized cost of waiting time is formulated as follows:

$$\alpha_{wait} \cdot \omega_{in-vehicle} \cdot T_{wait} \tag{11}$$

where

α_{wait} is a multiplier with respect to waiting time (=1);

$\omega_{in-vehicle}$ is the value of in-vehicle travel time; and

T_{wait} is waiting time.

The Manual also suggests that the space occupied by a unit passenger is given to be 0.5 m^2; above this threshold, waiting queues occur.

Method of valuing the reliability of rail service

Although the Manual does not provide any official method of valuing the reliability of rail service, it includes an example of an estimation of the benefit stemming from the improvement of service reliability. According to this example, the multiplier with respect to delay is assumed to be 1. This means that the formula for valuing the reliability of rail service is

$$\alpha_{delay} \cdot \omega_{in-vehicle} \cdot T_{delay} \tag{12}$$

where

α_{delay} is a multiplier with respect to delay time (=1);

$\omega_{in-vehicle}$ is the value of in-vehicle travel time; and

T_{wait} is the time delayed from the given schedule.

Example of valuing urban rail service: 2000 urban rail development master plan in Tokyo

The urban rail market in japan: the case of Tokyo

Tokyo is one of the most populated cities in the world, with approximately 36 million people in its metropolitan area as of 2005. Tokyo is also well known to be a rail-oriented city: daily rail use demand was 26.22 million passengers in 2005. Rail's modal share was 30 percent as of 2008 according to the 2008 Person Trip Survey, an increase from 25 percent in 2003. One of the reasons for the recent increase in rail demand is the development of an urban rail network. Recent changes in the population distribution pattern and sharp increase of gas prices may also influence individuals' modal choice. In any case, the economy of Tokyo is highly reliant on an efficient urban rail network.

Tokyo's urban rail market has unique characteristics. First, many rail services are provided by private rail companies. Each rail company has its own rail infrastructure and rolling stock with its own management system. They are, in essence, monopolistic firms in their own network. Note that one rail company's network may be physically connected directly with another rail company's network, but the service in a rail network is usually operated by the company that owns the rail network. Although they provide rail service monopolistically in their networks, these companies sometimes compete with other rail operators that may also have a rail network connecting the same pair of cities. For instance, Tokyo and Yokohama are connected by three rail lines operated by three different rail companies: JR East, Tokyu Co., and Keikyu Co. Competition between these firms is fierce, and as each rail operator has its own fare table and timetable in addition to its own infrastructure, they attempt to improve their service by improving fares, travel time, and station facilities to obtain more passengers.

Second, the rail network in Tokyo has been developed under the guidance of the central government. Long-term urban rail development plans, so-called "master plans," are made by the central government and have an important role in the decision-making of rail companies. Tokyo's urban rail master plan began in the early twentieth century, and is now over 100 years old (Morichi, 2000). At least ten master plans have been proposed by the government's committee under commissions by the Minister of MLIT. The latest master plan was issued in 2000 in Report No. 18 of the Council for Transport Policy (Morichi *et al*., 2001). It should be noted that the master plans do not have any statutory basis; a master plan lays out the government's vision regarding the future of the urban rail network in Tokyo, and the government cannot force rail operators to follow it. However, in the long history of the urban rail market in Japan, most rail developments have been implemented voluntarily following the master plans.

Third, Tokyo's rail users have suffered from chronic traffic congestion for many years (Kato *et al*., 2012). The urban rail demand for commuting increased sharply from the 1960s to the 1980s. This was caused by the constant growth of the working population, which was mainly due to migration from rural areas for job opportunities. Although rail operators tried to increase traffic capacity by investing in new rail lines, increasing service frequency, enhancing station capacity, and introducing high-capacity rolling stock, the speed of demand growth was much higher than that of supply increase. This motivated the government to spotlight a transport policy to reduce traffic congestion, and it also encouraged the evaluation of in-vehicle crowding since the 1980s in Japan.

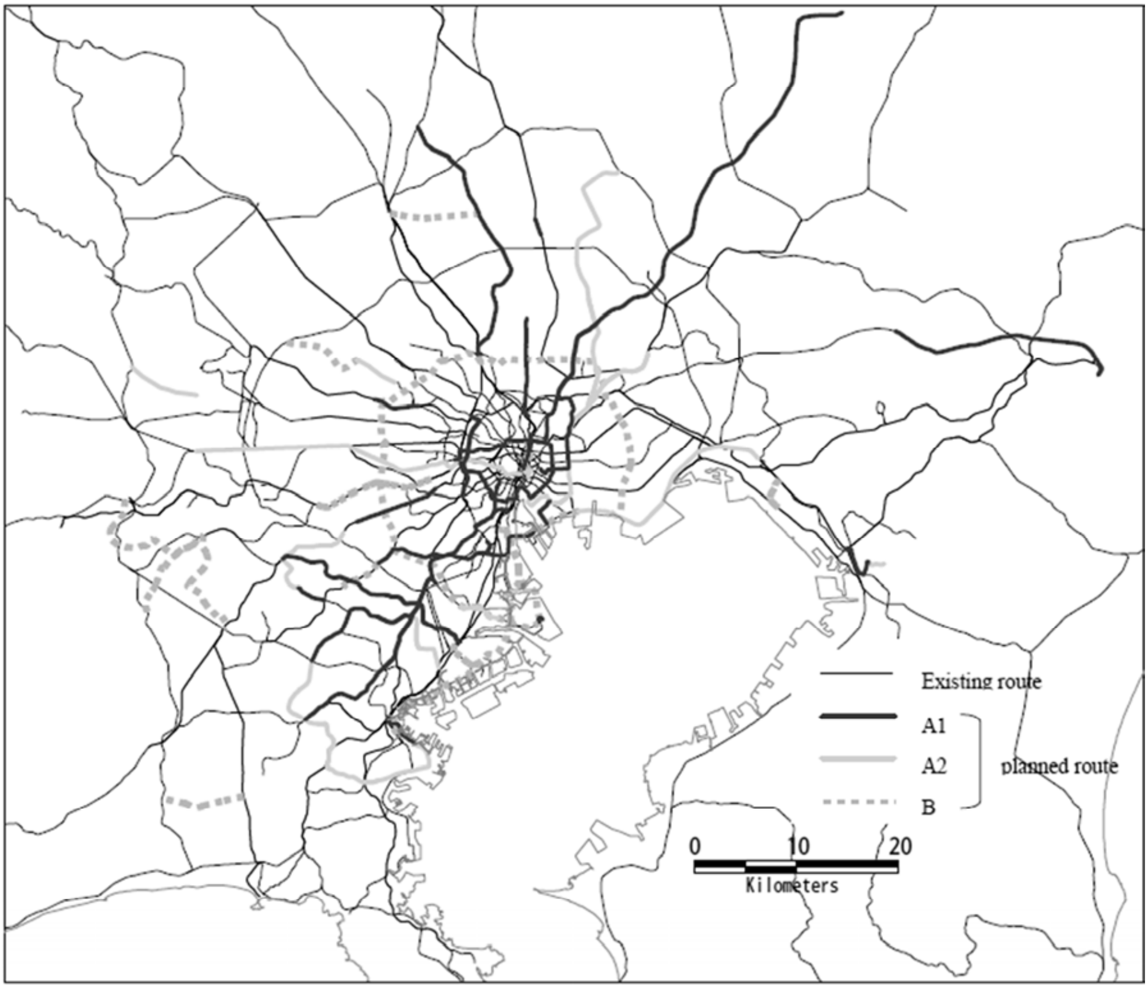
Fourth, a recent demographic trend should be also highlighted in Tokyo: rapid aging. The senior population—those ages 65 and over—comprised eight percent of the Tokyo metropolitan area's population in 1985; in 2005, it was 18 percent, and it is expected to reach 24 percent by 2015. The population of workers is also expected to decrease in the future. This aging issue may be faced by other OECD countries in the near future; thus, the experiences in Tokyo could be very useful for transportation policy there.

2000 urban rail development master plan for Tokyo

MLIT finalized the 2000 Urban Rail Development Master Plan in January 2000 (Morichi, 2000). This plan presents an ideal picture of the Tokyo Metropolitan Area's urban rail network in 2015 with the necessary rail developments. It identified five major targets to solve the expected problems in Tokyo's urban rail market: "Reduction of in-vehicle crowding," "Saving travel time," "Contribution to urban redevelopment," "Improvement of accessibility to airports and high-speed rail," and "Development of seamless transport network by introducing barrier-free facilities.” The first target is a congestion-related policy issue in Tokyo, and has not been solved yet. The government stated that the congestion rate in 31 major rail links should be equal to or lower than 150 percent during morning peak hours. Note the government has regularly monitored in-vehicle traffic congestion in major rail lines in Tokyo. The second target is related to the Tokyo metropolitan area’s decentralized land-use policy, in which satellite sub-centres have been developed for business. Saving travel time for rail connections between sub-centres was pursued in addition to saving travel time for commuting from residential areas to business districts. The third target aims to increase rail capacity, particularly in the central business district (CBD) of Tokyo. Since the 1990s, a number of high-rise buildings have been built both for business use and for residential use in the CBD. This is because seaside areas near Tokyo Bay have been redeveloped for business and residential use and because the younger generation has gradually changed its preference for living space from suburban residential areas to the central area. These land-use pattern changes are expected to generate a large traffic volume. The fourth target follows the globalization of business and tourism markets. The government has also implemented a globalization policy that includes the deregulation of the air transportation market and the promotion of tourism in Japan. The improvement of rail access to and from airports and high-speed rail are critical for better business and tourism conditions. Finally, the fifth target reflects the rapid aging of Japanese society. Social participation by seniors is widely understood to have a vitalizing effect on economic activities under the depopulation trend, and easy access to social services could be one of drivers to give them better mobility in urban areas. Thus, the introduction of new devices and upgrades to station facilities for handicapped passengers was highly recommended.

The 2000 Urban Rail Development Master Plan also presented a list of rail development projects that were recommended to implement construction or to study feasibility. The recommended network is depicted in a map shown in Figure 3.2 The proposed projects are categorized into three types: A1 routes that are suitable for operation by the target year; A2 routes that are suitable for starting development by the target year; and B routes that must be developed or studied in the future. Rail projects in A1 routes are considered the highest priority, which may mean that they are strongly supported by the government. In A1 projects, a consensus among stakeholders has been reached or almost reached; thus, these projects can be started immediately following the completion of the official process. Rail projects in A2 routes are regarded to be middle priority, which means that they are supported by the government but may have some reasons for not being immediately started, such as technical problems in construction or contract problems between different companies. B projects are typically considered important from the viewpoint of government targets, but they may not satisfy necessary conditions such as cost-benefit criteria or financial viability criteria. Thus, further feasibility studies are required. The total length of the proposed projects is 658 km. The length of the A1, A2, and B routes are 288.0 km, 166.8 km, and 203.3 km, respectively.

Figure 3.2 **Urban railway network master plan in the Tokyo metropolitan area.**



Source: Morichi *et al.* (2001)

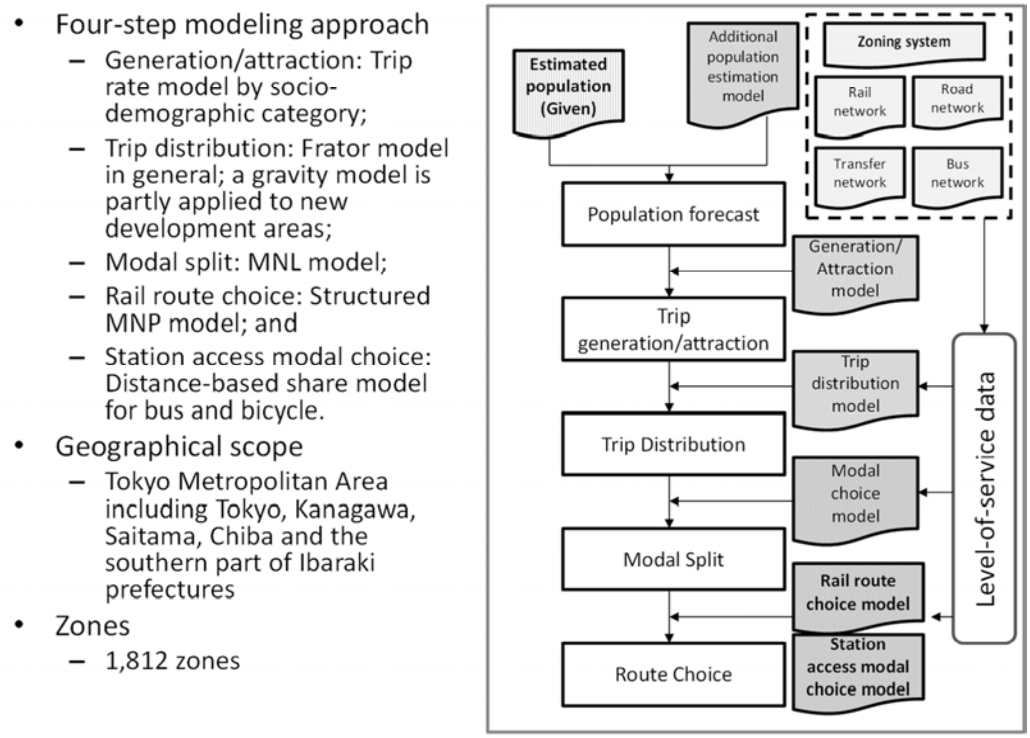
Rail demand analysis and project evaluation in the 2000 urban rail development master plan for Tokyo

The 2000 Urban Rail Development Master Plan for Tokyo was based on the typical transportation planning process. Future traffic demands of proposed rail lines and the related network were estimated with a traffic demand model, whereas the proposed projects were evaluated both from economic and financial perspectives.

Rail demand modelling and traffic demand forecasts have been included in the master plans for over 30 years. A mathematical travel demand analysis was first introduced into urban rail planning in Tokyo in 1972. In 1985, a four-step travel demand model was introduced into rail demand analysis. Multinomial logit (MNL) models were used for the modal choice and rail route choice models.

In the 2000 Urban Rail Development Master Plan for Tokyo, the four-step travel demand model was again used for travel demand forecasts (Figure 3.3). The MNL model was used for the modal choice analysis, while a probit-based stochastic user equilibrium (SUE) method was used for the route choice analysis. The probit model is used because it is necessary to incorporate the commonality of routes into the rail route choice analysis. A huge urban rail network with high density has already been developed in the Tokyo metropolitan area. Thus, to avoid an enormous amount of calculation time, the probit model with a structured error component was introduced (Yai *et al.*, 1997). We call this model the "structured probit model." The coefficients are estimated by the simulation method using the Geweke, Hajivassiliou, and Keane (GHK) recursive simulator (Geweke *et al*., 1994; Train, 2003). The details of the urban rail route choice model in the context of Tokyo have been also studied by Kato *et al*. (2010a).

Figure 3.3 **Travel demand analysis system in the 2000 urban rail development master plan for Tokyo**



- Four-step modeling approach
  - Generation/attraction: Trip rate model by socio-demographic category;
  - Trip distribution: Frator model in general; a gravity model is partly applied to new development areas;
  - Modal split: MNL model;
  - Rail route choice: Structured MNP model; and
  - Station access modal choice: Distance-based share model for bus and bicycle.
- Geographical scope
  - Tokyo Metropolitan Area including Tokyo, Kanagawa, Saitama, Chiba and the southern part of Ibaraki prefectures
- Zones
  - 1,812 zones

Source: Authors

The conventional cost-benefit analysis approach has been used for rail project evaluation. The 2000 Urban Rail Master Plan for Tokyo introduced a systematic cost-benefit analysis for all proposed rail projects. The with-project and without-project cases are defined, and the benefit and cost from the project will be estimated using the estimated traffic demand from the traffic demand forecast. The with-project case assumes the rail network and service under the condition that a new rail service has been introduced in the target year, while the without-project case assumes the current rail network and service in the target year. The benefit consists of the user's benefit, supplier's benefit, and other benefit. The user's benefit is estimated from the expected maximum utility divided by the marginal utility with respect to income, which is equal to the (expected) consumer's surplus. The expected maximum utility is derived from the (indirect) utility function in the rail route choice model, which is estimated in the traffic demand analysis. The supplier's benefit is also estimated with the expected profits of rail users using the estimated results of rail traffic demand. The other benefit is mainly the reduction of environmental impact. The details of the cost-benefit analysis follow the CBA Manual.

