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# COSTS OF INTERCHANGE: A REVIEW OF THE LITERATURE

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# 1. INTRODUCTION

Interchange within mode influences the demand for that mode through the effect it has on time spent waiting, time spent transferring between vehicles and the inconvenience and risks involved, whilst interchange between modes has additional implications in terms of information provision, through ticketing and co-ordination. The valuation and behavioural impact of each of these factors will vary with an individual's socio-economic and trip characteristics as well as with the precise features of the interchange.

A reduction in the costs of interchange brought about by an improvement to any of the above factors will lead to increasingly 'seamless journeys' and such benefits which must be quantified. Indeed, this issue has been identified as an area of key importance in the Government's Transport White Paper (DETR, 1998a) which states:

> *Quick and easy interchange is essential to compete with the convenience of car use.*

This message was reiterated by the draft guidance for Local Transport Plans (DETR, 1998b), which called for:

> *… more through-ticketing, better connections and co-ordination of services, wider availability of information and improved waiting facilities.*

Rather than being perceived simply as a barrier to travel, quality interchange is now also being regarded as an opportunity to create new journey opportunities. A recent report on the subject of interchange (Colin Buchanan and Partners, 1998) claimed that :

> *It will become more sensible and economic to base public transport networks around the concept of interchange rather than the alternative of trying to avoid it.*

whilst in response to the diffuse travel patterns made possible by increased car availability, CIT (1998) commented:

> *… people should readily be able to complete a myriad of journeys by changing services (and modes) if a through facility is not available. Ease of interchange should be something we take for granted.*

Regardless of the precise direction in which transport policy and public transport provision develop, practical constraints and the fact that the most heavily trafficked routes tend to have through services places limitations on the extent to which the need to interchange can be reduced whilst no matter how fully integrated different modes of transport are the need to transfer between them cannot be removed. In contrast, the need to change would inevitably increase with the adoption of a practice of building networks around interchange to create new journey opportunities. However, there is considerable scope to improve existing interchange situations or to design new ones which impose minimum costs. Although previous empirical research has focused on the need to interchange or not, and this remains important, it is essential that research is also directed at improvements which facilitate interchange.

The aims of this study, as set out in the terms of reference, are centred around the demand side response to interchange rather than the technical supply side issues relating to improving interchange and integration which have been covered in other studies (Colin Buchanan and Partners, 1998; CIT, 1998). The objectives are:

- to explore the extent to which the reality and perception of interchange deters public transport use, absolutely and in relation to other deterrents

- to investigate how public transport users perceive interchange; how they make choices and trade-offs in travel cost and time and the influence of interchange attributes (e.g. information, through ticketing) on those choices

- to assess which components of interchange act as the greatest deterrent to travel

- to investigate the extent to which interchange penalties vary according to journey purpose, distance and time of travel (or other factors).

A useful starting point is to conduct a review of studies which have contributed to understanding in this area and this is the purpose of this document. We must point out at the outset that there remains much to be researched in the area of interchange and integration, although there is more evidence than is widely regarded to exist albeit dominated by research conducted in the rail market. One of the most significant pieces of research into the demand for public transport (TRRL, 1980, p233) stated:

> *No general results are available to indicate under what conditions a 'line-haul' with feeder system is preferable to a more directly-routed system and more studies on these lines would be useful.*

The need for further research in the area of interchange remains, as was pointed out in the recent report to DETR (Colin Buchanan and Partners, 1998) and recognised, as we shall see, in a number of other studies.

Whilst many of the specific empirical results regarding interchange might not be appropriate to contexts other than those in which they were estimated, there are several aspects of the results which are much more transferable, including issues relating to methodology and what might be termed 'relative results' which indicate how values, behaviour, perceptions or attitudes vary across different circumstances. For example, although the absolute interchange penalties for inter-urban rail travel are inappropriate for urban bus travel, variations according to person type can be expected to be much more similar.

The structure of this paper is as follows. Section 2 sets out the theoretical background and outlines the key features of the different approaches that can be used to estimate interchange valuations. Sections 3, 4 and 5 review respectively the empirical evidence relating to interchange valuations, behavioural response to interchange, and integration. Qualitative research which has examined individuals' perceptions, preferences and attitudes is covered in section 6 whilst asymmetries in behaviour and alternative theories of choice are considered in section 7. Section 8 discusses studies which have addressed the issues of design standards and guidelines for interchange. An approach to interchange analysis centred around various types of effort involved is outlined in section 9 and section 10 provides concluding remarks and recommendations.

## 2. THEORY OF INTERCHANGE EFFECTS AND ESTIMATION METHODS

The evaluation of changes in interchange conditions, the degree of integration or in the need to interchange serves two possible purposes:

- to establish the impact of such changes on the demand for the mode in question and possibly on the demand for other modes

- to determine the benefits of the changes from a welfare point of view which requires valuations of interchange attributes in equivalent monetary or time units.

The two aspects are closely related: a social appraisal requires demand forecasts in addition to valuations whilst valuations can be used to forecast demand. We therefore examine interchange from both a valuation and a behavioural perspective.

### 2.1 Interchange Valuations

We regard the utility of having to interchange ($U_{int}$) as having three principal components:

- a requirement to interchange (I) which has a penalty associated with it ($\alpha$) independent of the amount of time spent interchanging

- the time spent transferring between vehicles (TT) with a weight $\beta$

- the time spent waiting for the connection (W) with a weight $\delta$

Expressed as a linear-additive function, this utility[1] of interchange is:

$$U_{\text{int}} = \alpha I + \beta TT + \delta W$$

[1] The utility of interchange can be regarded as the overall cost of interchange.

Both $\beta$ and $\delta$ are generally expected to be negative, and are traditionally taken to have twice the value of in-vehicle time, although both could conceivably be zero or positive; for example, because the time spent between services can be used for some productive purpose, such as shopping, or because it provides a break on a long journey. $\alpha$ is also expected to be negative but is not inevitably so.

However, prior to discussing the influences on $\alpha$, $\beta$ and $\delta$ in more detail, we must recognise that an individual does have some control over the disbenefits of interchange by means of their behavioural response. What we are essentially saying here is that we cannot take $U_{int}$ as exogenously determined, even for a fixed interchange location.

Disregarding the impact of interchange on mode choice, destination choice or on frequency of travel, a number of options can be open to a public transport user at the stage of planning the journey when faced with having to interchange. These are:

i) Interchange and use the closest connecting service

ii) Interchange and use the previous connecting service

iii) Take the previous interchange service

iv) Travel at some other time which does not involve interchange or where $U_{int}$ is lower

v) Travel by another route which does not involve interchange or where $U_{int}$ is lower

The interchange penalty will be less in option 2 than option 1 since the chance of missing the connection is reduced, but offsetting this is that option 2 will have a greater expected wait time and will also involve the additional disutility of having to depart sooner than preferred. MVA (1985) reported that 55% of inter-urban rail travellers sometimes travel earlier than necessary to be sure of catching a connection. Option 3 may be chosen to ensure arrival time constraints are satisfied and may involve a different interchange penalty to option 1 but certainly requires a less ideal departure time and generally arriving early. Option 4 incurs a large departure time shift whilst Option 5 must involve a longer journey time, or some other penalty, since it would otherwise be preferred. MVA (1985) found that 24% of the 17% who were on through trains had chosen it to avoid interchange whilst 13% of the 83% who had to interchange did so even though they could have made their journey by a through train. Through trains which are not particularly attractive may lead rail travellers to be prepared to change in order to achieve a faster journey, but there is also a relatively strong aversion to changing.

The values of $\alpha$, $\beta$ and $\delta$ will depend on:

- factors specific to interchange and the environment in which interchange is made

- socio-economic and trip characteristics specific to individuals.

How the values of α, β and δ can be estimated is discussed in section 2.5.

(i) Interchange Penalty α

The interchange penalty can be expressed as follows:

$$\alpha = \lambda_0 + \lambda_1 E(W) + \lambda_2 E(A) + \lambda_3 NL + \lambda_4 PJ + \lambda_5 TC$$

$\lambda_0$ represents a fixed level of penalty around which α varies. This represents the inconvenience of having to change vehicles, but note that it could actually be positive for some people who would welcome a break during the course of a journey. E(W) and E(A) are the expected additional waiting time due to a connection being missed and the expected difference in comfort . The latter might represent differences in the type of vehicle or changes in standing requirements. NL represents non-linear effects, for example, the value of a second interchange being different to a first interchange, and PJ is the position in the journey where the interchange occurs which could impact on the perceived penalty of having to change.

The expected additional wait time depends on the probability of missing the connection and the wait time until the next service along with the reliability of the connecting service. In turn, the probability that a connection is missed depends on the connection time, the reliability of the connecting service and whether the connection is guaranteed. Note that when a connection is not guaranteed, reductions in the connection time (TT+W) below some safety margin will actually reduce utility.

Finally, TC denotes the transaction costs of interchange. These relate to the gathering of information and any financial handicap or time penalties of rebooking. In addition, costs associated with integration between modes should also be included.

(ii) Transfer Time Value β

This value will depend upon the nature of the transfer between vehicles and could also depend on the amount of transfer time. In the case of a train journey, β will depend upon whether the transfer is cross platform, between platforms or between stations and also upon the conditions in which the transfer takes place. In addition, the between platform transfer value will depend on facilities at the station, such as lifts, stairs, subways and escalators and may well be very specific to the station concerned, whilst the between station transfer will depend on how the journey is made and the safety and comfort surrounding it. Assistance with luggage and how busy the station is will also have an impact. Analagous factors relate to the β for bus journeys. For example, the environment in which the transfer is made and the difficulty involved will vary according to whether the transfer is within a bus station, between bus stations, between a bus station and bus stops or between bus stops.

(iii) Wait Time Value $\delta$

The value of wait time will vary according to the comfort of the interchange location, the security of the interchange location and the opportunities for engaging in worthwhile activities, whilst the unit value could depend on the amount of waiting time.

The above discussion of variations in $\alpha$, $\beta$ and $\delta$ largely centres around different interchange types and conditions. These can in principle be measured. However, there are also variations in $\alpha$, $\beta$ and $\delta$ which relate to factors specific to the individual. In some cases this variation can be linked to observable and measurable characteristics, such as age, gender, journey purpose, distance travelled and group travel, whereas other sources of variation, such as those due to differences in expectations, aspirations and preferences, are less readily isolated.

## 2.2 Interchange and Behaviour

We here outline the relationship between interchange valuations and demand. This is here done from the perspective of conventional economic theory which dominates models of travel behaviour. Alternative theories, which we believe it is important to consider in this context, are outlined in sections 7.

A decision maker, whether it be individual or group, is assumed to choose amongst available travel activities and alternatives on the basis of highest utility. Thus if there are two options between which an individual can choose, such as two routes, two modes or two different departure times, option 1 will be preferred if:

$$U^1_{\text{int}} + U^1_{rest} > U^2_{\text{int}} + U^2_{rest}$$

where $U_{\text{rest}}$ denotes the utility associated with the travel attributes which influence choice other than those contained in $U_{\text{int}}$. What is termed compensatory decision making is here assumed, whereby the poor performance of one or more attributes can be compensated by the good performance of others in determining the overall attractiveness of an option.

Aggregate demand is the sum of individual choices. Elasticity measures can be calculated to indicate the sensitivity of demand to changes in the need to interchange or in interchange conditions. The elasticity will vary according to the factors which lead to variations in $\alpha$, $\beta$ and $\delta$.

