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ROUND TABLE 19

INFLUENCE OF COST, QUALITY AND ORGANISATION OF TERMINAL TRANSPORT AND INTERCHANGES

ON THE CHOICE OF PASSENGER TRANSPORT MODE

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

Paris, 1973

ECONOMIC RESEARCH CENTRE

REPORT OF THE NINETEENTH ROUND TABLE ON TRANSPORT ECONOMICS

Held in Paris on 16th and 17th November, 1972
on the following topic:

INFLUENCE OF COST, QUALITY AND ORGANISATION OF TERMINAL TRANSPORT AND INTERCHANGES

ON THE CHOICE OF PASSENGER TRANSPORT MODE

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

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INTRODUCTION

The co-existence of more and more transport technologies, spurred by innovation and combined with urban growth, has led to increasing specialisation within a hierarchy of transport modes. As a consequence, transfers between modes have become an important factor in urban and suburban modal split. Public transport users resent such transfers all the more strongly as they feel that they would be spared this inconvenience if they used their cars.

Problems of urban congestion and the authorities' oft-declared intention to promote the use of public transport made it all the more appropriate to hold a Round Table on this subject.

However, the Round Table made it quite clear that, despite the importance of the subject and its consequences on the future of mass transportation, research in this field has not progressed very far. The ECMT is accordingly most grateful to the rapporteurs for their contribution and to the participants for the work done as this has made it possible to take stock of the present position and to make progress in an area which has been much neglected.

There has been an increasing demand for copies of Round Table publications. These were hitherto issued free on request. In view of the work involved in dispatching them, it has been decided that they would now be charged for. Applications for copies of this publication should be sent direct to:

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LIST OF PARTICIPANTS

Professeur J. VOLMÜLLER (Chairman)
Technische Hogeschool Delft
Kanaalweg 2b
DELFT (Netherlands)

Mr. D.J. WAGON (Rapporteur)
Operational Research Officer
London Transport
Transad House
Leicester Square Station
LONDON WC2 (United Kingdom)

Mr. P.H. COLLINS (Rapporteur)
Operational Research Department
London Transport
Transad House
Leicester Square Station
LONDON WC2 (United Kingdom)

Professor G. BERGENDAHL
Department of Business Administration
Göteborgs Universitet
Vasagatan 3
S-41124 GOTEBÖRG (Sweden)

M. A. BIEBER
Institut de Recherches des Transports (I.R.T.)
2, Av. du Général Malleret-Joinville
94 - ARCUEIL (France)

M. A. BONNAFOUS
Directeur, Section Transport
Institut des Etudes Economiques
Université de Lyon
18, Quai Claude Bernard
69007 LYON (France)

M. A. BUDILLON
Institut de Recherches des Transports (I.R.T.)
2, Av. du Général Malleret-Joinville
94 - ARCUEIL (France)

Dr. F.X. de DONNEA
Institut d'Administration et de Gestion
Université de Louvain
Dekenstraat 2
3000 LOUVAIN (Belgium)

M. O. HIORTH
Chef de Recherche
Transportøkonomisk Institutt (TØI)
Stasjonsveien 4
OSLO (Norway)

Dr. G. HUPKES
Deputy-Director
Centrum voor Vervoersplannen
Willem Dreeslaan 16
UTRECHT (Netherlands)

M. F. MELLET
Maître Assistant Associé Urbanisme
Université de Paris VIII
Route de la Tourelle
75012 PARIS (France)

M. M. SAUVEZ
Institut de Recherches des Transports (I.R.T.)
2, Av. du Général Malleret-Joinville
94 - ARCUEIL (France)

M. J.M. SEGURO
Ingénieur-Inspecteur Supérieur de Travaux Publics
Directeur, Gabinete de Planeamento dos Ministerios
das Obras Publicas e das Communiçacoes
Rua da Prata, 8, 2°
LISBOA-1 (Portugal)

Dipl.-Ing. Arnim WIRSCHING
Hamburger Verkehrsverbund (HVV)
Domstrasse 15
2000 HAMBURG 1 (Germany)

M. T. BENDIXSON
Environment Directorate
O.E.C.D.

Secretariat: MM. A. LE WAELE
A. RATHERY

INFLUENCE OF COST, QUALITY AND ORGANISATION OF TERMINAL TRANSPORT AND INTERCHANGES ON THE CHOICE OF PASSENGER TRANSPORT MODE

D.J. WAGON and P.H. COLLINS
Department of Operational Research
London Transport Executive

ABSTRACT

This paper was prepared at the request of the European Conference of Ministers of Transport for their 19th Round Table (16th-17th November, 1972).

In it, various aspects of the design and location of interchange facilities and feeder services are discussed. The development of mathematical models to predict the effects of such schemes is described and some more general problems of integrating the evaluation of interchange schemes in an urban planning context are discussed. Finally the paper suggests tentative lines for future research.

The views expressed in this paper are those of the authors only. They do not necessarily represent the views of the London Transport Executive.

SUMMARY

Chapter 1

INTRODUCTION

1.1. Discussion

There has been much discussion on the importance of interchange in public transport. A report by an OECD panel(1) argued that the objectionable element of any journey is the time involved in transfers between services and in making secondary trips at the ends of the line haul journey. Any benefit to be gained from increases in speed in the main journey is likely to be marginal if other aspects of the total trip are ignored. To quote:

> "Taking into consideration time spent in transfers, in waiting and in secondary movements at the ends of the trips, the incremental benefit in terms of reduced door-to-door trip time to be derived from increased speeds during the main portion of the journey would be relatively unimportant."

They agreed that it is of primary importance to improve the quality of urban passenger travel by improving passenger comfort, the facility for transfers between modes, the design of terminals and by developing convenient, reliable all-weather transportation services with a high degree of predictability of arrival time.

The importance of effective interchange between rail, car and bus is being increasingly recognised by the authorities responsible for the planning of transport in the conurbations of Europe and the United States. In the past more attention was given to the provision of new lines and to the replacement of outdated vehicles whilst the improvement of existing infrastructure received little attention. There is now

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1) OECD "Future directions for research in urban transportation" (Report of a panel and papers), Paris (1969).

increasing evidence of the awareness that good interchange design and location may help public transport to compete in terms of cost, speed and general attractiveness and quality of service.

It is argued that there is little value in spending resources on the improvement of individual systems or lines if the means of gaining access and changing between the individual systems are not improved to comparable efficiency.

In London the Greater London Council have stated(1) that they see the provision of interchange facilities as "a key factor in determining the overall level of accessibility and flexibility of service that public transport provides" and in their policy statements they stress the need to improve what they consider "this weak link in the transportation system."

Elsewhere systems have been implemented which have the improvement and provision of interchanges as dominant factor in their planning - this is true of a number of European cities and metropolitan areas in America (where private transport is the main feeder into the rapid transit system).

A case in point is Toronto where R.G. Bundy, in an article(2) on parking in the city, states that "good interchange design (in Toronto) offers easy transfer from bus and tram to the Underground railway and so keen are the authorities to encourage park and ride that a large proportion of all off-street parking facilities in the city are located at Railway interchanges."

The problem in studying interchanges is however more complicated than the study of how to provide easy transfers between modes. It is also important to consider the role that interchanges play in different types and sizes of cities, and for different forms of public transport. Thus, it may well be possible to organise particular forms of public transport in such a way so as to minimise, over the whole transport system, the need to interchange.

Another interesting question is to enquire to what extent the need for interchange is a function of city size. For a small centrally oriented town the percentage of trips that

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1) Greater London Council: Greater London Development Plan: Report of Studies, London (1969).

2) Bundy, R.G., "The Parking Authority of Toronto": Traffic Engineering and Control 12 (5) September 1970, pp. 262-264.

require interchange movements may be very small. On the other hand, for a large town with its more complex pattern of trips and trip purposes, the percentage needing to interchange will be much higher. Appendix A discusses some preliminary analysis of findings in London, which suggest that as many as 50 per cent of all public transport trips involve at least one interchange. It would be of great interest to know how this proportion varies for different sizes of city.

Thus it is clear that interchanges are an important component of the public transport system of a city, particularly for the large cities and conurbations. It is also clear that they must be seen in the context of the whole transportation system of an area, and judged according to the role which it is proposed the system should play. This will be a major theme of this paper.

1.2. THE AIMS AND STRUCTURES OF THE PAPER

The broad objective of this paper is to explore the influence of interchange and terminal transport upon the choice of travel mode. Thus there is a need to increase awareness of the implications of good interchanges and on the provision of good co-ordinated public transport services feeding such interchanges. The argument being, that by providing improved interchange facilities a larger proportion of trips will be made by public transport, and consequently the deleterious effect of the motor car in congesting city centres may be diminished.

In discussing the provision of interchanges in a planning framework, such as this it is useful to start by considering aspects of the design of interchanges and of their location within the transport system.

This can best be done by structuring the discussion according the following hierarchy:

1) Detailed internal design of interchange facilities which reduce the time and effort for users of the system.
2) Studies of the location of interchange facilities within the existing transport system. This includes methods of determining where feeder facilities can best serve the main mode and studies to find the best

points at which to site park and ride facilities, or to build railheads served by feeder buses.

3) Studies of the relationship between the design of transport systems and the planning or urban areas, in order to reduce the number of interchange trips that are necessary.

These questions are at their different levels all aspects of the research side of the design question, and form the basis for Chapter 2 of this paper. Inevitably there is a wide variety of such research techniques that can be brought in to use as tools to aid the design of systems. Having done this it then becomes necessary to begin to set up the planning framework that is necessary to evaluate the alternative designs. This area too needs its own tools to use in the evaluation. However here it is also necessary to establish a method, so that the evaluation of alternatives can be done systematically. Chapters 3 and 4 will attempt to build up such a methodology. First Chapter 3 will review some of the research work that has been done in setting up modal split models, and will indicate the sensitivities that these models have to the various features of interchanges. Then Chapter 4 will discuss the use of such models in urban transportation studies and indicate the means whereby these enable interchanges to be considered as part of a total transport system.

Finally having seen the scope of the problem, Chapter 5 will attempt to suggest the lines that future research should take.

The intention behind this paper is that it should be a review of past work on the subject and an attempt to suggest future lines of research. It has been found that it is very difficult to identify a coherent body of knowledge that represents the present state-of-the-art in interchange studies. Instead it has been necessary to consult a wide variety of different kinds of reports and to try to establish as clear a framework for discussion as possible. In doing this, the authors are very aware that their view is inevitably only a partial one, and they may well have failed to do justice to the breadth of information available. If this is so, then apologies are due in advance, along with the hope that this deficiency will be made good in discussion at the Round Table.

1.3. DEFINITIONS

Before going on to the main body of the paper, it is worth fixing ideas by giving definitions of the situation to be discussed:

a) Interchange - Passenger transport interchange can take many forms covering anything from a local bus stop to a city centre rail, bus and car transportation centre. An operational definition postulated by Parker(1) which would seem to have a reasonable degree of common acceptance is: "a place where there is an interface between two or more modes of vehicular transport and where special arrangements are provided to facilitate transfers of travellers from one mode to another."

It is considered however that the definition of interchange should expressly include facilities where transfer can be performed between different services on routes of the same mode. The above definition is somewhat ambiguous on whether transfers between the same mode are included under the heading 'interchange'. In addition there is probably an advantage in expressly including pedestrian access to bus, rail and car-parking facilities within the compass of the definition. Thus we can define interchange facilities as essentially all interfaces between modes of travel and different services of the same mode and in the context of this paper are taken to embrace the following facilities:

1) facility for car 'park and ride' with rail or bus services
2) facility for car 'kiss and ride' (i.e. set down and pick up)
3) facility for buses to pick up and set down rail passengers (bus to rail) interchange
4) access between different rail services at stations (rail to rail interchange)
5) access between different bus services at bus stations (bus to bus interchange)

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1) Parker, John, "Transport Interchanges - All Change" OAP November 1970.

6) access to bus station and stops for pedestrians
7) access to rail station for pedestrians
8) access to car parking facilities for pedestrians
9) waiting facilities in bus or rail interchange stations

b) Terminal Transport - This is defined as the local feeder transport systems linked to the passenger interchanges as defined above. These can range from pedestrians aids within the physical confines of the interchange facility to bus feeder services spreading into its hinterland.

   However having defined these two words, nevertheless it will be found that confusion can arise in use according to the scale of distances involved. For when studying intercity trips the <u>intra</u> urban feeder trips to main line terminals could be classified as a terminal trip in relation to the whole intercity journey, whereas the same <u>intra-urban</u> trip could be the main leg of a commuter journey.

   In terms of journey classification this paper will concentrate on <u>intra-urban</u> trips since they account for the majority of trips performed in urban areas but most conclusions are also relevant to interchange facilities within urban areas for inter-urban travel, especially since time savings from faster speeds on the intercity links, be they by air, rail or road, may be offset by the unattractiveness of the urban terminal leg.

Chapter 2

ASPECTS OF DESIGN AND LOCATION OF INTERCHANGES WITHIN TRANSPORTATION SYSTEMS

2.1. INTRODUCTION

As stated in Chapter 1, it is possible to develop a hierarchy of improvements to interchange provision ranging from detailed design improvements in the physical fabric of an interchange facility to an investigation of the optimal location of interchange within urban areas and the development of transportation systems which minimise the need to interchange. The structure of this chapter adopts the classification based on this hierarchy and is divided into the following sections:

2.2.) improved design and organisation within the physical confines of the interchange facility.

2.3.) improved sub-modes that feed into the existing interchange facility

2.4.) improved locations for interchange with the existing transport system.

2.5.) improved total transport systems which reduce the need to interchange.

2.2. IMPLICATIONS OF DESIGN AND ORGANISATIONAL IMPROVEMENTS TO INTERCHANGE FACILITIES

This section deals with the first category of improvement and involves an analysis of the travel characteristics of interchange facilities. These can be classified into firstly those aspects associated with movement and expenditure of effort on the part of the users, secondly those related to waiting time, and thirdly those relating to the environment.

A breakdown of these user costs and possible methods of improving them is set out in Table 1.

Table 1

Components of user cost at interchange	Improvement possibilities
1. <u>Movement user costs</u>	
1.1 time spent walking	- reduce distances involved - introduce pedestrian movement systems - reduce conflicts in movement and bottlenecks which increase walking time - better and more consistent sign posting
1.2 extra effort/energy involved in travelling non-horizontal distances	- replace stairs by escalators/ lifts or other systems - reduce necessity to climb or descend
2. <u>Non-movement user costs</u>	
2.1 waiting time	- co-ordinate interfacing modes to reduce waiting time - increase frequencies - reduce users perception of waiting time by provision of ancillary services, seating and waiting rooms, shopping facilities, etc. - provide information on train arrival times
2.2 variability of time spent waiting causing frustration and uncertainty of ultimate arrival time	- improve predictability and regularity of modes interfacing at interchange
2.3 time spent obtaining tickets and information	- provision of 'through tickets' and improved information facilities
2.4 extra 'out of pocket' expenses	- provision of 'through tickets'

3. <u>Environmental user costs</u>	
3.1 exposure to unfavourable micro-climate	- reduce exposure to the elements by provision of covered ways (roofs, canopies) - provision of heating, draft control, air conditioning, and noise control
3.2 comfort	- provision of seating
3.3 safety/security	- reduce conflicts between and other modes within the interchange. Improve lighting and surveillance methods
3.4 drab appearance of facility	- improve lighting and decor

Empirical studies of the characteristics and, behaviour of passengers interchanging are indispensable for establishing design criteria for interchange facilities. From this type of studies it is possible to gain some indication of the disincentive effects of the various aspects of interchange which are set out in Table 1.

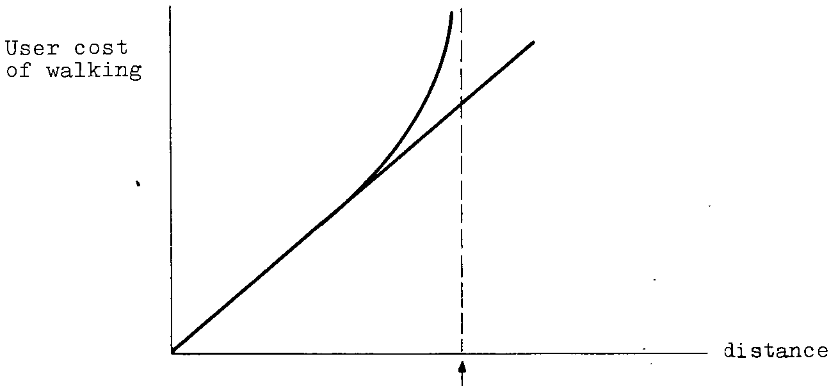
However, up to now, research has emphasised the effect of <u>time spent</u> in various stages of the journey, on the modal split. This is discussed in more detail in Chapter 3, the point of relevance here is that 'in vehicle' travel time is the base on which other aspects are valued and within the physical confines of the interchange none of the time spent is 'in vehicle' time. The user cost of other aspects of travel time, which are present in interchanging, have not been valued so precisely.

The physical effort required in walking or climbing stairs will, it is argued, increase the user cost of time spent doing this activity so that it is greater than 'in vehicle' time. A penalty of twice the value of 'in vehicle' time is usually applied in Britain to walking time and since so much of the time spent in interchanges is walking time this makes it an important component of the disincentive to interchange.

In addition it could be hypothesised that the penalty involved in such effort tends to increase more than pro rata with distance and time. The effect also varies according to whether travellers have to carry luggage and their physical condition. The evaluation of penalties involved in walking could take a non-linear form as suggested in Figure 1 below, however there is little empirical evidence to prove such a relationship, apart from some evidence of thresholds existing beyond which the disincentive effects are so high that people will not be willing to walk.

Figure 1

USER COST OF WALKING AS A FUNCTION OF DISTANCE



Threshold beyond which not prepared to walk

The other main element of travel time involved in interchanging between modes or services is waiting time. Penalty values of between two and three times the value of 'in vehicle' travel time have been estimated in modal split studies in Britain and again the amount of waiting time involved in interchanging will have important disincentive effects on usage of interchange facilities.

Waiting time is a function of the frequencies and co-ordination of services interfacing at the interchange and only 'never-stop' systems, or services which are timed to exactly coincide, remove the necessity to wait.

Unfortunately it is difficult to provide timed connecting services when one of the modes interfacing is a road service, which can be made irregular by road congestion. Since the majority of interchanges do involve a change in mode of which one, at least, is travelling on the public highway, waiting time will always be present. In addition, due to the irregularity and unpredictability of the arrival times of the services interfacing at the interchange, the time spent waiting may be very variable causing boredom and frustration and an uncertainty in knowing the time one will arrive at the ultimate destination.

Thus the amount and variance in waiting time are important categories of user cost involved in performing interchanges and as such must figure highly in deciding modal choice where interchanges are involved.

Of all the attributes of interchange in Table 1 the time spent walking and waiting are the only ones which are capable of relatively precise quantification and evaluation. Other more environmental aspects involved is interchange facilities are more difficult to assess in terms of their impact on modal split. The availability of covered walkways, seating and general improvement of the design and internal environment might all be expected to contribute to the attractiveness of the services involving interchanging, however as Peat, Marwick Kates(1) point out in their study of passenger transport interchange in Merseyside, there is little evidence that the absence of such facilities does detract unduly from the willingness of people to change at the present time provided that a faster overall journey can be made by doing so. Work by Olaf Lovemark(2) on the other hand in Sweden indicates that pedestrian behaviour in major activity centres can be affected by environmental factors. Pedestrians are sensitive to rain, cold weather and wind and from this one can infer that interchanges can be improved from the user viewpoint by reducing exposure to the elements. Unfortunately no behavioural research seems to have been completed which links the various elements of an interchange so that the relative importance of each element in determining mode choice, can be identified. The difficulty is in translating all the attributes into a common language, say time, which can then be incorporated into generalised user costs in money terms.

The Netherlands Railway maintain(3) that up to 8 per cent more traffic was attracted after replacement of some of its

1) Peat Marwick Kates & Co., Passenger Transport Interchanges on Merseyside - A demonstration programme.

2) Lovemark, Olaf, "New Approaches to Pedestrian Problems," Journal of Transport Economics and Policy, January 1972.

3) Rebuilding of Stations on the Netherlands' Railways, Railway Gazette, 18th March, 1966.

older stations with well designed interchanges however the problems of before and after studies make precise estimation difficult.

Possible approaches using results of attitudinal studies could give some guidance here.