Values of rail service estimated in the 2000 urban rail development master plan for Tokyo

Examples of valuing rail service can be provided from the estimation results of the rail route choice model in the 2000 Urban Rail Master Plan for Tokyo. Four rail route choice models were estimated by travel purpose—home-to-work, home-to-school, private, and business—using a sample dataset constructed from the 1995 Tokyo Metropolitan Transport Census (ITPS, 1996). The following variables are used in the linear utility functions: in-vehicle travel time, access and egress travel time, access travel time (only for home-to-school travel), egress travel time (only for home-to-school travel), transfer time (including waiting time), travel cost, and in-vehicle congestion index (only for home-to-work and home-to-school travel). Transfer time means the connection time from one train to another train, which mainly includes walking from one platform to another platform in the same station. The in-vehicle congestion index is defined as follows:

$$CI_{k,ij} = \sum_{pq} \delta_{k,ij,pq} \cdot T_{in-vehicle,k,ij,pq} \cdot \left(\frac{x_{pq}}{cap_{pq}} \right)^2 \tag{13}$$

where

$CI_{k,ij}$ is the in-vehicle congestion index of a rail route k from zone i to zone j;

$\delta_{k,ij,pq}$ is equal to 1 if the link from p to q is included in the rail route k from zone i to zone j and 0 otherwise;

$T_{in-vehicle,k,ij,pq}$ is the in-vehicle travel time of the link from p to q in rail route k from zone i to zone j;

x_{pq} is the traffic flow in the link from p to q; and

cap_{pq} is the traffic capacity in the link from p to q.

This means that the in-vehicle congestion function is assumed to be a quadratic function of the in-vehicle congestion rate. The estimated coefficients of the rail route choice model are shown in Table 3.5.

Table 3.5 **Estimation results of the rail route choice model**

	Home-to-work	Home-to-school	Private	Business
In-vehicle travel time (min.)	-0.0943 (-8.1)	-0.0597 (-5.8)	-0.0494 (-2.9)	-0.0499 (-3.3)
Access and egress travel time (min.)	-0.127 (-11.7)		-0.0583 (-4.3)	-0.0599 (-5.8)
Access travel time (min.)		-0.0691 (-6.2)		
Egress travel time (min.)		-0.0603 (-5.7)		
Transfer time including waiting time (min.)	-0.112 (-10.7)	-0.0793 (-8.7)	-0.0722 (-4.2)	-0.0687 (-4.5)
Travel cost (JPY)	-0.00200 (-4.0)	-0.00388 (-7.1)	-0.00233 (-3.0)	-0.00103 (-1.6)
In-vehicle congestion index	-0.00869 (-3.3)	-0.00177 (-0.8)		
Ratio of two variances	0.436 (2.7)	0.161 (1.4)	0.513 (1.2)	0.214 (1.1)
Log-likelihood ratio	0.390	0.331	0.172	0.156
Number of observations	1218	811	436	357

Source: Morichi *et al.* (2001)

Note: Values in parentheses are *t*-statistics.

The estimated values and multipliers of in-vehicle travel time, access/egress travel time, access travel time, egress travel time, and transfer time (including waiting time) are presented in Tables 3.6 and 3.7. Table 3.6 includes the results using both JPY and USD. The currency exchange rate as of November 1995 is used because the original data in the 1995 Metropolitan Transport Census was collected in late autumn.

Table 3.6 **Rail service values estimated with the rail route choice model**

	Home-to-work	Home-to-school	Private	Business
In-vehicle travel time	47.2 (0.46)	15.4 (0.15)	21.2 (0.21)	48.4 (0.48)
Access and egress travel	63.5 (0.62)		25.0 (0.25)	58.2 (0.57)
Access travel time		17.8 (0.17)		
Egress travel time		15.5 (0.15)		
Transfer time (including waiting time)	56.0 (0.55)	20.4 (0.20)	31.0 (0.30)	66.7 (0.65)

Note: Units are JPY per min. (USD per min.) as of November 1995 when 1 USD = 101.86 JPY.

Table 3.7 **Multipliers estimated with the rail route choice model**

	Home-to-work	Home-to-school	Private	Business
Access and egress travel time	1.35		1.18	1.20
Access travel time		1.16		
Egress travel time		1.01		
Transfer time (including waiting time)	1.19	1.33	1.46	1.38

Table 3.7 shows that the estimated multipliers of the value of in-vehicle travel time with respect to access/egress travel time vary from 1.01 to 1.35, whereas those with respect to transfer time vary from 1.19 to 1.46. Compared with the data shown in the CBA Manual, the estimated multipliers are in the range of the multipliers with respect to transfer time by transfer type shown in Table 3.4. Note that the estimated multipliers with respect to transfer time in Table 3.7 contain both transfer time and waiting time.

Next, an in-vehicle congestion multiplier is computed with the estimated coefficients in the rail route choice models. A single link is assumed for the computation, although the in-vehicle congestion index is, in general, defined as the sum of the link-based in-vehicle congestion disutility of all links in a given route. This means the in-vehicle congestion multiplier is shown as

$$\alpha_{cong} = 1 + \frac{\hat{\gamma}}{\hat{\beta}}\left(\frac{x}{cap}\right)^2$$

where

α_{cong} is the multiplier with respect to in-vehicle congestion;

$\hat{\gamma}$ is an estimated coefficient with respect to the in-vehicle congestion index; and

$\hat{\beta}$ is an estimated coefficient with respect to in-vehicle travel time.

The in-vehicle congestion multipliers computed for home-to-work and home-to-school travel are depicted in Figure 3.4.

Figure 3.4 **Computation results of in-vehicle congestion multipliers with the multiplier of the CBA manual.**

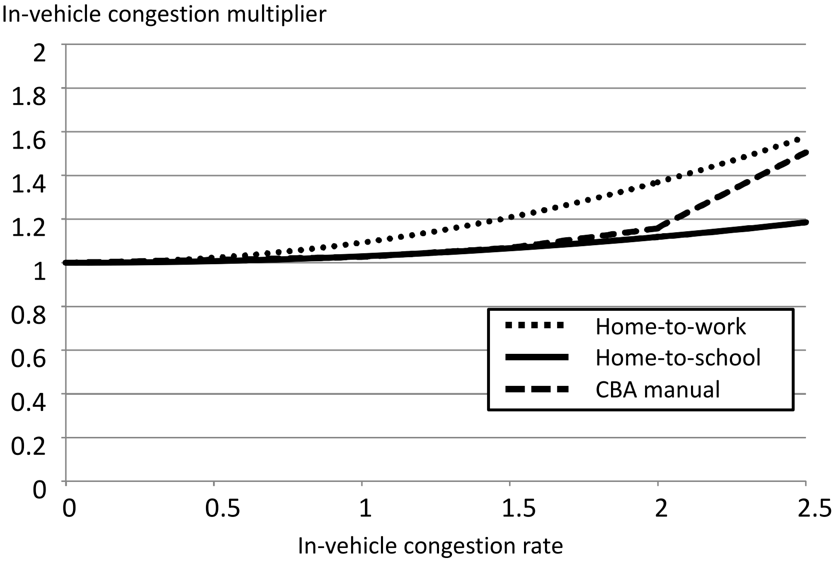


Figure 3.4 shows that the in-vehicle congestion multiplier increases to approximately 1.6 for home-to-work travel and to approximately 1.2 for home-to-school travel. In contrast, the formula shown in the CBA Manual is nearly equal to the multiplier of home-to-school when the in-vehicle congestion rate is lower than 2, and it sharply rises and becomes close to the multiplier of home-to-work as the in-vehicle congestion rate increases over 2.

Conclusions

This paper introduced the recent practices of cost-benefit analysis for urban rail investment projects in Japan, particularly focusing on the values of rail service, and showed examples of the valuation of rail service using the case of the 2000 Urban Rail Development Master Plan for Tokyo.

As seen in the CBA Manual for rail projects, the valuation of in-vehicle congestion has been highlighted in Japan for years. This is because the urban rail service has suffered from serious in-vehicle crowding in the urban rail networks of metropolitan areas, including Tokyo. The national government has also raised the issue of the in-vehicle congestion of urban rail networks in its railway development policy for many years; for example, it explicitly set the policy target that average in-vehicle congestion rates in 31 major rail sections in Tokyo should be 150 percent or less. In spite of the government's policy, however, the latest government review found the average in-vehicle congestion rate to be 164 percent as of 2010 (ITPS, 2013). One of the reasons for this is the recent prolonged economic recession, which has made it difficult for private rail operators to further invest in the expansion of traffic capacity.

In addition, the importance of valuating transfers at stations has been recognized in the CBA Manual. This reflects the recent socio-demographic trend in Japan of an aging population. Additionally, the social inclusion of handicapped people has been emphasized in recent years. The national government introduced the Barrier-Free Act in 2000, making the installation of elevators and escalators at large-scale rail stations mandatory. According to the government's review, as of 2010, 77 percent of rail stations whose daily passengers numbered 5,000 or more had installed barrier-free facilities (MLIT, 2011). As the further growth of the number of aged rail users is expected in the coming decade, the national government revised the Act in 2011 with a new policy target: that 100 percent of rail stations whose daily passengers numbered 3,000 or more install the barrier-free facilities.

For the further promotion of comfort and safety improvements in public transportation service, MLIT introduced the "Indexes of Comfortable and Easeful Public Transportation" (ICE-PT) in March 2004 (MLIT, 2004). ICE-PT contains nine indexes for operators in the Tokyo and Osaka metropolitan areas covering both urban rail and buses (see Table 3.8). MLIT regularly collects statistical data from public transportation operators and provides the indexes to the public every year. MLIT's goal is to monitor the performance of public transportation operators for benchmarking, based on which the government promotes the voluntary-based efforts made by private operators of public transportation service.

Finally, further issues are summarized, particularly in the Japanese context. First, parameters and multipliers in valuing rail service should be regularly monitored and revised. One of the barriers to this is the difficulty of data collection in recent years. Although regular large-scale travel surveys have been implemented in metropolitan areas in Japan, the government's prolonged financial problems may not guarantee a sustainable travel survey system in the future. Instead of a large-scale RP survey, a stated preference (SP) survey should be considered for estimating the values of rail service as a potential solution. Additionally, an SP survey for valuing rail services in OECD member countries may be helpful for sharing Japan's skills and experiences.

Table 3.8 **Definitions of nine indexes in "indexes of comfortable and easeful public transportation" proposed by MLIT, Japan**

Index	Definition
1. Rail in-vehicle congestion rate during a peak hour	Average hourly rail in-vehicle congestion rate at the most congested rail section during a peak hour
2. Share of step-free station	Share of rail stations with over 5,000 passengers/day that have introduced non-step routes out of stations
3. Share of non-step bus	Share of non-step buses out of total buses
4. In-vehicle comfort index	Share of rail vehicles in which high-performance air conditioners have been installed out of all rail vehicles
5. Availability of rail service information at platforms	Share of station platforms with light-emitting diode (LED) devices installed that display the service schedule, destination, and other information out of all platforms
6. Availability of rail service information in stations	Share of rail stations where display boards and announcement systems are installed to provide information about the type of rail service, destination, etc. out of all stations
7. Availability of rail service information in vehicles	Share of rail vehicles where display boards or announcement systems are installed to provide information about the next stop, etc. out of all vehicles
8. Accessibility of rail passengers to staff at stations	Share of station platforms where station staff are allocated or devices for communication between passengers and rail staff are installed out of all platforms
9. Accessibility of rail passengers to staff in vehicles	Share of rail vehicles where rail staff are allocated or devices for communication between passengers and rail staff are installed out of all vehicles

Source: MLIT

Next, the valuation of more detailed rail service categories may be necessary. For example, the multipliers of rail in-vehicle congestion may vary among different socio-demographic sub-groups such as aged rail users versus young rail users. These have not been explicitly taken into consideration in the CBA Manual, although some studies, such as Kato *et al*. (2003b), have challenged the empirical analysis. As rapid aging is expected in many OECD member countries, further investigation of multipliers/parameters may be needed and shared among them.

Finally, the comparison of the values of rail service with those of other public transportation services, such as bus service, bus rapid transit, inter-urban transportation, and air transportation, should be explored. The valuation of inter-urban transportation in the context of Japan has been challenged by some studies (e.g., Kato and Onoda, 2009); however, bus service values have not been well analysed in Japan even though bus service is important in many cities. Evidence from other OECD member countries in valuing other public transportation services may also contribute to the discussion in Japan.

Acknowledgements

Some data shown in this paper refer to documents used in the Committee on Current Problems and Future Direction of Railway Development in the Tokyo Metropolitan Area. Information about ICE-PT was kindly provided by MLIT, which also provided advice. I am grateful to Mr. Tomoharu Hase (MLIT), Mr. Kasuhiro Kishimoto (MLIT), Mr. Shinichiro Kato (Institute of Transport Policy Studies), Mr. Yoshihisa Yamashita (Creative Research and Planning Co.), and Mr. Satoshi Seki (Tokyu Co.) for their support with the data.

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Chapter 4

Valuing convenience in public transport in the Korean Context

Sungwon Lee[1]

Public transport patronage has been continuously declining in major Korean cities as levels of car ownership rise. Public transport has lost its competitive edge to private cars because people tend to prefer more convenient modes as their income increases. A promising way to reverse this trend is to provide more convenient modes of transport in terms of travel times and amenity. In Korea, we have implemented several policy measures aimed at increasing the attractiveness of public transport by reducing travel times and by providing more seats, etc. This paper analyses the post-policy impacts of these measures and compares the results with those of an ex ante quantitative policy effectiveness analysis. The main policy implication from the empirical analysis is that increasing the convenience level of public transport can be an effective way to increase public transport patronage. The measures to achieve this include reducing public transport travel times by increasing speeds or reducing headways, and by enhancing amenity levels. Following the reform of Seoul's public transport system, which reduced travel times by introducing exclusive median bus lanes and integrated public transport fares, we have actually seen an increase in the number of public transport users.

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Introduction

Public transport services such as urban rail and buses are regarded as energy-efficient and environmentally friendly forms of transportation in many cities around the world. However, public transport patronage has been continuously declining in major Korean cities in response to rising levels of car ownership. Public transport has lost its competitive edge to private cars because people tend to prefer more convenient modes as their income rises. A promising way to reverse this trend is to provide more convenient modes of transport in terms of time and amenity. In Korea we have implemented several policy measures aimed at increasing the attractiveness of public transport by reducing travel times and providing more seats, etc. This paper analyses the post-policy impacts of these measures which it then compares with the results of an ex ante quantitative policy effectiveness analysis. Policy implications will be drawn from the analysis.

Seoul, the capital city of Korea, conducted a major reform of its public transport system in 2004. The major components of this reform were the large-scale deployment of exclusive median bus lanes and the introduction of an integrated public transport fare system in which fares are charged according to the distance travelled, regardless of transport mode, by allowing free transfers between subways and buses. This fare system is designed to consist in a base fare which applies to the first 12 km of travel and an incremental fare reflecting the additional distance travelled. The result has been a resounding success. The reform has not only reversed the trend decline in public transport usage but has also increased the popularity of public transport modes in the capital city region of Korea.