## 2.3 Interchange and Integration

We have here made a distinction between interchange and integration. The definition offered by Stokes and Parkhurst (1996) is:

*the word integration implies that journeys can be made more easily using interchange*

Interchange involves transfer between vehicles. Within mode interchange can be zero but journeys which involve more than one mode inevitably require a transfer between them. The costs of this transfer between modes will additionally depend upon the extent to which they are integrated. Over and above the interchange conditions and environment, this includes factors such as information provision, through ticketing, the ease and cost of parking, provision for cycling and of taxis, and scheduling/co-ordination of modes. Studies which have examined integration are reviewed in section 5.

## 2.4 Interchange Barriers

Discussions of interchange, taken as both between and within modes, often distinguish between different barriers to travel. The recent report on interchange to DETR (Colin Buchanan and Partners, 1998) categorises the barriers to interchange as: physical, timing/reliability, ticketing/financial cost, information, organisational/institutional, quality and passenger expectations. The EU fourth framework project MIMIC groups barriers to intermodality as logistical/operational, psychological, institutional/organisation, physical design, local planning and land use, economic and social, and information.

The demand side aspects listed above are covered in our typology either directly or as factors which lead to variations in $U_{int}$ across individuals or situations. Although typologies along the lines above are useful, particularly in ensuring a structured approach to covering all the factors which could influence $U_{int}$, the categorisations are not particularly useful from the perspective of developing transport demand models. They are therefore a means to an end, rather than an end in themselves. However, we do favour the examination of interchange as a deterrent to travel by examining particular features at a very disaggregate level provided that they are sufficiently well defined rather than vague concepts. Indeed, the third of the study objectives requires an assessment of which components of interchange act as the greatest deterrent to travel.

As an example, standard market research often identifies factors which are most important to individuals. In the context of interchange, individuals might be asked to indicate the importance of ‘easy transfers’, ‘short connection times’, ‘adequate information’, ‘reliable services’ and ‘adjacent bus stops’. In order to obtain a broader perspective, these could be placed alongside other attributes such as ‘quick journey times’ and ‘cheap tickets’.

On the other hand, if we consider interchange barriers as much more well defined concepts, such as, ’10 minutes waiting time’, ‘cross-platform transfer’, ‘guaranteed connections’, ‘manned information points’ and ‘2 minutes between bus stops’, we will obtain much more usable answers. By asking the individual to rank them in order of importance, and by including some numeraire within the ranking, such as cost or time, it is possible to estimate the relative effects of different aspects of interchange and also their ‘absolute’ effects in money or time units. Such estimates would be particularly useful in appraising transport schemes which deal with very specific interchange barriers.

## 2.5 Estimation Methods

We can consider estimation methods from two different perspectives. The first is that of the individual decision maker. The second is that of collective behaviour which is the outcome of a whole series of individuals’ decisions. These two perspectives correspond with two different means by which the effect of interchange on the demand for travel can be quantified. These are termed disaggregate and aggregate approaches respectively.

### 2.5.1 Disaggregate Approaches

We briefly set out in section 2.2 the conventional economic theory that when faced with a range of alternatives, such as different modes, routes or departure times, or indeed combinations of them, the individual is prepared to trade-off amongst the attributes which characterise each alternative and chooses the alternative with the highest utility. The disaggregate approach makes the individual decision maker the unit of observation and aims to explain the sensitivity of individuals’ choices to relevant travel variables on the basis of comparing different individual’s choices in different situations. By far the most commonly used model is the logit model. In the case of choices between just two alternatives, which is the most widely analysed choice context, the logit model expresses the probabability than an individual chooses alternative 1 as:

$$P_1 = \frac{1}{1 + e^{u_2 - u_1}}$$

where:

$$U_i = U^i_{\text{int}} + U^i_{rest}$$

In turn, $U_{int}$ and $U_{rest}$ are related to variables that influence choice. Suppose $U_{rest}$ is simply a function of in-vehicle time (T) and cost (C), the utility function in its typical linear additive form is:

$$U_i = \alpha I_i + \beta TT_i + \delta W_i + \gamma C_i + \mu T_i$$

Other functional forms could be specified for $U_i$ whilst $\alpha$ could be separated into its constituent parts as outlined above.

The aim of the calibration process is to estimate the parameters ($\alpha$, $\beta$, $\delta$, $\gamma$, and $\mu$) which indicate the sensitivity of demand to the relevant variables. The utility function can be specified to allow the parameters to vary; for example, the interchange coefficients could vary with the type of interchange and according to individuals socio-economic and trip characteristics.

Relative values are derived as the ratio of parameters given a linear-additive utility function as above. Thus the time value of the interchange penalty would be $\alpha/\mu$ and the money value of transfer time would be $\beta/\gamma$.

Forecasts are obtained by substituting forecasting values of the explanatory variables into the utility function and calculating $P_i$ which is compared with the $P_i$ obtained for the base situation. Thus if we removed interchange in the forecasting scenario, I, TT and W would each be zero and the increase in $P_i$ would denote the impact on demand of removing interchange.

The data upon which these disaggregate models are calibrated can be based on individuals' real choices in the market place or individuals' choices amongst hypothetical travel alternatives. The two approaches are distinguished as Revealed and Stated Preference. The former has the attraction that it is based on what individuals actually do whereas the experimental nature of the latter means that it can examine a much wider range of different travel situations.

A range of different choice contexts can be used to estimate interchange values within both the Revealed and Stated Preference approaches. These include mode choice, route choice, time of departure choice and, within the Stated Preference approach, choices in an abstract context which have no real-world equivalence and where the only difference between the alternatives is in terms of the attributes that describe them.

### 2.5.2 Aggregate Approaches

The aggregate approach is based on the collective behaviour of groups of decision makers, such as those travelling between two locations by a particular mode. We might express the volume of demand (V) as a function of relevant transport and socio-economic variables:

$$V = f(P, T, H, U_{\text{int}}, C, E)$$

where P, T and H denote the price, time and headway of the public transport service, C represents the strength of competition from other modes and E represents exogenous factors such as income and population levels. The most common form of this function is to express the effect of interchange on demand independently of the other variables. However, interaction terms can be specified, whereby the effect of changes in $U_{int}$ on the demand for travel depends on the level of other variables.

In its simplest form $U_{int}$ could be a dummy variable denoting whether interchange is required or the number of interchanges. In this case, and adopting the most common form of model which specifies constant elasticities, the aggregate model would take the form:

$$V = P^{\tau} T^{\varpi} H^{\delta} e^{\gamma U_{int}} C^{\lambda} E^{\mu}$$

$U_{int}$ is specified in this form since it can take the value of zero. Given this, it makes little sense to specify the elasticity for interchange in the conventional manner as the proportionate change in demand after a proportionate change in interchange. A more sensible approach when $U_{int}$ takes only a few values including zero, is to define the interchange elasticity ($\eta_{Uint}$) as the proportionate change in demand after a change in interchange. In the above model form, this 'elasticity' would be:

$$\eta_{U\,\mathrm{int}} = \frac{\partial V}{\partial U_{\mathrm{int}}} \frac{1}{V} = \gamma$$

More sophisticated approaches would specify $U_{int}$ as a continuous variable denoting changes to interchange conditions and integration as well as whether an interchange was required.

A widely used formulation which would automatically make the interchange elasticity dependent upon the level of other variables is to combine the travel related variables into a composite measure of the attractiveness of the mode. This composite term may be generalised cost, where T, H and $U_{int}$ are expressed as monetary equivalents and are combined with P. A special case of this is contained in the Passenger Demand Forecasting Handbook (TCI-OR, 1998), which contains the recommended forecasting procedures used by British Rail and which are still widely used in the railway industry. It specifies a composite variable termed generalised time (GT) which contains only the service quality aspects in the form:

$$GT = T + \alpha_1 H + \alpha_2 U_{\mathrm{int}}$$

where again $U_{int}$ denotes simply the number of interchanges. The term is expressed in units of journey time, with $\alpha_1$ and $\alpha_2$ being the service frequency and the interchange penalties respectively which convert headway and the number of interchanges into time equivalents. Note that connection time is not separately distinguished and that T relates to the journey time between the origin and destination stations including any connection time. The interchange penalty therefore discerns the pure penalty plus the excess of the connection time value over the train time value.

The interchange penalties used in this framework to forecast rail demand make little distinction according to the nature of the interchange or the type of traveller, as well as failing to distinguish connection time, although a strong positive distance effect is allowed.

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The relationship between the volume of rail demand (V) and GT takes a constant elasticity form:

$$V = \phi GT^{\beta}$$

The implied point elasticities ($\eta$) are therefore:

$$\eta_T = \frac{\partial \mathrm{V}}{\partial \mathrm{T}}\frac{\mathrm{T}}{\mathrm{V}} = \beta\frac{\mathrm{T}}{\mathrm{GT}}$$

$$\eta_H = \frac{\partial \mathrm{V}}{\partial \mathrm{H}}\frac{\mathrm{H}}{\mathrm{V}} = \beta\frac{\alpha_1 \mathrm{H}}{\mathrm{GT}}$$

$$\eta_{Uint} = \frac{\partial \mathrm{V}}{\partial U_{\mathrm{int}}}\frac{1}{\mathrm{V}} = \beta\frac{\alpha_2}{\mathrm{GT}}$$

where again we have specified the interchange elasticity to denote the proportionate change in demand after a change in interchange. We can see that the elasticities depend upon the proportion that the variable forms of GT, and hence if the interchange penalty ($\alpha_2$) did not increase with distance, the interchange elasticity would automatically and quite dramatically fall as GT increases.

Most inter-urban rail demand models in Great Britain which have been estimated to ticket sales data have used this GT formulation, but there is no reason why they should do. Not only did Wardman (1994) estimate separate elasticities to time, headway and interchange, rather than to a composite GT term, but it was also shown that the elasticity variation implied by the GT approach outlined above was not empirically justified.

In the form adopted in the Passenger Demand Forecasting Handbook, $U_{int}$ denotes the number of interchanges but there is no reason why it cannot be extended to include transfer time, waiting time and the fixed penalty, although this would require re-calibration of models since the elasticity to GT ($\beta$) estimated to a narrow definition of GT would not be appropriate to this enhanced formulation.

The approach above rationalises an interchange penalty which increases with distance on the grounds that short distance travellers are more familiar with interchange and the services are more frequent. We shall also see that the empirical evidence suggests a strong positive distance effect. However, it must also be recognised that the main reason why there is a positive distance effect is that its absence from a GT formulation would mean that the interchange elasticity would fall dramatically as distance increased and the other components of GT formed a greater proportion of GT.

Finally, we can consider methods where the interchange elasticity is deduced. The simplest procedure, and one which is used in the railway industry in forecasting the effect of changes to variables other than P, T, H and $U_{int}$, is to express the change in question as an equivalent monetary or time amount and to translate the implied proportionate change in price or time into a proportionate change in demand through the appropriate fare or journey time elasticity. Alternatively, if we are prepared to accept the GT type formulation outlined above, we can deduce the interchange elasticity from, say, the journey time elasticity as:

$$\eta_{U\,\text{int}} = \frac{\alpha_2}{T}\eta_T$$

## 3. EMPIRICAL EVIDENCE: INTERCHANGE VALUATIONS

The methodologies for estimating values were described in section 2.5. Emphasis has been placed on SP methods based on disaggregate analysis of abstract choice contexts specific to rail and, to a lesser extent, the choice between modes.