For example some motivational research analysis has been conducted by the Bureau of Commercial Research for London Transport(1). This included an examination of traveller's perception of different components of the total journey on Underground trips. In this respondents ranked 18 components of Underground Travel giving a score of 10 for very pleasant aspects and 0 for very unpleasant (a score of 5 would indicate that on average people perceive a particular situation as neither pleasant nor unpleasant. The results were:

1.	Riding an escalator	6.37	
2.	Getting on a train	6.14	
3.	Getting off a train	6.08	
4.	Riding in a lift	5.96	
5.	Buying a ticket from a booking clerk	5.93	
6.	Buying a ticket from a ticket machine	5.75	
7.	Sitting on an empty train	5.68	Marginally pleasant
8.	Getting into, on or off an escalator	5.67	
9.	Getting into or out of a lift	5.60	
10.	Standing on an empty platform	5.01	
11.	Waiting for someone in a booking hall	4.43	
12.	Waiting for a train	4.41	
13.	Changing trains	4.36	Reasonably unpleasant
14.	Travelling in London	4.11	
15.	Changing platforms	4.00	
16.	Standing on a crowded platform	2.87	Quite - very unpleasant
17.	Sitting on a crowded train	2.86	
18.	Standing on a crowded train	1.27	

Although it may be dangerous to attempt too detailed an interpretation of these figures they do imply that travellers attitude to time spent under different conditions does vary with the different components of the journey.

1) Bureau of Commerical Research, "A Report on a Motivational Research Programme on the Underground" for London Transport Executive, September 1969.

Interchange elements are considered both pleasant and unpleasant. The very broad categories of changing trains and changing platforms are considered unpleasant, on a par with travelling in London in general, however those involving 'getting somewhere', e.g. getting on and off a train and being on the move with little effort, e.g. riding an escalator or lift are considered reasonably pleasant. On the other hand another aspect is disliked intensely, this is waiting for a train on a crowded platform.

Implications can be drawn from this study concerning the desirability of aiding interchange by the provision of passenger movement systems such as escalators and travelators at interchanges. It does seem that there is great scope for this since travellers time spent in the interchange which involves 'getting somewhere' and being aided in the accomplishment of this by pedestrian aids such as lifts, and escalators is considered the least arduous part of the interchange. As well as altering the travellers perception of the notional time involved, such pedestrian aids also reduce the actual time taken to perform a given interchange. Secondly since crowding is considered the most unpleasant aspect the capacity of interchange should be such that crowding and conflict are avoided where possible.

The capacity of the elements of the interface, i.e. the corridors, stairways and circulation areas are often determined by rule of thumb observation and capacity standards. Too low design standard can result in restricted walking speeds and extreme difficulty for these attempting cross flow or reverse flow movements. Fruin in a paper on the environmental factors in passenger terminal design(1) stresses the need to relate quantitative design standard to a level of service or quality concept. At levels lower than capacity there can exist congestion which is exactly analogous to that existing on highways.

Thus the application of a design capacity or standard without a thorough understanding of the characteristics of passengers in different flow situations (e.g. on stairs, in passages) and a knowledge of peaking over the day and between seasons can lead to poor and inappropriate scale of

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1) Fruin, John J., "Environmental Factors in Passenger Terminal Design," Transportation Engineering Journal, February 1972.

the design, which in turn leads to high user costs. There is however a trade off between providing sufficient capacity in the interchange to cope with the extreme peak and the high cost and possible extra walking time involved for every traveller if the scale of the interchange matches the extreme peak demand.

It should be remembered, however, that the above rankings are specific to the London Transport Underground and are a function of both user attitudes and the situation existing in London. For example, waiting time for a train when interchanging may in London be very short, due to the high frequency of operation, and hence the waiting time spent is not considered very unpleasnt relative to other factors, although intrinsically waiting time is disliked.

The results of other attitudinal studies in London and possibilities for future research in this field are discussed in the later chapters.

Conclusions on the extent to which improvements to the internal design and organisation of interchange facilities can affect usage, and more especially modal split, are at this stage only tentative. However two general inferences can be drawn: Firstly, where long walking distances and change of levels are necessary the effect of these can be minimised by passenger movements systems which, as well as reducing actual time, would also seem to reduce traveller's perception of time spent. Secondly the capacity of interchanges should be that crowding on platforms and conflict in corridors and passages is kept to a minimum. In general terms the capacity of the interchange should be balanced with that of the systems and modes which serve it; inadequate provision of space can cause queuing at stairs, barriers and passengers and overcrowding whilst waiting for services. Also the systems of transport serving the interchange should be balanced. There is little point in combining services with very different headways, since the waiting time at the interchange will be unnecessarily high.

2.3. PROVISION OF FEEDER MODES AT INTERCHANGES

This section investigates feeder modes to railway stations and these can be split in three main groups: walk, bus and car.

3.1 Walk mode

The number arriving by foot at a railway interchange is a function of the number of travellers living within walking distance of the station and, for any one station, this is a dependent on:

1) alternative station opportunities
2) density of population in the catchment area
3) socio-economic characteristics of the population which determine: firstly, the proportion who work in areas served by the railway, and secondly their car availability

A typical cumulative frequency distribution for walk mode to station/interchange by length of walk to station is set out in Figure 2.

At distances over 0.25 mile, walk and bus feeder modes are in competition both in suburban and central situations. In central areas with high flows of pedestrians, there is the potential to provide continuous pedestrian aids, such as moving pavements, to fill the 'transport gap' which probably exists in the range 0.25 to 1 mile. Despite the abundance of conceptual designs and feasibility studies few such systems have reached the stage of actual operation. Factors inhibiting their wider adoption, apart from technical feasibility, include uncertainty of passenger response, the cost of development and their economic performance. Conventional conveyor belts travelling at speeds around 2 m.p.h. are only adequate for short journeys under 400 yds. provided that travellers can walk along them. New systems of high speed conveyor belts are being developed giving speeds five or six times greater. They will, it is argued by Bouladon(1) fill a gap in mass transportation systems over short distances up to 1.2 miles and in high activity areas provide very efficient and speedy feeder systems to interchange facilities.

3.2 Bus feeder

The bus component of the modal-split of arrival at suburban railway stations generally comes from a catchment over 0.5 miles away from the station.

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1) Bouladon, G., General Transport Theory - OECD. Proceedings of 2nd Technology Assessment Review - Transportation Systems in Major Activity Centres, April 1970.

The number at any one station is a function of:

1) attractiveness of alternative stations;
2) density of population in the catchment;
3) socio-economic characteristics of the population;
4) level of service of the bus feeder;
5) level of service on transit line.

Examples of frequency distributions of distance travelled for the bus feeder mode to suburban stations in London are set out in Figure 3.

As can be seen these distributions vary enormously and this is due to the variability in the factors identified above. Example A is for Rayners Lane which has a very limited catchment due to the existence of other attractive stations nearby. Example C is of Cockfosters which because it is at the end of an Underground line has bus users travelling relatively long distances within a wide and extensive catchment area. Such a bus feeder service going deep in to the area beyond a terminal of rail line offers the advantages of fast rail services to more people by extending the feasible hinterland of the suburban station. Thus there is the potential to alter modal splits for journeys to the centre by provision of bus feeder services to suburban interchanges where fast rail services can be utilised for the main leg of the journey.

For this study we are interested in quantifying the impact of improved feeder bus services on the modal split. A number of studies have been implemented to develop relationships which estimate the proportion of inhabitants in zones who travel by car, feeder bus, and walk to suburban interchange stations, but little has been attempted to relate feeder modal split to the provision of bus services to the interchange point. Maltby and Cheney(1) conducted two surveys: one in London to assess the effect on modal split to the interchange station resulting from the introduction of a flat fare short distance bus feeder at two stations in North London (Harrow and Wealdstone, and Kenton); the second in Wallasey (Merseyside) was designed to examine the correlation between mode of travel used to reach an interchange (a ferry in this case) with the socio-economic character of the travellers' zone of origin and distance travelled to the ferry.

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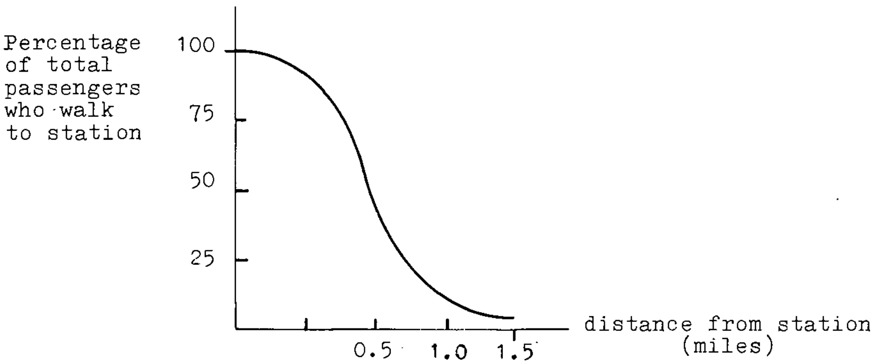
1) Maltby, D. and C.N. Cheney, "Factors Affecting the Design of Transport Interchanges," Traffic Engineering and Control, April 1971.

Figure 2

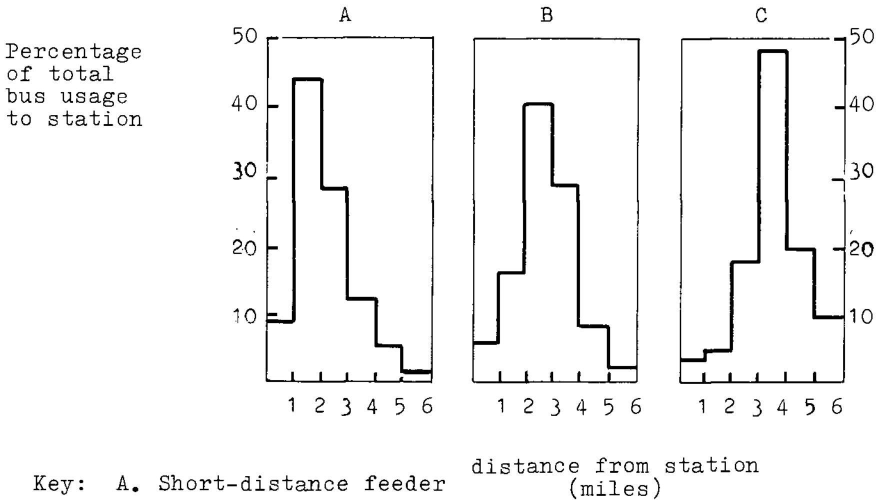
DISTRIBUTION OF WALKING DISTANCES TO
SUBURBAN UNDERGROUND STATIONS IN LONDON



Source: LTE Survey on passengers on the Victoria Line

Figure 3

PASSENGER JOURNEY LENGTH DISTRIBUTIONS ON
BUS FEEDER SERVICES INTO SOME
SUBURBAN RAILWAY STATIONS IN LONDON



Key: A. Short-distance feeder

B. average

C. long-distance feeder

Source: GLC/LTE Survey 1969 (unpublished)

The first study proved to be inconclusive from which they inferred that other factors were complicating the analysis which made it impossible to assert categorically the success (or otherwise) of the feeder bus in altering modal split. In their second study they claim that with socio-economic parameters of zones in the catchment area of suburban interchange (e.g. residential density or car ownership) it is possible to estimate the proportion of those wishing to use their cars, those who travel by feeder buses and those who walk.

The problem is, however, how to assess the effect of changes in the bus feeder services and, whilst such analysis of zonal socio-economic parameters may be useful in netting out other causes of variation in modal split, it cannot by itself assess the effects of improvements in the bus services. It is argued in the section on modal split that assessment of the impact of changed feeder transport system are better performed at a level that allows usage to be a function of user cost.

A study was conducted in London by Research Projects Ltd. on interchange at Morden station(1). The main purpose of this study was to assess the degree to which the nature of feeder services to the interchange station affected its use and the use made of cars. The approach was to intercept travellers passing through Morden station to ascertain the effects of bus frequency on:

i) distance walked
ii) rate of travel through Morden.

This was backed up by a household survey within the catchment area.

An indication of the impact of differing bus feeder services to suburban interchange on the feeder modal split can be obtained from the results for Morden Station in Tables 2 and 3. These show that areas served by a two-minute headway feeder bus service have a significantly higher bus usage to Morden than areas served by a bus with only an eight-minute headway. Reduced usage of a car to station is also associated with a high bus frequency in these figures.

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1) Research Projects Ltd.,"Morden Interchange Study in a Report on Modal Choice in Greater London," Vol. 2, June 1969.

It must be admitted that the direction of causality of these relationships cannot be confirmed but they do indicate a strong association between feeder bus service provided and modal split at the suburban interchange.

Table 2

PERCENTAGE MODAL SPLIT FOR WORK TRIPS TO CENTRAL LONDON DEPENDING ON DISTANCE FROM MORDEN - HIGH FREQUENCY BUS ROUTE

Observed Headway = 2 mins.

Distance from Morden (100 yds)	Through Morden To station			Car all way	Not through Morden
	Bus	Car	Walk		
10-12	15	3	64	18	0
12-14	44	3	36	11	6
14-16	54	0	17	20	8
16-18	75	5	7	14	0
18-20	59	7	11	22	0
20-25	Other bus routes nearer				

In addition to frequency of the bus feeder it is also important that the services should be reliable. If buses are subject to substantial and irregular delays due to traffic congestion then this could cause low usage levels, especially if the rail transit main mode service, with which the bus is interfacing, is a relatively low frequency, time-tabled service.

Table 3

PERCENTAGE MODAL SPLIT FOR WORK TRIPS TO CENTRAL LONDON DEPENDING ON DISTANCE FROM MORDEN - LOW FREQUENCY BUS ROUTE

Observed Headway = 8 mins.

Distance from Morden (100 yds)	Through Morden To station			Car all way	Not through Morden
	Bus	Car	Walk		
10-12	3	1	48	18	30
12-14	16	5	26	10	43
14-16	10	7	17	13	53
16-18	30	15	15	17	24
18-20	24	5	20	10	41
20-25	16	5	4	21	54

Source: Research Projects Ltd., Morden Interchange Study.

3.3 Car feeder mode

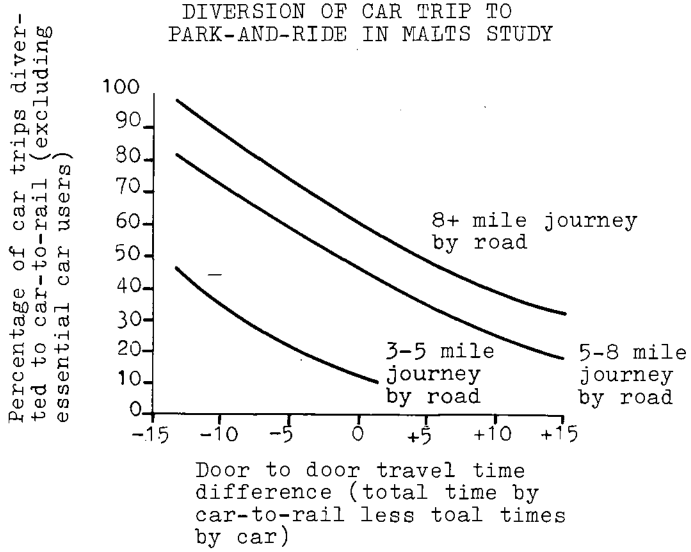
A policy to encourage the use of a car for the short leg to an interchange, with main mode being performed by public transport, instead of using the car for the total journey, is an obvious way of influencing modal split. Car feeder trips to railway stations consist of three types:

1) those who drive to station, park and catch a train ('park and ride' drivers);
2) those who are given a lift to a station by a park and ride driver (park and ride passenger);
3) those who are given a lift to a station by a driver who retains use of car during the day ('kiss and ride').

For those able and preferring to travel by car the provision of convenient car parks at suburban stations combines the 'door step' convenience of the car (in low density suburban areas without road congestion), with the time advantage offered by the train in more congested central parts of the conurbation. In Liverpool relationships were developed which demonstrate the estimated proportion of car users who cut their car journey leg short at a railway station(1). Figure 4 shows the sub-modal split (i.e. the split between car 'all the way' and 'park and ride') for different distance with differing comparative journey times.

Figure 4

DIVERSION OF CAR TRIP TO PARK-AND-RIDE IN MALTS STUDY



The relationship, of course, only considers comparative journey times, it provides no insight into the variations in modal split which might result from improvements in the quality and convenience of 'park and ride' interchange. In addition the function quoted is very generalised and gives results which, when compared with observations in Merseyside, tends to underestimate the car-to-rail journeys made via the local station.

The above approach depends on an initial modal split between public and private transport the latter then being sub-divided between car 'all way' and car to interchange trips. As such, it is dependent on the level of car ownership and the comparative journey times.

The increase in car ownership in Europe over the last twenty years has, as well as increasing the tendency for trips to be performed by car, also resulted in a substantial increase in 'park and ride'.

1) Peat Marwich, Kates, Op. cit.

The increase since the 1950s in car usage as a feeder mode in London can be illustrated by comparing data for 1954 from the Travel Survey for London(1) with more recent sample data for stations in London (Tables 4 and 5).

Table 4

PROPORTIONATE SPLIT OF FEEDER MODES (1954)

	Percentage of rail journeys using			
	Bus	Car	Walk and cycle	Total
Feeder to Underground Stations	29	1	70	100
Feeder to British Railways Stations	26	1	73	100
Distribution from Underground Stations	16	-	84	100
Distribution from British Railways Stations	26	1	73	100

In 1954 only 1 per cent of trips by Underground and B.R. Railway had a car feeder link to the station.

More recently in 1969 a sample of stations in London gave the following coverages for feeder modes to Underground and B.R. Stations.

1) London Travel Survey 1954 - London Transport Executive 1956.

Table 5

PROPORTIONATE SPLIT OF FEEDER MODES (1968)

Feeder mode	Percentage split	
Park and ride	10	16
Kiss and ride	6	
Bus	30	
Walk and cycle	54	
Total	100	

Thus it can be seen that the scale of 'park and ride' and 'kiss and ride' has increased dramatically as a proportion of the 'sub-modal' or feeder modals split to rail stations. Although this sample may have been biased towards suburban sites with a high innate 'park and ride' element, the order of magnitude is so much greater than the average for 1954 that one can conclude that the growth in park and ride is significant and it is now an important element of the feeder modal split. The above averages, however, disguise a wide variation in modal split for the stations quoted in Appendix B. This is shown in Table 6 below:

Table 6

THE MINIMUM AND MAXIMUM PROPORTIONATE SPLIT OF FEEDER MODES

Feeder Mode	Percentage split	
	Maximum	Minimum
Park and ride	17%	4%
Kiss and ride	11%	3%
Bus	51%	5%
Walk and cycle	75%	28%

The variation present is a function of many factors. Park and ride and kiss and ride levels at any station is related to, amongst other things: .

1) convenience at interchange facility (see Section 2.2) including availability of parking space;
2) quality of service on the main mode, including speed, regularity, seat availability, frequency of service and choice of destination;
3) convenience of car access to interchange including direct road access with park and ride facilities linked to main roads serving a number of directions.

Important factors are considered in more depth below:

Attractiveness factors associated with park and ride

1. Transfer distance

Transfer distances should be kept to a minimum, with convenient, quick, and direct access to the rapid transit station from the parking facility. In a survey of 'park and ride' in 75 cities and towns throughout the World, Pampel(1) identifies a range of distances adopted as maximum standards from 100 in Leicester, Marseilles and Gothenburg, and 200 m. in Cleveland, London, Stockholm to 300 m. in Boston, Hamburg and Milan. There is no generally valid maximum for the transfer distance since local circumstances determine this. Thus Pampel states that in Hamburg, transfer distances of 200 m. are only accepted in situations where the other prerequisites for park and ride are particularly good.

2. Seat expectation

The 'park and ride' traveller usually expects to find a seat for his journey by rapid transit. Hamburg, with its very extensive 'park and ride' facilities has guaranteed seating at 16 points and only a 50/50 chance at the other 7.

3. Service on the rapid transit

On most rapid transit lines with park and ride facilities surveyed the intervals between trains are 2 to 3 minuites during the peak hours so that waiting time is not appreciable.

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1) Pampel, F., "Park and Ride - Organisation and Operation," 39th Congress UITP.

4. Comparative journey time on public transit versus car
The probability of achieving a time advantage by park and ride compared with the journey entirely by car is dependent on the character of the city and its transport system and levels of congestion. Only a few towns in the above survey quote real time savings with Cleveland, Hamburg and Milan having about 10 minutes at the maximum and Boston 5 minutes.

5. Other factors
It is obvious that for the majority of park and ride travellers real time advantages are only minimal if they exist at all. Other factors come into their modal choice decision: very broadly 25 per cent of drivers in Chicago, over 50 per cent in Hamburg and 75 per cent in Boston choose a park and ride modal choice inspite of greater journey time, by this mode. Thus time saving is not always a necessary prerequisite for a mode choice decision to be made in favour of park and ride. Factors such as high parking charges in the centre, and the effort involved in driving cars in congested areas can have large influences on choice of mode.