This paper reviews the rationale behind the public transport reform by examining earlier quantitative impact studies of the effectiveness of policy instruments. The empirical study is based on stated preference methodology which analyses the impacts of hypothetical policy measures. The public transport reform is then discussed in detail and an ex ante evaluation made of the policy reform.

The results of this study could be transferable to other cities with similar characteristics. The policy recommendations could also be transferable in cases where such cities exhibit similar socio-economic and infrastructure-related conditions.

Rationale behind public transport policy reform in Korea

In countries like Korea, characterised by a high population density and advanced urbanisation, public transport services such as subway and buses offer great potential for saving energy and for mitigating various social costs associated with private transportation. In order to promote public transport, policy measures aimed at increasing the attractiveness of public transport are required. Such policy measures include increasing both the convenience level of public transport, by reducing travel and waiting times, and the amenity level by providing greater comfort.

Although the policy impact targets are known, there are still uncertainties about the effectiveness of the policy. A quantitative policy impact analysis and econometric analysis of demand elasticities are therefore required.

The quantitative policy impact analysis discussed here uses the stated preference methodology for impact analysis of hypothetical transport policy measures. The outcome of this analysis is then used as the basis for evidence-based transport policy intervention. In addition, econometric analysis is performed to test the hypotheses of related transport policies in order to compare the perceived cost to the real cost of transportation. The table below summarises the findings of previous studies on the elasticities of demand for urban transportation.

Table 4.1 **Price elasticities of demand for urban transportation**

Demand	Attributes	Elasticities		
		Short run	Long run	Overall
Fuel consumption	Fuel price	-0.27	-0.73	-0.48
Car use	Fuel price	-0.33	-0.30	-0.39
Car ownership	Fuel price	*	*	-0.21
Car ownership	Car price	*	*	-0.87
Traffic	Toll fee	*	*	-0.45
Demand for bus	Bus fare	-0.30	-0.65	-0.41
Demand for subway	Subway fare	-0.20	-0.40	-0.20
Demand for rail	Railway fare	-0.70	-1.10	-0.65
Mass transit	Fuel price	*	*	+0.34
Car ownership	Transit fare	*	*	+0.10

Note: Short run means usually within a year, and long run means 5 to 10 years.

Source: UK Department of Transport –Transport Elasticity Study

However, price and other elasticities of urban transport demand can vary from city to city, depending on the city's infrastructure conditions and the socio-economic conditions of its residents. A separate city-wise elasticity analysis is therefore required for evidence-based policy making.

Lee et al (2003) analysed the hypothetical policy measures' effectiveness in converting private car users to public transport in the Seoul metropolitan area by using discrete choice modelling based on stated preference methodology (SP).

A survey was conducted of 662 car users and produced 4,228 effective data points. The main purposes of passenger car use were for commuting (71.5%) and business trips (16.4%). The following formulas represent the utility function of cars and alternative modes (buses and subways):

$$U_{oricar} = \alpha + \beta_1 \cdot Fuel + \beta_3 \cdot Ivt + \beta_5 \cdot Park$$

$$U_{altmode} = \beta_2 \cdot Fare + \beta_3 \cdot Ivt + \beta_4 \cdot Ovt + \beta_6 \cdot Crowd$$

where *altmode = bus, subway, bus+subway*

(oricar: original mode of passenger car, altmode: alternative mode, bus: bus, sub: subway, bus+subway: dual use of bus and subway, Fuel: fuel price, Fare: fare of bus or subway, Ivt: in-vehicle time, Ovt: out-vehicle time, i.e., interval accessing bus and access time in the subway, Park: parking fee, Crowd: crowdedness, i.e., comfortableness as a service measure)

The table below represents the estimation results for the mode choice behaviour of car users. Although most variables were statistically significant, the fare for mass transit was statistically insignificant. This is because car users do not consider fare level to be significant as the fare is significantly lower than the cost of car use. Moreover, car users are more responsive to changes in bus fares than to changes in subway fares. The higher coefficient for out-vehicle time compared to that for in-vehicle time means that the disutility of waiting is greater than that of riding. Bus users are more sensitive to in-vehicle time than other modes and this suggests that an increase in express bus supply or HOV lanes can be effective in attracting bus users from cars. The estimated coefficient for parking fees is more than twice as high as that for fuel prices. This is because the perceived cost of parking is much greater than that of fuel, and car users are very sensitive to parking fees. The positive and higher coefficient for crowdedness in buses compared to the subway implies that car users are very sensitive to crowded buses.

Table 4.2 **Estimation results of mode choice behaviour of car users**

Variables	car-bus		car-bus+subway		car-subway	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Car dummy	1.6362	5.505	0.99752	5.207	0.50605	2.29
Fuel price	-1.01E-04	-3.067	-1.17E-04	-5.241	-6.10E-05	-2.848
Fare of bus or subway	-2.00E-04	-1.456	-1.41E-04	-2.862	-5.40E-05	-0.637
In-vehicle time	-4.21E-02	-8.106	-2.76E-02	-9.376	-3.80E-02	-10.717
Out-vehicle time	-4.41E-02	-3.486	-2.81E-02	-5.053	-6.49E-02	-7.089
Parking fee	-3.63E-04	-6.36	-2.49E-04	-6.188	-2.61E-04	-6.018
Crowdedness	0.83081	8.38	0.64431	9.306	0.58023	7.508
ρ^2 (Rho square)	0.19		0.20		0.22	
No. of responses	943		1,783		1,502	

Price elasticities can be estimated through the sample enumeration method. This method obtains arc elasticity rather than point elasticity if the underlying utility function is properly specified. However, our model does not have components which allow varying elasticity due to estimation-related constraints. Theoretically, arc elasticity offers a more accurate response estimation when the hypothetical attribute level changes are large. As shown in the table below, the fuel price elasticity of demand for passenger car use ranges between -0.078~-0.171, which shows an inelastic behaviour. With a 50% increase in fuel price, a modal shift from car to bus or subway is expected at 3.9% minimum and 8.5% maximum. Additionally, dual users of bus and subway show a higher price elasticity than single users. This is because dual users are more sensitive to fuel price as they are relatively longer-distance commuters. Overall, the estimated transport demand elasticities in Korea are generally smaller than the U.K. elasticity cases shown in Table 4.1, reflecting differences in socio-economic and infrastructure-related conditions.

Table 4.3 **Fuel price elasticities of demand for car use and change of modal share**

		Fuel Price Elasticities	Change of Modal Share from car to transit modes (%)
Car-bus	10% price increase	-0.086	0.86
	20% ”	-0.086	1.72
	30% ”	-0.086	2.59
	40% ”	-0.086	3.45
	50% ”	-0.086	4.32
Car-subway	10% ”	-0.078	0.78
	20% ”	-0.078	1.55
	30% ”	-0.078	2.33
	40% ”	-0.078	3.11
	50% ”	-0.078	3.88
Car-bus+subway	10% ”	-0.171	1.71
	20% ”	-0.171	3.41
	30% ”	-0.171	5.11
	40% ”	-0.171	6.79
	50% ”	-0.169	8.47

Source: Author

In Table 4.4, the cross-price elasticities of demand for passenger car use are estimated through the sample enumeration technique. The fare cross-price elasticity ranges between 0.016~0.084, which shows an inelastic behaviour. Also, a modal shift from car to mass transit with a 50% fare decrease result in at most 4.35%. From this, we can expect that implementing policy for subsidising transit fares will not bring about a significant reduction in car usage.

Table 4.4 **Fare elasticities of demand for car use and change of modal share**

		Fare (cross price) elasticity	Change of Modal Share from car to transit modes (%)
Car-bus	10% fare decrease	0.058	0.58
	20% ”	0.058	1.16
	30% ”	0.058	1.75
	40% ”	0.058	2.33
	50% ”	0.058	2.92
Car-subway	10% ”	0.016	0.16
	20% ”	0.016	0.33
	30% ”	0.016	0.49
	40% ”	0.016	0.66
	50% ”	0.016	0.82
Car-bus+subway	10% ”	0.086	0.86
	20% ”	0.086	1.73
	30% ”	0.087	2.60
	40% ”	0.087	3.47
	50% ”	0.087	4.35

Source: Author

Table 4.5 shows the change in modal share due to an increase in the parking fee. When the monthly parking fee increases by US $33.00, car use decreases by 13~15%. Similarly, when the monthly parking fee increases by US $66.00, car use decreases by 25~30%. Because current individual levels of parking fee are not all the same, the cross-price elasticity of parking fees cannot be estimated.

Table 4.5 **Change of modal share due to increasing parking fee**

			Modal share before and after the change of parking fee	Change of modal share (%)
+40,000 won per month	Car-bus	Car	0.660 → 0.562	-15
		Bus	0.340 → 0.438	29
	Car-subway	Car	0.576 → 0.502	-13
		Subway	0.424 → 0.498	18
	Car-bus+subway	Car	0.567 → 0.495	-13
		Bus+subway	0.433 → 0.505	17
+80,000 won per month	Car-bus	Car	0.660 → 0.460	-30
		Bus	0.340 → 0.540	59
	Car-subway	Car	0.576 → 0.428	-26
		Subway	0.424 → 0.572	35
	Car-bus+subway	Car	0.567 → 0.423	-25
		Bus+subway	0.433 → 0.577	33

The cross-elasticity of the in-vehicle transit time for car use demand can be estimated using the sample enumeration technique. When the in-vehicle transit time is decreased by 10~50%, the cross-elasticity ranges between 0.46~0.57. Moreover, when subway speed improves by 50%, 29% of car users will transfer to the subway. Introducing either an express subway transit system or an express bus service will therefore be an effective policy for reducing car use and traffic congestion in Seoul if there is not much latent demand for car use. The result of the cross-elasticity in-vehicle transit time for car use demand is shown in Table 4.6. The subtle differences in elasticities in Tables 4.6 and 4.7 reflect sample enumeration related errors.

Table 4.6 **In-vehicle time elasticities of demand for car use and modal share**

		In-vehicle (cross) time elasticity of demand for car use	Change of modal share from car to transit modes (%)
Car-bus	10% decrease	0.459	4.59
	20% ”	0.471	9.42
	30% ”	0.481	14.43
	40% ”	0.489	19.57
	50% ”	0.495	24.77
Car-subway	10% ”	0.549	5.49
	20% ”	0.559	11.18
	30% ”	0.567	17.01
	40% ”	0.572	22.89
	50% ”	0.575	28.73
Car-bus+subway	10% ”	0.512	5.12
	20% ”	0.517	10.35
	30% ”	0.520	15.61
	40% ”	0.521	20.84
	50% ”	0.520	25.99

Source: Author

The cross-elasticity of out-vehicle transit time for demand of car use can be estimated using the sample enumeration technique. The cross-elasticity of out-vehicle time is lower than that of the in-vehicle time.

As shown in Table 4.7, when the out-vehicle transit time decreases by 10~50%, the cross-elasticity ranges between 0.19~0.38 and the modal shift from car to transit modes can change by up to 19%. If a policy aimed at increasing the frequency of bus and subway services were to be implemented, it would be very effective in promoting the use of transit modes and reducing traffic congestions in Korea.

Table 4.7 **Out of-vehicle time elasticities of demand for car use and modal share**

		Out-vehicle (cross) time elasticity of demand for car use	Change of modal share from car to transit modes (%)
Car-bus	10% decrease	0.197	1.97
	20% ”	0.200	3.99
	30% ”	0.202	6.05
	40% ”	0.204	8.15
	50% ”	0.206	10.28
Car-subway	10% ”	0.364	3.64
	20% ”	0.369	7.38
	30% ”	0.373	11.20
	40% ”	0.377	15.08
	50% ”	0.380	18.99
Car-bus+subway	10% ”	0.208	2.08
	20% ”	0.210	4.19
	30% ”	0.211	6.33
	40% ”	0.212	8.48
	50% ”	0.213	10.65

Source: Author

In this study, the level of service in transit modes is defined as the level of crowdedness. As shown in Table 4.8, when the congestion of transit modes decreases by one step, defined as the possibility of securing a seat in crowded public transit, 18~25% of car users will transfer to alternative modes. Moreover, improving in-vehicle congestion is very important for promoting the use of transit modes and reducing traffic congestion in Seoul.

Table 4.8 **Car users' response to service variable of in-vehicle congestion**

		Change of modal share
Car-bus	Improving one step	25.05 % from car to bus
	Worsening one step	21.92 % from bus to car
Car-subway	Improving one step	17.85 % from car to subway
	Worsening one step	17.47 % from subway to car
Car-bus+subway	Improving one step	20.71 % from car to bus+subway
	Worsening one step	20.46 % from bus+subway to car

Source: Author

By utilising elasticity estimates, we were able to analyse the effects of hypothetical TDM policies in terms of modal shifts. As a result, we determined that fuel price policy and fare-related policy had very limited impacts and were very ineffective policy measures. On the other hand, there were many effective policy measures such as parking regulations, pricing policies related to parking, express buses, express urban trains and HOV lanes. In addition, reducing crowdedness in bus and subway by increasing the frequency of public transit services is also an effective policy measure.

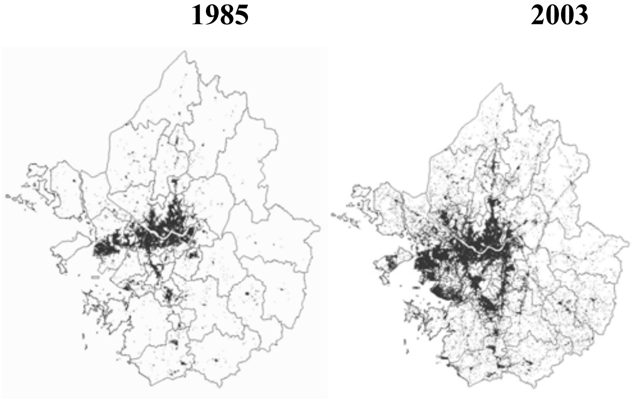
The results of the empirical analysis given above suggest which policy intervention measures would be effective in revitalising public transport use in the Seoul metropolitan region. These include providing faster and more frequent services and increasing the amenity level of public transport. The following sections describe how these policy measures have been implemented in Seoul.

Seoul's Public Transport System

Seoul is the capital of South Korea with a population of approximately 10 million inhabitants living in an area of 605.2 km2 and with a GRDP (Gross Regional Domestic Product) of 283,651 billion won (based on 2011 figures). Although the Seoul area accounts for merely 0.6% of South Korea's total surface area, it contains 20.1% of Korea's entire population. The SMA (Seoul Metropolitan Area) includes Seoul, Incheon and Gyeonggi and has a population of 26.6 million (49.3%), covering an area of 11,818 km2, and has GRDP of 585,979 billion won (based on 2011 figures).

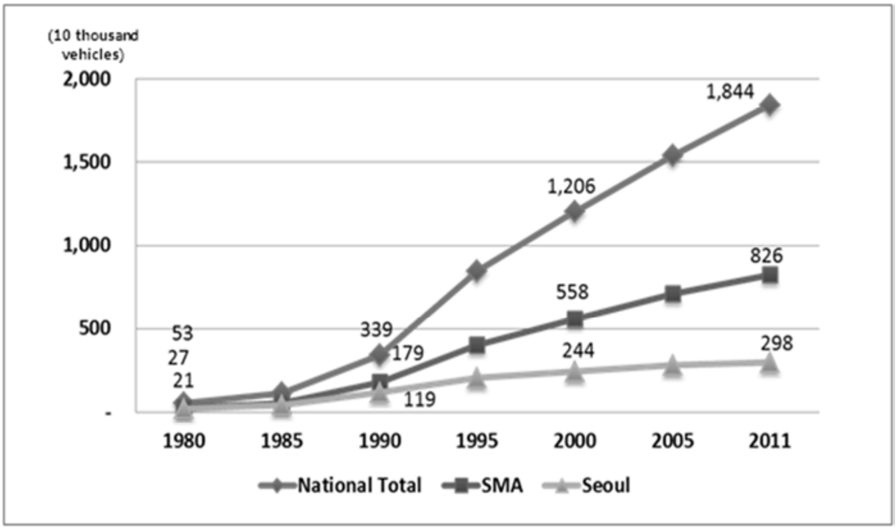
A study was conducted to observe the urban sprawl of the SMA over two periods of time. Between 1989 and 1996, 5 towns and 292, 000 houses were built in an area of 50.1 km2, accommodating a population of 1.17 million. Between 2001 and 2012, a further 12 towns and 671,000 houses were built in an area of 146.1 km2, accommodating a population of 1.75 million. Although the periods were of differing durations, the rate of urbanisation was higher in the second period than in the first.