Although research conducted in the bus industry is less likely to reach the public domain than in the rail industry, our impression is that far more quantitative research into travel behaviour has been conducted within the rail industry than in the bus industry. This is borne out in a large scale review of British empirical evidence based on disaggregate models estimated since 1980 (Wardman, 1998) where all but 2 of the 51 values were for train travel.

Jones (1993) examined route choices for travellers who could use Thameslink services to avoid interchange in London and the interchange penalty was estimated at 37 minutes using actual route choice data and 47 minutes using SP choices. For inter-urban travellers, MVA (1991) obtained values of having to interchange from an SP exercise of 32 minutes. However, the penalty in both these studies included an element of connection time since this was not separately specified within the longer journey time. Toner and Wardman (1993) estimated an RP mode choice model to leisure travel in the South East and obtained an interchange penalty of 23 minutes again including a connection time premium. The relatively low value is presumably the result of familiarity with the network and the high frequency of onward services along with the relatively short distances involved.

London Transport has conducted research (LT, 1988, 1995) into interchange penalties, distinguishing between the fixed penalty and the walk and wait time involved albeit with the latter constrained to be weighted at twice the rate of in-vehicle time. The analysis was based on peak period passengers' actual choices between direct routes and routes involving interchange. LT (1988) found an average penalty of 5.4 minutes. A repeat of the analysis using 1990 in place of 1980 data (LT, 1995) estimated a peak period interchange penalty of 3.7 minutes, again for walk and wait time weighted at twice in-vehicle time[2]. These values are noticeably lower than those obtained for other rail services. One reason is that the LT values denote a pure interchange penalty, whereas the values obtained in other studies additional discern some of the connection time effect, whilst LT journeys are relatively short and the service frequencies and familiarity level are both high, each of which will operate to reduce the interchange penalty.

Interchange penalties for bus have been estimated at 3 to 4 minutes of waiting time over and above the actual waiting time (NBPI, 1970; Daly et al., 1973). A current ITS study has estimated the value of bus interchange to car users of 39 minutes, although this will also contain the amount of time spent interchanging since this was not separately identified.

### 3.1 Variations in Values by Person and Trip Type

Possible influences on interchange valuations from person and trip type include the effect of journey purpose, distance and mode used as well as factors such as age, gender, social class, income level and group size.

Wardman (1998) contains a comprehensive review of British evidence on interchange penalty valuations, much of it from unpublished reports. Whilst the values relate almost exclusively to rail interchange, they cover train, car and bus users and a range of other circumstances. A regression model was estimated to 44 monetary interchange penalties to examine variations in these valuations essentially according to person type. A number of plausible findings emerged, and these are reported in Table 1.

The interchange penalty is, as expected, found to increase over time as GDP increases whilst there is also a pronounced effect from distance. The latter is consistent with the forecasting procedures widely adopted in the railway industry. Those making business trips have, as expected, higher values than those on private travel. Noticeably, commuters have lower values than the base group of leisure travellers. This may well be because they are more familiar with interchanging and because the generally higher service frequencies in the peak reduce the risks involved in interchange. Car users have very much higher values than public transport users. Whilst it could be argued that this merely represents an income effect, the study found the values of time to be similar for car and rail users and hence this seems to reflect an additional aversion to interchange on the part of car users. A worrying finding is that the valuation of interchange is much lower when obtained from SP data, particularly given that we might expect any incentive to strategic response bias to lead to inflated values.

[2] It should be noted that LT (1988) produced a penalty of 4.2 minutes when the same logit estimation was used as in LT (1995).

**Table 1: Money Value of Interchange Model**

| Variable | | Effect |
|---|---|---|
| Distance | 0.485 (4.59) | |
| GDP | 0.843 (7.89) | |
| EB-1st | 0.921 (1.18) | +151% |
| EB-Std | 0.770 (1.99) | +116% |
| Commute | -0.719 (1.90) | -51% |
| Car User | 0.545 (1.17) | +72% |
| SP | -0.542 (1.56) | -42% |
| South East | -0.766 (1.75) | -54% |

Note: The dependent variable was the natural logarithm of the value. Hence the dummy variable coefficients denote a proportionate effect on the valuations whilst the coefficients for distance and GDP are elasticities.

Finally, the values for travellers in the South East are lower, despite their higher incomes on average. This is again presumably a function of the familiarity and high service frequency effect, whilst it may also be that interchange facilities are better in the South East and that there is an appreciation of a more integrated transport system which uses interchange to promote a wider range of journey possibilities within a relatively high quality and large network.

The above review compared interchange values across studies and did not examine variations in interchange penalties that occurred within a study except those which were due to journey purpose and mode used. However, there are a number of studies which reveal variations in the valuations of interchange with person and trip type.

A pioneering application of the SP approach in Great Britain (Steer Davies Gleave, 1981) estimated time values of the interchange penalty, which would have included a connection time premium, of 19 minutes for business travel and 38 minutes for leisure. However, the money value for business travel of £1.72 was much higher than that for leisure of 31 pence, reflecting the much higher values of time for business travel.

Oscar Faber TPA (1993) estimated interchange values in a joint RP-SP mode choice model for inter-urban travellers. The value of interchange will include the fixed penalty and, because the model included the total time between boarding the first vehicle and alighting from the last vehicle and did not specify a separate connection time, it will also include an element representing the premium valuation of connection time relative to in-vehicle time. For employer's business trips, the rail interchange penalty was estimated at 87 minutes with 24 minutes for bus. The corresponding figures for leisure were 102 and 28 minutes. It is not clear why the rail values are so much higher. Interchange penalties having the same basis were estimated by Oscar Faber TPA (1992). No distinction was made between journey purposes but car and rail users had a rail interchange penalty of 59 minutes whilst coach and rail users had a value of 12 minutes for rail interchange and 11 minutes for coach interchange. These figures demonstrate the higher values associated with interchange by car users, although public transport users perceived little difference in the penalties associated with rail and coach interchange.

MVA (1991) estimated season ticket holders to have an interchange penalty of 11 minutes whereas all travellers making journeys of less than 50 miles had values of 45 minutes. Given the values include connection time, these results could in part reflect lower connection times for commuters as a result of higher frequencies. However, we would also expect familiarity and the lesser risk because of higher frequencies to also have had an influence here. Although LT (1995) found the interchange penalty for peak travellers of 3.7 minutes to be larger than the 3.0 minutes for off-peak travellers, the differences was not statistically significant. The Passenger Demand Forecasting Handbook recommends interchange penalties for season tickets that are 30-35% less than those for other tickets.

LT (1988) found that the interchange penalty varies considerably across individuals. It was estimated that around 30% had virtually no penalty, with 50% having a penalty of less than 3½ minutes and 10% having a value over 14 minutes.

A strong distance effect is apparent in Table 1. In MVA (1991), the time values of the interchange penalty were 45 minutes for less than 50 miles, 81 minutes and 23 minutes for 50-140 miles for full and reduced fares respectively, and 31 minutes for journeys of over 140 miles. The money values followed a similar pattern and journey purpose is here suspected of influencing the results. A different approach has been based around analysis of ticket sales data and the estimation of interchange penalties consistent with observed changes in rail demand. (OR, 1992a, 1992b). For interchange valuations which reflect the pure penalty and include the premium value of connection time over train journey time, the estimated values were 50 minutes for a journey of around 50 miles and separately 50 to 110 minutes for journeys between 50 and 300 miles. However, in contrast to the findings for rail, the interchange penalty for underground travellers in LT (1995) did not vary with distance.

Wardman (1983) offered rail passengers trade-offs between avoiding an additional interchange and incurring additional travel time, and the interchange penalty was estimated at 35 minutes on average, with less frequent travellers having higher values and, for journey purpose, business travellers having the lowest values and holidaymakers the highest. This value would not include connection time but it made no distinction between connection time and in-vehicle time.

MVA (1985) estimated the value of interchange time for a number of segments, and the value would be independent of the penalty given that each SP scenario required an interchange. There was little variation in the valuation of interchange time around a central figure of 2.7 minutes of in-vehicle time across age and income groups. However, the figure was somewhat higher for females (3.5) than males (2.6), for employers' business trips (3.2) than other trips (2.7) and for those with awkward luggage (4.0) and luggage of average difficulty (3.1) compared to those with no luggage (2.6). The study suggests that weighting interchange time as twice in-vehicle time will understate the disutility of interchange,

### 3.2 Variations in Values by Interchange Type

MVA (1985) found that an interchange involving a change of platform via a subway or bridge relative to a cross-platform transfer was valued at 9 minutes of connection time. However, a change of station was valued at 27 minutes. The values of good facilities at the interchange station compared to poor and medium facilities were 18 and 9 minutes of interchange time respectively whilst good information relative to poor information was equivalent to 7 minutes of interchange time. On the other hand, LT (1988) report that there was no difference in penalty between cross platform and other interchanges once allowance was made for walking.

TCI-OR (1996) estimated that a station which was rated good would have an interchange penalty four minutes lower whilst a station rated poor would have an interchange penalty nine minutes higher than a station rated as medium. An early piece of work to examine interchange (Survey AKU-68) found that the penalty varied with the quality of interchange. It was lowest for underground-to-underground transfers, followed by surface rail-to-rail, bus-to-rail and bus-to-bus transfers.

There is not a great deal of evidence on how interchange values vary according to the type of interchange, certainly less than is available for trip and personal characteristic effects. However, there does seem to be a difference in interchange penalties between underground interchanges and surface rail interchanges with the former being lower. In part this might reflect different types of journey, but there seems to be an element here of interchange valuations depending on the interchange environment.

### 3.3 Valuations of Interchange Components

We have seen that there are various components to the valuation of interchange. However, few studies have separated out these various components. Not only is this a shortcoming if we wish to evaluate different types of improvement, but it can also be misleading at a less detailed level since in some studies it is unclear what the interchange penalty represents. In some studies, the interchange penalty relates purely to the fixed penalty and excludes any connection time, in other studies it contains an element due to connection time, whilst in studies which specify an interchange penalty alongside door-to-door time but do not distinguish connection time it will contain the fixed penalty and also an amount representing the higher valuation of connection time relative to in-vehicle time. Different interpretations will lead to markedly different results in practical evaluation.

One of the few studies, and certainly the earliest, to attempt to distinguish between the interchange penalty and interchange time was conducted by MVA (1985). Using an SP experiment, the value of interchange time on London flows was found to be 2.8 times in-vehicle time whereas it was 2.5 on Non-London flows. The interchange penalty was insignificant for London flows but was 20 minutes on Non-London flows. Note that lower interchange penalties are estimated when they are isolated from connection time. However, the design of the SP experiment was not ideal for distinguishing between the interchange penalty and interchange time because the latter only took three levels.

MVA (1987) conducted a study of Network SouthEast suburban services and estimated an interchange penalty of 13 minutes if the connecting service was guaranteed to be on time.

This increased to 20 minutes if there was a 10% chance of it being delayed 5 minutes and to 39 minutes if the delay was as high as 30 minutes. These results indicate the effect of reliability on the interchange penalty. Another study dealing with related issues was conducted by TCI-OR (1996) whose analysis of trade-off data found that a guaranteed connection was worth 20 minutes of journey time, although of course in general this value depends on the risks involved in interchanging which is a function of the reliability of the connecting service and of the minimum connection time. We are not aware of evidence which indicates how the value of a guaranteed connection varies with these factors.