The complexity of reasons for using 'park and ride' facilities is illustrated by the following data from a survey of park and ride users in Hamburg(1), where:
44 per cent use park and ride because there is no (free) parking at their destination.
26 per cent however mention cost and time advantages as well as the shortage of parking space.
46 per cent of these asked use 'park and ride' because they can reach their destination quicker.
27 per cent mention cost advantages as a motive.
7 per cent of travellers mentioned the comfort of the railway journey as their sole motive: this factor being considered worthy of mention by a total of 22 per cent.

The motivation for using 'park and ride' in Hamburg varies greatly with distance. Figure 5 overleaf shows how the cost advantage increases and the importance of parking in the centre reduces as motives for using park and ride as one moves away from the centre.

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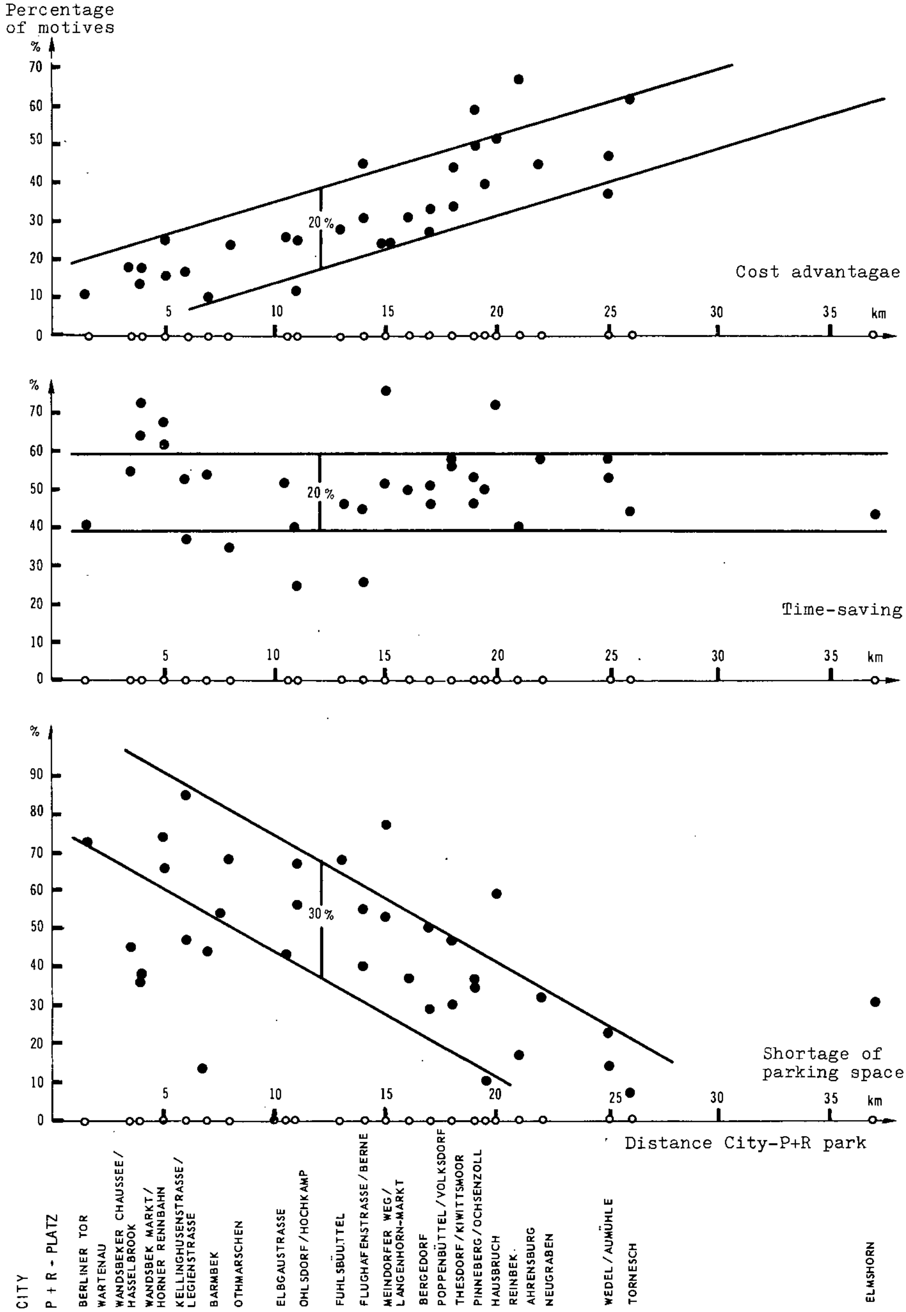
1) Pampel, Op. cit.

Figure 5

MOTIVATION FOR P + R DEPENDING ON DISTANCE BETWEEN CITY CENTRE AND P + R PARK



Source: Pampel, *Op. cit*.

In Stuttgart, Germany, a study(1) showed that these factors of time and cost savings seemed of equal importance in motivating travellers to use a 'park and ride' mode. Table 7 illustrates the reasons given for use of park and ride facilities

Table 7

REASONS FOR COMMUTERS' USE OF PARK AND RIDE IN STUTTGART, GERMANY

Reasons	All commuters		Commuters to Stuttgart Rail Station	
	No.	%	No.	%
Saving in time	51	38	24	43
Economical	49	36	17	30
Comfortable	43	32	21	38
Lack of parking space in central area	32	24	17	30
Safety	21	16	9	16
Other reasons	23	17	7	12
Total number of persons interviewed*	133	100	56	100

* Sum is greater than 100 per cent as more than one reason can be given by each interviewee.

In North America, where ownership of a private car has become almost universal, the development of park and ride facilities is seen to be very important in influencing the modal split of work trips for the purpose of allieviating road congestion.

1) Schenk, G., "Elements des Park and Ride Systems aus der Sicht der Berufspendler," University of Stuttgart, 1968.

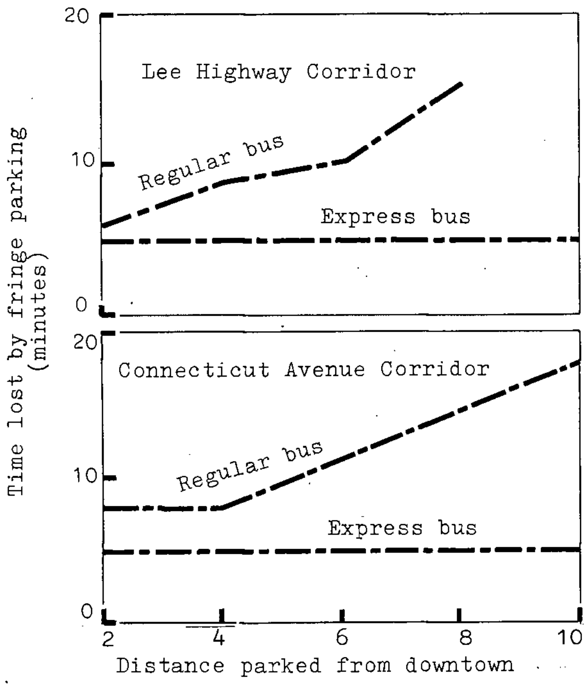
Park and ride can be developed in connection with either rail or bus transit systems for the main mode and, in the main, its predominant use has been for long duration work trips destined to the CBD.

A study has been conducted by Deen(1) on experience of park and ride in a number of American cities, focussing especially on Washington, D.C. The concentration in the study is on park and ride related to bus transit for the main mode and, because bus transit does not have the speed advantage over the car that rail transit gives, the traveller's decision to park and ride is determined by the trade-off between inconvenience and lost time in parking and changing to a bus, against the high parking costs and driving in congested traffic involved in travelling 'all way' by car. The extra time cost involved in park and riding on bus transit in Washington is given in Figure 6 below.

Figure 6

TIME LOST BY FRINGE PARKING AT VARIOUS DISTANCES FROM DOWNTOWN

(Assumes 2 min. walk and 3 min. wait at fringe parking bus stop; travel times as reported by a 1959 Federal employee parking study)



1) Deen, T.B., "A Study of Transit Fringe Parking Usage," Highway Research Record No. 130, Highway Research Board, 1966.

Deen also quotes results of a survey of park and riders attitudes and preferences in Washington which gives insights into the effect on modal split of park and ride facilities. These relate to bus transit park and ride and the more significant results, which are quoted more fully in Table 8, are that over 50 per cent of these interviewed would have preferred to drive all the way if parking space in the central area had been readily available and at a low cost and, secondly, that 25 per cent of the park and riders travelled all the way by car and 18 per cent used a car pool before they began using the park and ride facility.

Although no quantitative correlation of the factors affecting modal choice in relation to park and ride was attempted in the paper by Deen, it does present qualitative evidence providing some useful conclusions. They centre on the fact that where park and ride is associated with bus transit then the avoidance of 'down-town' parking costs is the main motivation of park and riders in the Washington area and a secondary motivation is dislike of driving in congested traffic.

In the Washington area these factors are traded-off against likely longer journey time since the bus transit has slower speeds and there is interchange time involved in park and ride.

In a study on Fringe Parking and intermodal choice in five United States cities, Peat, Marwick, Mitchell(1) conducted a survey to assess the factors influencing a traveller to choose fringe parking in Atlanta and Cleveland. Respondents were asked to list the factors which were of importance to them in choosing fringe parking as opposed to their next best travel alternative. The replies are tabulated in Table 9 overleaf.

It can be seen that Peat, Marwick, Mitchell and Co. found that cost was the most important reason for choosing fringe parking: fringe parking is simpl less expensive than the next best travel alternative. This response indicates the importance of pricing the fringe parking - transit service so that it remains competitive with other mode - route combinations. Convenience was the next most important factor

1) Peat, Marwick Mitchell, "Fringe Parking and Intermodal Passenger Transportation; Operation Experience in Five Cities," November 1971.

Table 8

HABITS AND ATTITUDES OF PARK AND RIDERS
AT THREE WASHINGTON AREA FRINGE LOTS
(Fairfax, Soldiers Home and Carter Barron)

Mode of arrival at lot:	All Lots (per cent)
Drove	76
Was driven in car parked here	9
Was driven in car not parked here (iss and ride)	9
Walked	3
Other	3
Purpose of trip:	
Work	92
Other	4
Not reported	4
Job location of persons going to work:	
Downtown Washington	96
Other or no answer	4
Mode to work before began using fringe lot*:	
Drove all the way	25
Parked on street and rode bus	14
Walked to bus stop	15
Was driven to bus stop	9
Car pool	18
Other	18
Factors influencing decision to use fringe lot:	
Downtown parking costs	64
Dislike of driving in congested traffic	50
Dislike of parking on the street and riding bus	22
Percentage who would prefer to drive all the way if downtown parking were plentiful and cheap	53
Percentage who normally use lot at least five times per week	93
Per cent living in Virginia or Maryland	91

* These percentages include only those who live and work at the same locations as they did before using lot.

Table 9

FACTORS INFLUENCING FRINGE PARKING

Factors	Atlanta		Cleveland	
	Number of Responses	Percent of Respondents	Number of Responses	Percent of Respondents
Cost	103	74	181	70
Convenience	78	56	151	58
Travel time	15	11	62	24
Avoidance of downtown traffic	59	42	8	3
Safety	28	20	19	7
Availability of public transportation	11	8	15	6
Ecological considerations	2	1	1	-
Exercise associated with walking	-	-	16	6
Total number of responses	296		53	
Total number of respondents	139		262	
Average responses per respondent	2.1		1.7	

Source: Peak, Marwick, Mitchell & Co. Surveys, 1971.

in both Atlanta and Cleveland. This response covers many aspects of a fringe parking facility, including its location with respect to access freeways, the availability of public transportation, and features such as fee collection procedures and shelters.

Avoidance of downtown traffic was the third most important factor in Atlanta, whereas travel time savings were the third most important factor in Cleveland. In Atlanta, fringe parking facilities are located so that fringe parkers do not have to drive on heavily congested streets during peak hours. The importance of travel time in Cleveland is perhaps correlated with the fact that public transportation was the travel alternative for 35 per cent of the fringe parkers, whereas transit was the travel alternative for only 20 per cent of the fringe parkers in Atlanta.

In summary, these results agree with the previous study quoted and suggest that fringe parking facilities and their associated transit service must offer a significant cost and travel time savings to the travellers.

From American experience it would seem that as a broad generalisation park and ride by bus offers cost savings to those who would drive all the way as an alternative whereas it offers travel time savings to those who would otherwise use regular, as opposed to express, bus transport. Turning to park and ride associated with rail transit, current United States transport planning interest is intensely focussed on methods of co-ordinating and providing interchanges between highways and existing and planned rail transit systems, in urban areas.

Cleveland is an example of a city which has recognised the need to develop park and ride facilities in association with rail transit. Provision for over 6,000 free parking spaces has been made on its 14-station system and typically 35 per cent of users of the system are park and riders and 45 per cent use feeder bus services, which are integrated with the railway system. At outlying suburban stations the feeder modal split can be as high as 51 per cent for park and ride and 15 per cent for kiss and ride, leaving 33 per cent for bus feeder services and only 1 per cent for walk mode.

Thus for rapid transit system such as in Cleveland co-ordinated car and bus interchange is a necessary prerequisite for success of the rail transit system and, if it were not available, would have a profound effect on the total modal split. This lesson has been learnt in the planning of the Bay Area Rapid transit, with provision for car and bus access again forming an integral part of the development of the system. Its 33-station network will have 24,000 parking spaces; initially at 23 suburban stations. This figure rises to over 30,000 at later stages of development and in addition Quinby(1), in an article on Co-ordinated Highway Transit interchange stations, specifies all the other 'access to station' modes, for which special consideration is being give, in the planning of BART. Table 10 below sets out the stimated access modal split and the anticipated typical range of percentages that each mode will represent at any of the 23 stations selected for interchange development.

Table 10

ESTIMATED ACCESS MODES TO BART

Access mode	Range of typical modal split
	%
Walk	5 to 15
Bus feeder	14 to 58
Park and ride	10 to·50
Kiss and ride	5 to 30
Taxis	1 to 3
Cycle	negligible

In Quinby's paper it is stated that the stimates of usage and access modal split for each station are the product of extensive BART studies into "travel times, travel patterns, modal split, rapid transit patronage, fares levels and structure." Unfortunately none of the methodology is set out so it is difficult to assess whether the methods would be sensitive enough to assess the impact of improving interchange arrangements. What it does show, however, is the importance attached in America to attracting potential passengers, to transit stations so that they do not travel all their journey into the centre of urban areas by car. To have this effect on modal split not only must the rapid transit itself be fast, economical, and comfortable but the interchange facilities required to attract patrons to the system

1) Quinby, H.D., "Co-ordinated Highway Transit Interchange Stations," in "Origin and Destination: Methods and Evaluation," Highway Research Record 114 - V.I.T.P. - Biblio Index No. 197-66.

must be abundant and convenient to use. "Transit stations, therefore, become critical elements of transition between highway and transit travel"(1).

Park and ride in such environments expands the catchment area of the rapid transit beyond the limits set by either acceptable walking distances or practical bus feeder operation. Park and ride facilitates the integration of fixed route public transport with low density residential land use and, as such, has implications, not only on the modal split to public transport, but on the complex relationships between residential development patterns and the accessibility provided by transportation systems.

Railheading

There are, however, ways in which provision of parking space in relation to interchanges may increase the use of cars and hence alter the modal split against public transport. Apart from feeder trips to suburban stations being performed by car instead of by bus, a phenomenon termed 'railheading' may occur. Railheading can be defined as the tendency for a rail traveller, using a car for the feeder trip, to drive to a distant park and ride interchange nearer his destination, rather than board a train at his nearest station. The provision of parking spaces on the fringe of central business districts, from where journeys can then be made into the CBD by rail transit, is a case in point. Thus the total public transport modal split may be reduced since car drivers are encouraged to 'railhead' and use the private car for the main mode instead of using public transport.

Whilst this is a consideration which should be borne in mind when planning an interchange policy, its importance should not be overemphasised since generally the comparative advantage of such rapid transit speeds compared with the car in congested urban areas makes substantial railheading unlikely.

To summarise this section, from the above discussions it is apparent that the operational and locational aspects of park and ride are of crucial importance in the choice situation which confronts the individual when he is deciding

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1) Quinby, Op. cit.

on whether to use a park and ride mode. Choudbury(1) categorises what he considers the most important factors in the individual's trade-off and sets out the operational and locational criteria which should be adhered to for successful park and ride. These be identified as:

Operational

1. An easy-accessible interchange car park with adequate space
2. An efficient, comfortable and inexpensive public transport connection.

Locational

1. Interchanges located at points served by an above average car ownership population and a density sufficiently low to warrant the use of a car. And at the same time a trip length on public transport from interchange to destination which offsets the interchange time.
2. Location at points where the public transport service frequency is good and adequate car parking can be provided.

This leads on to the next section where location of interchanges within urban areas is considered in more depth.

2.4. LOCATION OF INTERCHANGES WITHIN TRANSPORT SYSTEMS

The previous two sections considered the impact of improved internal design within the physical confines of the interchange facility and the organisation of feeder modes at interchanges. This section considers the location of interchanges within the total transportation system of the urban area.

In discussing the effects of improving interchange at this strategic level, it is considered that an analysis of why interchanges develop at various points in the urban space field is necessary. In this respect a distinction can be made between interchanges where different modes of travel interface and between interchanges where different services of the same mode come together.

1) Choudbury, A.R., "Park and Ride as a Modal Choice for the Journey to Work," Traffic Engineering and Control, Vol.13, No. 6, October 1971.

In the former case of complex intra-urban trips, consisting of two or more vehicle modes, a typical home-based journey can be classified into the following component legs:

1) residential collection,
2) line-haul leg,
3) destination distribution leg.

The necessity for mixed mode trips is a function of the scale of the urban area; only in large urban areas does functional specialisation by mode produce an intra-urban transport hierarchy, with high speed line haul modes such as railways, Underground railways and trams, being fed by bus, car and other terminal transport systems. In addition to scale there is another prerequisite before a fully developed transport heirarchy is developed: this is that activities must be concentrated within the urban space so that 'line haul' mass transportation systems are justified. An example where this is not present is, of course, Los Angeles. Here, although the scale of the urban area is very large, activities are dispersed and densities generally low. In comparison, London, with its large-scale and high concentration of activities in the centre, has a highly developed multi-mode transport system which offers potential to perform mixed mode trips and hence many types of choices of transfer between modes.

Table 11 is taken from a report by SCPR(1) and it shows how in London the probability of interchanging increases with the length of the total journey and, since the length of journey is correlated with the mode, there is also a strong correlation between main mode of transportation and the probability of interchanging. Table 12 shows that B.R. trips, which tend to be longer than trips on other modes, have the greatest probability of changing, closely followed by the Underground.

The changes enumerated in Tables 11 and 12 include change of service within a mode as well as the changes in the mode itself. The level of the former is a function of the structure of the network. The majority of interchanges involving underground to underground transfer occur in the centre where many lines converge due to the radial nature of the system.

1) Hoinville, G. and E. Johnson, "The Importance and Values Computers Attach to Time Savings," Social and Community Planning and Research (SCPR), 1971.

Table 11

NUMBER OF CHANGES FOR COMMUTERS INTO CENTRAL LONDON
BY DISTANCE TRAVELLED IN 1971

Number of changes	All respondents	Total journey time			
		16-40 minutes	41-55 minutes	56-70 minutes	71-90 minutes
	%	%	%	%	%
No change	43	68	43	34	26
One change	40	27	41	41	51
Two or more changes	17	5	16	25	23
	100	100	100	100	100

Table 12

NUMBER OF CHANGES FOR COMMUTERS INTO CENTRAL LONDON
BY MODE IN 1971

Number of changes	All respondents	B.R. train	Underground	Bus	Private transport
	%	%	%	%	%
No change	43	37	41	71	89
One change	40	42	43	29	9
Two or more changes	17	21	16	-	2
	100	100	100	100	100

Bus to bus transfer is more evenly spread over the L.T. area. Similarly B.R. transfer can be widely spread since interchange between services on B.R. is not only performed to change into another line which serves the destination desired, but also to transfer to a quicker train which may go to the same destination as the train the traveller is already on. This also occurs, but to a lesser extent, on the Underground system where there are paralleled lines of different average speeds.