Figure 4.1 **Trends in urbanisation in the Seoul metropolitan area**



Source: Seoul Metropolitan Government

Figure 4.2 **Trends of vehicle registration**

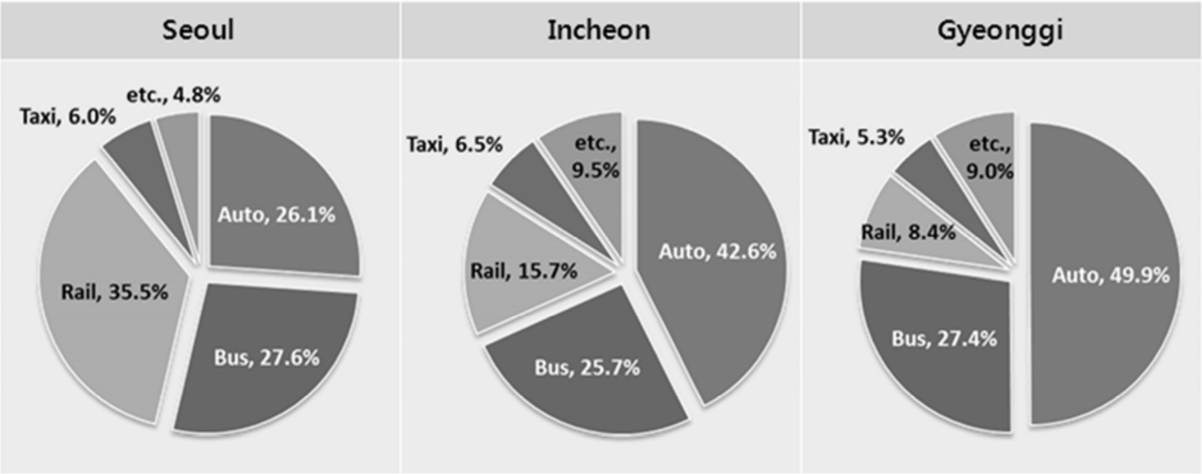


Source: Seoul Metropolitan Government

The above figure illustrates the number of vehicles registered in Seoul, the SMA, and the Republic of Korea for specific years. As a city develops and becomes increasingly urbanised, more people will be attracted to move there to experience a higher standard of living compared to rural areas. This trend is also closely linked to the increase in the number of new vehicle registrations. In 2011, for example, the number of vehicles registered per person in Seoul increased from 0.02 in 1980 to 0.3.

The SMA has some of the most highly developed transport infrastructure in Korea. The SMA has some 24,070 km of road, 3,694 bus routes (26,847 vehicles), and 825.2 km of railway lines (521 stations). Although Seoul takes up a small proportion of land area in the SMA, its transport infrastructure comprises about 8,199 km of road, 447 bus lines (9,340 vehicles), and 346.3 km of railway lines (321 stations).

Figure 4.3 **Mode share for each SMA region**



Source: Seoul Metropolitan Government

The Seoul Metropolitan Transportation Authority has conducted a study to determine transport conditions in the major regions in the SMA. Seoul accounts for approximately 20.011 million of the 49.660 million intra-city trips per day in the SMA. As shown in the figure above, the majority of people in Seoul make use of the well-developed public transportation network. The congested traffic conditions in Seoul make subways and buses the most viable options. In contrast, a higher proportion of people in Incheon and Gyeonggi use private cars.

Seoul Public Transport Reform Achievements

The reform of Seoul's public transport system had two main objectives: firstly, to increase the speed and punctuality of bus services, and secondly to integrate all modes of public transport. The speed of bus services was increased by installing exclusive median bus lanes. The integration of public transport services called for the semi-public provision of bus services and introduction of an integrated public transport fare which allows strictly distance based fares regardless of the number of transfers involved. These policy measures were generally in line with the policy implications derived from our quantitative studies of policy instrument effectiveness.

Infrastructure Development

Although Seoul's transport infrastructure is relatively advanced compared to other cities in Korea, several development projects can help to improve the quality of transport services and infrastructure. First, the upgrading of existing railway lines in Gyeonggi-do, Incheon, and Gangwon-do not only relieves congestion in Seoul, but also helps the spread of Seoul's population. As the concentration of people and economic activities has increased in the Seoul Metropolitan Area, dispersion and balanced regional growth have been major policy objectives in Korea. Furthermore, expanding the capacity and electrification of train services allows more efficient operations. Last, constructing new lines in Ansan, Gwacheon, Ilsan, Bundang, and Pangyo helps to support new town development. The lines connected to Seoul can also help improve traffic conditions. New lines are financed by levying development charges.

Semi-Public Bus Operation and Integrated Fares

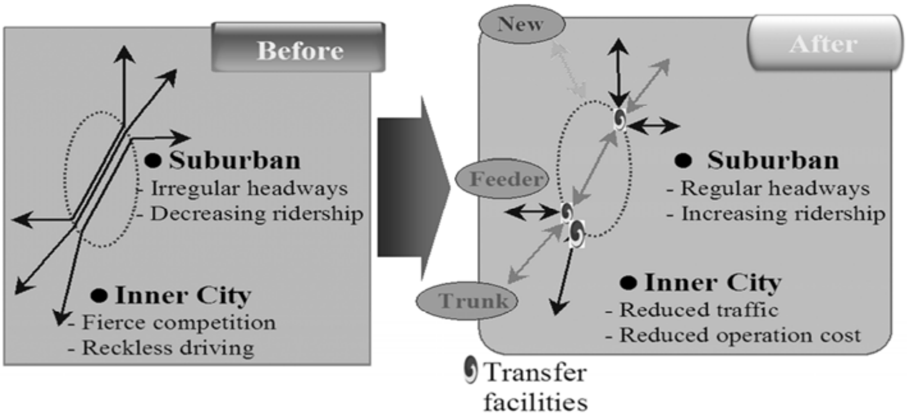
The need to reform public transport services was clear from the vicious circle in which bus services found themselves. The increasing number of vehicles on the roads and lack of bus priority policies, such as bus lanes and subsidies, were responsible for the poor punctuality, lack of reliability and slow speed of bus services. The resultant operating conditions and congestion generated stress in bus drivers, which could lead to unfriendly services and traffic accidents. Moreover, limited road capacity and congestion also resulted in routes being abandoned, periodic increases in fare and labour disputes. Since routes were owned by private bus companies, it was difficult to adjust routes to demand. As a result of reduced operations and increased fares, the number of bus users had decreased, resulting in cuts in bus services, reductions in staff levels and the bankruptcy of bus companies.

In order to address the above issues, the Seoul Metropolitan Government proposed and implemented the following reforms of the transport system.

A new revenue system and main routes bidding system were introduced for bus services. While the previous revenue system was based on the number of passengers, this new system is based on the distance covered by services (veh-km). Furthermore, these revenues are jointly managed.

The new bus network lines are colour-coded according to the type of service they are designed to provide. Blue lines are trunk lines linking suburbs to the downtown area at the regional level. Trunk lines also provide fast and punctual services. Green lines are feeder lines feeding into trunk lines and the subway network in order to meet local traffic demands. Yellow lines are circular lines providing local services within the downtown area. The circular lines are mainly designed for business and shopping trips. Lastly, red lines provide services at the level of the metropolitan area as a whole by providing express connections between satellite cities and the downtown area. Metropolitan area lines also help to provide alternative transport for passenger car commuters. The following two figures illustrate the situation before and after creation of the new networks.

Figure 4.4 **Trunk & feeder bus system**



Source: Seoul Metropolitan Government

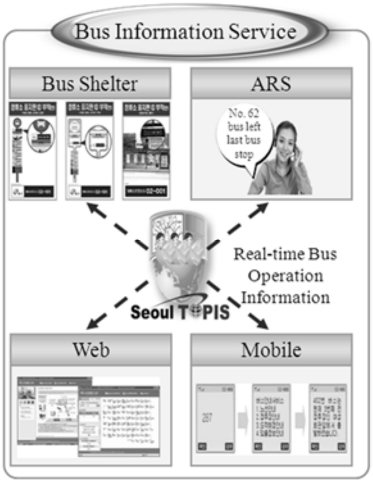
Figure 4.5 **New trunk & feeder network**

Source: Seoul Metropolitan Government

Seoul has introduced distance-based fares for its public transport transits. For single subway trips, a basic fare of 1,000 Korean won (1 US Dollar) is charged for trips of up to 12 km and an extra fare of 100 Korean won added for every additional 6 km. In the case of single bus trips, users pay a single fare of 1,000 Korean won. For trips involving transfers, Korea's public transit system utilises a cumulative distance-based fare system. Transferring between subway lines is free of charge. A basic fare goes up to 10 km and an extra fare is paid for every additional 5 km.

Bus Management/Information System

Figure 4.6 **Bus information service**



Seoul TOPIS (Transport Operation & Information Service) provides real-time information on bus operations through the ARS, the Internet, mobile applications and bus shelters. Bus information, such as real-time location, the interval between buses, arrival times, routes and transfers, can be easily accessed by both passengers and bus companies. Bus companies use this information to manage bus services efficiently.

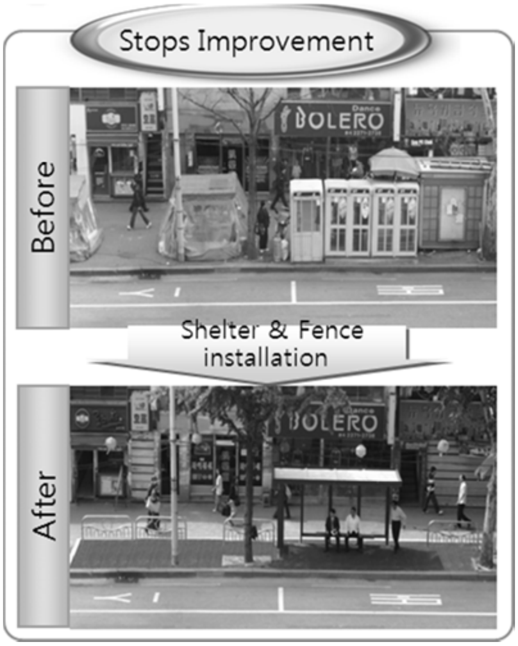
Infrastructure: Exclusive bus lane, Station Improvement

Exclusive bus lanes allow faster and more reliable bus services to be provided within the SMA's service area. In 2011, there were 157 km of bus lanes installed along 13 corridors. Furthermore, the introduction of exclusive median bus lanes also helped to improve the efficiency of bus operation. As a result, it has attracted patronage from private vehicles and increased the number of bus users.

Figure 4.7 **Exclusive median bus lane**

Source: Seoul Metropolitan Government

Figure 4.8 **Bus stop improvement**



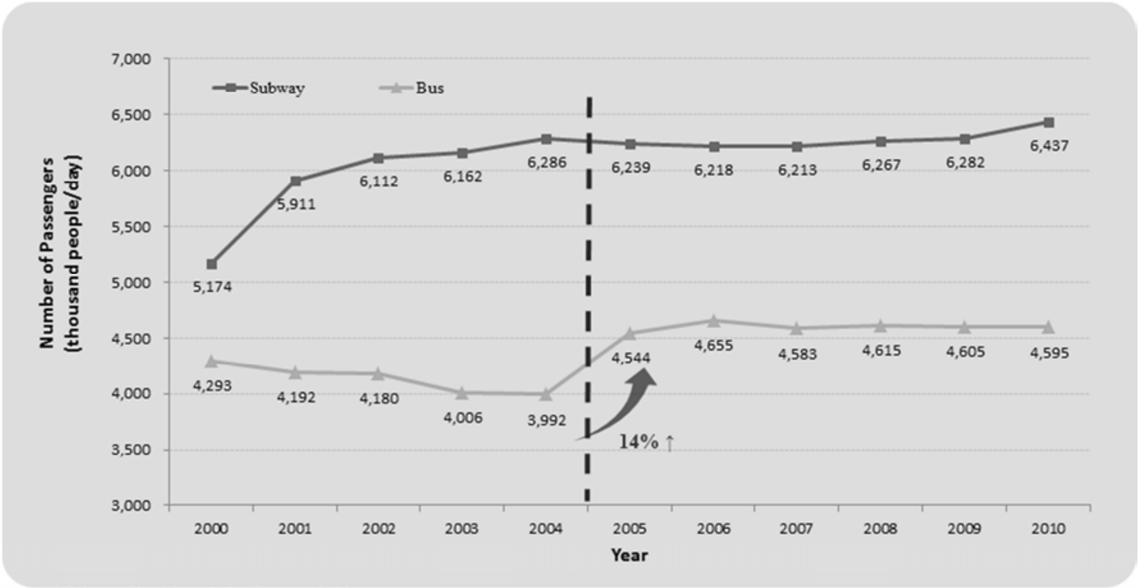
Source: Seoul Metropolitan Government

As shown in the figure above, bus stops have been drastically improved. Shelters and fences have been installed to provide bus users with a suitable area in which to wait. In addition, some bus stops display real-time bus information so that users know exactly when the next bus is coming.

Summary and Results of the Reform of Public Transport Services

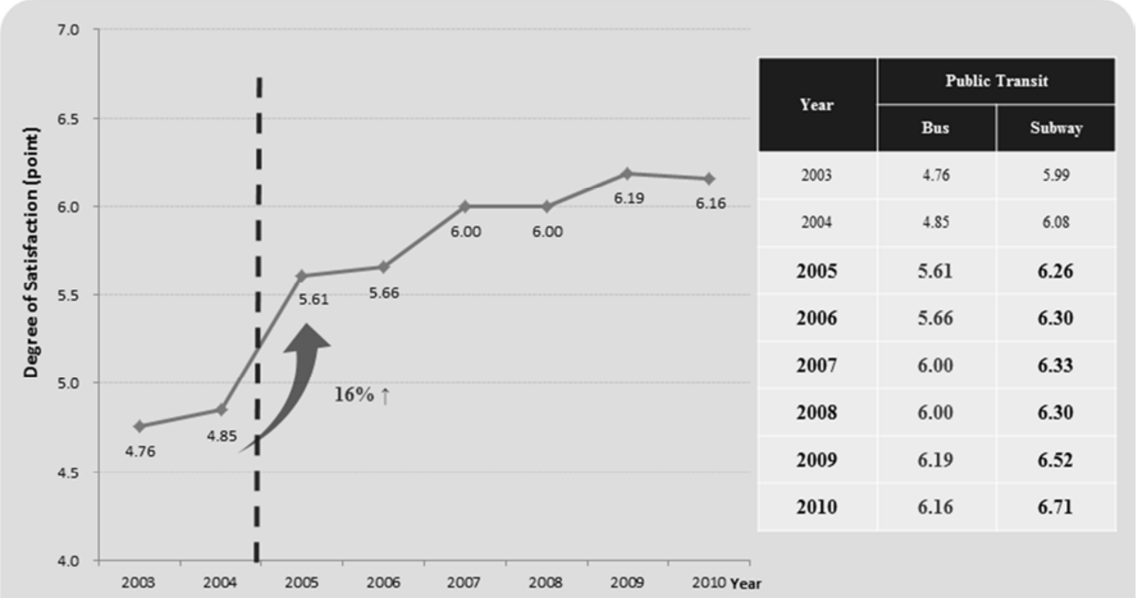
Empirical studies of public transport in Korea suggest that improving the attractiveness of services by reducing travel times and improving amenities can strongly increase public transport patronage. Travel time related attributes are estimated to be more important than monetary attributes in the Seoul metropolitan region. As people are accustomed to high amenity levels in private transport they tend to require more amenities in public transport services. Empirical evidence of this thesis in Korea can be found in Lee *et al* (2003).