## 4. EMPIRICAL EVIDENCE: BEHAVIOURAL RESPONSE

Interchange has been observed to have a large effect on the demand for public transport, although there is more evidence regarding valuations than there is direct evidence on behavioural response. In contrast to the studies which have estimated valuations of the various aspects of interchange where SP methods have dominated, evidence relating to behavioural response has often been based on RP data.

Although most valuation studies could have deduced the behavioural response to interchange, most did not examine the implicit elasticities. However, the valuations can be used to deduce behavioural response and this is particularly true of the approach recommended in the Passenger Demand Forecasting Handbook and outlined in section 2.5.2 above. The interchange elasticity implied by that approach is:

$$\eta_I = \frac{\partial V}{\partial I}\frac{1}{V} = \beta\frac{\alpha_2}{GT}$$

If interchange formed around 50% of GT, which is possible on short journeys, the removal of an interchange would be predicted to increase demand by around 45% given the recommended GT elasticity (β) of –0.9. This falls to around 25% where interchange forms around 30% of GT and to 10% where it is only 10% of GT which could apply on a slow and infrequent long distance service. On London Underground, where lower interchange penalties are used, interchange forms around 20-25% of GT on flows where a change is required (LT, 1988).

These interchange elasticities are based on a considerable amount of evidence from a number of studies where the volume of rail demand, as measured by ticket sales, is related to GT. An alternative approach adopted by Wardman (1993) relates the volume of rail demand directly to interchange rather than indirectly through GT. The introduction of an additional interchange penalty on Non-London inter-urban routes was estimated to reduce rail demand by 20% (±11%) independent of any journey time effect. This is similar to work based on Stated Intentions data (Wardman, 1983) which estimated that 25% of inter-urban rail travellers would no longer make the journey by train if an additional interchange was introduced. It has also been possible to develop models to ticket sales data which have discerned the effect of changes in coach interchange on the demand for rail travel on Non-London inter-urban routes (Wardman, 1997).

Cross-sectional analysis of rail ticket sales data by White and Holt (1979) and Wardman (1983) estimated that the presence of an interchange reduced inter-urban rail demand by 45%

and 31% respectively over and above any journey time effects. Using a time series approach, the latter study estimated that the introduction of an interchange reduced demand by 28% and the removal of an interchange increased demand by 22%, both in addition to journey time effects. Steer Davies Gleave (1981) and Wardman (1995) using SP data and ticket sales data respectively, both found larger effects on demand from the introduction of interchange than its removal.

The implied proportionate reduction in rail demand after an additional interchange, but keeping journey time constant, was estimated at around 4% by Toner and Wardman (1993), with a corresponding figure for bus travel of 7%. The low effect is due to the relatively low interchange penalty estimated for travellers in the South East for the reasons discussed previously. However, there are circumstances in the South East where large impacts have been observed. OR (1991) examined the effect on cross-London rail flows of removing the need to interchange. The new Thameslink service effectively removed two interchanges and analysis of increases in rail demand, admittedly from a low base and in a situation where making the journey by car is difficult, found a very large interchange elasticity. Whilst this is something of a special case, it does indicate that serious interchange barriers, such as crossing between London termini, can have a very large impact on public transport demand.

There is some evidence that interchange can influence car ownership. Algers (1973) estimated the elasticity of car ownership with respect to the number of public transport transfers at 0.27 for those with one car and 0.29 for those with two or more cars.

An indication of the behavioural impact of interchange in the bus market is provided by the figures in Table 2 which are derived from the National Travel Survey (DETR, 1996) and which show that the vast majority of bus trips involve only a single stage. Interchange is more common amongst rail travellers, and there may be an expectation effect at work here in that rail journeys are generally longer distance where there is in general a lesser expectation of a through service than for urban trips. Nonetheless, these figures suggest interchange is a very large barrier to bus travel. Commenting on the low proportion of bus trips involving interchange, CIT (1998) stated, “That statistic in itself ought to be a red alert to us all”.

**Table 2: Journey Stages By Mode in the UK**

| No of Stages | Car | Rail | Local Bus | LUL | Total |
|---|---|---|---|---|---|
| One | 99.5% | 35% | 96.8% | 70.6% | 97.9% |
| Two | 0.5% | 46% | 3.0% | 26.3% | 1.7% |
| Three | 0% | 18% | 0.2% | 3.1% | 0.4% |
| % of journeys | 83.1 | 0.1 | 9.0 | 0.9 | 100 |

Note: Reproduced from Colin Buchanan and Partners (1998)

## 4.1 Variations in Behavioural Response by Person and Trip Type

Although variations in values by person type have been estimated in a number of studies, none of these examined the variation in the implied interchange elasticities by person type.

Jones (1993) examined flows affected by Thameslink using a combination of ticket sales data and survey data. The replacement of a cross London transfer, taken to be two interchanges, by a cross platform transfer increased rail demand by 24% on flows other than Gatwick Airport and by 39% on flows to Gatwick Airport. As might be expected, those travellers with luggage and facing a fixed departure time with serious consequences of late arrival are more sensitive to interchange. It is also to be expected that there is an influence here from the type of interchange.

The stated intentions approach used by Wardman (1983) found that the loss of rail traffic after an additional interchange varied considerably across market segments. The loss was greater for employer's business trips (40%), visiting friends and relatives (32%) and holidays (27%) than for other journey purposes; greater for women (30%) than men (21%) and much greater for the over sixties (51%) than other sectors of the population.

Oscar Faber TPA (1993) estimated a point elasticity using a function which contained the number of interchanges in an individual's journey and hence the elasticity was very low given the predominance of zero interchanges in their sample. We have reworked their calculations assuming that in the base situation there are no interchanges and in the forecast situation each individual would face an interchange and 15 minutes additional journey time. For rail travel, this reduces both business and leisure demand by 88% whilst the corresponding figures for bus are 63% and 60%.

### 4.2 Variations in Behavioural Response by Interchange Type

We are not aware of evidence which directly indicates how the responsiveness of demand to interchange varies across different types of interchange.

### 4.3 Behavioural Response and Interchange Components

We are not aware of direct evidence which segments the interchange elasticity into separate components relating to the fixed penalty, transfer time and waiting time.

## 5. EMPIRICAL EVIDENCE AND INTEGRATION

Integration is concerned with interchange, and specifically that between modes, but it also encompasses other inter-modal issues such as through ticketing, information provision and co-ordination of services. There have also arisen in recent years issues of integration between operators within both the bus market and the rail market.

Integration is particularly important if the aim is to build public transport networks to facilitate a wide range of journey opportunities whilst greater integration between modes leading to 'more seamless journeys' is regarded by many as essential for effective competition with the private car in typical circumstances.

There is less evidence regarding integration than there is interchange. For example, the Passenger Demand Forecasting Handbook (TCI-OR, 1998) contains a significant body of evidence relating to interchange, but very little about integration with access and egress modes. However, it is an issue which is beginning to be addressed, with a stimulus here being the widespread ownership of train operating companies by organisations with significant bus operations.

Stokes and Parkhurst (1996) examined interchange in its widest sense, including integration between modes. The study emphasises that the biggest barriers to integration are a lack of marketing and connection information. In their words the ultimate situation,

> "*Would allow a person to set off on a journey by public transport without having looked at a timetable or route map, with the confidence that a motorist can*".

When making a journey for the first time a motorist will probably consult a map, or another motorist, but can usually set off and follow a known route, or use road signs through a set of known places, confident of arriving at the destination without undue delay except that caused by roadworks or accidents. En route, the motorist can listen into radio broadcasts, and now reference more sophisticated systems to gain more information on possible hold ups.

To achieve this for the public transport user, the study advocates ticketing policies that allow through travel on more than one mode such as the London travel card. However, it feels that the most important element to ensuring integration is to view all transport nodes as *travel points* which could be used to encourage people to become aware of the travel possibilities which exist. In this context a travel point would be a sign which indicated that some form of travel was available, and would have information about the travel services/modes that called there and about interchanges to other modes, usually the ones easily reached from the service serving the point as well as links to the major settlements.

The study goes on to outline a *hierarchy of travel points*, for instance:

Level 1 Signs pointing to basic travel points, such as a bus stop. These might be signed at minor road junctions, or at shops and facilities.

Level 2 Bus stop or similar which contains information on routes passing, and information which equates with an 'all other directions' sign, pointing the traveller to the next stage up.

Level 3 Interchange between modes.

To assist in integration, the study also advises that travel maps and timetables be integrated and easy to understand (the *time map*). For example, bus routes should be presented as 'tube style' maps and include frequencies and departure times at each stop.

Bailey (1998) reports the findings of a trial linked taxi service scheme that began in January 1998 at Totteridge and Whetstone and at Cockfosters, two North London rail stations. The scheme was a response to the 'Quality of Interchanges Study' (London Transport, 1997) and the 'Marketing Plan' (London Transport, 1996) which identified that public transport modes were perceived to be poorly integrated and that there was a need for London Transport to compete with the private car by examining the door to door needs of customers.

The linked taxi programme aims to increase public transport use by reducing the anxiety of customers, and potential customer, about travel from suburban rail stations to their final destination, particularly in the late evening. The scheme is available to registered users and operates with vetted minicab companies. The user telephones either: the designated minicab company directly or the London Transport Travel Information Service who will provide a number for a designated minicab company. The phone call has to be made at least 15 minutes in advance of arrival at the designated station, but preferably once the journey to the station has begun. The user informs the minicab company of their estimated arrival time and upon arrival is met at a designated linked taxi area immediately adjacent to the station. A set of zonal fares are used and no tip is expected, both of which reduce the cost uncertainty of travelling home from rail stations by normal taxi.

A pilot market research exercise was performed in early March and found that, in general, the respondents were generally happy with the service. In summary, whilst the research was not conclusive, it indicated that:

- 20% of the respondents indicated that they are using the Underground 'more' than before they registered for the scheme;
- 80% of respondents consider it very or fairly likely that they will use the service in the future;
- the vast majority of respondents registered for the scheme to use it as a 'back-up' to walking or asking someone else to pick them up in bad weather or on occasions when they arrive late at night at the station.

We are also aware of a similar scheme being introduced by Stagecoach Oxford on their Oxford to London coach services by which passengers will be able to order a taxi via the drivers' radio to meet them when they arrive in Oxford. As yet it is too early to assess the scheme's impact.

The concept is similar to the trein-taxi service in the Netherlands whilst train operating companies in Great Britain are examining possibilities for improved integration. We are also aware that train companies have provided new bus links, often as part of franchise bids, and there have been combined rail-bus ticket initiatives particularly where the same company owns the rail franchise and operates bus services. However, the bus links that have been introduced have not all been successful and some have been removed. Whilst we are aware that studies have been conducted in this area, we are not aware of published evidence.