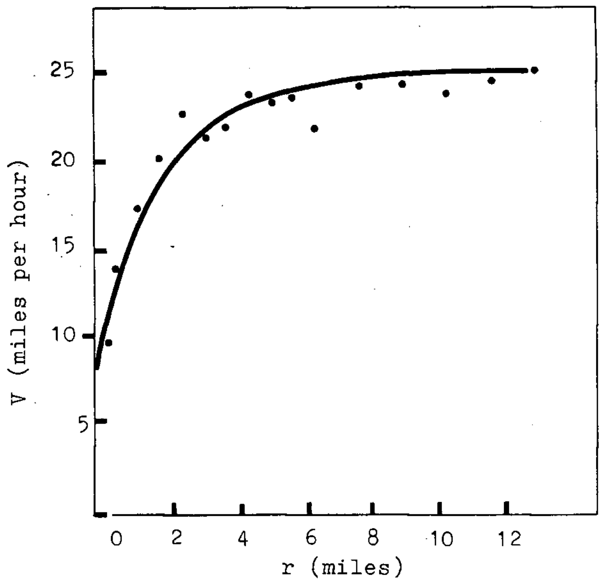
Up to now this section has concentrated on a general discussion of the relationship between changes on the one hand and size and structure of the urban area on the other hand. It would seem that high interchange usage will only occur in large urban areas with an extensive and hierarchical urban transport system.

Turning to the location of interchanges within the urban area, as a policy for improving interchange trips, it is argued that to know where to improve and develop interchanges within the urban area is as important as knowing what to improve within the interchange facility. In relation to this question it is possible to develop broad analytical representations of possible optimum placing of interchanges. One approach would utilise car journey speeds on links in the urban area and identify approximately the boundary within which car speeds decline as they approach the centre. This would indicate broadly where other modes could take over for journeys to the centre and where interchange would be appropriate between public and private modes.

Data for Manchester, calculated by Angel and Hyman(1), are set out in Figure 7 and it can be seen that journey speeds

Figure 7

AVERAGE VELOCITY AS A FUNCTION OF DISTANCE FROM CENTRAL MANCHESTER, 1965



The fitted curve takes the form:

$$V(r) = 24.9 - 16.9e^{-0.56r}$$

where r is measured in miles and V in miles per hour.

1) Angel, S. and G. Hyman, "Urban Transport Expenditures," CES Working Paper 7 , November 1971.

begin to change significantly at about 3 to 4 miles from the centre.

It is possible to integrate this equation to obtain travel time for a journey to the centre by distance from the centre.

By comparing similar curves for other modes of transport, especially bus and rail modes, a broad indication of locations for interchange can be derived based on comparative journey times.

Budillon(1) in a study on interchange in French provincial towns attempts to relate interchange locations as functions of distance from the centre of the urban area. This analytical study is based on the approach set out above in a comparison of journey times by different modes to identify where interchange between modes might minimise total journey time.

A formulation is derived, which calculates (under given assumptions of comparative public and private journey times) the minimum distance that park and ride facilities must be from the CBD for there to be any time (or cost) advantage to car users changing to park and ride.

Such an analysis would seem essential for any interchange policy which aims to affect modal split. If interchange facilities are set up in locations where there are no time or cost advantages in transferring, they cannot hope to be successful unless there are extraneous factors like parking restraint in the centre.

His formulation for minimum distance for park and ride interchange locations away from the centre is:

$$d \geqslant A \frac{Vp.\ Vtc}{Vtc-Vp}$$

where Vtc = speed of public transport

Vp = speed of private transport

A = waiting and walking time at the interchange

d = distance of park and ride interchange from centre

The formulation for minimum distance is directly proportional to the waiting time. If for example the latter is 3 minutes, then the effect of different comparative public and private transport journey speeds on the distance is shown in Table 13.

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1) IRT Budillon, "Les Ruptures de Charge dans les villes de province," Rapport de recherche IRT nº 6, 1970.

Table 13

MINIMUM DISTANCE TO LOCATE PARK AND RIDE INTERCHANGES FROM THE CENTRE OF URBAN AREAS

V_p \ V_{tc}	15 km/h	18 km/h	21 km/h	24 km/h
12 km/h	3 000m	1 800m	1 400m	300m
15 km/h	-	4 500m	2 625m	2 000m
18 km/h	-	-	6 300m	3 600m

As Budillon points out, however, this is an oversimplification as a more complete modal split analysis would consider all the components of generalised cost, and not be based solely upon time advantage. This further analysis is undertaken in an appendix to his paper. However it is still based upon the concept that if it is cheaper (in generalised cost terms) to use car then car will be used, whereas if it is cheaper to use "park and ride" then "park and ride" will be used. The trouble with this kind of approach is that it is evidently very sensitively affected by the actual values of the generalised cost parameters. It could be argued that such an "all-or-nothing" use of generalised cost is inadmissable as it does not allow for variations in individuals' perception of cost. Thus it may be that the use of a single measure of generalised cost is only admissable in a probabilistic model which averages over individuals variations. The "all-or-nothing" nature of this method is similar to some problems encountered in network analyses using generalised cost (see Chapter 4).

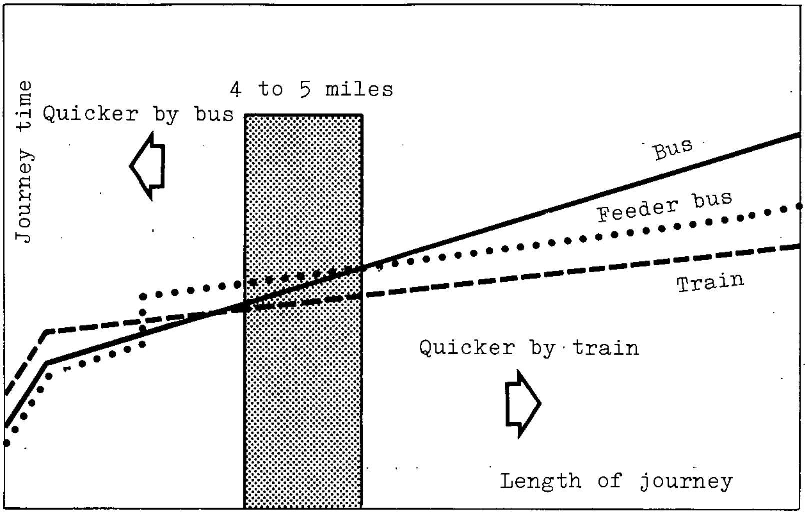
In England a report by Peat, Marwick Kates on a possible passenger interchange programme for Merseyside(1) (the Liverpool conurbation) investigated the passengers interchange location. They identified, in the Merseyside conurbation, a distance of 4 to 5 miles from the centre at which trips by train have such an advantage in terms of speed that trips to the centre could be made more quickly by taking a bus to the nearest railway stations than by the alternative of

1) Peat Marwick Kates & Co., Passenger Transport Interchanges on Merseyside - A demonstration programme (for the Merseyside Passenger Transport Executive and the DOE). October 1971.

travelling by bus all the way. This situation is illustrated in the following Figure 8 for the Merseyside conurbation.

Figure 8

COMPARISON OF JOURNEY TIMES BY
DIFFERENT FORMS OF PUBLIC TRANSPORT



Thus there have been a number of simple approaches which attempt to identify critical locations for interchanges within urban transport systems; however there does seem to be a lack of research based on more theoretical network analysis to determine optimum location of interchanges on transport networks within urban areas. This point is considered further in Chapter 5 when discussing possible future lines of research.

2.5 TOTAL TRANSPORT SYSTEMS WHICH REDUCE THE NEED TO INTERCHANGE

The question here is whether transport networks should be constructed with a greater variety of through facilities or should the emphasis be on networks with fewer routes but more frequent services, relying on interchange? The question is raised because, as we have seen there is a strong dislike of interchange per se. Interchange is associated with many disagreeable aspects of the journey from the traveller's viewpoint. In London, for example, SCPR(1) have

1) Hoinville, G and E. Johnson, "The Importance and Values Commuters Attach to Time Savings," Social and Community Planning Research (SCPR), 1971.

shown that, for the commuter journey to Central London, the number of interchanges in the journey is associated with the amount of waiting time and the frequency of delays. These relationships are illustrated in Tables 14 and 15 respectively.

Table 14

Waiting time	All Respondents	Number of changes		
		None	One	Two or more
	%	%	%	%
5 minutes or less	47	62	40	29
6-9 minutes	31	26	32	37
10 minutes or more	22	12	28	34

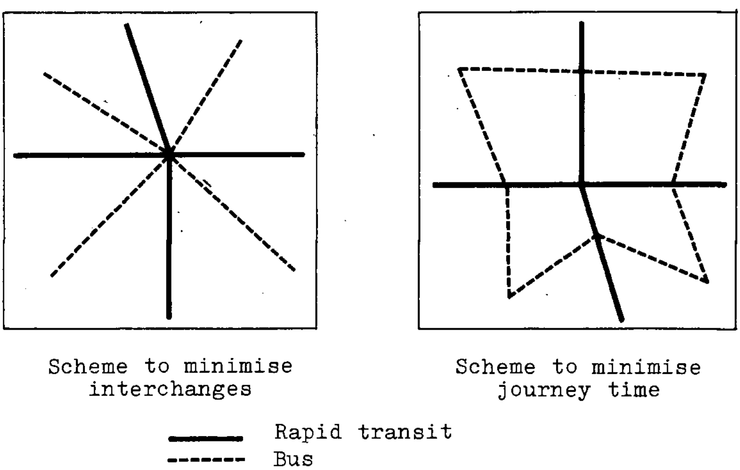
Table 15

Frequency of delays	All Respondents	Number of changes		
		None	One	Two or more
	%	%	%	%
Once a week or more	31	28	30	39
Every two weeks	29	26	30	33
Rarely/never	40	46	40	28
	100	100	100	100

In addition the same study examined the preferences and attitudes to many journey attributes (including reliability, seat availability, walking and waiting time, cost, and travel time). They found that interchanges did not appear as a particularly dominant priority for change amongst respondents until they started to look at their present situation. It was because many of their respondents had already achieved a relatively favourable journey in this respect that this variable appeared to be of less significance in the overall desire to change. In practice, they concluded that minimisation of the number of interchanges is one of the top priorities. Thus this points to the possible policy of limiting the number of interchanges necessary in a transport network to implement a given journey. Of course in the transportation network of any urban area there is a trade-off between a network of self-contained systems on the one hand and a more integrated system where different modes are designed to co-ordinate and offer a total transport system on the other. The former approach reduces the necessity to interchange but may result in low frequencies and high travel times when services are being asked to perform types of journey for which they are not suited. Budillon(1) who has implemented some preliminary research on this topic quotes a simple example where the choice between self-contained radial routes to the centre, both bus and rail, on the one hand and a system of bus feeders to the radial rail network on the other. The choice is illustrated in the following Figure 9.

Figure 9

ALTERNATIVE TRANSPORT SOLUTIONS



1) Budillon, Op. cit.

Budillon demonstrates that for interchange to be worthwhile there must be a significant speed differential between modes and that the interchange point must be sufficiently far from the centre (the point of destination) for the speed advantage of the rail transit to compensate for the time involved in performing the interchange. In the example he quotes of a rapid transit speed of 48 k/hr, a bus speed of 12 k/hr, and an interchange time of 2.5 minutes then the interchange must be at least 3.3 km away from the centre. Thus once again the conclusion is that towns must be over a certain size in order to support an interchange based network, but once the urban area is of such a size there are benefits to be derived from the functional specialisation of different modes. In such cases benefits can be gained by travellers using different modes for the 'line haul' section of their trip as opposed to the collection and distribution legs, despite the fact that this necessitates the inconvenience of modal transfer.

In future, however, combined transport systems may be developed (which do away with the necessity for modal change) by performing effectively both the collector/distributor legs and the line-haul leg of the journey. The simplest method of achieving such a combined system is to use buses which can operate on normal roads to perform the collection and distribution but are given segregated right of way over the line haul section. In such a case conditions would approach those of a rail transit 'line-haul' operation. This approach can be supplemented by incorporating guidance systems for the buses on reserved tracks. Further into the future the need for interchange could also be reduced by selective routes systems which provide automatic personalised transport throughout a network.

Chapter 3

RESEARCH INTO THE EFFECT OF INTERCHANGES UPON DEMAND

3.1. INTRODUCTION

Having discussed at length many different aspects of the provision of interchange facilities it is now important to start to review the methodologies that can be established to predict the impact of interchange schemes. It is useful to divide the discussion into two separate areas. The first concerns itself with the research necessary in order to establish quantified relationships and is the major subject of this chapter. The second relates these research studies with their use in the context of the planning environment, and will be the subject of the next chapter.

At each stage of this paper it will become evident that the number of relationships and variables that can be considered will diminish. Thus in the previous chapter, many factors have been introduced which in some instances, at any rate affect the usage of an interchange facility. In this chapter it will be seen that it is not possible to quanitfy the effect that all of these have upon demand.

This may occur for several reasons, for example:

i) It is genuinely not possible to measure the effect of particular variables, e.g. the difficulty of quantifying the benefits of improved station amenity.

ii) The variables are so inter-related that their separate effects cannot be measured. Thus one measure may stand proxy for another.

In the further discussion of the next chapter, even fewer variables will be included, as in any planning study it is usually necessary to simplify the forecasting process.

The next part of this chapter revises the present "state of the art" in the development of modal split models and the establishment of generalised cost measures. It then goes on to discuss the findings of some of these studies in as much as they relate to interchanges.

3.2. OUTLINE OF MODAL CHOICE DEMAND MODELS

2.1. Introduction

Many different models have been presented in the literature in an attempt to explain the reasons why people choose between one mode of travel and another. They attempt to make this division by considering in varying degrees:

a) Personal differences,
b) Specific modal characteristics,
c) Geographic modal differences (network and service configurations).

Different studies will use different combinations of variables from each of these sets, according to the purpose of the study, and the particular features of behaviour that are to be examined.

At the same time it is also possible to classify modal split models according to their level of aggregation. These are:

i) Area wide (global),
ii) Zonal,
iii) Individual.

Thus models of type (i) will attempt to calculate the percentage of a study areas trip makers that will use each of the available modes, as a function of the characteristics of the area, its inhabitants and broad measures of transport availability. Models of type (ii) are however much more spatially specific and will at their best explain the percentage split of trips made between zones of the study area as a function of the availability of particular modes in that corridor. They are, however, still probabalistic models and they need to make approximations about how accessible zones are to transport networks. Nevertheless they are important in that they are the kind of model that has been in most common use in transportation studies undertaken in the United

Kingdom. At the most detailed level of aggregation, is is necessary to examine individual's decisions and to explain his behaviour in terms of the choices with which he is confronted. In such models it is, theoretically, possible to avoid approximation and to deal in direct journey characteristics. However, as most surveys have to rely upon individuals estimates of distance, time taken, etc., there are still many sources of inaccuracy. The advantages of these kind of models lie in the use that can be made of techniques like discriminant analysis to separate a population into two modes according to alternative components of travel that confront the individuals of that population.

Whilst all of these model types have their uses, nevertheless, for the purposes of finding the effect that interchange quality has upon modal choice, attention must be concentrated upon those which attempt such an explanation as a function of the alternative characteristics of travel which confront users. Thus our interest is primarily in models of types (ii) and (iii) which attempt to look at the problem at a fairly detailed level of a real aggregation using variables (c) relative to the geographical layout of transport systems. Having said this, it should not be thought that the other less spatially specific variables are unimportant, indeed several writers have commented upon the effect that, for example, cleanliness can have upon social acceptability and hence usage (for example)(1).

There is also a place for such investigations at an area wide level which might establish the relative importance of expenditure upon interchange improvement as opposed to other transport improvements. Nevertheless, it seems very important that the question of interchanges should be seen in the whole context of the existing transportation system and the objectives of change that are sought.

2.2. Form of modal split models

Many of the studies which have attempted to explain modal choice as a function of the travel characteristics of the alternative modes have started by assuming a single measure of travel impedance C which can be expressed as a linear sum

1) Century Research Corporation, "Human Factors in Transit User Transferring," 1966.

of variables associated with the travel characteristics of the mode. Thus:

$$C^k = \sum_i a_i^k X_i^k$$

where C^k is the impedance experienced by mode K users
X_i^k are the variables associated with the measurable characteristics of mode k
a_i^k are weighting factors

As the measure of impedance is often referred to as a cost (generalised cost, perceived cost or behavioural cost) the weighting factors are assumed to be "values" to be associated with journey characteristics. In their study of modal split in London, Research Projects(1) contest this argument on philosophical grounds and suggest that they are merely "mathematical conveniences". Thus, as mentioned earlier it may be that some apparently significant variable, is significant only because it is correlated with some other variables. For example, waiting time may have a high disutility simply because it is associated with poor amenity standards in interchanges. This kind of effect becomes very significant when deciding the kinds of improvement that are possible. Money may be spent on either decreasing waiting time, or on improving station amenity - and a simple minded interpretation of the significance of waiting time - may produce bad decisions. Despite such problems of causality, nevertheless we shall adopt the common usage and refer to the a_i^k as values. It is important however that such considerations should be borne in mind at any rate qualitatively before decisions are reached. Many studies simplify further and assume that the values of the components a_i^k must, in order to be meaningful as descriptions of behaviour, be independent of the mode of travel itself; thus travelling time is travelling time regardless of the mode of travel it is spent upon. There is much to be said for this argument in theory if it were possible to postulate <u>rational</u> perceptions of <u>all</u> the components of travel. However, it is likely that in any practical study some variation between parameters will remain as proxies for those elements of particular modal characteristics that are not being measured in any of the variables for that mode.

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1) Research Projects Ltd., "Modal Choice: Studies of the Use and Non-Use of Public Transport in the Greater London Area," 1969.

However it is often useful to <u>assume</u> that these constants are independent of mode and hence it is possible to express the difference between modal costs as:

$$C^1 - C^2 = \; _{i}\, ai(Xi^1 - Xi^2)$$

and to use this difference now as the descriptor of modal split. Analogously it is possible to conceive of a wide range of measures of relative travel cost - and the following have all been used in models at various times and in various circumstances:

$$C^1/C^2 = ai(i^1/Xi^2)$$

$$\text{Log } C^1/C^2 = ai\text{Log}(Xi^1/Xi^2)$$

The following discussion will assume that the cost difference form is used. However similar formulations are possible for all other measures of relative cost.

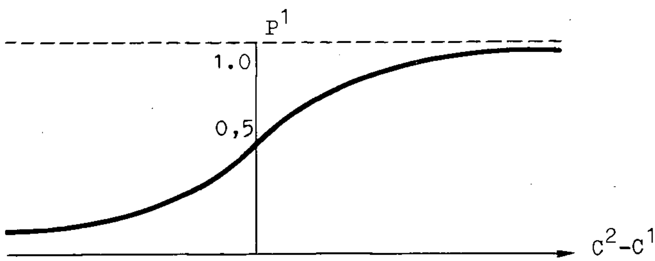
The task of the modal split analysis is the estimation of the values of ai(or ai^k). This can be done either at the individual level [(iii) introduced earlier] or at the zonal level (ii). At the individual level it is common to use a technique like discriminant analysis to distinguish between the modal populations. This is a technique which effectively maximises the ratio of the between group variation to the within group variation. Under certain assumptions this can then be expressed in a probabilistic form for the two populations as a logistic curve:

$$P^1 = \text{Probability of travelling by mode 1} = \frac{1}{1 + e^{-(c^2 - c^1)}}$$

where is a constant of calibration. For the cost difference formulation above, this gives a relationship of the form:

Figure 10

MODAL SPLIT DIVERSION CURVE BASED UPON COST DIFFERENCE



As an alternative to using analysis of individuals' behaviour it is possible at the zonal level to use regression analysis on this model.

$$P^1/P^2 = e^{-(c^2 - c^1)}$$

and hence:

$$\text{Log}(P^1/P^2) = -(c^2 - c^1) = - ai(Xi^1 - Xi^2)$$

and the ai can be calculated by regressing $\text{Log}(P^1/P^2)$ against $(Xi^1 - Xi^2)$.

There are, however, two problems in this approach:

a) It is not able to deal with flows between zone pairs where one of the modal flows is zero (in any transportation study based upon a sample home interview survey this is a common occurrence) assuming fine zone disaggregation.

b) There are problems of aggregating the measures of travel characteristics to apply to aggregate zone to zone trips, e.g. access time to bus stops will be highly variable across even a small zone.

These two difficulties are in mutual conflict; one require fine zoning; the other requires coarse zoning. It is very difficult to effect a satisfactory compromise, and for this reason many such studies have used the results of individual analysis (e.g. discriminant analysis) and applied then at zonal level, finally adjusting as a calibrating statistic(1).

The above examples have assumed a logistic model based upon cost differences. However very similar arguments apply (in varying degrees) for other functional forms.