Figure 4.9 **Increase in public transport patronage**



※ Subway ridership excludes free-pass holders.
Source : Seoul Year Book

Figure 4.10 **Trend in citizens' satisfaction with transit services**



Year	Public Transit	
	Bus	Subway
2003	4.76	5.99
2004	4.85	6.08
2005	5.61	**6.26**
2006	5.66	**6.30**
2007	6.00	**6.33**
2008	6.00	**6.30**
2009	6.19	**6.52**
2010	6.16	**6.71**

※ Rating is based on a scale of 0 to10.
Source : 2010 Seoul Survey

The reform of public transport in Seoul can be regarded as a success. The reform was well received by citizens and was also benchmarked in many other cities in Korea as well as in other countries.

Bus ridership actually increased by about 14% after the reform, reversing the earlier trend decline. According to an official survey, public satisfaction with the Seoul public transport system also jumped by 16% after the reform. Bus users rated increased punctuality and shortened travel times as highly effective factors in encouraging people to switch to public transport. The introduction of distance-based integrated fares was another important element of the reform, as it also enhances the attractiveness of public transport.

The results of public transport policy reform are consistent with ex ante empirical analysis outcomes. These suggest that empirical studies can play a practical role in predicting hypothetical policy measures effectiveness with a reasonable degree of accuracy.

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Chapter 5

Crowding on public transport for Île-de-France

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Since the mid 90's, public transport patronage in Île-de-France (the Paris region) has increased substantially: over the last decade alone a 20% growth was observed. This growth, even though it was an aim of the Sustainable Urban Mobility plan adopted in 2000, was not completely anticipated. Renewal of the rail infrastructure and rolling stock is necessary to cope with this situation. But renewal alone will not be enough. Major investments are planned to increase capacity by either building new lines, or by increasing capacity of existing lines. The Grand Paris Express is the best known of these projects. For the socio-economic appraisal, it is necessary to quantify all impacts of these investments. However, little is known about the value that passengers attach to these reduced congestion levels. The Syndicat des Transports en Île-de-France commissioned Significance in 2011 to conduct a new study focused on the perception of comfort inside public transport vehicles in general, and more particularly on the issue of crowding. This study covered all modes of public transport in Île-de-France.

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Background

Since the mid 90’s, public transport patronage in Île-de-France (the Paris region) has increased substantially: over the last decade alone a 20% growth was observed. This growth, even though it was an aim of the Sustainable Urban Mobility plan adopted in 2000, was not completely anticipated. Consequently, the capacity is no longer sufficient to meet the demand during the peak hours, particularly on several parts of the network in the dense central area of the region. This results in over-crowded vehicles and long waiting times for passengers at rail platforms and bus stops. The lack of maintenance and modernisation of the transport system causes additional operational difficulties.

Renewal of the rail infrastructure and rolling stock is necessary to cope with this situation. But renewal alone will not be enough. Major investments are planned to increase capacity by either building new lines, or by increasing capacity of existing lines. The Grand Paris Express is the best known of these projects. Furthermore, a number of bus lines will be transformed into tramway lines, railway lines are being renovated, and new automatic systems for railway operation will allow shorter headways between subsequent trains, and thus more capacity. All these projects together should reduce the shortage of capacity substantially by 2020, and totally eliminate it by 2030. As a consequence, crowding levels in public transport will be highly reduced.

For the socio-economic appraisal, it is necessary to quantify all impacts of these investments. The impact on travel and waiting times can be determined by using standard traffic models, such as the ANTONIN model that is used in the Île-de-France area. The reduction in congestion levels can also be forecasted by more using advanced traffic models. However, little is known about the value that passengers attach to these reduced congestion levels (for a review of existing literature, see section “ Literature review ”).

Therefore, STIF commissioned Significance in 2011 to conduct a new study focused on the perception of comfort inside public transport vehicles in general, and more particularly on the issue of crowding. This study was to cover all modes of public transport in Île-de-France.

Objectives and research approach

The study reported here aimed at estimating the perceived value of crowding in public transport vehicles in Île-de-France. Different values and preferences for each available public transport mode had to be derived, where necessary. All results had to be valid for the Île-de-France. The final values are intended for use in cost-benefit analyses appraising the socio-economic effects of public transport projects; and in passenger demand forecasting models predicting mode choice and route choice by public transport users in Île-de-France.

The research approach used for this study consisted of four phases:

- The first phase included a literature review of French and international scientific publications on the value that public transport passengers attach to comfort and particularly to crowding inside the vehicles.
- The second phase was a qualitative investigation of the key factors driving the perception of comfort by different categories of public transport passengers.
- The third phase consisted of the design, execution and analysis of a stated preference survey, to derive coefficients on the value of comfort. Comfort was considered in all its dimensions, but specific focus was put on crowding. In addition to the stated preferences surveys, questions were asked about the passengers' attitudes towards public transport, which resulted in a typology of the respondents.
- The fourth phase consisted of a revealed preferences survey to verify the results of the stated preferences survey. Passenger counts and interviews were carried out at different rail stations to measure the proportion of passengers actually preferring to wait for the next vehicle instead of taking the (more crowded) first vehicle.

The present publication concentrates on the estimation of the value of crowding inside public transport vehicles, and the application of the results obtained in cost-benefit analysis.

Literature review

The literature review demonstrated that only limited knowledge is available about consumers' valuation of crowding inside France, while the value of comfort is almost an entirely new subject. But also outside France the literature on the subject is fairly limited. Li and Hensher (2011) reviewed the international literature available until then, and Wardman and Whelan (2011) provided a synthesis of 20 years of rail crowding valuation studies carried out in the UK. Earlier work includes Douglas Economics (2006) which reported results of rail oriented stated preference research carried out in New Zealand. Other earlier crowding work includes Cox *et al.* (2006), Baker *et al*. (2007), Oxera (2007), MVA (2007) and Whelan and Crocket (2009). In France two studies reporting crowding results can be mentioned: a recent one by Haywood and Koning (2011), and another one by Kroes *et al*. (2006). We shall briefly discuss some of the most interesting results in the following paragraphs.

Li and Hensher (2011) reviewed public transport crowding valuation research using studies conducted in the UK, the USA, Australia and Israel. They identified three measures to value crowding: (1) a travel time multiplier, (2) a monetary value per time unit, and (3) a monetary value per trip, but did not provide a comparison between their performances. They also described associated ways to represent crowding in stated preference experiments, and implied that Stated Preference research is the preferred way of conducting valuation research for crowding. Despite the highly different characteristics of the studies they reviewed, they note that they all reported that crowding would increase the value of travel time savings, which, according to them, “can be viewed as an additional component of generalised time”.

Wardman and Whelan (2011) reviewed the extensive research that has been carried out in the United Kingdom into the value of crowding for rail transport during the last two decades, particularly using Stated Preference studies. They did this in a meta-analysis project. They found that, particularly for those passengers that have to stand in the vehicles, there appears to be a substantial disutility of travel. They expressed this disutility as a multiplier for travel time: when crowding levels are low the multiplier is close to one, but when not all passengers can travel seated the multiplier increases to values up to 2.7 for standing passengers in extremely full trains, and 1.7 for seated passengers. This means that the disutility of travel in a very crowded situation is for standing passengers more than twice as high as compared with a situation when seats are available. And even for seated passengers the additional disutility is substantial.

In Paris, Haywood and Koning (2011) reported their study about “Pushy Parisian Elbows” along part of metro line 1 in Paris. Using contingent valuation the authors quantified the passengers’ trade-off between crowding and travel time. They found that metro passengers were prepared to travel on average 8 minutes longer per trip to reduce the high peak hour level of crowding to the substantially lower level of crowding experienced outside the peaks. This is roughly equivalent to a value of about 1.5 euro per trip, which is clearly non-negligible.

Also in Paris, but a few years earlier, Kroes et al (2006) conducted research based upon SP experiments for travel on interurban rail lines. Although the study aimed primarily at measuring the value of punctuality, it also produced penalties for travelling under crowded circumstances, which were expressed as minutes of equivalent travel time. For commuting to central Paris, for instance, they found that the penalty for travelling standing was equal to 4.9 minutes per trip plus 0.3 minute per minute of travel time. So a 20 minute trip would have a penalty of 10.9 minutes additional perceived travel time.

In summary, we have seen a number of common elements emerging from the literature:

- Crowding inside public transport vehicles generates substantial disutility, which adds to the generalised cost of travel;

- The research that has been conducted into the valuation of crowding has almost exclusively used Stated Preference data to estimate the values. This is likely to be related to the fact that it is extremely difficult to find real-life situations where passengers can be observed to trade crowding against travel time or cost;

- Most studies express the disutility of crowding using a travel time multiplier, which is a function of the level of crowding, and which is different for seated and standing passengers.

Qualitative research

In order to learn more about the key factors driving the perception of comfort (crowding and other elements of comfort) in public transport vehicles, and in order to prepare for the Stated Preference surveys in our study, five focus-group discussions were organized. These consisted of young adults, frequent commuters, occasional and non-commuter traveller's, seniors, inhabitants of more remote suburbs.

The group discussions aimed specifically at understanding passenger's perception of physical comfort inside all types of public transport vehicles in order to identify which dimensions and features are important, and what consequences discomfort has on behaviour. Comfort while waiting at platforms and bus stops was not included in this project.

It was found that the perception of physical comfort in public transport covers a range of aspects including crowding, stability of the vehicle, seat comfort, temperature, smells, noise, comfort when standing, ease of access, and ease of on board circulation. For each aspect of comfort, participants were asked to define what a perfect, a correct, an uncomfortable and an unbearable level was. Table 5.1 shows the results for the aspect of crowding.

Table 5.1 **Levels of perception with respect to crowding**

	Level of perception			
	Perfect	Correct	Uncomfortable	Unbearable
Descriptive	*"there are a few persons"*	*"almost all seats are occupied. A few people are standing, one can move easily"*	*"all seats are occupied. There are people standing, it is not easy to move"*	*"all seats are occupied. Standing passengers are next to each other"*
Impact on passenger	*"one can stay where one wants"*	*"one can choose where to stand but not choose one's seat"*	*"one has to stand but has a little space to move. One can stay near the seats to be able to sit when one gets free or near doorways to exit easily"*	*"one cannot move"*

Crowding was found to have the following consequences:

- It influences physical comfort;
- It requires not paying too much attention to one's psychological comfort;
- It generates crowd behaviour;

- It is a cause of irregularity of operation of service.

However, even though crowding has a negative impact on public transport image, it was reported to have only a minor impact on trip behaviour for obligatory trips such as commuting. For trips with other purposes crowding was said to have an important influence, and to lead to an increased use of less crowded modes and more travel during off-peak hours.
Behaviours to avoid discomfort that were quoted during the focus groups were:

- Letting one or two vehicles pass by before boarding, especially for modes with little capacity (bus) or with a high frequency (metro);
- Changing itinerary, even if the alternative itinerary is longer and/or requires more transfers;
- Changing the timing of travel, which includes leaving home earlier in the morning for commuters;
- Changing position inside the vehicle.

The results of the qualitative study were used to clarify the questionnaires of the stated preferences study, especially with regard to the presentation of crowding levels to the respondents.

Stated preference research

In order to appraise *a-priori* the perceived benefits of future reductions of crowding levels in public transport, it is necessary to know what economic value passengers attach to specific improvements. One way to estimate this value is to conduct a “stated preference” choice experiment (see eg. Louviere *et al.* 2000). In such an experiment a sample of passengers is offered a series of choices between two (or more) hypothetical alternative public transport services. These services differ in some key characteristics, such as travel time, waiting time for the next service and level of crowding inside the vehicles. Passengers are asked to state their preferences for one of the alternatives. In the Île-de-France project it was decided to choose this methodology to conduct the research.

The design of the stated preference survey was based upon previous experience with crowding research reported in the literature (e.g. Li and Hensher 2011, Kroes et. al. 2006, and Wardman and Whelan 2011) and the qualitative research reported in section “ Qualitative research ”. Some of the main elements are summarised below.

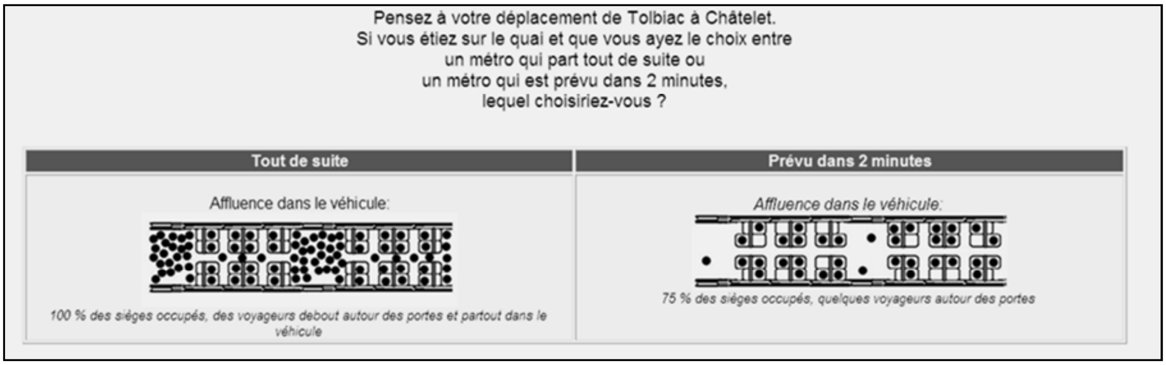
The choices and choice variables

In order to prevent biases, we designed two different choice experiments to measure the value of crowding:

- In SP1 six choices were offered between taking a crowded service immediately, and waiting for the next service that would be less crowded. Each choice differed in the level of crowding of the immediate and next service (both were specified using eight possible levels) and the waiting time (five levels), An example of such a choice is given in Figure 5.1;

- In SP2 six choices were offered between taking a very crowded train with a short travel time, and taking a less crowded train with a longer travel time. Additionally, for each alternative it was specified whether the respondent would be able to find a seat, or that (s)he had to stand. Each choice differed in the level of crowding of the both services (each had eight possible levels), in the travel time (each had eleven possible levels, pivoted on the reported (current) travel time of the respondent), and in the possibility of finding a seat. An example is given in Figure 5.2.