CENTRO (1993) conducted a bus/rail interchange survey. The aim of the survey was to gain a better understanding of the nature and extent of the market for multi-modal tickets and the strengths and weaknesses of current bus/rail interchange. The study found that the bus/rail interchange market could be defined as one where leisure and shopping trips predominate, reflecting the greater concentration of employment in areas such as city centres where direct public transport services are generally provided, whilst 15% of respondents were also found to be first time users. The survey also found that the interchange market consisted of under 25 year olds (30% of the week day market compared to 19% of the population regionally); tended to be in the upper social groups ABC1 (47%) than other rail users (68%); and had a car ownership rate (37%) nearly half that of the region as a whole (66%). The main form of ticketing payment on these journeys was cash accounting for 44% of rail trips and 40% of bus trip payments. Although pre-payment ticketing was also available, of those daily travellers not holding a Centro-card but knowing of the pass 25% stated that the reason for non-possession was 'not getting around/being bothered to get one'. The study found that most people (91%) caught one bus to the rail station and that the bus/rail interchange market was restricted in terms of users depending solely on bus rail travel. In the absence of bus feeder services to stations people were found to walk to rail stations especially at smaller suburban stations. At intermediate sized stations 15% would catch a bus to their final destination. The study found that the removal of bus feeder services would result in a loss of 15% of all journeys. Quite surprisingly, the survey also revealed that 90% of respondents felt that the bus/rail interchange process was easy.

Runkel (1994) examined integration between operators. The Verkehrsverbund were established to remove the fares barriers to interchange which resulted from public transport being operated by different organisations. The Verkehrsverbunds, which began as groups of operators, pool the revenue and distribute it to the different operators according to vehicle kilometres or seat kilometres for different types of service and mode. More recently the public authorities have become closely involved and are also a channel for major subsidies.

Runkel notes that interchange appears to be higher in the Germany than in the UK, with 50% of Hamburg's 1.5 million daily passengers interchanging. He notes that this reliance on interchange increases as urban structure decentralises. The main barriers to interchange are regarded to be loss of time, inconvenience as a result of long walkways and steps and the danger of missing connections. In his view the 'primacy of cross platform interchange' is the simplest and best solution between bus, rail and light rail. However, it is recogniosed that this is not always possible and in such instances the following are desirable: good direct connecting walkways; escalators; protection from the weather; clear visibility; layouts which are instantly readable by users; good timetable connections; safeguarding systems so that connections are maintained when vehicles are delayed; a passenger friendly environment; retail outlets and comprehensive design.

DoE et al. (1973) examined the impact of greater integration of rail services in Merseyside through additional parking spaces and the reduction or removal of charges and also through improved bus links with through-ticketing. The parking improvements were regarded to be a success from a financial perspective yet the performance of bus links was less successful. The latter indicates that greater integration between rail and bus will be difficult given the current policy environment and that fewer people will now access rail by bus given increased car ownership.

A study by Steer Davies Gleave (1998) focused on the importance of seamless travel in encouraging people in London to switch from using their cars. The study had three main aspects relating to seamless travel and attracting more people to use public transport, the obstacles to seamless travel and the means of overcoming the barriers to seamless travel.

A review of the literature indicated that, in London, significant numbers of car users would consider using public transport if it was sufficiently attractive. Public transport could be made more attractive by general improvements, such as greater reliability, more convenient or cheaper, or by making the journey more seamless, mimicing the car to a greater degree than is currently the case. This involves more accessible information, more convenient interchanges, greater co-ordination between modes and more compatible ticketing.

Surveys with public transport operators revealed that they recognised the need to increase public transport attractiveness but that institutional issues of ticketing had to be overcome to enable operators to willingly participate in such a scheme. Interchange facilities were deemed to be critical to the provision of a seamless journey and information was also regarded as important.

From the point of view of travellers, including both users and non-users of public transport in London, it was found that the core elements of public transport had to be improved in addition to making travel more seamless. Seamless travel was regarded as a secondary issue, but vital for public transport to compete effectively with the car. Important aspects of seamless travel were information, accessibility to and within stations, station facilities and security, connections between bus and rail and flexible ticketing. The main barriers to seamless travel were categorised as timetable, ticketing, interchange, information, and design and planning. However, the study did not provide estimates of the valuation or impact on demand of achieving a higher level of seamless travel.

There have been relatively few studies which have examined integration between modes, and we are unaware of evidence which indicates the impact on public transport demand of a range of measures which achieve varying degrees of greater integration.

## 6. PERCEPTIONS, PREFERENCES AND ATTITUDES

The research outlined above has been of a quantitative nature yet a number of studies have conducted qualitative analysis of interchange effects. We distinguish here between studies which have examined individual's perceptions and studies which have explored preferences and attitudes.

### 6.1 Perceptions

There are two aspects to perception. Travellers have perceptions of the interchange variables themselves and also of the disutility attached to them. In terms of the $U_{int}$ formulation containing interchange penalty, transfer time and waiting time, travellers may misperceive $\alpha$, $\beta$, and $\delta$ on the one hand or I, TT and W on the other.

CIT (1998) claimed that much of the reluctance to use interchange stems from widely perceived penalties which are often over exaggerated. It is not clear to us whether this misperception relates to the utility weights or the levels of the variables, although in any event they do not provide evidence to substantiate this claim.

#### 6.1.1 <u>Perceptions of the Utility Weights</u>

From the studies investigated as part of this review, we can conclude that there is no evidence that the issue of the perception of utility weights has been addressed. An example would be a study which found that, once experienced, the disutility of a given need to interchange or a specific connection time was regarded by travellers to be different to the perceived level of disutility prior to the experience.

However, the information obtained and reported in sections 6.1.2 and 6.2 clearly indicate, and this is confirmed by the focus groups and in-depth interviews undertaken in stage 1 of this study, that interchange itself is seen as a penalty independent of the time spent waiting. There is a strong preference for zero interchange or to avoid interchange, although there is a difficulty in establishing whether people correctly perceive the various utility weights relatively and absolutely in different interchange environments.

### 6.1.2 Perceptions of the Attribute Levels

Oscar Faber (1996) examined rail passengers' priorities for improvements to the quality of interchange which included analysis of perceptions of interchange. The major findings of the study were that: 75% of rail journeys required only one interchange with a further 20% needing two changes; 23% of passengers expected a same platform or cross platform interchange, 30% expected to use a covered bridge with escalators, 7% expected other interchange arrangements within the station, 7% expected to change stations whilst one third of respondents did not know what the interchange arrangements would be at the start of their journey. 70% of respondents expected to wait between 5 and 30 minutes at the interchange station and 4% of passengers who had already changed trains missed their planned connection.

Part of the survey examined the importance of station quality and how existing station quality was perceived. The figures are reproduced in Table 3.

**Table 3: Importance of Station Quality and That Achieved**

| Aspect of Quality | Station Quality | |
|---|---|---|
| | % stating important or very important | % stating good or excellent quality |
| Waiting Environment | 87% | 47% |
| Facilities | 92% | 53% |
| Information Provision | 96% | 64% |
| Visible Staff Presence | 74% | 47% |

Among different groups of respondents, some relatively minor differences did emerge. For example, elderly and retired passengers tended to have rather more favourable perceptions of stations than younger travellers; infrequent rail users tended to have more neutral views than regular rail travellers; those travelling on holiday were also likely to have neutral opinions, perhaps because such trips are generally infrequently made; respondents accompanied by other adults and children were less likely to regard stations favourably and more likely to have neutral views than other users; and frequent travellers tended to be less satisfied with information provision.

Whilst studies of this type give an indication of how individuals perceive interchange, they do not indicate the extent to which these perceptions are accurate. Indeed, we are not aware of studies which have systematically tested the relationship between the perceptions and reality of interchange attributes.

## 6.2 Preferences and Attitudes

Passenger preferences are the basis for the interchange values and behavioural responses reviewed in sections 3 and 4 above. However, there have been studies which have elicited passenger preferences amongst interchange attributes without conducting quantitative modelling of them. There have also been a number of studies which have examined attitudes to various aspects of interchange.

Oscar Faber (1996) in their study of passenger preferences for improvements to interchange conditions, examined passengers' attitudes and preferences towards alternative physical links between trains. The results are given in Table 4. This showed a strong preference for same platform or cross platform interchanges. Conversely, cross town interchanges were disliked considerably by 74% of the respondents.

**Table 4: Response to Different Types of Interchange**

| Type of Interchange | Don't Mind At All | Don't Mind Much | Dislike Little | Dislike Lot | Dislike Very Much |
|---|---|---|---|---|---|
| Same/Adjacent Platform | 95 | 3 | 2 | 0 | 0 |
| Covered bridge | 64 | 26 | 8 | 1 | 1 |
| Open bridge | 42 | 12 | 26 | 10 | 10 |
| Ramped subway | 44 | 19 | 21 | 8 | 8 |
| Stepped subway | 34 | 16 | 25 | 14 | 11 |
| Adjacent station | 20 | 11 | 28 | 27 | 14 |
| Cross town station | 5 | 2 | 8 | 11 | 74 |

Analysis by market segment revealed a number of interesting findings. Women were slightly less willing to accept the covered bridge option than men and substantially less willing to accept the other options and the willingness to accept anything other than a cross platform interchange declines with age. The elderly are less willing to accept changing platforms or stations and students have less objection to changing platforms within a station than other passengers. Passengers making work, shopping or leisure trips are less concerned than average about the interchange linkage, while those visiting friends and relatives or going on holiday are more concerned. Changing platform or station is less acceptable to passengers in a group, especially if the group includes children, and passengers with luggage are less willing to change platform or station than those without but this effect is surprisingly weak.

Ninety three percent of respondents would not find a 20 minute connection time unacceptably long. The preferred interchange time for 79% of respondents was 20 minutes or less whilst the majority of passengers were not worried about the availability of seats on the second train.

SYPTE (1991,1993,1996) conducted a series of surveys on interchange attributes. The attributes assessed by these studies included the provision of amenities, the level of security and the provision of information. Four amenity issues were consistently rated highly. These were the provision of phones, shelter, toilets and a clean environment. Safety issues became more important over the surveys. Information in the form of timetables at bus stands and how to find stops was consistently rated as important whilst having staff available and providing TV information screens have become more important.

Wardman (1983) found that the most disliked aspect of interchange for inter-urban rail travellers was luggage handling (22%) followed closely by waiting time (20%). Having to move (16%) and concerns about a seat on the connecting train (15%) were next most important whilst concern about catching the wrong train (9%) and missing the connection (7%) were relatively unimportant.

MVA (1985) examined attitudes towards various aspects of interchange. It was found that 37% of rail travellers thought that waiting was the worst aspect of interchange, with missing the next train accounting for 25% of responses and 11% stating that dealing with luggage was the worst aspect. However, frequent travellers were more concerned about missing connections than waiting time, presumably because they were more suitably prepared for the waiting time whilst retired people have a relatively high concern with luggage. The study also examined the impact of interchange conditions on attitudes to interchange. The positive impacts on attitudes, starting with the most important, were familiarity with the station, same platform transfers, cross platform changes, small stations and travelling with others. The most negative impact on attitudes was accompanied by young children, followed by footbridge transfers, carrying luggage, having to change station and changing in London. 69% of the sample were worried about missing connections. Of these, 26% stated that the anxiety was primarily caused by short connection time, with 22% stating the cause as a late train and 16% stating a business appointment. No other cause exceeded 10%. Of the factors which would cause travellers to be more prepared to wait longer were the availability of refreshments (59%), if they were travelling with others (41%), if it was a large station (40%) and if it was a long journey (39%). Travellers were more averse to waiting on the return journey.

MORI (1995) examined the relationship between actual and expected performance of different aspects of bus service provision. In all cases, performance did not match expectations. The areas where the gap was greatest were bus stops and stations and information provision, both of which are relevant to interchange. Attitudes towards the improvements that could be made to bus services to increase bus use were also explored. This revealed that cheaper fares would have the largest impact, with 47% of respondents stating that this would increase use. Making bus services more reliable was second most effective, followed by through ticketing and bus services linked up with each other and with other modes of transport. Journey time reductions were regarded as least effective, with only 27% stating that this would encourage more use. Issues concerned with interchange and integration are therefore regarded to be important.