2.3. Route choice demand models

In addition to the many models which attempt to value parameters of travel characteristics in the light of observations of persons' choice between modes, there are also studies which have attempted the same kind of analysis based upon the choice passengers make between routes. The majority of these have been based upon drivers' choice of car route and hence are not particularly useful in a study of interchange behaviour. However, some studies have been done (notably by RATP) upon passengers' choice of route through public transport systems.

1) For example, South East Lancashire North East Cheshire (SELNEC) Transportation Study - Technical Working Paper No. 7 Model Calibration.

This makes their results very important and we shall quote these later in this chapter. However, it is true that the techniques for this kind of analysis are less well developed than those for the binary choice of travel mode. For in these studies there are many more alternatives to be considered.

3.3. FACTORS AFFECTING THE ACCEPTABILITY OF INTERCHANGES

3.1. The foregoing sections have described, in general terms, some of the techniques that are available for use in modal split models.

In particular it has shown some of the ways in which it is possible to effect such an explanation using a linear measure of disutility or cost. It is the purpose of this section to review some of the work that has been done on such studies, and which has produced results relevant to a study of interchanges. It must however be said at the start that the data is scanty and refers to only a few of the variables. Accordingly discussion on some of the components will be purely qualitative.

As this work is firmly based in the theory of modal split models most of the references which we have perused are similar to those quoted in an earlier paper for an ECMT research round table (Harrison and Quarmby)(1). In this paper the authors pursue in considerable depth many different aspects of the valuation of time, and discuss many problems of interpretation. These arguments will not be rehearsed further in this paper, but it is important to note that inasmuch as nearly all results are dependent upon an existing value of time, that the same arguments apply, a fortiori, to the valuation of interchange parameters. It is perhaps, useful, to review each of the parameters in turn - following roughly the layout of components in Table 1.

3.2. The fact of interchange

Several studies have suggested that the mere fact of having to make an interchange has a serious deterrent effect upon the use of public transport modes, quite independent of

1) Harrison, A.J. and D.A. Quarmby, "The Value of Time in Transport Planning: A Review," Sixth Round Table on Transport Economics.

the effects due to transfer time. This particular relationship can be established if a component of the cost equation is "number of interchanges" (separate from any other transfer time variables). In general, the evidence for this particular parameter comes not from mode choice models, but from route choice models. Thus RATP(1) find this variable particularly significant in most situations and indeed very much more dominant than transfer time variables. It takes values from 2 to 9 equivalent minutes of travelling time. This is corroborated to a certain extent in the London Transportation Study where the Transitnet (public transport assignment) programme, assumes a constant equivalent to 4 minutes of travelling time.

However in modal split studies the number of interchanges has often not turned out to be a significant variable at all. Unfortunately as such findings have been somewhat negative there are no published references. However both LGORU (who have been engaged upon research work into modal split studies)(2) and Coras Iompair Eireann (who have established a modal split model for Dublin)(3) have found the variable not to be significant. It could be argued that this is due to the poor sample size for multi-interchange trips and therefore high errors. On the other hand it could represent a difference in perception of costs for different kinds of individuals' decisions - this will be discussed further in the next chapter.

3.3. Time spent in interchange

This falls as shown in Chapter 2 into two main areas:

a) Walking time - the time spent physically walking from platform to platform on the underground system or from bus station, or car park to rapid transit. Many studies have expressed the weighting to be associated with this time expenditure as a factor times the value of travelling time (usually two to three). However once again it is possible that the departure of this factor from unity occures as this is acting as a proxy measure of other variables below.

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1) RATP, "Economical Value of Comfort in Public Transport," FORS Congress, April 19 1.

2) Rogers, Townsend, Metcalf, "Planning for the Work Journey," Local Government Operation Research Unit (LGORU), 1970.

3) Coras Iompair Eireann - private communication.

b) Waiting time - This represents a very important factor in interchanges. The simplest ways of measuring waiting times at particular points is as an average value which is a function of the scheduled frequency of the service to be boarded. This kind of method has been used in transportation studies where waiting time functions have been designed as inputs to public transport routeing and assignment algorithms(1). However:

i) These can be improved upon if services can be co-ordinated. Thus there will be differences between behavioural waiting time functions at public transport mode access, and waiting time functions which are determined at interchanges by the co-ordination of timetables. This will apply in general only to low frequency services.

ii) For high frequency services, although waiting times will on average decrease, nevertheless an important factor will be the degree of irregularity. Means of measuring regularity have been defined by the Operational Research Department of LTE(2). Here the problem is part psychological. If there is perceived to be a possibility that another service might be delayed then passengers behaviour may be determined by that, even if it is an inaccurate estimate of the likely delay. Thus passengers unfortunate experience of waiting times on particular occasions may well make them overstate their average delay. Thus variability of headways on public transport services is very critical.

It is also worth observing at this point that means are available to reduce the disamentiy of waiting time, e.g. availability of shops, cafes on platform or at bus stand.

These two variables, waiting time and walking time are frequently combined in modal split studies into a single

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1) For example, SELNEC Transportation Study - Working Paper No. 6. Also see Figure 14.

2) London Transport Executive, "Modelling a Bus Route and Measuring Regularity," Operational Research Report R188.

measure of excess time. Quarmby(1) finds a combined value of excess time of two to two-and-one-half times that of travelling time. However, in a private communication he has suggested that there is some evidence in his results that walking time is valued slightly lower (one-and-one-half to two-and-one-half times travelling time) than waiting time (two to two-and-one-half times). LGORU(2) on the other hand suggest that waiting time should be valued at one-and-one-half times travelling time, whilst walking time should be valued at two-and-one-half times. IAURP(3) also suggest that excess time should be valued at twice travelling time, but unfortunately do not split this down to the two components. Finally Lisco(4) quotes a value of walking time three times that of travelling time derived from an analysis of parking charges.

RATP in their route choice study produce several different estimates in different situations. These range from 1.00 to 1.80 times in-vehicle travelling time. However, this is on the basis that there is also a "fact of interchange" penalty. So the equivalent comparison can only be made by taking both terms in an equation. Thus if <u>t</u> is the transfer time in minutes the weighted time reflecting the disutility of interchanges ranges from:

$$1.0t + 2.5$$

to:

$$1.8t + 9.5$$

according to broad classification of peoples attitudes towards interchanges.

Clearly there is a fairly strong concensus that walking and waiting times should be valued at approximately twice the value of in-vehicle time. Unfortunately there does not appear to be a similar concensus about the break down of excess time into its two major components. The only other piece of circumstantial evidence known to the authors is that in the public transport assignment programme developed for

1) Quarmby, D.A., "Choice of Travel Mode for the Journey to Work: some findings," Journal of Transport Economics and Policy, Vol. 1, No. 3.

2) LGORU, Op. cit.

3) IAURP, "Choix du moyen de transports par les usagers," October 1963.

4) Lisco, "The Value of Commuters Travel Time," 1968.

the SELNEC study(1) it was found necessary to revalue walking time on interchange links of the network to the same value as in-vehicle travelling time, in order to improve the assigned flows. Whilst this is not suggested as a researched judgement nevertheless it does seem to be a plausible hypothesis as most people would agree that time spent waiting is more frustrating than time spent on the move and "doing something".

3.4. Out of pocket costs

These can occur at interchanges particularly:

a) Park and ride - parking fees. These will affect the acceptability of park and ride - although usually this will be as a result of cheaper fringe parking followed by rapid transit to city centre, compared with direct city centre parking charges. In this case certain parking facilities have provided combined parking and travelling fees /for example Leicester City Transport(2)/ in order to remove the disutility of double payments (wasting interchange time and increasing uncertainty).
b) In some situations different public transport modes will require different fare levels (e.g. bus and rail). This will clearly affect individuals' mode choice decisions within the public transport system.

3.5. Energy and effort involved in interchanges

The degree to which these are significant are in general more questions of internal interchange design. Thus, if all interchanges were cross platform then energy would not for the majority of abled bodied users, be too significant. However, the provision of such good interchanges may itself only be possible at very high costs to the layout of the public transport network. An alternative in this case will be the provision of mechanical means of transport - escalators, moving pavements, etc.

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1) SELNEC Transportation Study - Technical Working Paper No. 7: Model Calibration.

2) Leicester City Transport: Park 'n' Ride, 1972.

3.6. Comfort

Degrees of overcrowding on different parts of a transport system may well have a profound effect upon behaviour. As in the case of service levels, this is once again made psychologically worse by the uncertainty attached to it. Thus, will a seat be available on the service to which I intend to change? It may be that the chances of one being available are much higher than perceived due to exceptional unfortunate experience. In fact this factor is very highly correlated with the previous one of waiting time, as irregular services (on metropolitan transit systems at any rate) usually also have a high variability of loadings, and hence seat availability.

3.7. To summarise then:

1) Some studies have found then that the effect of an interchange per se, is equivalent to 2 to 8 minutes of travelling time.
2) That walking and waiting time should be valued approximately twice that of travelling time (except that this might be decreased if a constant interchange penalty has been included). Unfortunately it is not possible to assert that walking time should be valued at a lower rate than waiting times with any real confidence. However it might be justified to assume that walking time has a factor of 1.5 whilst waiting time a factor of 2.5.
3) The effect of out-of-pocket cost variables can be included directly - so long as a suitable value of time can be justified to bring all the excess time variables of (1) and (2) above to a monetary cost.
4) That the effects of most other variables have not been established satisfactorily. There are also many remaining queries about the causal justification of the above time variables given the likelihood that these are highly correlated with other aspects of interchanges which have not been fortunate enough to find a place in the disutility function due to measurement problems!

3.4. ATTITUDINAL AND MOTIVATIONAL STUDIES

So far we have assumed that values of travel characteristics can only be measured by direct observation of people's behaviour. There are clearly good reasons for this rather cautious approach, as the more direct method of asking individuals what their attitudes and motivations are, is clearly fraught with difficulties.

Nevertheless it may be that the time has come for the pendulum to swing a little further back in favour of such studies. It is clear that for many of the more "difficult variables" which have yet to be valued in the context of behavioural studies (e.g. overcrowding costs), one of the prime problems is to find suitable trade-off situations where there is sufficient variance in the data about peoples behaviour to allow the kind of analyses we have discussed above. In this situation it is possible that the best way forward may be to tighten up the techniques and methodologies of market research and develop tools that can be applied to transport situations.

One of the advantages of the use of motivational surveys may be that they can assist in eatablishing the causality of valuations derived from behavioural studies. Thus it may be (as suggested earlier) that the true reason for waiting and transfer time being valued higher than travelling time, is due to other presently correlated disutilities (poor environment, no seats available). Before techniques using such valuations can successfully be used in prediction tools it is important that such questions of causality are identified and solutions found. It may be that this is an important use for motivational and attitudinal surveys. Thus they may take the role of arbitrating between various possible causalities rather than establishing causalities directly.

One of the standard techniques of motivational studies is to attempt to establish a points rating for various attributes of systems to be evaluated. This is sometimes further refined to establish scales of preference, along the lines of the work done for LTE which has been quoted earlier (Section 2.2). However, it is probably necessary to go somewhat further and to establish much more systematic techniques in order to produce consumer preferences, that can usefully be compared and contrasted with those derived from behavioural analyses. A more sophisticated and systematic approach studies is displayed by SCPR in their study of commuter preferences in London(1). In this they use a technique which they have developed which is based upon a device called the priority evaluator. This is a visual aid to help respondents to conceptualise different aspects of their journey. It is used first to establish a points scoring of their existing journey - based upon eight characteristics of their present journey:

i) Walking time
ii) Waiting time
iii) Travelling time
iv) Number of interchanges
v) Frequency of getting a seat
vi) Degree of crowding
vii) Reliability
viii) Journey cost (out of pocket)

Each of these attributes is given a points score of 1-4. Having established the existing journey characteristics it is possible to:

a) Find how respondents would prefer to allocate their points score;
b) Respond to an increase in "wealth", i.e. allow them to have a higher number of points to allocate;
c) Respond to a revaluation of the individual components.

There are many points on which it is possible to criticise such a methodology. It is not clear for example, how to interpret results based upon a "closed" economy of eight goods only when "wealth" is increased. It is also not clear that the interelationship between variables is satisfactorily established. For example, it was found that many respondents would accept an increase in crowding, if it was associated with a higher likelihood of getting a seat, which in most situations are mutually exclusive goals.

However despite these criticisms, there are many interesting results particularly in the re-allocation of existing points. Perhaps most significant for our present purposes was the fact that interchanges came out as a dominant priority

1) Hoinville, G. and E. Johnston, "Commuter Preferences: A Summary Report," SCPR, 1972.

(the fact of interchanges, rather than their inconvenience as measured in waiting and transfer times). Those currently with the worst journeys (two or more interchanges), wanted an improvement - whilst those with the best journeys, wanted to retain their advantage. Waiting time did not appear to be a very high priority for change, and travelling and walking time were apparently very low on the scale of priorities. Another interesting discovery was that people were willing to accept longer walking times very readily, in order to gain benefit elsewhere. This suggests tentatively that some of the observations made earlier about the relative values of walking and waiting time may be justified.

These results are interesting in that they are at variance with some of the behavioural studies in which we have found that it was not the fact of interchange that was of dominant importance but the associated waiting and walking times. However, it is perhaps worth just adding two observations:

a) There is a difference between valuing variables (like estimating time valuations) and asking priorities for improvement, inasmuch as people may already put such a high value on time as to have very consciously optimised their journey. This is particularly true for the journey to work.

b) In the behavioural studies the variables are frequently standing proxy for others not directly measured, in the way discussed previously.

Another interesting finding of the study was that only one-third of the respondents had any effective choice. This corroborates a finding of Research Projects(1).

Another interesting piece of attitudinal analysis is given by Golob, Canty, Gustafon and Vitt(2) in their study of consumer preferences in public transportation systems. They used a system of paired comparisons to calculate a scale of preferences - which they were able to disaggregate as between different income and socio-economic groups. The most important consideration however appeared for a variety of social groups to be that of arriving when planned, but the avoidance of interchanges came very close behind. Again it appeared that

1) Research Projects, Op. cit.

2) Golob, Canty and Gustafon and Vitt, "An Analysis of Consumer Preferences for a Public Transportation System," Transportation Research, Vol. 6, No. 1, 1972.

the fact of interchange was more important than the difficulties of interchange as measured in walking and waiting times.

Whilst this analysis is very helpful it is possible that the use of paired comparison techniques could be expanded to give a more thorough explanation of the values associated with the various components of transport systems, and indeed to allow such attitudinal studies to be much more closely related and compared with behavioural studies. This will be discussed further in the final chapter on further research.

Chapter 4

THE EVALUATION OF INTERCHANGE SCHEMES IN TRANSPORT NETWORKS

4.1. INTRODUCTION

The purpose of this chapter is to draw together some of the threads of the previous two chapters. In particular it is intended to suggest the kinds of ways in which interchange schemes could be assessed, and an evaluation methodology will be proposed based upon the demand models that have been discussed in Chapter 3.

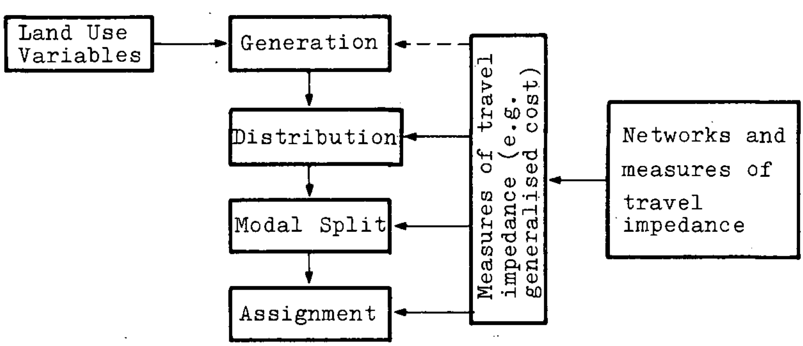
As a basic requirement of such a methodology it is important that an interchange should be discussed in the context of the transport system of an area. It cannot be evaluated in isolation, as it is dependent upon the objectives that the transport system as a whole is attempting to pursue. Thus fringe parking with rapid transit feeders to the city centre may only be a viable means of transport, if it is backed up by an appropriate pricing policy for car parking, e.g. high at the centre, low at the fringe. In this case it would be of little benefit to take great care in optimising the internal efficiency of the fringe car parking spaces, if it was associated with an inappropriate pricing policy. The study of all transport proposals abounds with examples of these kinds of interdependencies, and it is for these reasons that most United Kingdom towns and cities have now undertaken at least one transportation study and some have started a second. The primary aim of such studies is to sort out the strategic problems of transport, before concentrating on the financial and physical problems of implementation. The study of interchanges is no exception to this rule, and the second chapter of this paper has concentrated attention on this by describing the problems at different levels. Indeed it is true to say that there are even higher levels where it becomes important to go beyond transportation planning, to land use planning. For the need for interchanges is fundamentally affected by the urban geography of an area. However, at this level there are so many other non-transport criteria that must be included in any evaluation, that it is probably not profitable to pursue such considerations too far in this paper. However at the strategic transport planning level, it is possible to look at alternative public transport configurations to see if interchanges are necessary. Or it may be possible to choose on the basis of minimising the proportion of journeys that will need to interchange. Problems of this kind are strategic problems and they require suitable strategic tools for their evaluation. The only such tool that is currently available is the urban transportation study, and the ways in which interchanges can be introduced into such studies will now be discussed.

4.2. URBAN TRANSPORTATION STUDIES

First the structure of a transportation model will be briefly reviewed. This generally follows the form (with many variants):

Figure 11

THE STRUCTURE OF AN URBAN TRANSPORTATION STUDY



The four main phases can be construed as representing the different choices that confront potential trip makers:

1) Trip Generation - whether to make a trip?
2) Trip Distribution - where to go to? or how to locate with respect to employment?
3) Modal Split - what mode of travel to use?
4) Assignment - what route to follow?

Each one of these phases (apart from the Generation model at present) can model the outcome of such decisions as a function of the generalised costs that confront the potential user. Thus, in the distribution model the number of trips between origin and destination zones is usually assumed to be a decreasing function of the travel impedance (or generalised cost). In a similar way we have already seen how the modal split can be expressed as a function of the relative generalised costs of the alternative modes.

Clearly inasmuch as it is possible to include some components of cost associated with interchanges into the generalised costs then it is possible to make the outputs of transportation models sensitive to the quality of interchange to be provided. A more detailed description of the way this can be done will be described in the next section.

However, before going on to this, it is perhaps worth mentioning a problem that does arise, and which is not primarily associated with interchanges as such, but is a more general reflection on the nature of generalised costs. The problem is whether it is safe to assume that the valuations of different components of cost remain constant between the various sub-models of the study. Thus, are city centre parking charges perceived in the same way when deciding where to live with regard to a central employment opportunity, as they are when deciding on a particular morning whether to travel by car or by public transport. This is a particularly extreme example where, the kinds of decisions that are being made in the two cases are of a quite different kind, but the problem may in fact apply in many other slightly more subtle situations - some of which may concern interchange characteristics. The particular problem discussed above arose in the SELNEC study when the distribution and modal split models were being calibrated(1). It was found that central area parking charges had to be included to get an accurate representation of the modal split to the central area, whereas they definitely distorted any attempts to calibrate a distribution model. Another possible example of changes in impedance perception is that of the interchange penalty discussed in Chapter 3. In this case it was found that a pure interchange penalty (independent of the ease of interchange) had been found necessary in several route choice studies to explain travellers' behaviour. It has not been found to be necessary to the authors' knowledge in modal split studies. Whilst neither of these are conclusive, and many other explanations of the phenomena are possible, nevertheless it does suggest that caution should be exercised in the wholesale use of generalised cost throughout transportation studies. This point is further elaborated by Wagon(2) in a study of the elasticity of trips to parking charges under different model assumptions.

4.3. NETWORK INPUTS

It has been shown in Chapter 3 that the main components of interchange impedance that can be introduced into generalised cost are walking time and waiting time. These have to be introduced into the transportation study via the network coding and network building stages. Figure 12 gives an example of a particular interchange and Figure 13 shows how complex such network coding can become. This particular example is again taken from the SELNEC Study(3) but is typical of many such studies. Having coded such a network the next task is to build minimum generalised cost routes (trees) through the network using computer algorithms. In doing this, most programme packages allow the introduction of weighting factors of the kind described in Chapter 3. Hence minimum generalised time routes can be derived. Bruggeman and Worrall(4) have

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1) SELNEC Transportation Study - Technical Working Paper No. 7 Model Calibration (to be published).

2) Wagon, D.J., PTRC Car Parking Seminar.

3) SELNEC Transportation Study - Technical Working Paper No. 6 Network Specification.