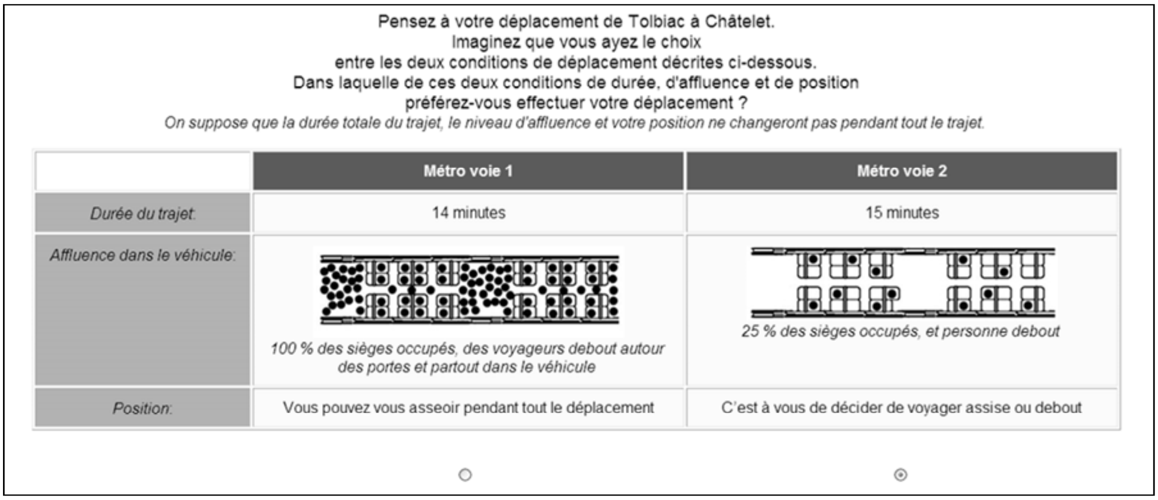
Figure 5.1 **Example of a choice situation from the SP1 experiment**



Pensez à votre déplacement de Tolbiac à Châtelet.
Si vous étiez sur le quai et que vous ayez le choix entre
un métro qui part tout de suite ou
un métro qui est prévu dans 2 minutes,
lequel choisiriez-vous ?

Tout de suite	Prévu dans 2 minutes
Affluence dans le véhicule: *100 % des sièges occupés, des voyageurs debout autour des portes et partout dans le véhicule*	*Affluence dans le véhicule:* *75 % des sièges occupés, quelques voyageurs autour des portes*

Figure 5.2 **Example of a choice situation from the SP2 experiment**



Pensez à votre déplacement de Tolbiac à Châtelet.
Imaginez que vous ayez le choix
entre les deux conditions de déplacement décrites ci-dessous.
Dans laquelle de ces deux conditions de durée, d'affluence et de position
préférez-vous effectuer votre déplacement ?
On suppose que la durée totale du trajet, le niveau d'affluence et votre position ne changeront pas pendant tout le trajet.

	Métro voie 1	Métro voie 2
Durée du trajet:	14 minutes	15 minutes
Affluence dans le véhicule:	*100 % des sièges occupés, des voyageurs debout autour des portes et partout dans le véhicule*	*25 % des sièges occupés, et personne debout*
Position:	Vous pouvez vous asseoir pendant tout le déplacement	C'est à vous de décider de voyager assise ou debout
	○	●

The presentation of crowding

Based upon the literature and the tests conducted during the qualitative research, the eight different levels of crowding were presented by means of both a graphic presentation and a description. Both were adapted to the mode of transport used by the respondent: different presentations were used for rail modes (metro, RER, train, tram) and for the bus. Table 5.2 shows the graphic presentations that were used.

The sample

In total 3,000 public transport users participated in the stated preference survey. They were recruited among the members of a large internet panel. Respondents had to live inside Île-de-France, and had to have made a journey by public transport recently. They were spread over the different passenger segments that were under investigation. These segments differed by:

- public transport mode used;
- residential area;
- age category;
- gender;
- working status (active versus non-active).

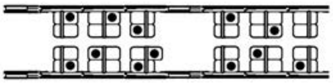
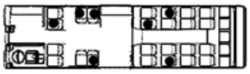
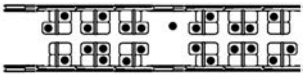
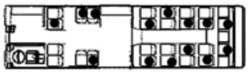
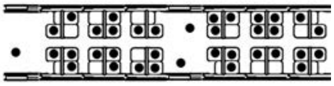
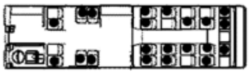
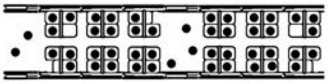
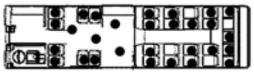
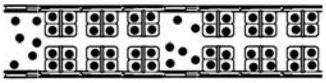
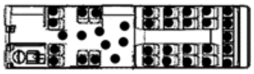
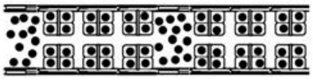
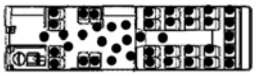
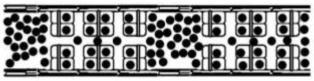
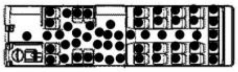
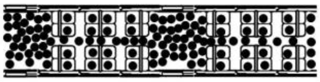
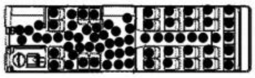
The recruited public transport users were interviewed by internet, using a personalised questionnaire based upon their reported travel characteristics for a recent journey. The interviews took place between September and December 2011.

All responses were subjected to a strict quality control process, checking the following elements:

- responses with out-of-scope origins and destinations were eliminated:
- responses with very short survey completion times were eliminated;
- respondents which did not answer all stated preference questions were eliminated;
- respondents with unrealistically long travel times were eliminated.

After this process we had the SP choices of 2,711 respondents (about 90% of the original sample) available for analysis.

Table 5.2 **Presentation of the crowding levels by mode**

Level	**Number of passengers** *(% of total number of seats)*	**Metro, train, RER, tram**	**Bus**
1	25%		
2	50%		
3	75%		
4	100%		
5	125%		
6	150%		
7	200%		
8	250%		

Typology based upon attitudes

All respondents that participated in the stated preference survey were also asked to answer a series of questions concerning their attitudes towards public transport. They were invited to give a score from 1 to 10 to express their level of agreement with fourteen statements related to public transport, such as *"In public transport, having to stand during your journey is a nuisance"* and "*When it is very crowded in public transport I do not respect anything, it is everybody for himself*".

A statistical analysis was carried out to identify segments of passengers that were similar in terms of their attitudes with respect to public transport. This resulted in four groups of passengers that were homogenous in their public transport attitudes. These four groups ("types")were:

- Type 1: *Passengers fearing closeness of other passengers* (34% of sample). These passengers have more often than average fear for crowds, for dirtiness and for incidents. Standing is tiresome for them and they consider they have the right to get a seat in public transport. Avoiding underground modes and searching for comfort are important criteria in their route and mode choice when using public transport. This group contains, more than average, (i) women, (ii) persons travelling with time constraints, (iii) persons using surface modes, and (iv) persons who are less mobile.

- Type 2: *Passengers enjoying a time of their own* (23% of sample). For this group, the time spent in public transport is a moment of pleasure and relaxation because they can do things they want during their trip. They are not disturbed by the conditions of transport mainly because they experience public transport only when it is not crowded. This group is, more often than average, (i) male, (ii) retired, (iii) using surface transport modes, and (iv) travelling during off-peak hours.

- Type 3: *Passengers wanting to save time* (18% of sample). For these people travelling is not a moment of pleasure: reducing their travel time is important and they attach importance to being seated. This group is more often than average: (i) female, (ii) relatively young, (iii) students or persons working in private sector, (iv) passengers travelling at fixed hours they don't control, (v) users of underground modes, (vi) passengers travelling during peak hours, and (vii) people not owning a driving licence.

- Type 4: *Passengers acting as individualists* (25% of sample). For this group, comfort, punctuality and travel time do not have a major influence on their choices. They are rather insensible to the world surrounding them and they don't care much for other people. When crowding is high, those persons may show impolite behaviour. This group is more often than average: (i) men, (ii) young people, (iii) students, (iv) travelling at fixed travel time they don't control, (v) travelling off-peak.

This typology shows that behaviours towards comfort and affluence differ a lot according to these different groups of travellers. Two underlying causes may explain these differences:

1. the ability of different travellers to choose different modes, routes and departure times. Some can choose when to travel or which mode (public or private) to take. For others, constraints are stronger and they have no choice: they have to travel by public transport and/or at a certain time.

2. intrinsic character differences between travellers: some people are less sensitive to public transport discomfort and annoyances than others.

Analysis of stated preferences

When analysing the responses of the respondents, we noted that a relatively large percentage of the public transport passengers indicated that they were prepared to wait a few minutes in order to travel in a less crowded train: from 13% when the current train is hardly crowded to 75% when the current train is absolutely packed and the next train has seats available. We found this percentage intuitively rather high.

We analysed the choices of the public transport users in the stated preferences experiments to derive the utility weights of each of the service quality variables using discrete choice analysis methods – in this case simple logit analysis based upon maximum likelihood estimation (see eg. Ben-Akiva and Lerman 1985). We have tested a large number of different model specifications. Here we report only some of the most interesting findings.

Crowding level of first train versus next train

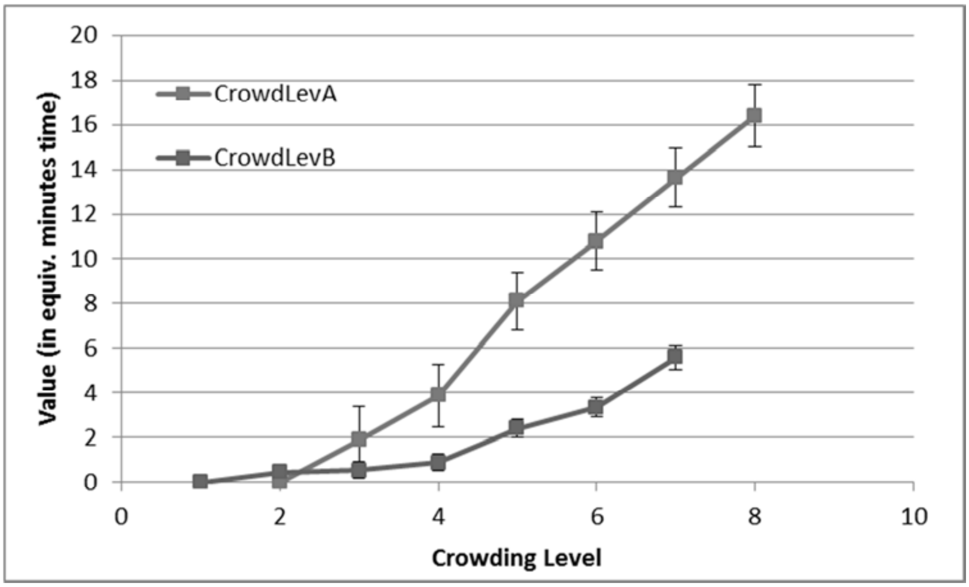
In a first very simple model we estimated only the following coefficients on data from SP1 only:

- seven constants for the crowding levels (level 2 – 8) of the first train[1]. The lowest level was constrained to zero.
- seven constants for the crowding levels (level 1 – 7) of the next train. Again, the lowest level was constrained to zero.
- a linear coefficient for the waiting time between the first and next train,
- and a constant which indicates an intrinsic preference to wait for the next train (i.e. an alternative specific constant).

All coefficients had the expected sign and all were highly significant. The sensitivity of the coefficient to the crowding level of the first train was much greater than that of the next train. The passengers appeared to base their choice primarily on the crowding level of the first train to come, as can be seen from Figure 5.3. Note that in this Figure the crowding coefficients have been divided by the waiting time coefficients to give a vertical scale that can be easily interpreted. A small jump in both the value of the crowding of the first and the next train can be observed between crowding levels 4 and 5, which is exactly the transition to a situation where the traveller can no longer sit if he wants to.

The constant had a value equivalent to 5.2 minutes of waiting time. This can be interpreted as a strong preference to wait for the next train, all other things being equal. Whether this is a real effect, or a statement from the respondents that they are very unhappy with crowded trains, is unclear at this point in the analysis.

Figure 5.3. **Estimated coefficients on crowding**



Constant value per trip versus travel time multiplier

To express the disutility of crowding one can use a single constant value (or penalty) per trip, as was done in the previous paragraph, or one can use a travel time multiplier value. The first type of specification assumes that the crowding effect is irrespective of the duration of travel, the second specification assumes that the crowding effect is proportional to the travel time. The last specification seems intuitively appealing: the longer the journey, the more important it is to travel comfortably. On the other hand it is rare for travellers making long journeys not to find a seat at some stage during the journey, so the crowding does not produce a constant nuisance during the whole journey.

Therefore, we estimated a second model, again on data from SP1 only, with the following coefficients:

- seven coefficients on travel time, each interacting with a crowding level (level 2 – 8) of the first train. The lowest level was constrained to zero.
- seven coefficients on travel time, each interacting with a crowding level (level 1 – 7) of the next train. Again, the lowest level was constrained to zero.
- a linear coefficient for the waiting time between the first and next train,
- a constant indicating an intrinsic preference to wait for the next train,
- and a coefficient on travel time, indicating an intrinsic preference to wait for the next train that is proportional to travel time.

Table 5.3 presents the estimation results for both models. From this, we conclude that the constant value per trip provided a significantly better statistical fit to our stated choice data than the multiplier specification:

Table 5.3 **Estimated coefficients for a model with constants and a proportional model**

```
                       CONSTANTS MODEL  PROPORTIONAL MODEL

Observations                      7638                7638
Final log (L)                  -4477.9             -4645.3
D.O.F.                              14                  15
Rho²(0)                          0.154               0.123
Rho²(c)                          0.141               0.109

Time_Wait              -0.2425 (-24.9)     -0.2160 (-23.0)
CrowdLvA2                    0     (*)           0     (*)
CrowdLvA3              -0.4615  (-1.3)    -0.04453  (-2.5)
CrowdLvA4              -0.9425  (-2.9)    -0.06402  (-3.9)
CrowdLvA5               -1.969  (-6.3)    -0.08944  (-5.6)
CrowdLvA6               -2.615  (-8.4)     -0.1104  (-6.9)
CrowdLvA7               -3.304 (-10.7)     -0.1279  (-8.0)
CrowdLvA8               -3.975 (-12.8)     -0.1452  (-9.1)
CrowdLvB1                    0     (*)           0     (*)
CrowdLvB2              -0.1083  (-1.2)    -0.00484  (-1.5)
CrowdLvB3              -0.1353  (-1.5)    -0.00553  (-1.7)
CrowdLvB4              -0.2172  (-2.4)    -0.00752  (-2.3)
CrowdLvB5              -0.5858  (-6.2)    -0.01868  (-5.5)
CrowdLvB6              -0.8149  (-8.1)    -0.02493  (-7.0)
CrowdLvB7               -1.359 (-10.5)    -0.04303  (-9.5)
ASC_Wait                -1.273  (-4.3)       1.080  (16.5)
ASC_WaitP                    0     (*)    -0.09836  (-6.2)
```

Source: Authors

where Wait is waiting time, CrowdLvA2 is the utility for crowding level 2 for vehicle A (first arriving vehicle), CrowdLvB1 is the utility for crowding level 1 for vehicle B (next vehicle) etc., ASC_Wait is a constant for waiting, ASC WaitP is a preference for waiting proportional to travel time.

It is clear that the CONSTANTS model fits the data much better than the PROPORTIONAL model, even though that model has one additional coefficient. For the SP2 we came to the same conclusion. We also tested a combined model with both constants and coefficients proportional with travel time.

This result is remarkable in that almost all studies in the United Kingdom and several studies conducted elsewhere use the travel time multiplier value to express the disutility of crowding.

Simultaneous estimation using SP1 and SP2

We have estimated separate models for SP1 and SP2, and then we have tested a single joint model using both data simultaneously. It turned out that the resulting values of crowding were not significantly different between both experiments for any of the crowding levels, provided that we used separated scale factors for both SP experiments to account for differences in error. Consequently we have used the simultaneous model specification for deriving the final application coefficients.