In 1997, Greater Manchester Passenger Transport Executive (GMPTE, 1997) undertook a survey of passenger opinion on the facilities offered at bus stations and the performance of bus stations on providing these services. Passengers were asked to rate on a scale of 1-10 (where 1 is not at all important and 10 very important) how well their bus station performed on each criteria. The study found that all safety and security issues (video cameras and security staff) were regarded as important with scores of over 9. Lighting was found to be the most important safety and security issue. Information including: availability of an information office; signage; availability of timetables; availability of staff; clocks; and help buttons were all rated at 8 or 9. The most important factors relating to information however were signage of boarding points, the display of bus times and the availability of accurate timetables. The importance attached to particular facilities found within bus stations varied widely. The factors identified in order of importance were: shelter from the weather, ease of getting on and off the bus, safe and well defined crossing points, ventilation and freedom from fumes, seats, toilets and cleanliness.

Harris Research (1993) conducted a survey of travel in Merseyside for Merseytravel. The home interview survey sought information on the travel characteristics of individuals, their perception of the role and profile of Merseytravel, and their attitudes to the characteristics of bus and rail services and to new forms of public transport. Six groups of travellers were targeted: public transport users generally; 14-18 year olds, car users, the mobility impaired, the elderly and women. Of all those surveyed, 60% felt that better quality bus stations would have no or little effect on their use of bus services. Of the 40% who stated that it would encourage use, 12% felt it would have a great effect. Respondents aged 45-65 and women were more encouraged by better quality bus stations. 55% of respondents stated that improved personal safety at bus and rail stations was relatively unimportant. 37% of women however rated safety 7-10 in order of effect. Easier boarding and alighting was regarded as of no importance by 38% of respondents, but significant by 24%. The elderly and women regarded this attribute as marginally more important.

Public transport users were asked to rate on a 1-10 point scale features of bus services including personal safety, ease of boarding and alighting, and service information including real time. Personal safety was regarded as very important by 70% of users, while boarding and alighting was regarded as very important by 51% of users. 84% of the elderly regarded boarding and alighting as very important. Knowledge of when the next bus was due was regarded as important by 73% of public transport users. The surveys also revealed that 15% of public transport users interchanged between the same public transport modes, or between private and public transport, on a regular basis . Of these, 48% were bus to bus, 39% were bus to train and 10% were train to train. At interchange sites personal safety, shelter, and printed timetable information were regarded as the most important attributes of interchange. Real-time information, telephones and toilet facilities were regarded as less important. Safe car parking was in comparison seen as unimportant. Mobility impaired persons, who represented 19% of respondents, identified getting to stops or stations as the most problematic aspect of making public transport trips. 4% stated that they found difficulty in knowing which bus or train to catch. Younger people in the surveys wanted vandal proof shelters and cleaner and safer waiting areas. Women felt that personal safety levels were poor at bus stations (25%) and rated as top priority the re-introduction of bus conductors. On-vehicle luggage space, more 'hail and ride' services, service frequency and reliability were regarded as important but less of a priority by this grou*p.*

A more recent study by London Transport (1997) on passengers attitudes towards interchange revealed a number of key findings relating to customer information; physical infrastructure; service integration; staff; and the travel environment. The key findings from this work are summarised in Table 5. Further work undertaken for London Transport (Conquest Research, 1997) using a combination of focus groups and in-depth interviews found that passengers, particularly commuters and business users, select the fastest more direct route. Interchange for this group is seen to offer no benefits beyond minimising journey times and indeed is seen as a potential cause of delay. Trips made for leisure purposes and by the retired, where time is less critical than for the journey to work, may involve trade-offs at the margin between journey time and other factors such as comfort and convenience. Interchange was also seen to involve physical effort and mental stress. Poorly designed interchange facilities although a factor in non-users' rejection of public transport were rarely the main factor. Older people and those whose mobility is impaired, either due to poor health or carrying luggage, suffer most from poor physical design and bus to rail links are generally perceived as being the worst in this respect. This study also identified staffing and safety as major issues for passengers at interchange locations. Increased staffing levels was seen as a key to raising passenger perceptions of safety. Travel information was felt to be an important factor in alleviating uncertainty. Regular travellers felt that real-time information was important, particularly when services are delayed, while travellers on unfamiliar routes wanted journey planning information and reassurance at key 'decision points'.

**Table 5: Key Findings - London Transport Study**

| | |
|---|---|
| Customer Information | • passengers don't plan their route in advance preferring to work it out en route. Off-site information therefore less beneficial than on-site information;<br>• maps tend to be preferred to leaflets and timetables for journey planning;<br>• real-time on-site information is viewed as the best type of information for multi-modal journey planning;<br>• real-time bus passenger information systems whilst allowing passengers to plan their journey also enhances feelings of personal security;<br>• passengers do not like the points of the compass to be used in signage to describe route direction |
| Physical Infrastructure | • certain groups of passengers (including the disabled, people with small children, or people carrying luggage) may be discouraged from using the Underground due to the lack of lifts;<br>• passengers expressed a preference for escalators rather than lifts;<br>• passengers, especially female passengers, perceive route ways as being less secure than platforms or booking halls (50% of passengers reported feeling insecure in passageways);<br>• passengers concerned about crime and overcrowding at busy interchanges, particularly busy platforms. |
| Service integration | • infrequent users cite lack of access as a key reason for not using the underground;<br>• more than 50% of Londoners claim to live more than 15 minutes from an underground station;<br>• 5% of Londoners claim that using a bus is impossible or difficult - difficulty in getting to the bus stop is the main reason for finding. |
| Staff | • passengers concerned about staff availability;<br>• live human voice rather than pre-recorded messages is preferred by passengers - this was felt to give the feeling that someone was in control;<br>• passengers prefer human interaction to ticket machines when buying |

| | |
|---|---|
| | tickets;<br>• staff do not feel that giving information about other operators' services is their responsibility, although the benefits of providing this information is recognised;<br>• the presence of staff is a major factor in increasing a passengers sense of personal security. |
| Travel environment | • station buildings perceived as functional - cleanliness, good lighting, high level of maintenance is seen as important;<br>• natural light important especially in tunnels and route ways;<br>• ticket hall seen as the main focus for obtaining journey planning information. |

Qualitative research undertaken for London Transport (London Transport, 1993) on multi-modal transport information needs of Londoners found that staff tended to think in terms of information methods rather than needs. The research found that customers felt that staff had poor knowledge of the local area they worked in and of information about other modes of transport. The study identified several aspects of real-time multi-modal transport information needs including:

- general information about services;
- route planning;
- where and how to interchange;
- information about the disruption to other operators' services.

A study of interchange outside Central London has been conducted at 11 rail stations, predominantly underground stations, where the volume of rail interchange movement is higher than the volume of passengers entering or leaving the station (London Transport Planning, 1997). The study found that the number of interchange movements outside Central London at National Rail Network (NRN) stations is much smaller than the number of interchanges to underground services because there are normally higher frequencies on Underground services; Underground services provide access to a greater range of destinations in the central area; Underground services provide for interchange at most points where lines cross although this is not always the case for NRN services and faster more direct services on the NRN network mean that the majority of interchanges with the underground take place at the Central London termini. Walking was found to be the main mode of access to rail stations, accounting for 70% of trips, followed by bus for underground stations (16%) and car for NRN stations (15%). Car to rail interchange movements were greater than those made by bus to rail. Outside the central area bus to rail movements account for just under half of interchange movements.

A study of attitudes to public transport among commuters in Stockholm revealed that 30 minutes was regarded as a reasonable travelling time to the city centre and to work. Respondents living in the city centre were found to be more satisfied with public transport than those living in the suburbs. 5 minutes was quoted by most as a reasonable walking time between home and the bus stop. The study also revealed that 80% of respondents living near the centre and 90% of those living in the suburbs considered it important not to have to change from train/underground to bus or between buses. The survey also found that the importance of getting a seat increased with increases in travel time - 13% stated that they started earlier in the day in order to get a seat whilst many also stated that they would move house and or work if they had to habitually stand on public transport. Many also stated that they began to use there cars for this reason. The most important improvements that could be made to public transport cited by respondents were: better bus shelters at stops, higher service frequency and no interchanges. A 1976 study, also conducted in Stockholm amongst households without cars, revealed that those without cars were more satisfied with public transport than those with cars. Dissatisfaction with public transport was found to focus on service frequency, routing of services and fares. Older people in the surveys stated that they would prefer shorter walking distances to the stops, ease of getting on and off, access to seats and no interchanges. Young people wish to have greater service frequency and more evening services (Andreason, 1976).

Gothenburg (Gothenburg Traffikkontoret, 1991) undertook a study of interchange points in the city. The report concluded that interchange points must be designed as an integral part of the journey and identified that the main factors in interchange decisions were distance between different services and differences in the length of wait. The study also concluded that in town centre locations clear layout and safe movement of travellers are most important. The proposals to improve interchange related to new terminal designs, facilities which improve the waiting environment and information for passengers prior to arrival at the terminal.

The results of these attitudinal studies suggest that interchange valuations and behavioural response will vary strongly across both individuals and interchange conditions.

## 7. ASYMMETRY, PACKAGES AND TARGETS

### 7.1 Alternative Choice Rules

The theory of consumer behaviour outlined in section 2.5 assumes compensatory decision making. Individuals are assumed to choose that alternative from the set available which has the highest utility and this utility is represented as a combination of the levels of relevant attributes and their utility weights. In determining which alternative has highest utility, individuals are prepared to trade-off poor performance on one attribute against good performance on another.

Although this theory is persistently criticised as unrealistic, it has remained remarkably resilient to this criticism as witnessed by its domination of empirical studies. This is in no small part due to the absence of studies which have tested whether modelling approaches based on other theories are more appropriate and also due to the fact that it is more straightforward to base travel behaviour models on the compensatory decision making approach.

The conventional compensatory theory of travel choice implies that, in the absence of income effects, the following two cost variations would be the same:

- the increase in the cost of car which is just sufficient to persuade a car user to use the next best alternative mode, ceteris paribus

- the reduction in the cost of the best alternative mode that, ceteris paribus, would be just sufficient to cause a switch to that mode.

There may well instead be asymmetries in behaviour. A persuasive example is that car users are satisficers and, provided that car remains at least satisfactory, they are not interested in other modes. An extreme version of this is that it is possible to force car users away from car but it is not possible to entice them to other modes. If this is so it has important implications for whether policies to induce modal transfer as based on 'carrot' or 'stick' measures.

A proponent of the compensatory approach would state that this behaviour is consistent with the conventional theory on the grounds that the cost reduction on the best alternative would have to be larger than the actual cost of that mode and hence, in a world of positive prices, it is hardly surprising that car users could not conceive of themselves switching.

This is an important issue given its implications for demand models and policy measures and that the alternative theories cannot be dismissed as implausible. However, we are not aware of British evidence which has convincingly addressed this issue. Evidence was discussed in section 4 relating to the asymmetric effect on rail demand of the removal of interchange and the introduction of interchange, although this 'irreversibility' could be due to different degrees of awareness of each type of change or because of some more fundamental behavioural change, such as the purchase of a car, whereby a person who stops using public transport when an interchange is introduced would not return to it if the interchange was subsequently removed.