4) Bruggeman, J.M. and R.D. Worrall, "Passenger Terminal Impedance," HRB Research Report No. 322, 1970.

examined means whereby appropriate estimates of the impedance of terminals may be calculated using queuing simulation models. This is however of a higher degree of sophistication than the normal transportation study assumes. Some public transport planning packages introduce waiting time functions for all access and interchange movements. These again are described for the SELNEC Study(1) and an example is shown in Figure 14. The logic of this diagram is that for low headway services the average waiting time is half the headway whilst for high headway services the waiting time is proportionately less as people are aware of timetables. Both these assumptions are open to some objections. (i) It is unlikely given the fact of unreliability on most low headway services that the average waiting time will be half the headway, a figure like two-thirds may be more realistic. (ii) Whilst the timetable assumptions are valid for access to the public transport system, it is much more likely that for interchange situations average waiting time on high headway services will be a function of the co-ordination, or lack of it, of timetables.

This then is the way in which minimum generalised cost (or time) routes can be built up. From these cost matrices can be derived that give end to end journey costs between all pairs of zones of the study area, for input into the various sub-models of the transportation model.

In any given study, it is often the case that there is insufficient time or resources to enable values of the weightings of all components to be established for the particular area. Frequently, in this situation, standard values are assumed, which have usually been derived from modal split studies on individuals. This raises several problems:

i) The previous queries about whether values of parameters remain fixed between different models (modal split and assignment).

ii) Whether there are aggregation problems in moving from models based upon individuals to models based upon average zone to zone characteristics.

iii) Whether generalised cost techniques are appropriate to "all-or-nothing" routeing models. These are extremely sensitive to the values of parameters assumed.

1) SELNEC Transportation Study - Technical Working Paper No. 6 Network Specification.

Figure 12

CODING OF FEEDER BUS ACCESS TO RAILWAY STATIONS
IN SECOND SERIES OF MODEL RUNS

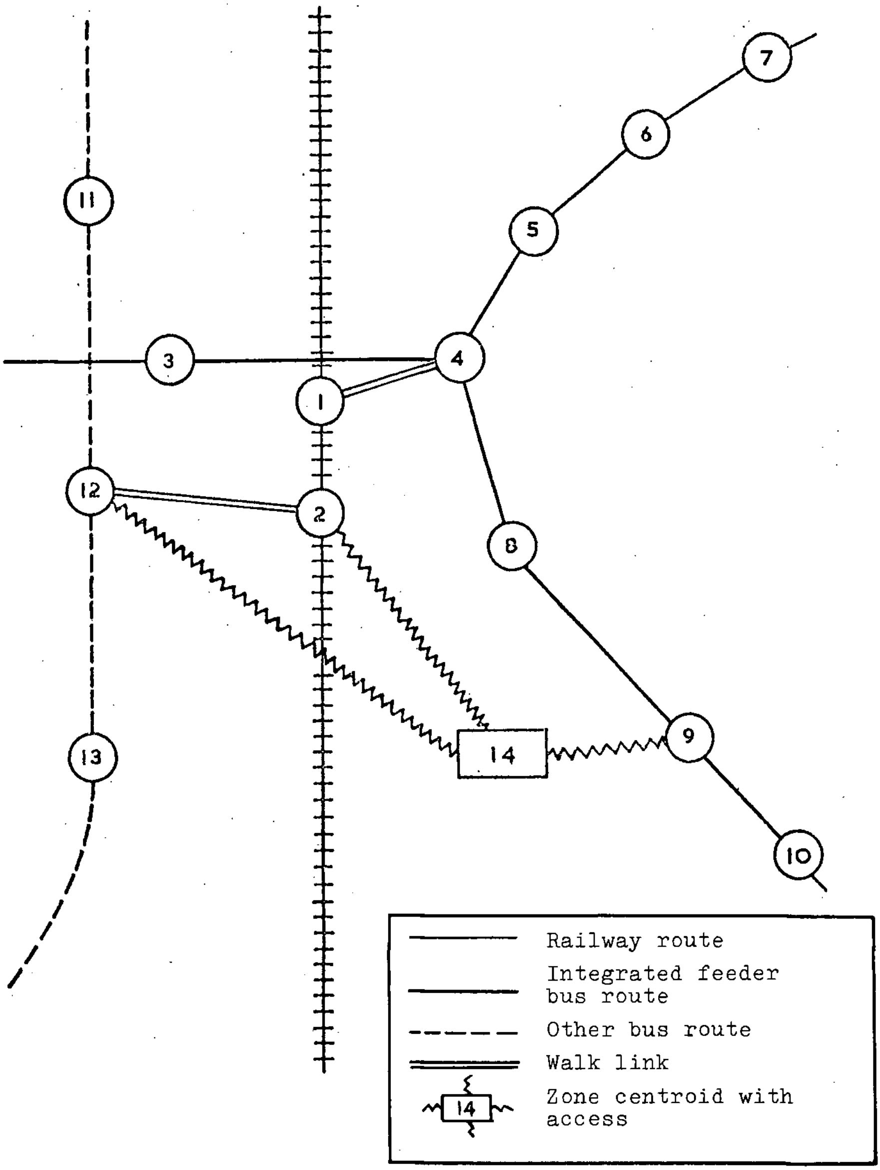


Figure 13

SECTION OF CODED P.T. NETWORK

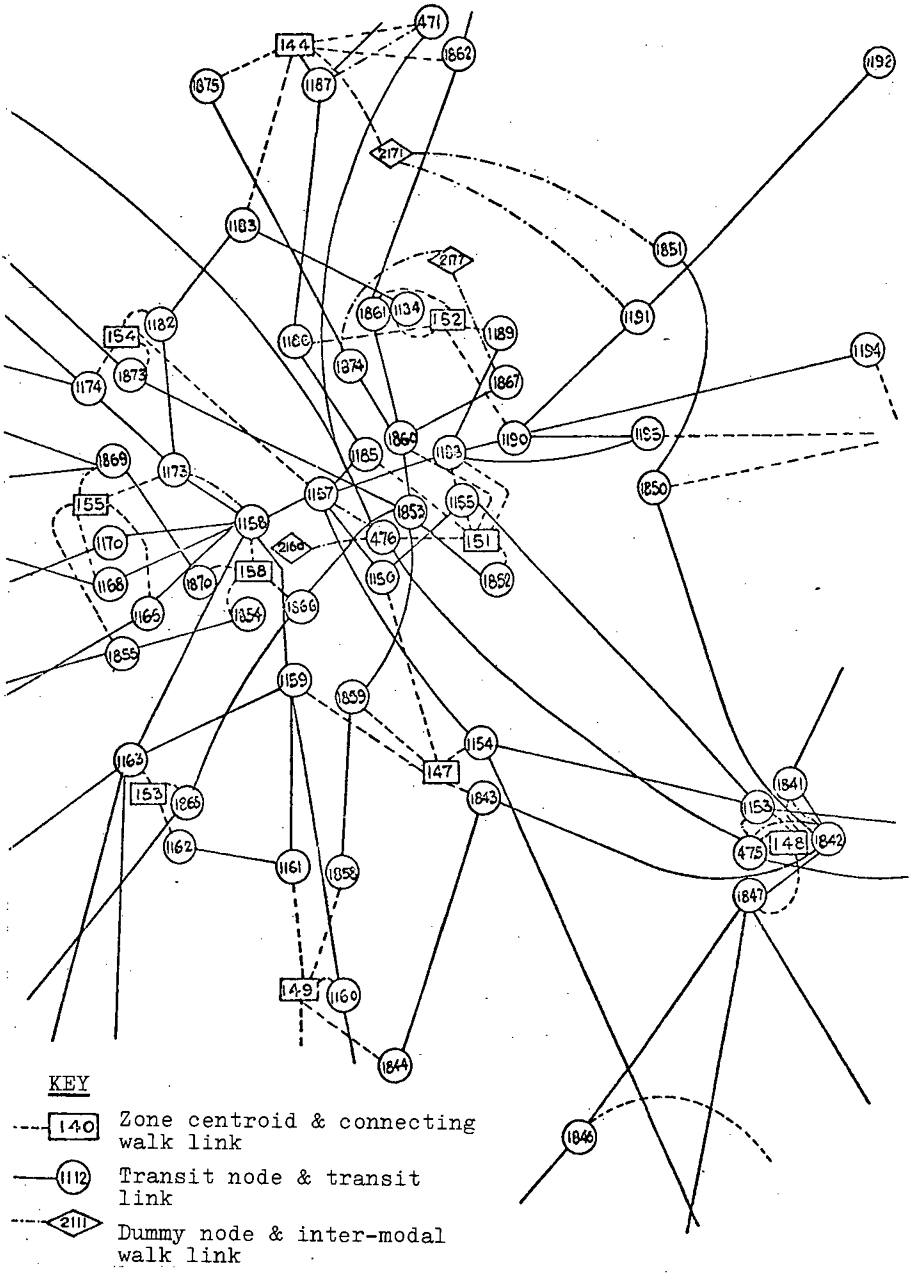
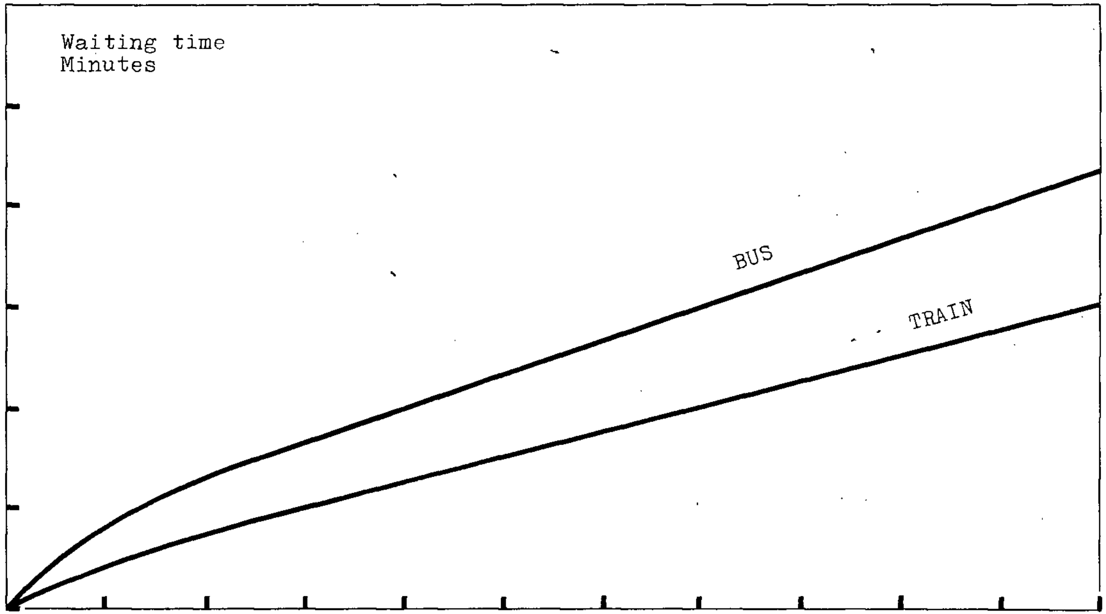


Figure 14

WAITING TIME FUNCTIONS



IRT(1) make a similar point in their criticism of generalised cost as a measure of performance for interchanges.

iv) Arising out of (iii) it is often found that in order to get good assignment loadings it is necessary to make non-systematic and heuristic changes to the network configuration and in some cases to the parameter valuations. This is a "fact of life" of transportation studies. It does, however, have serious impacts upon interchange schemes, since they are usually only a small part of the total network.

The above sections have described some of the problems that can be encountered in introducing interchange proposals into transportation studies. The next section discusses the outputs that can be expected from such studies.

4.4. EVALUATION METHODS

At the strategic level of transportation studies the evaluation of interchanges should be seen as similar to the evaluation of any other transport system. In fact it is an area wide evaluation of a strategy, one component of which may be a series of particular interchanges. The methods and techniques for doing this have now become firmly established, and in the United Kingdom at any rate, use the concept of consumers surplus as the basis of benefit measures. This is thought to be particularly important in the new schemes are substantially different from the existing ones (as they usually are over the timescale of a transportation study). These methods are described in a DOE working note(2).

Having selected the desired strategic plan for the area the next need is to focus down upon the particular interchanges that are proposed and to evaluate the alternative layouts that should be considered. Almost without exception it is at this point that life gets really difficult for the transport planner as there are usually no systematic ways of moving to a finer level of aggregation. This need for hierarchical models is one of the main proposals for further work that is

1) IRT, "Les ruptures des charges dans les villes de province."

2) McIntosh, P.T. and D.A. Quarmby, MAU-N-179, internal publication of the United Kingdom Department of the Environment.

made in the next chapter. The need for such techniques is clearly shown by the difficulties that some studies have found in using data from transportation study forecasts. An example of one that has had more than usual success is one undertaken by De Leuw Chadwick OhEocha in Bolton(1) using data from the SELNEC Transportation study. In this study an impressive cost-benefit analysis is built up from a few model run results for 1981. Unfortunately this procedure is very sensitive to the accuracy of these results. Another study that has looked at a similar problem is that of Peat Marwick Kates on a demonstration programme of interchanges for the Merseyside area(2). At one point of this study they compare the likely volume of passengers who use present interchanges according to the model, and those that in fact were found to, in detailed surveys. The comparison is in fact very much better than it might have been. These are however still problems about the use of such data for interchange design purposes.

This need to be able to focus down from the strategic level of an urban transportation study, to the design level at particular points in the system is quite fundamental. Unfortunately the present Transportation Study is all too often seen by the engineer as a cumbersome tool that has little to offer to his needs. At present it is hard to argue against this unless more flexible tools can be developed. This development may take the form of improvements in computer technology (making computer model runs cheaper or faster) or it may take the form of very much more sophisticated models and their associated data bases.

An example of an attempt to evaluate a particular interchange scheme is shown in a technical report of the United Kingdom Local Government Operational Research Unit. In this they describe a method whereby the results of their modal split studies(3) can be used to evaluate a proposed Bus station

1) De Leuw Chadwick OhEocha, "Bolton Interchange Feasibility Study," February 1972.

2) Peat Marwick Kates, <u>Op. cit.</u>

3) L.G.O.R.U., <u>Op. cit.</u>

at Easthampstead(1). It is evident, however, that the major problems of such a study are concerned with the difficulties of representing its affects upon the rest of the transport system, e.g. change in road congestion. It is however an interesting paper and contains a very useful checklist of factors to include such an evaluation.

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1) Mackie, S.N.H. and A.E. Metcalfe, "A Technical Report on Methods and Procedures for Evaluating the Easthampstead Bus Station Proposals L.G.O.R.U.," Report T40, 1972.

Chapter 5

FUTURE RESEARCH AND CONCLUSIONS

5.1. INTRODUCTION

The following proposals for future research are put forward as a tentative direction that research might take. In putting them forward it is useful to structure the discussion as follows:

a) Basic research. This activity is essentially "truth seeking" and concerns the development of scientific observations and lines of inference. It is concerned with establishing relationships rather than applying them.

b) Methodological research. Having established working relationships it is necessary to develop the methods to use such relationships. This is different from activities (a) in the same way that Chapter 4 is different from Chapter 3. Its emphasis is upon application and planning methodologies.

c) Implementation and monitoring. Having established relationships and evaluated alternative proposals there is still the need to test that the results produced, match up to expectations. The difficulties in this area that necessitate research are tied up with the problems of performing "before and after" studies.

Each of the above areas will now be discussed separately in Sections 5.2 to 5.4.

5.2. BASIC RESEARCH

a) Urban Geography. Chapter 2 has discussed some aspects of interchanges in the geography of an urban area. These are however only very tentative findings. It would be of great interest to attempt to establish the effects that urban form, urban size, network densities, etc., have upon the success of interchanges. In certain areas, most notably London and other large cities, the need to interchange is accepted as a concomitant of living and working in such cities. There is a need to establish by comparison between cities whether this relative success or acceptance of interchanges is a result of:

i) Size of urban area
ii) Form of urban area
iii) Layout of networks
iv) Restriction on car use (parking policy, congestion in historic centres, etc.)
v) Social attitudes (Is public transport socially acceptable?)

Clearly these are all closely interelated issues and it is going to be difficult to establish clear causalities. However, it should be possible to make a start in this direction by establishing the present incidence of interchange trips (either percentage interchanging at least once, or time spent in interchange) for many different European cities in a similar, but hopefully better way to that shown in Appendix A. Attempts could then be made to relate such measures of interchange use, to the various factors mentioned above.

Although such work would only be descriptive in character, it might well indicate those situations where the provision of interchanges is a necessary part of urban social organisation, and also those situations where interchanges can never play a major role in public transport movements. These might help to extend and corroborate such findings of those of IRT(1) concerning the necessary size of urban areas. Undoubtedly there will remain many "grey areas" in between where the

1) IRT, Op. cit.

success of interchanges will be determined by much more detailed considerations. Nevertheless it would be very helpful to have the boundaries of the problem established and the range of uncertainty limited.

b) Idealised city models. It seems clear that it should now be becoming possible to study in theoretical terms the layout of possible transport networks for various categories of urban form (linear, centrifugal, centripetal) with a view to finding how best public transport services can be oriented so as to minimise the need to interchange. These studies would be essentially theoretical in nature and quite separate from any network studies in the context of a transportation study. They would relate in a general way the form of an urban area, to its transport networks so that the latter could be organised in such a way as to minimise the number of trips that needed to make an interchange.

A starting point for such work might be some of the studies that have been undertaken on the location of interchanges within an area. An example of this is the study by Schneider et al(1) of the best location in which to establish VTOL terminals within an urban area. This work studies the urban part of interurban trips, and is therefore along rather different lines than would be required for the study of urban interchange points. However, work of a similar generalised nature, but which make more specific allowances for network design, could play an important role in the pre-planning of strategic alternatives to be tested in a transportation study.

c) User valuations of interchange characteristics. From Chapter 3 it is evident that there are many deficiencies in out knowledge of the value to put upon the various different aspects of interchange design and organisation. Thus although most findings would agree that walking and waiting time should be valued higher than in-vehicle travelling time, it is not clear whether they should be equally valued, or whether the uncertainty attaching to waiting time means that it should be valued even higher. It is not attributable to other characteristics of interchanges. These deficiencies are quite basic to any attempt to incorporate interchange planning

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1) Schneider, J.B., J.G. Symons and M. Goldman, "Planning Transportation Terminal Systems in Urban Regions," Transportation Research, Vol. 6, pp. 257-273.

into the total transport planning, and it is accordingly important that some work is done on establishing values more adequately.

There are two lines of approach. The first, behavioural approach, would be to try to identify trade-off situations where mode or route choice decisions are affected by specific interchange characteristics. In this respect further work along the lines of RATP study(1) of comfort on the Paris metro would be of assistance, along with more detailed modal split studies - possibly based on demonstration projects of the kind discussed in the next section. It seems, however, that these kind of methods are unlikely to succeed fully in distinguishing between the various factors.

The second approach which might help could be the use of attitudinal and motivational surveys. These may be especially important in helping to disentangle some of the queries discussed earlier about causality. However, it is clear that the studies will have to be of a sophisticated kind. Some of the best of them can produce valuations of product characteristics very similar to those of the more standard behavioural choice studies. Thus Klahr(2) in his study of cigarette brands, describes the use of paired comparisons. This merely requires respondents to rank the "proximity" of paired alternatives, and then establishes methods of identifying the co-ordinates of each alternative in n-dimensional space of product characteristics. This seems a very promising approach to adopt in a number of areas in transport planning. The main difficulties would seem to lie in determining situations where users perceive themselves to have sufficient alternatives. Harrison(3) in a paper on evaluating demonstration projects proposes some similar ideas. Finally it is likely that the use of techniques like SCPR's priority evaluation(4) (mentioned in Chapter 3) should be further examined.

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1) RATP, Op. cit.

2) Klahr, "A Study of Consumers Cognitive Structure for Cigarette Brands."

3) Harrison, A., "A Review of Two Attitude Behaviour Models," Traffic Engineering and Control, December 1971.

4) Hoinville, G., R. Berthoud and P. Prescott-Clarke, "Priority Evaluation Research Methods," Development Report SCPR, 1972.

5.3. METHODOLOGICAL RESEARCH

It has been emphasised throughout this paper that there is a distinction between research that is just arrived at understanding the reasons for revealed behaviour, and research whose primary objective is to develop methods of measuring the impact of new schemes and evaluating costs and benefits. This latter area is particularly concerned with the implementation of planning models as part of the decision making process, and is exemplified by the present development of transportation planning packages.