Table 5.4 **Estimated coefficients for separate and joint models**

	SP 1	SP 2	SP 1+2
Observations	7638	13116	20754
Final log (L)	-4477.9	-7755.3	-12241.5
D.O.F.	14	15	18
Rho²(0)	0.154	0.147	0.149
Rho²(c)	0.141	0.141	0.141
Time	0 (*)	-0.1767 (-28.9)	-0.1768 (-29.0)
Time_Wait	-0.2425 (-24.9)	0 (*)	-0.1643 (-16.8)
CrowdLvA2	0 (*)	0 (*)	0 (*)
CrowdLvA3	-0.4615 (-1.3)	-0.3482 (-1.0)	-0.3291 (-1.6)
CrowdLvA4	-0.9425 (-2.9)	-0.8730 (-2.5)	-0.6973 (-3.7)
CrowdLvA5	-1.969 (-6.3)	-1.335 (-4.3)	-1.345 (-7.3)
CrowdLvA6	-2.615 (-8.4)	-1.798 (-5.8)	-1.796 (-9.6)
CrowdLvA7	-3.304 (-10.7)	-2.210 (-7.1)	-2.238 (-11.8)
CrowdLvA8	-3.975 (-12.8)	-2.734 (-8.8)	-2.723 (-13.8)
CrowdLvB1	0 (*)	0 (*)	0 (*)
CrowdLvB2	-0.1083 (-1.2)	-0.2910 (-3.8)	-0.1534 (-3.2)
CrowdLvB3	-0.1353 (-1.5)	-0.2965 (-3.8)	-0.1670 (-3.5)
CrowdLvB4	-0.2172 (-2.4)	-0.3627 (-4.6)	-0.2280 (-4.6)
CrowdLvB5	-0.5858 (-6.2)	-0.3915 (-5.4)	-0.3745 (-7.6)
CrowdLvB6	-0.8149 (-8.1)	-0.7417 (-9.7)	-0.6375 (-11.6)
CrowdLvB7	-1.359 (-10.5)	-1.066 (-11.5)	-0.9783 (-13.9)
ASC_Wait	-1.273 (-4.3)		0.8292 (4.9)
ASC_Q		0.7128 (2.4)	0.7938 (4.4)
StandDum2		-0.6625 (-20.1)	-0.6477 (-20.6)
Scale3	1.000 (*)	1.000 (*)	1.000 (*)
Scale2A	1.000 (*)	1.000 (*)	1.474 (18.7)

Source: Authors

A few words about the different time variables that were included in SP1 and SP2: SP1 contained waiting time, and SP2 contained travel time. The ratio between the coefficients for waiting time and travel time can be computed by multiplying the waiting time coefficient in Joint SP 1+2 with the Scale2A coefficient, and dividing by the travel time coefficient. That gives a value of 1.37, which may seem a bit low but is broadly of the expected order of magnitude.

Differences between passenger types

In section “ Typology based upon attitudes ”, we have concluded that four types of respondents can be distinguished based upon their attitudes. We have tested for observed heterogeneity in the results using a range of different socio-economic variable, a number of trip related characteristics, and the typology presented in section “ Typology based upon attitudes ”. We found that generally there was only limited variation in the results between different groups of passengers, but that the typology showed the largest differences. Below we show the results for the four types we distinguished.

The passengers of type 1, fearing closeness of other passengers, are clearly averse of other passengers: for crowding level 4 they already show a significant disutility, they have the highest standing penalty (4.6 minutes) and a relatively large percentage will wait for another train if that can reduce their level of crowding from level 8 to level 4 (53%).

The passengers of type 4, acting as individualists, also show a relatively high percentage of passengers prepared to wait in order to reduce their level of crowding from level 8 to level 4 (55%).

The passengers of type 3, wanting to save time, show rather different preferences: they clearly dislike waiting (high wait penalty), and consequently relatively few passengers of this type are prepared to wait for a less crowded public transport vehicle (40%). Still the difference relative to type 1 and type 4, the other extremes, is not large in absolute terms.

The passengers of type 2, enjoying a time of their own, fall somewhere in between the types 3 and 4 in terms of percentage waiting for a less crowded vehicle (50%). They do not seem to mind very much to wait for another service, or to stand inside the vehicle.

Overall it is clear that there are differences in preferences for avoiding crowding between the four types of passengers, which are plausible and consistent with the definition of the passenger types. But these differences are not very large.

Table 5.5 **Estimated coefficients for each passenger class**

```
                   ALL PASSENGERS          TYPE 1            TYPE 2            TYPE 3            TYPE 4
                                          FEARING          ENJOYING           WANT TO            ACT AS
                                        CLOSENESS              TIME         SAVE TIME     INDIVIDUALIST

Observations                20754             7198              5007              3858              4691
Final log (L)            -12241.5          -3982.1           -2953.3           -2261.1           -2858.1
D.O.F.                         18               18                18                18                18
Rho²(0)                     0.149            0.202             0.149             0.154             0.121
Rho²(c)                     0.141            0.186             0.142             0.151             0.104

Time              -0.1768 (-29.0)  -0.1847 (-17.2)  -0.1911 (-15.2)  -0.2067 (-14.2)  -0.1391 (-11.2)
Time_Wait         -0.1643 (-16.8)  -0.1777 (-10.1)  -0.1701  (-8.9)  -0.1812  (-7.3)  -0.1418  (-6.9)
CrowdLvA2               0     (*)        0     (*)        0     (*)        0     (*)        0     (*)
CrowdLvA3         -0.3291  (-1.6)  -0.4204  (-1.3)  -0.1481  (-0.3)   -1.268  (-1.8)   0.5137  ( 1.1)
CrowdLvA4         -0.6973  (-3.7)  -0.8340  (-2.6)  -0.6195  (-1.6)   -1.419  (-2.0)   0.1506  ( 0.4)
CrowdLvA5          -1.345  (-7.3)   -1.446  (-4.6)   -1.344  (-3.6)   -2.257  (-3.2)  -0.4335  (-1.1)
CrowdLvA6          -1.796  (-9.6)   -2.060  (-6.4)   -1.656  (-4.4)   -2.567  (-3.6)  -0.9738  (-2.5)
CrowdLvA7          -2.238 (-11.8)   -2.500  (-7.6)   -2.260  (-5.9)   -2.936  (-4.0)   -1.343  (-3.4)
CrowdLvA8          -2.723 (-13.8)   -2.912  (-8.5)   -2.936  (-7.4)   -3.419  (-4.6)   -1.775  (-4.5)
CrowdLvB1               0     (*)        0     (*)        0     (*)        0     (*)        0     (*)
CrowdLvB2         -0.1534  (-3.2)  -0.1862  (-2.2)  0.00201  ( 0.0)  -0.1425  (-1.4)  -0.3096  (-2.9)
CrowdLvB3         -0.1670  (-3.5)  -0.2701  (-3.1) -0.00709  (-0.1)  -0.1621  (-1.6)  -0.1886  (-1.8)
CrowdLvB4         -0.2280  (-4.6)  -0.3076  (-3.4)  -0.1591  (-1.5)  -0.2120  (-2.1)  -0.2405  (-2.2)
CrowdLvB5         -0.3745  (-7.6)  -0.4859  (-5.4)  -0.2527  (-2.5)  -0.3848  (-3.7)  -0.3543  (-3.3)
CrowdLvB6         -0.6375 (-11.6)  -0.7561  (-7.6)  -0.4859  (-4.4)  -0.6634  (-5.4)  -0.6627  (-5.7)
CrowdLvB7         -0.9783 (-13.9)   -1.018  (-8.2)  -0.9339  (-6.4)  -0.9667  (-6.2)   -1.037  (-6.7)
ASC_Wait           0.8292  ( 4.9)   0.6939  ( 2.4)    1.065  ( 3.0)    1.782  ( 2.6) -0.09981  (-0.3)
ASC_Q              0.7938  ( 4.4)   0.6585  ( 2.1)    1.006  ( 2.7)    1.754  ( 2.5) -0.03105  (-0.1)
StandDum2         -0.6477 (-20.6)  -0.8457 (-14.9)  -0.5516  (-8.6)  -0.7337 (-10.0)  -0.4390  (-6.9)
Scale3              1.000     (*)    1.000     (*)    1.000     (*)    1.000     (*)    1.000     (*)
Scale2A             1.474  (18.7)    1.470  (10.9)    1.395  (10.3)    1.762  ( 7.7)    1.314  ( 8.3)


Wait penalty fac   1.37             1.41             1.24             1.54             1.34

Standing penalty (in equivalent minutes of travel time)
                   3.66             4.58             2.89             3.55             3.16

Difference in crowding utility between A8 and A4 (in equivalent minutes of travel time)
A8-A4             11.5             11.3             12.1              9.7             13.8

Percentage waiting 10 minutes for an improvement of A8 to B4
                   51%              53%              50%              40%              55%
```

Source: Authors

Coefficients for application

Having observed that the constant crowding effect per trip provided a better explanation of the stated choices than the travel time multiplier value, we have nevertheless derived a set of coefficients for application usage based upon the multiplier specification. Crowding penalties that are proportional to travel time can easily be added to the models that are used for appraisal purposes, whereas constant penalties are much more difficult to apply in practice. This has to do with the use of public transport assignment software, and the uncertainty about the application of constants for interchanges (does one apply a bus penalty once or twice for a bus-bus interchange?). Also for application in cost-benefit analyses we often know the occupancy rate between different stops, but not the exact numbers of passengers boarding/leaving at each station.

The coefficients for application are given below in Table 5.6, first for all public transport modes except coach, and then separately for different (combinations of) modes. Here we have constrained the coefficients for crowding levels 1, 2 and 3 to 0 as the values were insignificant.

Table 5.6 **Estimated mode-specific coefficients for a proportional model**

	ALL NOT CAR		METRO		TREIN+RER		BUS+TRAM	
Observations	20754		4490		7668		8596	
Final log (L)	-12534.9		-2737.7		-4471.1		-5266.4	
D.O.F.	14		14		14		14	
Rho²(0)	0.129		0.120		0.159		0.116	
Rho²(c)	0.120		0.110		0.145		0.110	
Time	-0.1473	(-24.4)	-0.1535	(-11.8)	-0.1514	(-15.2)	-0.1434	(-15.2)
Time_Wait	-0.1311	(-12.3)	-0.1219	(-5.4)	-0.1513	(-7.9)	-0.1384	(-7.8)
CrowdLvA23	0	(*)	0	(*)	0	(*)	0	(*)
CrowdLvPP	-0.01217	(-15.8)	-0.01187	(-6.3)	-0.01100	(-10.7)	-0.01465	(-9.8)
CrowdLvB1	0	(*)	0	(*)	0	(*)	0	(*)
CrowdLvB24	-0.00392	(-3.1)	-0.00254	(-1.0)	-0.00539	(-2.8)	-0.00282	(-1.2)
CrowdLvB5	-0.01044	(-6.4)	-0.00630	(-2.1)	-0.01350	(-5.5)	-0.00813	(-2.8)
CrowdLvB6	-0.01620	(-9.0)	-0.01263	(-3.5)	-0.01770	(-6.6)	-0.01680	(-5.2)
CrowdLvB7	-0.02599	(-11.1)	-0.01608	(-3.5)	-0.02762	(-8.0)	-0.03068	(-7.2)
StandDum1	0	(*)	0	(*)	0	(*)	0	(*)
StandDum2	-0.01495	(-6.2)	-0.01553	(-2.8)	-0.01377	(-4.1)	-0.01634	(-3.6)
StandDumPP	-0.00330	(-3.5)	-0.00220	(-1.1)	-0.00375	(-2.9)	-0.00333	(-1.9)
StandDum3	0	(*)	0	(*)	0	(*)	0	(*)
ASC_Q	-0.9021	(-20.9)	-0.8900	(-9.8)	-0.9780	(-12.8)	-0.9062	(-13.5)
ASC_QP	0.03307	(11.6)	0.03861	(5.4)	0.02608	(6.8)	0.04513	(8.1)
ASC_Wait	0.6460	(10.7)	0.5277	(5.0)	1.001	(7.4)	0.6132	(6.5)
ASC_WaitP	-0.03080	(-12.4)	-0.03645	(-5.7)	-0.02796	(-7.7)	-0.03893	(-8.2)
Scale3	1.000	(*)	1.000	(*)	1.000	(*)	1.000	(*)
Scale2A	1.645	(13.2)	2.088	(5.6)	1.546	(8.7)	1.616	(8.2)

Source: Authors

These multipliers for application usage were derived for all modes together but also separately for metro, train+RER (i.e. regional rail), bus and tram. The results are given in Table 5.7. Note that we have based these values upon the crowding level of the first train only.

Table 5.7 T**ravel time multipliers as a function of the level of crowding for different public transport modes in Île-de-France**

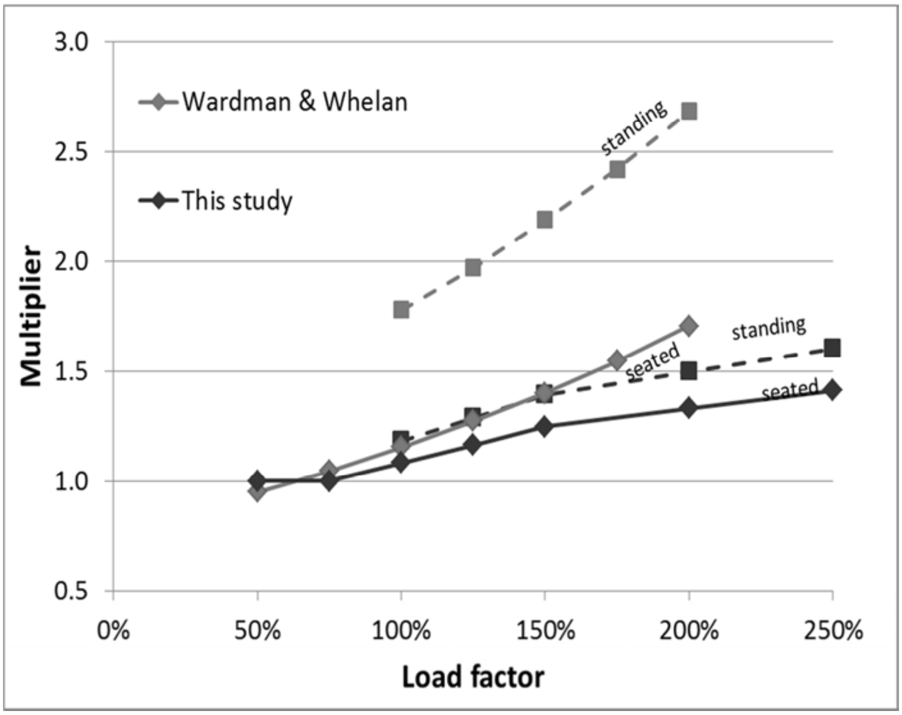
Crowding level	All modes		Metro		Train+RER		Bus+Tramway	
	Seated	Standing	Seated	Standing	Seated	Standing	Seated	Standing
1	1.000		1.000		1.000		1.000	
2	1.000		1.000		1.000		1.000	
3	1.000		1.000		1.000		1.000	
4	1.083		1.077		1.073		1.102	
5	1.165	1.289	1.155	1.270	1.145	1.261	1.204	1.342
6	1.248	1.394	1.232	1.362	1.218	1.358	1.307	1.467
7	1.330	1.499	1.309	1.453	1.290	1.456	1.409	1.593
8	1.413	1.604	1.386	1.545	1.363	1.553	1.511	1.718

Source: Authors

These multipliers can be compared to the multipliers found by Wardman and Whelan (2011) for (longer-distance) rail travel in the United Kingdom. For crowding levels 5, 6, and 7 standing they found respectively 1.97, 2.19 and 2.69, substantially higher than our values (see Figure 5.4). We can add to that that professor Wardman (2012) has indicated previously that he felt that those UK values, based upon SP, seemed intuitively rather high.