This discussion relates closely to the decision making procedure where individuals choose amongst available alternatives on the basis of them achieving certain targets. Conventional models will allow, for example, the need to interchange and a poor interchange environment to be compensated for by, say, lower prices. However, demand forecasts based on such a model would be misleading if car users were not prepared to accept poor interchange conditions regardless of how low the price of public transport became. Nonetheless, unlike the theory above, they would be prepared to switch to public transport if it achieved the target levels of a range of attributes. We are not aware of empirical evidence on whether this choice rule is relevant in the evaluation of changes in the need to interchange or in interchange conditions and environment .

Related to this 'elimination by aspects' approach of choosing between alternatives according to their satisfaction of certain standards or targets is the issue of whether a package of improvements can have a bigger effect than the sum of the effects of the constituent improvements separately introduced. Again evidence is sparse, but there is anecdotal evidence that the impact on bus demand of introducing a package of improved frequency, better information, faster journey times and new vehicles is proportionately greater than the separate impacts.

### 7.2 Indirect Evidence

Empirical evidence on the most appropriate choice rule to forecast travel behaviour, or of means to identify whether one approach is more appropriate to some travellers and another approach is more suitable to others, is sparse. However, there are studies which although not having the explicit purpose of testing alternative choice rules do nonetheless shed some light in this area and indicate that further research is warranted.

The research conducted for London Transport using focus groups and in-depth interviews (Conquest Research, 1997), as discussed in section 6.2, seems to suggest that the degree of trading-off between attributes by commuters and business users is less than would be desired by models based on the compensatory approach.

A recent study as part of MIST (Maidstone Initiative for Sustainable Transport) revealed that although a sizeable proportion of the population expressed a preference to use the car less, the car was, as expected, viewed more positively than public transport travel (Hodgson, May, Tight and Conner, 1997). Work in the Netherlands has also highlighted the need for public transport to project a positive image. This compares to a strong positive image for the car (Stopher, 1982). Other work has identified lifestyle, defined as a set consisting of behaviour, values and attitudes, as an important factor in mode choice (Berge and Nondal, 1994). Stokes (1996) reports on findings from a questionnaire survey of behaviour and attitudes of 450 commuters into central Liverpool. The study found that views and level of persuadability to a change of mode varied considerably. Quality of public transport in this case was of less importance than knowledge about it. Some would need little persuasion while some would be very resistant. Characteristics such as knowledge and use of public transport for other purposes, as well of length of driving experience, age and gender were found to be the most important factors.

In a study into public awareness of transport issues conducted by Colin Buchanan and Partners for the City of Edinburgh Council (1996), motorists were asked what would make them switch to public transport for the journey to work. The findings are reported in Table 6. It can be seen that about 30% of the sample stated that nothing would make them switch but for the rest of the sample direct and frequent public transport and financial issues had the most impact.

**Table 6: What Would Make Motorists Switch to Public Transport?**

| Reason | Commuters | Visitors |
|---|---|---|
| More frequent public transport | 11 | 8 |
| Direct bus route | 11 | 8 |
| Financial reasons | 7 | 5 |
| Direct train route | 5 | 3 |
| If car was needed by someone else | 5 | 6 |
| Moving to a more convenient location | 5 | 5 |
| Cheaper public transport | 5 | 9 |
| Parking constrained/ higher priced | 2 | 4 |
| Park and Ride | 2 | 4 |
| Better public transport | 4 | 2 |
| Other | 13 | 13 |
| Would never switch | 30 | 33 |

| | | |
|---|---|---|
| Total | 100% | 100% |
| Sample | 189 | 100 |

Findings which in some ways contrast with the theories discussed in section 7.1 were provided by the Tayside Public Transport Household Survey (Travel Dundee, 1996). It suggested that positive measures to improve bus services are more likely to promote bus usage than negative measures to discourage travel by car. Some results of the survey are presented in Table 7. Of the bus improvement measures cited in the survey, the most highly rated were a reduction in fares, greater reliability, faster services, greater cleanliness, better routes and more bus information. However, most interestingly, the survey also found a group of committed car using households representing 28% of those generating fewer than 5 bus trips a week where the offer of free travel would be unlikely to entice them onto the buses. Survey results also suggest a commitment to the car amongst car owning households because the household has invested in the car and the perception amongst this group is that in order to make the same journey by bus they would have to change services.

**Table 7: Importance of Factors Affecting Bus Use (1=Very Important 4=Not Important)**

| | Average Score by Car Ownership Level | | |
|---|---|---|---|
| | 0 Car | 1 Car | 2+ Cars |
| Lower fares | 1.6 | 2.0 | 2.0 |
| Better bus routes | 2.1 | 2.1 | 2.1 |
| Quicker journeys | 2.2 | 2.1 | 2.1 |
| Park and Ride | 3.4 | 2.8 | 2.8 |
| More reliable bus | 1.8 | 2.1 | 2.1 |
| Increased parking charges | 3.7 | 2.9 | 3.1 |
| Lack of parking spaces | 3.6 | 2.3 | 2.5 |
| Increase in petrol prices | 3.4 | 2.8 | 2.9 |
| Better bus information | 1.9 | 2.2 | 2.2 |

## 8. DESIGN STANDARDS AND GUIDELINES FOR INTERCHANGE

The literature has also been concerned with the specification of guidelines to help define the architectural/design requirements of interchange from a traveller and operator perspective.

Briaux - Trouverie (1995) identifies a range of barriers within interchanges that prevent disabled persons from using multi-modal public transport for their trips. These are:

- physical barriers, including the inadequate planning of the connection between modes, length of walkways and lack of rest places;
- barriers to understanding - including signing and legibility of environments;
- situation barriers relating to the inability to a disabled passenger to transfer quickly between modes;

- psychological barriers, including personal security, fear of being stranded when a service is not provided;

- pricing barriers, including the diversity of prices and incompatibility of tickets.

Preliminary work has indicated that the physical design of interchanges are of key importance to the disabled traveller. In the interchange area the key factors which influence the decision-making of the disabled traveller were walkways, the information provided in the waiting area and the comfort of the waiting area. This work found that comprehensive signing could reduce the time spent at ticket dispensers, give directions to telephones and coffee machines. In addition, sign-posting and information about how to move between different services within the interchange can also have a large impact on connection time. The work also discussed the need for signing to be legible.

Barham et al. (1994) produced guidelines for the design of public transport infrastructure, including interchanges, terminals and stops. At the time of writing this work was in the process of being updated by the Mobility Unit at DETR. The original guidelines were based on experience and empirical research from around the world which had looked at what design met the needs of sensory and physically impaired people. To date however there is no recognised international or world standard in place and different countries still produce their own guidance. The guidelines provide information on: siting and general considerations for bus stations and interchanges; general design principles for bus and rail stations; access to and within buildings and railway stations; station accommodation and furniture; bus and railway services; public transport information and signs. The report (Barham et al., 1994, p7) states that:

> "*Good design is an essential ingredient if passengers are to find travel by public transport both convenient and safe and enjoyable, and architecture and interior design should always give priority to passenger needs. Little research is available on the reasons (often psychological and difficult to define) why passengers fail to use - or stop using - public transport. Clearly service frequency and reliability, far levels the accessibility of vehicles and staff attitudes are all involved, but the general ambience, clarity of design and information, and the comfort found at bus stops and stations are also major factors*"

London Underground have also produced guidelines on the design of stations and also on station planning standards and best practice guidelines for all works at stations that affect passenger movement (LUL, 1991a; LUL, 1998). The guidance establishes that the key benefits of establishing interchange links are:

- shortening connections and thereby reducing journey times;

- improving the ambience and comprehension of available options and routes;

- extending the transport network as a whole;

- initiating more effective use of the network;

- reducing congestion at key point especially at main line terminals.

The guidance argues that it easier to achieve improved bus interchange facilities than rail to rail facilities. Guidance has also been produced for the Jubilee Line Extension (LUL, 1991b; 1993). Advice on access to the underground for elderly and disabled people is provided by the London Transport Unit for Disabled Passengers (1993). This provides detailed information in tabular form of the facilities and layout of each station including factors that can affect accessibility to stations such as for example stairs, lifts and ramps. Codes of Practice have been produced by the Office of the Rail Regulator (1994) and the Disabled Persons Transport Advisory Committee (DPTAC, 1994; Office of the Rail Regulator, 1994) on meeting the needs of disabled passengers and the legibility of timetables and leaflets. The emphasis within both documents is on the quality of information about public transport provided by operators and the design of stations.

A public transport interchange study undertaken by Ove Arup (1995) for West Midlands Passenger Transport Authority obtained information on the facilities and conditions available to passengers at 50 bus stop locations. The report provided site specific information on these locations including surrounding land uses, the pedestrian environment, the bus stop location, road crossing facilities and walk routes. The report concluded that issues of vandalism may be pronounced at interchange sites and that the passenger environment should be controlled similar to that in bus stations. The study also indicated that the quality of passenger facilities needs to be improved for these locations and found that there was a lack of information about services provided at stops. The study recommended that:

- information at bus stops should be provided and that this should correspond to an agreed minimum standard;

- adequate lighting at bus stops be provided;

- systematic interchange signing between stops;

- interchanges should be identifiable from buses with for example distinctive place names or markings;

- all stops should be compulsory stops;

- bus stops should be located on common route sections to enable interchange with out the need for a walk to another bus stop;

- a need for comprehensive treatment of interchange locations to create a bus station quality environment on street. This would include for example all bus stops to have a shelter and seats, stop plates with route details and all stops to include a route map and other interchange information.

Wood and Peck (1995) provide some insights into the considerations required in order to make trams accessible including level of boarding, vehicle and platform design. The paper also identified the need for both vehicle and service information, for example, stop location, route information, information on connecting services and timetables, to be readily available. The Bus and Coach Council (1992) produced a report "Better Buses". The code of practice is concerned with the physical design standards for bus services, provides guidance on the location of bus stops and shelters and the design of the bus stop environment. The main recommendations were that:

- the walking distance to a stop should not exceed 400 metres;
- bus stops should be 300-400m apart;
- the provision of bus shelters to improve the quality of the wait time;
- to improve perceptions of safety `bus stops should be transparent, well lit and in a prominent position to oncoming passing traffic so that users can be seen;
- route and timetabling information should be provided.

Williams, Foster and Anderson (1995) discussed research undertaken for the CrossRail project. The paper reports findings from CrossRail Passenger Access Study which included two passenger surveys on the London Underground and the Tyne and Wear Metro. The surveys indicated that London Underground is failing to attract about half the potential passengers who are mobility impaired due to the systems poor accessibility (step free access is available at 43 out 270 stations on the Underground. In comparison the Tyne and Wear Metro is fully accessible). The Tyne and Wear Metro was found to attract nearly double the proportion of mobility impaired passengers compared to the Underground in London. Study concluded by estimating that if the Underground became step free that demand would increase by 5% (assuming demographic similarities between London and Tyneside) and that the size of the potential market should provide operators with necessary incentives to make investments. The increase market share was expected to come from mobility impaired passengers, parents accompanying young children, and greater use of the system being made by able-bodied passengers making modal interchanges. A report by London Underground, 1995) also examined the implications of step free access to the Underground.

Much work has been undertaken on safety and security issues on public transport and has been fed directly into guidelines and guidance notes for the public transport industry (Directors of Planning, 1996; Mersey Travel, 1995; CENTRO, 1995). The reports identify design strategies and approaches which can be used to target crime at all stages of a public transport trip, that is, journey to the public transport system, terminals and on vehicles.