On the subject of interchanges there is a need to graft on to the present area-wide transportation study techniques, methods whereby it is possible to focus down on to individual pressure points in a network and deal with these in detail. Thus the present techniques of transportation studies are only able to deal with interchanges at a strategic planning level - deciding in broad terms the location and number of such interchanges. It is important that they should then be able to go on to answer more detailed design questions about the layout of such interchanges. From this it would then be possible to feed back and to find the effect that improvements have had upon the performance of the interchange.

Thus there is a need to develop hierarchical model systems that can work at varying levels of aggregation. This has been discussed in the context of land use models by Broadbent(1), however, there are many practical problems of aggregation and disaggregation of transport models that have not yet been explored sufficiently to suggest the best way forward.

5.4. DEMONSTRATION PROJECTS

In addition to desk studies and planning model evaluations of the need for, and organisation of public transport interchanges, there is a clear need for some experiements with different kinds of interchanges. These experiments are a necessary final check that travel behaviour can be affected in the way in which planning models suggest.

1) Broadbent, T.A., "A Hierarchical Interaction-Allocation Model for a Two-Level Spatial System," Regional $tudies, Vol. 5, No. 1, 1971.

A good example of this kind of work is described by Peat Marwick Kates in their proposals for Demonstration projects to be undertaken in the Merseyside conurbation(1). These are designed to gauge the relative importance of, and assess the part played by, a number of factors in determining the choice of travel mode. They distinguish between policy variables (i.e. controllable) and other more circumstantial factors (e.g. the level of car ownership). Some of the policy variables considered are different aspects of an interchange facility (mostly park and ride) like ease of access, parking price, etc. It is of interest that this programme of projects grew out of the proposals which the same consultants (under a different name) had made in the recommendations of their strategic study of the future transportation system for the Merseyside area(2). The interchange report again contains a good example of the need to focus down upon particular parts of a strategic plan - a need that has already been identified in the previous section.

The report also outlines the form that the necessary "before and after" studies of the projects should take. This is clearly a key feature of the organisation of demonstration projects and it is a feature that the United Kingdom Department of the Environment puts a great deal of emphasis upon. It is all too easy for the lessons of any demonstration project to be lost as a result of the inadequate preparation of monitoring techniques. There are two main difficulties:

i) Other things often change between the before and the after-situation that are quite extraneous to the experiment, e.g. public transport fares change, car ownership changes, the economy moves into a different part of its cycle. Any such effects can alter the level of trip making. Some of the effects are measurable and can therefore be included on an evaluation. Many more circumstantial differences are more difficult to deal with, e.g. the weather, the staff situation on public tranaport services. Usually the answer is to use adequate controls, but the selection of

1) Peat Marwick Kates, "Study of Transport Interchange on Merseyside," a demonstration programme.

2) "Merseyside Area Land Use Transportation Study," Traffic Research Corporation, 1969.

suitable controls is frequently very difficult as all usually seem to have special features which make them atypical.

ii) It is usually impossible to select samples of users both before and after the change which are comparable. Some studies attempt to use the same set of individuals - in this case difficulties arise because individuals' behaviour changes - people move house, change jobs, etc., and even over a short period of time this causes severe difficulties. The alternative is to stop worrying about individuals and to concentrate on producing "before and after" groups with similar characteristics. This means that the data can only be used on a much more aggregate basis (and hence much of the necessary variance is lost) or else there are severe statistical error problems. However, having said all of this, there is a clear role to be played by demonstration projects in assessing interchange performance. But equally clearly there is a strong need for the development of the associated techniques of "before and after" analysis.

5.5. CONCLUSION

The need to interchange remains one of the most inconvenient aspects of a journey. This in part, at any rate, is likely to be a consequence of the lack of integrated planning over a period of years. This in its turn was, and in many cases still is, an institutional problem which has arisen out of the historically competitive basis of many public transport organisations. Fortunately there are signs that this problem is being recognised in the establishment of more global planning frameworks for public transport organisations (for example in the United Kingdom, Passenger Transport Authorities have been set up in the large conurbation to assist in the joint planning of raod and rail public transport). However, there is still a long way to go before this institutional framework is fully established.

Even when this has been achieved, there will be a large backlog of poor interchanges which will need a large injection of funds in order that waiting and walking times can be improved to an adequate extent.

However, as we have seen the problem is even more complex than this, as there are yet higher levels of difficulties. Is it possible to reorganise the network to eliminate the need for some interchanges? What is the role of interchanges in the transportation strategy for the area?

One important aspect of this paper has been the attempt to show that interchange problems come at many different levels of the planning process, from the strategic viewpoint, right down to the physical design viewpoint. At each of these levels it is important that analytical tools are available, both to predict the effect of change, and to evaluate the benefits of change.

There is another aspect of the provision of interchange facilities which has not been explicitly discussed in this paper, but which is implicit throughout. This concerns the balance of investment. Funds for transport improvements will always, at least in the foreseeable future, be limited. This means that it will remain important that funds are allocated well between the various parts of a transport system. It is very easy to concentrate attention on improving the line haul parts of journeys by improving link speeds in a network, and in so doing to ignore the benefits that can be achieved by investing in access and interchange links.

It may well be that in terms of end to end journeys there are much larger social benefits to be gained by improving interchanges design and organisation than there are by squeezing the maximum speed on line hauls. It is likely that improvements in the latter are reaching or may have reached, a point of diminishing returns, whilst considerable gains for relatively low costs are available from the improvement of interchanges. It is extremely important that this point of balance in the allocation of funds is identified now, and that positive attempts are made to move towards it.

Appendix A

EXTENT TO WHICH TRANSFERS ARE MADE BETWEEN ROUTES OR MODES OF PUBLIC TRANSPORT IN A HIGHLY DEVELOPED SYSTEM. SOME ANALYSIS OF LONDON'S TRIP PATTERN

In order to assess the importance of interchange on modal split it would be interesting to have some idea of the importance of interchange in the typical journey. This can take the form of either information on the probability of performing an interchange or the proportion of time involved in interchanging. The former approach is simpler and some orders of magnitude can be obtained from surveys conducted in London. The following table from a study conducted in 1954 by London Transport(1) shows that the probability of transferring between, or within public transport (i.e. bus to rail or rail to rail transfer) was 0.34. The probability of a London Transport rail trip involving a transfer to another underground line was 0.30

	Percentage of journeys by public transport requiring				Average number of rides per complete journey
	One ride	Two rides	Three or more rides	Total	
London transport					
Road services	83	15	2	100	1.20
Rail services	70	28	2	100	1.31
British railways	89	11	-	100	1.12
All public transport	66	26	8	100	1.43

1) London Travel Survey - London Transport, 1954.

Since 1954 when this survey was made the bus service in London has declined. It is likely that journeys which were relatively inconvenient to perform by rail due to interchanges will, with the decline in competing bus routes, now be relatively more attractive and be performed by rail. In addition since 1954 the main change in the London Transport rail network has been the addition of the Victoria Line. Whilst no general survey is available yet for the total London Transport rail network a survey of Victoria Line usage shows that in 1969 60 per cent of Victoria Line underground journeys involved at least one change onto another line. The magnitude of this figure when compared with the 30 per cent for the whole system in 1954 is probably partly a function of the character of the Victoria Line. Much of it is in Central London where the opportunities to interchange are greater and also it was specifically designed to give convenient interchange with many other lines.

Thus we have a range of between say 40 per cent and 60 per cent on different lines. This finding is backed up by further motivational research conducted by Research Projects Ltd.(1) in 1966 which indicated that nearly half the Underground travellers in their sample made a change of trains.

The proportion changing in any transfer system is of course a function of the scale and complexity of the transport system and one would therefore not expect anything like such a high proportion changing in other urban areas with less developed rail transit systems.

The second indicator fo the importance of interchange is the proportion of total journey time involved in interchanging. This has, on the whole, received little study to date. However, for London the Greater London Council Transitnet assignment model of the 1962 London Transportation Study(2) has produced the following average times spent in interchange movement:

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1) Richmond Study - Research Projects Ltd. as part of L.T.S. Phase III, October 1966.

2) London Transportation Study, Phase III, G.L.C. (unpublished report).

	Main line termini (mins)	Major suburban stations (mins)
Bus/British Rail	3.8	2.3
L.T. Rail/British Rail	5.0	1.2
L.T. Rail/bus	-	2.0

Viewed against an overall average of some 20 minutes on public transport, for all journey durations in the London area involving any public transport content, interchange movement time is therefore a not inconsiderable proportion, even on an average basis.

Also, further study of Transitnet data shows that the average movement times, quoted above, are exceeded in some cases by 50 per cent, or more.

Appendix B

MODAL SPLIT OF FEEDER JOURNEYS TO SOME RAIL STATIONS IN LONDON

The following table gives comparative figures for 1969 showing the modal split by percentages of the journeys to stations:

Station	Park and ride	Kiss and ride	Bus	Walk and cycle	Total Passengers (8-hour period)
Bexley	10%	7%	21%	62%	1,751
Bexleyheath	4%	3%	18%	75%	4,510
Bromley North	13%	4%	37%	46%	2,982
Bronley South	12%	6%	43%	39%	4,746
Ealing Broadway	6%	8%	34%	52%	11,409
					(16-hour period)
East Croydon	15%	6%	51%	28%	10,329
Sidcup	4%	3%	35%	58%	3,779
Surbiton	14%	7%	25%	54%	6,012
Wimbledon	6%	4%	22%	68%	7,344
Elephant L.T.E.	9%	6%	44%	41%	6,360
Kennington	13%	7%	5%	75%	3,843

	Park and ride		Kiss and ride	Public trans-port	Walk and cycle **	Total Passengers (8-hour period)
	Drivers	Passen-gers				
Burnt Oak	6%	1%	4%	35%	54%	3,887
Cockfosters	17%	2%	8%	11%	62%	1,671
Elephant and Castle	6%	1%	3%	62%*	28%	9,386
Gants Hill	6%	1%	5%	34%	54%	5,342
Harrow-on-the-Hill	11%	2%	9%	31%	47%	4,796
Kennington	12%	2%	5%	8%	73%	3,993
Leytonstone	9%	2%	4%	11%	74%	6,523
Osterley	18%	2%	11%	14%	55%	1,871
Park Royal	8%	1%	5%	36%	50%	1,023
Rayners Lane	5%	1%	5%	16%	73%	4,635

* This is made up of bus/coach 30 per cent, Underground/ B.R. train 32 per cent. At the other stations the bulk of public transport travel consists of bus/coach journeys, which are basically local in origin.

** The cyclists are included here as they are numerically numerically insignificant by themselves.

Source: G.L.C./L.T./B.R.B. Survey

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SUMMARY OF THE DISCUSSION

With the growth of cities and the more or less concimitant development of the means of transport serving them, the problem of transfers from one vehicle to another within the same mode or between different modes has become more and more acute. The size of conurbation combined with technological progress has led to a hierarchic and specialised pattern of transport modes and to the co-existence of several transport technologies. Public transport users are often obliged to transfer from one vehicle to another once or even several times in the course of a journey, and they resent this all the more because use of a car would save this inconvenience.

There can be no doubt that transfers are one of the main deterrents to the use of public transport, yet this is the only real solution to the problem of road congestion in large cities(1). The scantiness of research in this field is surprising, for a knowledge of users' attitudes to transfers would be of great help for the design of modern transport systems and for improving existing interchanges. The 19th Round Table has endeavoured to ascertain the present state-of-the-art in this field, and to define the directions which future research should take if some light is to be shed on a problem which has so much bearing on the future of public transport.

Having studied and specified the improvements which should be made to interchange operations and facilities, and also to feeder services, the participants in the Round Table judged that a method of analysis should be formulated for the problem of transfers and that it should be used as a basis for research in this field.

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1) The qualification that this statement calls for would go beyond the scope of this report. See in this connection Professor Klaasen's report for the 5th Symposium, "The Impact of Changes in Society on the Demand for Passenger and Freight Transport" (pp. 15-20).

1. IMPROVEMENTS IN INTERCHANGE OPERATIONS AND FACILITIES

The problem of developing a transport system in which transfers are minimised is not dealt with in Section 1 below. It need to be looked at from a broader angle and can more suitably be fitted into Section 3, as it calls for the prior formulation of method for analysing transfer phenomena. In the following paragraphs therefore, the discussion is restricted to ways of improving interchange facilities without considering how transfers might be eliminated in the course of network design.

Transfers have two aspects: a negative aspect which is much resented by the user - mainly because of the time wasted in the process - and a positive one, too often overlooked, i.e. the plain fact that without them many journeys would not be practicable to all, but this is no reason for disregarding the ways of mitigating the inconvenience of transfers, in particular, by improving interchange facilities.

1.1. Two conceivable main courses of action

Time costs have a vital bearing on transfers. Minimisation of users' costs and users' time is without question an essential objective in the design and development of interchange facilities, but the user's valuation of time in the course of a transfer is influenced by the two following factors:

1) the feeling that time is being wasted and what could be done with it instead;
2) the circumstances in which the time is spent.

These are the two main point offering scope for action in the design and construction of interchange facilities. On the first point, the aim should be to shorten the time spent, especially the waiting time; on the second point, the aim should be to improve the circumstances in which this time is spent. There is clearly far less scope for the first type of action than for the second as it normally involves considerable capital costs. Consuequently, action has to be limited in most cases to improving the circumstances surrounding transfers.

1.2. The range of action

Improvements in interchange facilities must not be considered with an eye to large cities alone and only for transfers from car or bus to rail or from rail to underground and vice-versa. The range of action is extremely wide and due regard should be paid, inter alia, to walking and cycling which play so important a part in countries such as the Netherlands.

It seems, for instance, that bus stops receive little attention despite their importance as an interchange facility in medium-sized cities. A study undertaken at Leeuwarden, in the Netherlands, shows the wide scope for action in this respect. In that city with a population of about 90,000, only 40 per cent of bus users are provided with sheltered (i.e. roofed and glazed) bus stops and these account for only 7.5 per cent of all the city's bus stops. It has been calculated that if all the bus stops used by 70 or more passengers (that is 82 per cent of all bus stops) were sheltered, 76 per cent of all bus users would be catered for. This shows that action in this field has not always matched up to requirements; protection from wind and rain would certainly be a very effective and relatively inexpensive way of alleviating the discomfort associated with waiting time, and would promote the use of a mode of transport which still has a promising future in medium-sized cities.

1.3. Possible improvements

The participants in the Round Table were fully agreed on Table 1 (Chapter 2.2) of the introductory report which contains a list of possible improvements, but considered that it should be supplemented on various points:

1) The difficulties facing the traveller who carries luggage, and the improvements which can be made to resolve them, were not sufficiently emphasized under "movement user-costs".
2) The pre-sale of tickets was not mentioned as a possibility of wasting less time in buying tickets ("non-movement user-costs").
3) Under "environmental user-costs" noise abatement was omitted.

4) Studies undertaken in the German Federal Republic have shown that uncertainty is an important factor in the user's assessment waiting time. Less frustration is felt if the time of the next bus or train is plainly displayed.

It seemed necessary to add to the three headings in Table 1 (and hence to the three bread categories of possible improvements) a fourth heading entitled "organisation user costs". Movement at interchanges calls for prior "organisation"; in particular, all the information that would-be passengers have to collect on transport system before they can use it. The mere fact of using a public transport service implies costs. A public transport user needs far more information than anyone using his own means of transport. It is much easier for motorists than for public transport passengers to get back on the right track when they have gone the wrong way. The latter have to inquire about timetables, routes, fares, etc. - no easy task when transport modes or services are involved - hence the emphasis laid upon the need for a single information centre embracing every mode.

The following table lists the various "organisation costs" which the user incurs at interchanges and the possible improvements in this respect.

The participants in the Round Table considered that the best way to bring about the foregoing improvements and reduce transfer costs would be to provide integrated interchanges, especially when several modes are involved. They did, however, regretfully point out the institutional obstacles to action of this kind, including the unco-operative attitude sometimes shown by public transport undertakings.

1.4. A wider approach to the problem

The Round Table stressed that the improvement of interchange facilities should not be considered from the angle of the "transport" function alone. This would be too narrow an approach. Two other functions should be taken into consideration for the design and equipment of interchanges:

1) the "passenger safety" function. Transfers should be convenient and safe in every respect. Besides the hazards inherent in any plant or machinery, yet another problem has arisen with the growing frequency of acts of violence on public transport services.

	Car Driver	User	Requirements
1 INFORMATION	can leave at any time "his car being there waiting for him"	must first find out at what time he can start, at what time he will arrive and leave at each interchange, and at what time he will arrive at his destination point	A timetable for all means of transport; information covering all means of public transport
	has a continuous and unbroken journey; can easily adjust his course if he goes the wrong way	must know exactly where he is before transferring to another vehicle	Stops should be announced, and interchange services plainly displayed inside vehicles. Plans of rail and bus services should also be displayed there
	can sidestep traffic jams due to accidents or road congestion	when connecting services are late, because of a traffic breakdown, has to find out how long it is likely to last	Loud speakers at interchanges should give all the necessary information
	can work out his mileage costs on a uniform basis	has to pay successive fares	Journeys involving interchange should not cost more than through journeys for a given distance; Fare structures should allow free choice of means of public transport (zonal or flat rates)
2 TRANSPORT CONDITIONS	covers several hundred kilometres with a single filling of petrol	must have the exact change for each journey	Season tickets and facilities for payment through giro or bank account (as for electricity bills or TV licences)
	has free access to his car	turnstiles at each interchange	Open entry and exit; controls restricted to spot checks
	can carry at will, and without additional cost, children, pets, luggage	additional charges for children, pets and luggage (repeatedly when changing from mode to mode) and variability of conditions of access and fares according to mode	Free transport within specified limits for children, pets and luggage

2) the "shopping and advertising" function of the interchange.

These two functions have an important bearing on the surroundings of public transport users at interchanges. The possibilities of conflict between those two functions cannot, however, be overlooked and this will sometimes imply a difficult choice. Some interchanges have been considerably altered by their shopping function. Where people used to simply "pass through" they can now congregate and this has raised safety problems.

More generally, interchange facilities should not be studied from a narrowly specific angle; an overall view is required. An interchange should not be designed as a kind of box - in one end and out the other - but as an integral part of its neighbourhood and environment. Though such studies are no doubt more useful for installing new interchanges than for modernising old one, they do help to see more clearly how they work and, in particular, to analyse both the transfer process as such and the conditions surrounding the arrival and exit of passengers. Investigation of feeder services and how they can be improved should be integrated in the study of the interchange itself because of their important bearing on the public's decision whether or not to use public transport and whether or not to make use of the interchange.

2. FEEDER SERVICES

The modal split of feeder services for mass rapid transit (usually rail or underground) deserves to be examined within a geographical context other than that of London as in the introductory report. Such a study would give a more general view and show in better perspective the factors affecting the modal split of feeder services. Certain broad tendencies and characteristic trends may also emerge from such an analysis. It might, in particular, draw attention to the increasing role (which will doubtless become vital in future) of the car as a feeder mode for mass public transport, i.e. of "Park and Ride".

2.1. Modal split of feeder services

2.1.1. Coverage

The analysis of feeder modal split must not be limited to certain modes; buses, cars and walking are not the only means of access to mass public transport systems.

The part played by bicycles and mopeds in some countries must also be borne in mind. Nor should taxis be omitted for they contribute most usefully to terminal transport facilities and in distributing the flow of public transport passengers from mass transit terminals to city centres.

To disregard the potentialities of each mode and refrain from providing better conditions for transferring from them to (or from) public transport systems means forfeiting resources which, properly arrayed, might attract custom to public transport.

2.1.2. The relativity of feeder modal splits

The figures for feeder modes in the introductory report (Section 2.3) relate to specific sets of circumstances and cannot therefore be regarded as generally representative of this type of modal split.

For instance, detailed French studies on walking to (and from) stations and on the effect of the distance of stations on this mode of access have given very different results according to the type of station (underground, railway, bus) and, even in cases of stations of the same type, according to their location.

Any analysis of feeder modal split must be qualified according to the type of transport system considered and its urban environment.

A study conducted in 1967 on the means of access to railways stations in the Netherlands illustrates this relativity of feeder modal splits. Not only do results differ from those, based on British experience, in the introductory report, but they also vary from station to station and from one city to another.

FEEDER MODAL SPLIT (PERCENTAGES) AT RAILWAY STATIONS

	Walking	Bicycle or moped	Train or bus	Private car	Total
Amsterdam (main station)	35	10	50	5	100
Hilversum (commuter station)	45	33	12	10	100
Rotterdam Lombardyem	70	20	5	5	100
(suburban station)	70	20	5	5	100

If modal split is measured within a radius of 1 km., the results are different.