Our results cannot be directly compared to the previous studies in Paris (Haywood and Koning 2011, Kroes *et al.* 2006), since these researches did not derive travel time multipliers. However, we have converted our final values into similar units as used in these studies, and from this comparison it turned out that our values were in agreement with those results.

Figure 5.4. **Comparison between multipliers obtained in this study and those reported by Wardman and Whelan 2011**



Source: Authors

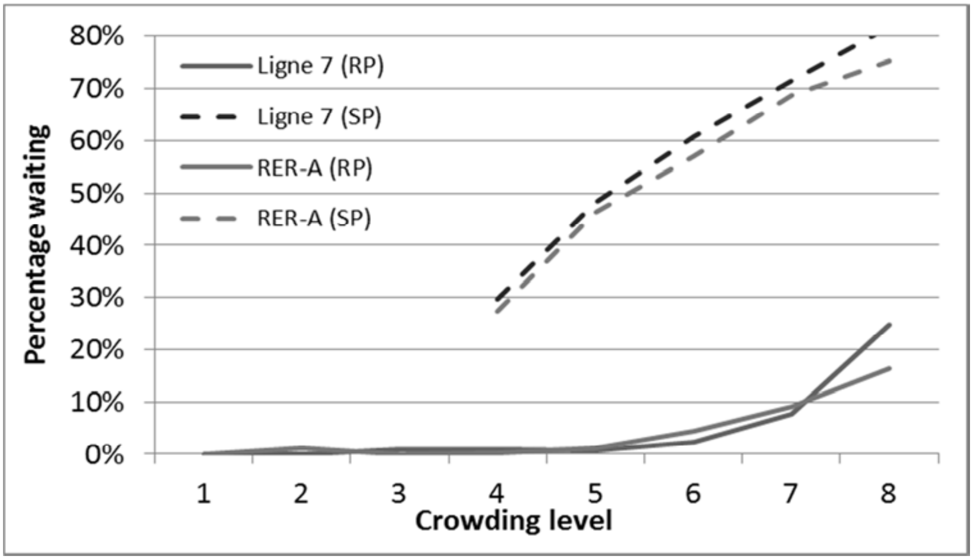
Revealed preference research

We have looked for possibilities to verify the findings of our SP survey in a real-world (or Revealed-Preference) situation. We identified some locations where public transport travellers were making trade-offs between waiting time and level of crowding, somewhat comparable with the choice situations in SP1. Just before the metro stations Maison Blanche and Tolbiac (line 7) and just before the RER station Vincennes (line A) two branches of the same railway line come together. These branches have the same frequency of service, but very different passenger numbers. As a result, crowded and less-crowded metros/trains are alternating systematically during the morning peak (in the direction of the city centre). Passengers who are familiar with these locations can be expected to be aware of this alternating pattern, and hence the fact that very crowded trains are likely to be followed by a much less crowded train.

During 12 days, we counted both the number of passengers that boarded the crowded trains directly, and the number of passengers that waited for the next (less-crowded) train. This allowed us to determine the percentages of waiting passengers in reality, as a function of the crowding level of the arriving train and the next train, and with a short waiting time between subsequent trains. We interviewed travellers about their reasons for waiting, in order to correct the observed percentages for those people who waited for valid reasons which had nothing to do with the crowding level (e.g.

destination not served by certain train). The resulting percentage of passengers waiting (after correction) varied from 0% when the current train was hardly crowded to some 25% when the current train was absolutely packed, see Figure 5.5.

Figure 5.5 **Percentage of passengers waiting for next train as a function of crowding level of current train**



Source: Authors

Figure 5.5 also shows the percentage passengers waiting as derived from the SP models. It appears that the percentages of passengers observed to wait in reality are substantially lower than those obtained from the SP data. So there seemed to be a substantial difference between the SP answers and the RP observations. In the next section we discuss possible reasons for this.

Discussion and resulting values of crowding

The question now is what values should be used for application for socio-economic evaluation: the values derived from the seemingly high SP-percentages or values derived from the substantially lower RP-percentages? After some reflection we came to the following reasoning.

There are a number of reasons why it might be useful, and even necessary to correct the results of our SP experiments for application in a CBA context: the possibility of SP bias, the fact that the SP questions assumed constant crowding during the entire journey, and the fact that in the SP questions respondents are 100% certain about crowding level of current and next vehicles and the exact waiting time.

There are also several reasons why the RP data may possibly be flawed as well: not all passengers will know that the next train was likely to be less crowded, in reality passengers have no certainty about the waiting time and about the crowding level of the next train[2].

So in reality only those passengers who were very experienced might decide to wait, and they would still have uncertainty about what their cost (waiting time) and benefit (improvement in crowding level) would be. This would lead to less passengers waiting relative to the theoretically ideal situation to determine the value of crowding, which would be measured when there is certainty about the variables that are being traded (waiting time versus reduction in crowding level).

On the balance, the SP data may be subject to error, but the direction and the size of the error are unclear. The RP data are also likely to be subject to error, but here the direction of the error is clearer: here we would observe fewer waiting people than would be the case in the ideal trading situation for measuring the value of crowding.

When it comes to answering the question which results, based upon SP or based upon RP data, comes closest to providing the pure value of crowding, we are inclined to give the following answer:

- The real value of crowding is likely to be somewhere between the values provided by the SP data and the RP data.
- Theoretically the real value of crowding could be even higher than the SP values;
- But it is extremely unlikely that the real value of crowding will be lower than the RP values; quite the opposite, the value based upon the RP data are almost certainly an underestimation of the real value of crowding;
- On the balance, we feel that the value based upon the SP data is likely to be closest to the real value of crowding.

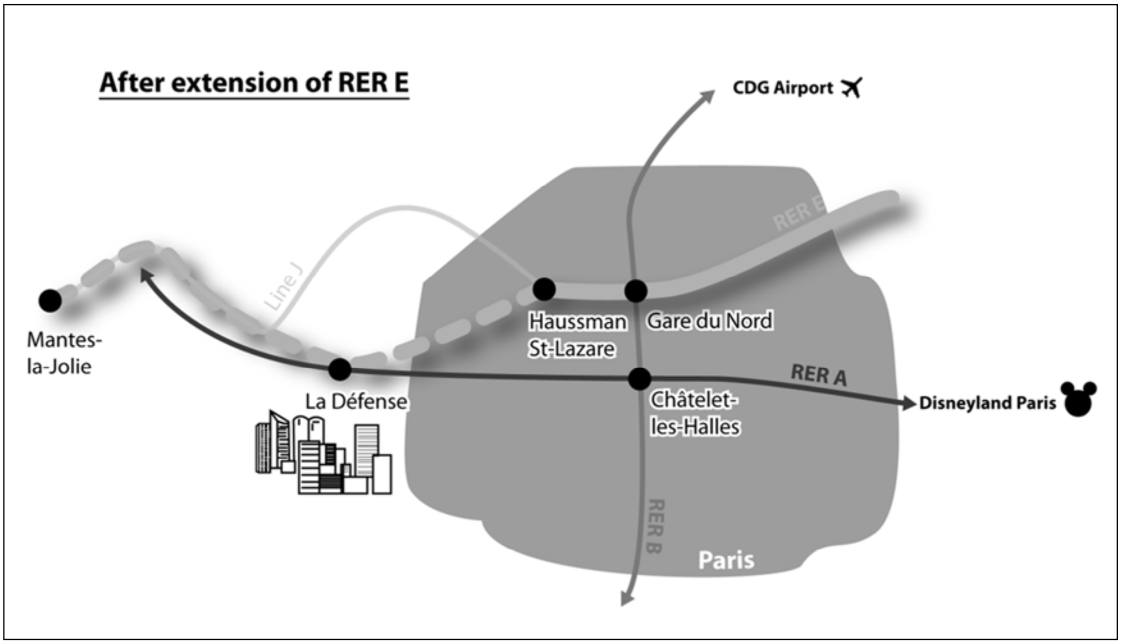
So we concluded that the SP values were to be used for socio-economic evaluation.

Example of cost-benefit-analysis application

Extension project of RER E

The resulting values of crowding as reported in Table 5.5 have been applied to a specific project: the extension of the regional rail line RER E to the western suburbs of Paris (see Figure 5.6). The underground tunnel will be extended towards the La Défense business district and connected to an existing suburban railway line which will be upgraded. It will offer an alternative to the existing RER A line, which partially runs in parallel to the RER E extension. At its western end, the line will serve the Seine Aval territory and strengthen the projects of urban regeneration and economic development planned in this area. The cost of investment of the RER E extension is estimated between 3,1 and 3,5 billion Euros. The public inquiry was conducted in 2012 and the project granted approval thereafter. It is planned to open in 2020.

Figure 5.6 **RER A, RER B, RER E and extension (dashed) in their central sections within Île-de-France**



Source: STIF

Estimation of the discomfort reduced by the project

The estimation of the discomfort that passengers will no longer experience after the construction of RER E, when travelling by RER A and B, is based on the following steps.

Step 1: Traffic forecast

A demand model was used to estimate the number of passengers during the morning peak hour for each link connecting two stations, with and without the extension. Only the sections of RER A and B lines, where high crowding levels have been observed, are expected to experience significant impacts and have been selected for analysis. The project will lead to a diminution of traffic on these links, which are indicated in Table 5.8.

Table 5.8 **Results of traffic modelling without and with the extension of RER E**
(forecasts on a morning peak hour in 2020)

Line and direction	**From**	**To**	**Traffic volume**		**Change** (%)
			Without extension	With extension	
RER A westbound	Vincennes	Nation	35,300	34,900	-1%
	Nation	Gare de Lyon	37,100	36,500	-2%
	Gare de Lyon	Châtelet-Les H.	44,700	39,400	-3%
	Châtelet-Les H.	Auber	44,700	39,400	-12%
	Auber	Etoile	40,600	32,300	-20%
	Etoile	La Défense	37,000	28,700	-23%
RER A eastbound	La Défense	Etoile	24,100	20,400	-15%
RER B southbound	Gare du Nord	Châtelet-Les H.	27,400	24,800	-9%

Step 2: Calculation of benefits in equivalent travel time

Traffic levels have been converted into levels of crowding as used in the stated preferences surveys with levels from 1 to 8. At level 4, all seats are taken and at level 8 people are also standing and the maximum capacity of services is reached.

The results of the stated preferences survey gave multipliers to apply to real travel time to obtain perceived travel time according to the experienced level of crowding inside a vehicle. For the specific case of RER E, the corresponding RER coefficients have been used (see Table 5.2). For the calculation for the RER E project, the expected future capacities for RER A and B were needed:

- For RER A, a capacity of 62,400 travellers per hour during peak hours is considered for the westbound direction and 52,000 for the eastbound direction, 36% of the total passenger capacity consists of seats in both directions.
- For RER B, the capacity during peak hours is the same in both directions: 28,600 travellers per hour, 26 % of the capacity are seats.

The change in time perceived by the passengers is calculated using the following formula:

$$\Delta \mathrm{Time}_{perceived} = (N_{PAXseatedbefore} \cdot \alpha_{seatedbefore} + N_{PAXstandingbefore} \cdot \alpha_{standingbefore}) - (N_{PAXseatedafter} \cdot \alpha_{seatedafter} + N_{PAXstandingafter} \cdot \alpha_{standingafter})$$

where $\Delta \mathrm{Time}_{perceived}$ is the change in perceived travel time between before and after the project, $N_{PAXseatedbefore}$ the change in the number of seated passengers before the project and $\alpha_{seatedbefore}$ the multiplier is for seated passengers before the project, etc. The calculations are done link by link and added to obtain the total value. The results are given in Table 5.9 below.

Table 5.9 **Perceived travel time with and without RER E extension during morning peak hour taking crowding into account for all passengers per link**

Line and direction	From	To	Travel time (min.)	Perceived travel time (hours)	
				Without extension	With extension
RER A westbound	**Vincennes**	**Nation**			
	Nation	**Gare de Lyon**			
	Gare de Lyon	**Châtelet-Les H.**			
	Châtelet-Les H.	**Auber**			
	Auber	**Etoile**			
	Etoile	**La Défense**			
RER A eastbound	**La Défense**	**Etoile**			
RER B southbound	**Gare du Nord**	**Châtelet-Les H.**			
Total					

In total, during one morning peak hour, the diminution of perceived travel time due to the RER E extension project is estimated at 1,239 passenger hours. To expand the result from one peak hour to a year, this number has been multiplied by 5 to obtain daily results (2 peak hours in the morning and 3 in the evening) and by 210 to obtain yearly results (working days except summer holidays). The result is a total of 1,3 million passenger hours saved in one year.

Step3: Conversion into monetary benefit

Using the standard value of time for public transport project appraisal in Île-de-France (€17,7 per hour, value 2010), this 1.3 million hours has been converted into a benefit of €23 M for a whole year, or €480 M summed over a period of 30 years using a discount rate of 8%. This result can be compared with the investment costs of the project (3.1 to 3.5 Billion Euro) and the operating cost (estimated at 88 M per year). Note that the travel time benefits generated by the project over the 30 year period were estimated at €6,100 M, and the modal shift benefits at €2,300 M. In comparison the crowding effect adds about 6% to the total project benefits.

Concluding remarks

The most important findings of this research are:

1. We found that passengers' decisions to wait for a less crowded public transport vehicle were primarily determined by the level of crowding of the first vehicle to arrive. The (announced) crowding level of the next vehicle appeared to be much less important;
2. We found that a constant utility per trip specification provided a clearly better fit to the stated choice data than the travel time multiplier specification commonly used in literature. Despite this better fit we have chosen for a multiplier specification for our application coefficients. This choice, however, was entirely based upon practical reasons, the ease of application, rather than upon data-based evidence;

3. We found that the heterogeneity between different groups of passengers was fairly limited. The attitude-based typology showed the largest discrimination in preferences for avoiding crowding, with for instance the time-sensitive type of passengers (Type 3) being clearly less inclined to wait for another less crowded public transport service than the (Type 1) passengers fearing closeness of other passengers.
4. We found that revealed preference data suggested a much lower willingness to wait for less crowded vehicles than the stated choice data suggested. However, there are many reasons why it is likely that the RP data underestimated the real willingness to wait, and therefore we kept the values derived from the stated choices without any downward adjustment;
5. The values of crowding that we found were broadly in agreement with those obtained in two other studies carried out in the Île-de-France region. Compared to the values found for rail travel in the UK, however, they were substantially lower.

It is clear that more value of crowding studies, conducted in similar and different contexts, are needed before more definitive and more general conclusions can be drawn with respect to the value of crowding in public transport. In the meantime, our results will be used for cost-benefit evaluations of transport projects in the Île-de-France region.

Acknowledgements

We want to thank STIF who financed and supervised the study reported here. Of course the final responsibility for the paper remains entirely and solely with the authors.

Notes

1. In this section, we refer to first “train” and next “train”. However, the analysis was done on a joint dataset for all modes (train, RER, metro, bus, tram).

2. One might argue that in reality there is always uncertainty about waiting times and crowding levels of next trains. However, our aim is to establish values of crowding to assess the crowding benefits of a service that is structurally less crowded, which is the case if you build a parallel line or if you increase the frequencies of vehicle capacities. In these cases you remove the uncertainty, so you want to have a value without uncertainty.

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The user experience, in terms of reliability, comfort and above all convenience, is critical in determining demand for public transport services, at least where there is a choice of alternatives. The success or otherwise of policies to attract urban car users to public transport hinges to a large degree on convenience of use. But current transport evaluation methods tend to focus on speed and price and undervalue or neglect convenience. This skews planning and investment decisions.

This report aims to facilitate more systematic consideration of convenience in transport planning and policy making. It reviews operational definitions of convenience, evidence for the willingness of users to pay for convenience and the use of indicators to access and improve the convenience of public transport.

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