Colin Buchanan and Partners (1998) conducted a survey of those involved in co-ordinating public transport. This elicited views on best and worst practice throughout Britain which is useful in identifying issues which are important in designing interchanges and which should be accounted for in a study of the impact of interchange on demand. The views of the public transport co-ordinators of the key features of good interchange were: reliable services, high frequency services, good connections, high capacity services, short walking distances, staff availability, car parking availability, through ticketing, enquiry facilities and cheap or free parking. Bad practice was regarded to be represented by long walking distances, absence of car parks, low service capacity, poor infrastructure, poor waiting facilities, lack of weather protection, lack of through ticketing, poor connections, lack of personal security and low frequency services.

## 9. EFFORT

As noted, interchange valuations will vary strongly across both individuals and interchange conditions. Individuals' perceptions of the utility of interchange conditions will determine whether they tend to approach them with enthusiasm or trepidation or, indeed, endeavour to avoid them.

Any undertaking requires the expenditure of resources of physical effort, mental effort and affective effort in order to meet the demands of the situation. Travelling is no exception. Mode choices and mode changes entail not only the expenditure of time and money in order to reach one's goal or destination but also the expenditure of effort.

At an interchange, transferring from arrival platform to departure platform, especially if burdened with baggage, will expend physical effort. Seeking out and correctly interpreting transit information will involve cognitive or mental effort whilst waiting time can be worry time where affective energies are expended on concern with missing connections and with personal safety, comfort and well-being.

In a current study (Stradling, Meadows and Beatty, 1999) motorists were asked to rate the importance of various features of public transport provision. Four aspects were rated as 'Extremely' or 'Very Important' by three-quarters or more of the respondents and these are listed in Table 8.

**Table 8: Extremely or Very Important Aspects of Public Transport Provision**

| | |
|---|---|
| How reliable the service would be | 97% |
| How frequent the service is | 87% |
| How convenient you thought any interchange was likely to be | 81% |
| The ease of getting information about services | 75%. |

In this, as in many other such studies, service reliability is an almost ubiquitous customer requirement. Reliability enables travellers to meet their travel plans and obligations, avoids additional effort on remedial plans and actions, and reduces worry. Indeed <u>in</u>convenience to a traveller probably involves unanticipated and unwanted expenditures of physical, mental and affective energies. There is a requirement therefore to unpack components of the individuals utility function and increase understanding of how these differ in different interchange locations.

Taking a new approach to unpacking the components of the individual's utility function, we recommend the investigation of the extent to which ratings of the amount of physical, cognitive and affective effort that would need to be expended in various interchange scenarios correlate with stated preferences. Instead of taking valuations in time or money units as proxies for the felt personal costs of choices, it would seem sensible to attempt to measure these more directly. It is an interesting empirical question whether effort ratings prove to be already well captured by the time and money proxies, or whether they add an important new dimension to predicting consumer preferences.

# 10. CONCLUDING REMARKS AND RECOMMENDATIONS

We here briefly summarise the key findings of our literature review and make recommendations on the basis of this review for the second stage of the study. Note that the focus groups and in-depth interviews conducted alongside this literature review in the first stage of this project will also have a strong bearing on stage two of the study. The conclusions from all the aspects of this first stage of the research will be drawn together in the stage one final report.

## 10.1 Summary

Although interchange has a cost associated with it, which can in some circumstances be considerable, and it is an important factor in travel choice, it does open up a wider range of journey opportunities by public transport. CIT (1998) point out that the London experience, as well as experience abroad, shows that interchange can be acceptable. However, there remains a considerable degree of uncertainty regarding the likely outcomes of policies which lead to changes in the need to interchange and particularly those which vary interchange conditions and environments.

The conventional view is that there has been little research on interchange values, behavioural response to interchange and the impact of greater integration between modes. For example, Colin Buchanan and Partners (1998) stated:

> "*the literature available on interchange appears to be relatively sparse and rather old*"

The GUIDE project (MVA, 1998) concludes that:

> *"There is very little literature on network integration benefits"*

and that:

> *"Overall it appears that the literature is sparse also on the topic of [interchange] evaluation"*

The conclusions of the GUIDE project with regard to the existing state of knowledge are quite apparent from their recommendations for further studies. These include research in the areas of ticketing and interchange, information and interchange, interchange and its effect on mode split, passenger attitudes and behaviour and how they change, and interchange in transport modelling including the interchange penalties and other aspects of generalised cost that are used to forecast.

CIT (1998) make a large number of sensible recommendations aimed at practical ways of improving interchange and integration within the confines of current policy considerations and practical constraints. However, they recognise that it would be difficult to evaluate the benefits and impacts on patronage of many of the recommendations because of the gaps in knowledge:

> *"The CIT supports research proposed by DETR to assess how passengers' travel choices are affected by the need to interchange and the likely effects on patronage and modal shift of making specific interchange improvements".*

Our view is that there have been rather more studies on interchange values and interchange elasticities than is commonly appreciated, and this is borne out by the number of studies that we have reviewed. Nonetheless, there are limitations to the body of existing evidence:

- the research has a heavy bias towards rail and particularly that which is inter-urban.

- there is relatively little on the subject of integration and less evidence about interchange elasticities than interchange values.

- there has not generally been a clear distinction made between the penalty, transfer time, waiting time and integration components of interchange.

- although there is a reasonable amount of evidence on how interchange valuations and interchange elasticities vary with person type, there is little evidence on how the valuations and elasticities vary with interchange conditions.

In addition to reviewing the valuations of and behavioural responses to interchange and integration, we have considered perceptions and attitudes. There is a considerable amount of evidence of a qualitative nature relating to attitudes and preferences towards interchange attributes. It indicates that considerable variation in interchange valuations and elasticities can be expected according to person type and interchange type. In stark contrast, relatively little research has been conducted on the extent to which individuals correctly perceive either the utility associated with interchange attributes or the levels of the interchange attributes themselves. It may be that improvements could be made at modest cost by altering perceptions of interchange conditions rather than the actual conditions themselves.

We have considered that there are plausible competing theories of travel behaviour to the conventional compensatory approach. However, there is little evidence which tests whether choice rules based on targets or satisficing have a role to play. The presence of such choice rules would have important implications for the evaluation of improvements to interchange and integration. Similarly, the introduction of a package of public transport improvements may provide a proportionately much more effective means of achieving modal transfer than more piecemeal measures.

We have outlined a new approach to unpacking the components of the individual's utility function which investigates the extent to which ratings of the amount of physical, cognitive and affective effort that would need to be expended in various interchange scenarios predict behaviour. Instead of taking valuations in time or money units as proxies for the felt personal costs of choices, attempts could be made to measure these more directly. It is an interesting empirical question whether effort ratings prove to be already well captured by the time and money proxies, or whether they add an important new dimension to predicting consumer preferences.

The balance function, which is the preferred or optimum balance between physical, mental and affective 'expenditures', will likely vary from person to person, from time to time and from trip type to trip type. Appropriate multivariate statistical procedures, such as factor analysis, should enable us to group together interchange conditions according to which type of effort they demand from the traveller. And analysis by demographics such as age, gender, social class, income and by trip type such as travel to work, travel on work, leisure or pleasure should assist in much more detailed market segmentation by delineating what balances are optimum for which groups of travellers. Although it is discussed in more detail in companion reports, the in-depth interviews and focus group findings do seem to support this approach.

The matrix in Table 9 serves three purposes. It lists the key policy variables as far as this study is concerned (ROWS), it identifies the principal factors which impact upon the policy variables (COLUMNS), termed segmentation variables, and it summarises what we regard to be the current state of knowledge for the combinations of policy and segmentation variables (CELLS). The amount of empirical evidence regarding a particular issue is described as considerable (C), moderate (M), little (L) or none (N).

Although we have listed the principal variables within each segmentation category, such as age, gender, impedance and socio-economic factors within the person type category, further disaggregation of the matrix into these specific variables would serve no useful purpose since at such levels the evidence is generally sparce.

The table summarises the main thrust of our conclusions that, despite there being more evidence than is widely believed, there is genuinely considerable scope for further work in this broad area.

**Table 9: Summary of Current State of Knowledge**

| | **Trip Type** | **Person Type** | **Interchange Type** | **Amount of Variable** | **Interchange Components** | **Alternative Theories** |
|---|---|---|---|---|---|---|
| | Mode<br>Purpose<br>Distance<br>Group<br>Constraints | Age<br>Gender<br>Impedance<br>Socio-econ | Comfort<br>Security<br>Opportunity<br>Uncertainty | Non-linear<br>Interaction | Penalty<br>Transfer<br>Wait<br>Transaction<br>Integration | Asymmetry<br>Targets<br>Package |

| | | | | | | |
|---|---|---|---|---|---|---|
| Interchange Value | C | M | L | N | L | N |
| Interchange Elasticity | M | L | N | N | N | N |
| Integration Value * | L | L | N | N | N | N |
| Integration Elasticity * | N | N | N | N | N | N |
| Attitude and Preferences | M | M | C | N | M | N |
| Perceptions | L | L | L | N | N | N |
| Effort | N | N | N | N | N | N |

Note: * Various travel choice and behavioural studies provide estimates of the values and demand effects of improved accessibility to public transport, improved car parking, through ticketing and better information. However, none deal simultaneously with the full range of integration issues.

## 10.2 Recommendations

A number of recommendations emerge from this review of the literature with regard to future research directions. Although this study cannot be expected to satisfactorily address all the issues identified, we recommend further research in the following areas:

- A clear distinction needs to be made between the penalty, transfer time and waiting time elements of interchange. It is not satisfactory to assume that connection time is valued at twice in-vehicle time nor to estimate interchange penalties which include elements of other effects. Detailed analysis of factors which influence the costs of interchange requires disaggregation into the above component parts and the avoidance of results which represent 'average' interchange sites and conditions.

- Research should be conducted on how the various interchange values and the behavioural response to interchange vary with the characteristics of the person and the trip. In particular, more emphasis needs to be placed on the bus market.

- There is a need to examine in greater detail how different interchange conditions and environments influence the costs of interchange and the interchange elasticity.

- Issues associated with integration need further research, particularly the expected impact on demand.

- The relatively straightforward market research techniques which are widely used to examine basic attitudes and preferences should be enhanced to examine the importance of well defined barriers to interchange in relation to each other and also in relation to time or money.

- The extent to which individuals, particularly non-users, misperceive the levels of interchange attributes and the utility weights associated with these attributes should be analysed.

- Possible asymmetries in travel behaviour and the possible presence of decision rules which are not compensatory, such as those based on achieving certain targets, should be examined.

- The existence of package effects needs to be explored.

- An alternative approach to the analysis of behaviour is based around the various types of effort involved. Research should examine whether such an approach can provide a better account of behaviour than the conventional approach based on elements of generalised cost or indeed whether to some degree the two approaches can complement each other.

There is also ongoing research funded by the European Commission: the MIMIC project aims to construct models to predict demand changes whilst the PIRATE study is examining perceptions of interchange and GUIDE is establishing a guide to good practice. The Department of the Environment, Transport and the Regions has commissioned a study on interchange whilst we understand that the Office of Passenger Rail Franchising is interested in commissioning fresh empirical research after having conducted a review of the issue. Any further research should therefore pay attention to developments that are being made elsewhere.

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