	Walking	Bicycle or moped	Train or bus	Private car	Total
Amsterdam	75	5	15	5	100
Hilversum	75	15	3	7	100
Rotterdam Lombardyem	85	10	3	2	100

The relative character of figures for modal split of feeder transport and for urban transport generally is such that, before proceeding with any analysis of an urban transport system and, more especially, any study of interchange conditions within the transport system, data should first be carefully collected on actual transport conditions in the considered zone.

Notwithstanding this, the studies conducted on feeder services have brought out some general trends and highlighted the factors which have a bearing on whether or not to use a particular type of transport.

2.1.3. Factors affecting the use of feeder modes

The determinants for using the various types of feeder services are carefully set out in the introductory report (Section 2.3). The comparison of studies conducted in different countries enabled the participants to express their general agreement with this presentation of the case.

However, it was pointed out that though the use of feeder modes is indeed linked to the level of service offered, to the socio-economic characteristics of the population and to its density (i.e. factors to which attention was drawn in the introductory report, it also very largely depends on the quality of service provided on the line haul, as this can indeed induce the decision to use public transport rather than go the whole way by car and hence make use of a feeder mode to get to the station and transfer to a mass transport facility.

2.2. The car as a feeder mode and the "park and ride" system

Though the results of studies on the subject often vary and though precise conclusions of general significance cannot always be drawn from them, one point which does emerge is the beg future of the motor car as a feeder mode. A comparison of studies made in London in 1954 and 1969 (introductory report paragraph 2.3.3.) makes this quite clear. The demonstration project on interchanges for the Merseyside area (i.e. the Liverpool conurbation) has produced similar results: "figures available at this stage indicate however the "car-to-rail" has a significant part to play in the future. . . .patronage has nearly doubled on average at car parks included in the programme of experiments"(1). The wide-ranging significance of this assertion prompted the Round Table to discuss the feeder mode concerned in greater detail, especially the "park and ride" system which is linked with it and which enables users to transfer to rapid transit more conveniently.

2.2.1. The two main categories of "park and ride" users

These are:

1) Millward, C., A.H. Coleman and J.E. Dunford, "Passenger Transport Interchanges - Theory and Practice on Merseyside," Traffic Engineering and Control, Vol. 14, No. 12, April 1973.

a) users who are in practice willingly "chained" to public transport - those who for various reasons (cost, safety, time or other grounds) will use it in any event. In their case, the car is quite distinctly the feeder mode and public transport the main mode.

b) users who are "compelled" to use public transport - those who would like to go the whole way by car but are deterred from doing so for different reasons (congested roads and high parking charges at city centres, etc.). In their case, the car is the main mode and public transport merely a "distributor service". It is among this category of user that what is known as "railheading", i.e. the tendency to drive to a distant park and ride station, to which the introductory report refers, is the most evident.

Obviously, it depends mainly on geopgraphical, demographic, social conditions, etc.,whether users of park and ride station belong to one or the other of these categories.

The location and design of park and ride facilities should pay due regard to the wishes of individual users; care should be taken to distinguish between users who are reluctantly surrendering the use of their cars and those who would in any event be willing to use mass transportation. Their reasons, their objectives and, hence, their requirements, are not the same.

It has to be admitted that there is hardly any information available on this matter. Studies should be undertaken on the distinction between the two types of users of park and ride facilities and on its implications. Before a park and ride facility is provided there should first be a "demonstration project" covering the type of user it will cater for. This is a prerequisite (besides many other factors) to the success of any park and ride policy.

2.2.2. <u>The conditions for a rational "park and ride" policy</u>

A park and ride policy is not always successful; many past failures confirm this. Several clearly defined conditions must first be fulfilled. The participants in the Round Table, considered that the failure or success of a park and ride interchange depends on at least three factors:

1) the mass public transport system to which the car park is connected must provide a good quality of service;
2) the site of the car park must be carefully selected;
3) the park and ride policy must be integrated in a wider policy framework.

Failure to fulfill any one of these three conditions is enough to defeat a park and ride policy

a) <u>Quality of service of mass public transportation</u>

An example illustrates the importance of this factor for the success of a park and ride policy. Two park and ride interchanges in the Paris area, one at Bagnolet, the other at Saint Germain en Laye, have met with very different degrees of success depending on the quality of service provided by the adjoining public transport service. The Saint Germain en Laye facility alongside the R.E.R. which provides a fast, comfortable and not overcrowded service is well-filled, whereas its Bagnolet counterpart, which is connected to overcrowded public transport service, has very little patronage.

For the park and ride system to be successful, the public transport service to which it is connected must provide a reasonable alternative. Motorists will not leave a comfortable car, and the certainty of a seat, for an overcrowded and uncomfortable train or bus; there is little point in improving interchange conditions unless the public transport service is of good enough quality. This being so, it seems that a park and ride facility can be successful only if connected to an own-track transport service ensuring reliable journey time. It follows that a park and ride interchange linked to one or more bus services of conventional type does not seem to provide a satisfactory answer.

b) <u>The siting of park and ride interchanges</u>

Various studies, including one at Stuttgart, have shown that the nearer the destination, the less inclination there is to use park and ride facilities. A prerequisite to the success is that they should not be too close to city centres as in this event the "psychological", i.e. "perceived" distance from car park to city centre is an inducement to go all the way by car.

Clearly, the minimum distance from the park and ride facility to the centre varies with the conditions peculiar to the urban area concerned and a special study is accordingly required before choosing the site of such a facility. At Hamburg, for instance, studies have shown that park and ride interchanges should be at a distance of at least six kilometres from the city centre. At Marseilles, the corresponding figure is three to four kilometres.

On the whole, the participants in the Round Table were of the opinion that park and ride interchanges should be fairly remote from the centre, and they referred to Amsterdam where these facilities were as much as 25 kilometres away from the city centre and yet had a good occupancy factor. They also pointed out that park and ride interchanges should be sited with due regard to road traffic conditions, that is, before bottlenecks and not beyond; those located immediately within city boundaries are bound to prove a failure because that is precisely where traffic difficulties are most troublesome. The Porte d'Italie car park in Paris is a case in point; as it is sited just after the bottleneck at the entry into Paris, motorists have little inducement to give up their cars because the flow of traffic then becomes easier. Park and ride facilities are far better situated immediately alongside motorway exits on city outskirts.

It has been noted, however, that most of the studies conducted in this field were mainly concerned journeys to work, and the same applies to the foregoing comments. For journeys other than commuting, shopping trips, for instance, consideration should perhaps be given to locating park and ride facilities on different sites (probably nearer to city centres) and linking them to public transport services (e.g. minibuses) different from those used for commuters, but further studies would be needed to confirm these assumptions.

c) A co-ordinated overall policy

A park and ride policy cannot be planned in isolation nor applied independently of other measures. Park and ride interchanges on the outskirts of large cities will not prove successful unless traffic and parking restraints in city centres are introduced at the same time. Park and ride policy has often failed for this reason and that is why it must be fitted into a wider frame of reference.

Another, more serious, reason lies behind these failures. It very often happens that while park and ride interchanges are being built, decisions entirely at variance with their principles and purpose are being taken at the same time.

It is pointless to try to promote public transport with park and ride facilities if at the same time, as is alas too often the case, private cars continue to be lured to city centres by providing central car parks and more indoor parking without widening urban roads, and by providing easier access to city centres with motorways leading to inadequate distributors. There is nothing worse than a policy which tries to embrace everything and in practice dodges any plain objective.

The Round Table drew attention to another snag. In the foregoing paragraphs, and in the introductory report itself, attention was drawn to the importance of certain traffic and parking restraints in city centres (prohibition of on-street parking, parking meters, hgih parking charges). It would be wrong to believe that such measures can be effective in themselves and that they are enough to sway the user's choice of transport mode, for though this may be true in the short term, if nothing else is done to promote the long-term use of public transport (for instance by providing park and ride facilities), it is not modal choice which will be affected by these measures but the actual pattern of traffic. If a reasonable alternative (i.e. efficient public transport) is not available, trip patterns will be different and there will be a shift towards other nodes and destinations. Brussels is a case in point. The problem then cases to be restricted to transport and embraces urban planning. Before imposing traffic and parking restraints in the city centre, the kind of city one wants should be decided first. If the city is to be multi-noded, the historic centre may lose all vitality and the only way to prevent this is a concomitant zoning policy, but if the status of the city centre is to be fully preserved, there must be an active policy for promoting public transport - the only suitable mode of transport for that particular purpose.

Thus, a policy for promoting public transport, notably by providing park and ride facilities, is not conceivable without restraints on car traffic in city centres and, conversely, these measures cannot be taken singly, that is, unaccompanied by improvements to public transport, without throwing urban structures out of balance.

What should in fact be sought is a properly balanced socio-economic city structure and any action, including provision of park and ride facilities, should be integrated in an overall policy designed to achieve that balance. To attain this objective, the whole transport system must be planned as a single unit. There may be more than one rational and comprehensive way of doing this. If so, the choice between the various solutions proposed by the transport expert will be a political one, but it is essential that the system proposed should be such as to meet transport demand and match the needs of the type of city wanted (here again the political decision-maker must choose on the basis of the information provided by economists, town planners and sociologists).

Having thus considered in detail, and from a somewhat empirical angle, the improvements which could be made to interchange facilities and feeder services, the participants in the Round Table judged it necessary, in view of the importance of interchanges in the layout of urban transport systems, to outline a method of the problem which would help to enlighten the political decision-maker in his choice and enable economists to prescribe a rational solution to transport problems.

3. A METHOD FOR ANALYSING THE PROBLEM OF INTERCHANGES

The subject is an interdisciplinary one. The economicst, geographer, town planner, psychologist, socologist, all have something to contribute.

The main difficulty lies in working out a method of analysis which would be a compromise between highly theoretical and abstract studies such as those conducted in the United States and the down-to-earth empirical ones relating to quite specific interchanges. The method should make it possible to evaluate the effects of improvements to interchanges and hence the usefulness, of such improvements and to integrate interchanges rationally in transport systems and networks.

Formulation of a method for analysing interchange problems raises three main questions:

i) Should the angle of approach be "Supply" or "Demand"?

ii) Should the level of analysis be "Microscopic" or "Macroscopic"?

iii) What should be the technique of analysis and on what criterion should evaluation be based? Should the problem be studied by means of models based on generalised cost as the parameter or should a different approach be adopted?

In replying to these three questions the participants in the Round Table tried to outline a method for analysing the problem of interchanges.

3.1. The angle of approach

In the introductory report, the problem of interchanges is considered from the demand angle alone. This approach is necessary, indeed fundamental,as it is, of course, the user who eventually decides whether or not to use the interchange. It is therefore essential to know what is or is not acceptable to him and to determine the location of interchange points to suit their users' needs. However, this approach does not entirely meet the case. The "output" aspect of the "collection function" in the broad sense must also be taken into account. In other words, the "supply" angle should not be overlooked in the analysis of interchange problems. If urban and sub-urban transport services are considered from the supplier's angle, three levels can be traced in the passenger collection hierarchy or "tree":

a) the "twigs" which, however sophisticated the technology, can never be served by public transport, labour costs being so large a component of total costs. In any case this is less of a problem in these days of wide-spread car ownership.
b) the zones where it becomes possible to group flows and so provide a bus or minibus service, i.e. where a public transport service can be envisaged.
c) lastly, transport for which more elaborate techniques are required, i.e. where one can transfer from buses to more powerful means of transport requiring less manpower.

From the supplier's standpoint, instead of having a large number of services directly serving the city centre which could hardly pay their way, it is obviously far more attractive to provide few links of the type referred to under (c) and to "funnel" all secondary flows on to more powerful transport means better suited to serving city centres. The "breaks of bulk" (i.e. interchange) and systematic funnelling of trips that this network configuration involves enables the transport operator to achieve substantial economics of scale, especially by saving on labour. From the "transport supply" angle, this is a very positive aspect which cannot be disregarded in any general analysis of the interchange process.

To allow for the impact of interchanges on the level of supply, output functions or cost functions are accordingly needed to quantify the savings which the transport operator can obtain through interchanges. It is essential to work out functions of this kind especially before taking any decision on network design. This was done tentatively in the course of the studies on the transport service to be provided for Evry in France, and it was thus possible to compare two proposed solutions (dual-mode buses with no interchange or bus to underground with interchange) and so calculate the costs and savings of interchanges, albeit somewhat roughly for in this case it was indeed found that determining cost functions is difficult even when labour is the largest cost component and that such functions are influenced by local conditions and cannot therefore be generalised.

Thus, a general analysis of interchanges must embrace both supply and demand aspects. The economist has to calculate the impact of interchanges on the supplier and on the community. At Evry for instance, the supplier's interest was invariably balanced with the interest of the community; for each variant of transport service, the transport operator's costs and benefits were evaluated to with the impact on users, including the loss of custom due to each interchange. Only if an analysis covers these two aspects can the decision-maker be properly briefed.

3.2. The level of analysis

The problem of interchanges cannot be tackled by studying a single interchange point regardless of its environment and general context. It must therefore be seen as an integral part of an entire transport system, but since the structure of transport networks differs from one city to another, analysis of interchange problems within their transport network context must necessarily be on a somewhat ad hoc basis. Typological analysis of interchanges seems a promising approach in this respect as it makes it possible to locate interchange points by reference to the environment and its particular features.

3.2.1. Analysis by reference to transport system

On this point the Round Table was entirely in agreement with the views of the authors of the introductory report. Interchanges are an important component of the public transport system of a city; it is clear that they must be seen in the context of the whole transportation system of an area, and judged according to the rôle which it is proposed that the system should play.

Effective improvements to interchanges and, more generally, their design and prop location, calls for a knowledge of the functions that each of them performs within the transport system which it serves. Three Paris underground stations: Pont de Sèvres, Chatelet and Saint Lazare, can be taken as a case in point. They cannot be considered in isolation because the roles they play within the transport system as a whole are altogether different. The transfers they cater for are not of the same kind and they are consequently not amenable to the same type of improvement

a) Pont de Sèvres mainly caters for changes from underground to bus and vice versa. The problems here mainly concern passenger flows from buses and improvements are required to facilitate the movement of pedestrians from bus to underground.
b) Chatelet is essentially an interchange point for several underground lines.
c) Saint Lazare with its rail to underground transfers plays a very important role as a "central distributor"; it is also an important interchange between underground lines and there is a considerable output from its exits.

These examples show how essential it is, in any interchange analysis, to consider interchange points by reference to the whole system. Otherwise, the discussion might run the risk of being confined to a particular interchange point and so lead to the adoption of "microscopic" solutions as a result of too narrow a vision. Moreover when one moves from the existing scheme of things to the design, location and creation of future interchanges, there can be no alternative to a method of analysis which integrates them within the system as a whole.

When studying interchange problems, only by taking the whole system into account can due weight be given to feeder services which play so big a part in the success or failure of an interchange and to the impact that the improvements referred to in the foregoing pages can have on the user's choice.

Interchange problem must be discussed not only in the context of the system as it now is but also with an eye to how it should develop. Particular attention must be paid to the network as it will be in future so that the right distinctions can be made between the different types of interchange.

Thus, the interchange problem (whether for the design of new interchange points or the improvement of existing stations) should be integrated in the planning of the whole system. It is important in any event that the system should be seen as a single entity and it can fairly be assumed that many of the existing differences between public transport modes are of an institutional character and will tend to fade out. On the other hand, because of the wide differences from one system or city to another, each analysis has to be on a somewhat specific basis in actual practice.

3.2.2. Analysis of a specific case

The data relevant to any transport system are highly specific and vary from city to city. A study of the interchange problem in the context of the whole system and of the city is accordingly much influenced by local circumstances; it is necessarily ad hoc and difficult to apply generally.

The problem of interchanges does indeed seem to be fairly closely related to the size of the city. The results of a study, conducted in the Netherlands (see table below) clearly show a relationship between city-size and transfer frequency.

Cities	Population	Percentage of journeys by public transport requiring interchange
Groningen Utrecht Eindhoven Apeldoorn	125.000 - 450.000	20-25%
La Haye	600.000	27%
Rotterdam Amsterdam	750.000 - 900.000	34%

In France, similar results have been obtained: in Paris, 30 per cent of journeys on public transport involve an interchange; in Nantes, 10 per cent and in Caen 3 per cent. This correlation must obviously be taken into account.

Some participants in the Round Table considered that, in the present state-of-the-art, it would be most useful to single out the influence of the "city size" factor on interchanges and try to determine the minimum size below which interchanges are no longer worthwhile.

They also pointed out that the question of city size had been neglected so far and often even ignored because studies on interchange points had been focussed mainly on conurbations. Medium-sized cities should also be considered, and more systematic research is needed as findings relating to conurbations were probably not applicable to them and vice-versa. Thus, a bus-to-bus interchange system may be effective in medium-sized cities if carefully designed (e.g. Utrect) but is ill-adapted to the needs of conurbations. On the other hand, the fact that the number of interchanges was not considered significant in the LGORU and Coras Iompair Eireann studies (see p. 58 of introductory report) may be due to the medium size of the cities considered. However, though there does seem to be some link between city size and use of interchanges, it cannot be absolutely rigid because other factors (such as network structure, car ownership and use of bicycles) play a part and it follows that use of interchanges varies widely for cities of equal size.

Another distorting factor is that propensity to use interchanges also depends on the city's function. New towns whatever their size fulfil very specific functions which have a bearing on the behaviour of transport users as does their proximity to large cities. More generally, network design and, hence, the design of its interchange component depend on the raison d'être of the city.

If interchange studies are to fulfil their purposes they must be conducted at a level which embraces all the factors and implications already mentioned. To find rational solutions to the problem of interchanges its analysis must be very detailed and carefully tailored to suit each case. The complexity of the problem is such that none of its aspects, however marginal it may seem, should be disregarded. In order to cover all these factors which a narrowly-focussed study would miss out and to examine the interchange problem within the context of city and of the transport system, interchange typology seems a promising approach for the right level of analysis.

3.2.3. A typological analysis

Typological analysis of interchange stations seems to be an appropriate way of investigating the problems they involve as it meets the need for something ranging far enough to embrace the environment and transport system besides being sufficiently refined to take into account all the distinctive features of interchange points.

The Round Table did not attempt to list exhaustively the elements to be included in a typology of interchange points, i.e. the elements referred to in the foregoing pages, but did emphasize the importance of three elements:

a) An urban planning element, that is, an element relating to the urban structure. Interchanges vary according to type of city. In cities with a "radial-concentric" structure, for instance, three types of interchange can be traced and the respective importance of each of them is bound up with this particular urban fabric.

   i) Interchanges intended by operators to achieve economies of scale by funnelling traffic flows. These are the most common type in the ciries referred to.

   ii) Interchanges located in central zones. In the smallest cities this essentially refers to the public transport/walk interface.

   iii) Interchanges for transferring from one urban corridor to another. At Toulouse, for instance, they account for only 2 per cent of all transfers.

   In very large, structurally different, urban areas, the typology is more difficult to define: other types of interchange come into the picture and the respective importance of each type is not the same as in cities with a "radial-concentric" structure.

b) A technical element: the technical aspect of interchange point (i.e. their physical characteristics, the modes involved) must be included in an interchange typology.

c) An institutional element: the institutional status of each transport undertaking and the fare structure of each mode must be taken into account. This is however, a somewhat lesser factor and its importance is further declining.

To determine an adequate level of analysis, as outlined above, was no easy task. The participants in the Round Table did not unanimously agree on this topic, especially as regards the last two points (specific analysis and typological analysis). Though there was a majority in favour of the line of thinking outlined above, several objections were put forward, notably by the authors of the introductory report as they considered that a specific approach and hence a typological analysis for each and every case was not warranted:

a) For practical reasons; carefully detailed interchange studies covering all the peculiarities of transport systems and differences between cities are of course highly expensive. In practice, simplification is essential for reasons of cost and intelligibility, and though there are indeed differences from one city or system to another, many problems can be stated in identical terms in any interchange study.

b) For theoretical reasons; specific analysis is pointless because the functional differences of interchange points are usually due to differences in types of user. On the same side, it was also argued that the very different costs relevant to different types of interchange could be safely taken care of by incorporating a suitable parameter as part of a general analysis technique.

For all these reasons, some participants, challenging the majority view, considered that the level of analysis should not be specific; the same method should be applied irrespective of the type of interchange. This difference of opinion inevitably also applied to the analysis technique as such, one side (the majority) preferring a fairly pragmatic technique, i.e. one suited to each case, the others opting for a generally applicable one comprising only a single criterion (generalised cost) to cover different sets of circumstances.

3.3. The technique of analysis

The introductory report refers to generalised cost as the criterion for appraising interchange projects and measuring the effect of interchanges on modal split. It also suggests that models incorporating this same criterion should be used to determine and, more especially, to forecast, the effects of an interchange within a transport system.

In the wide exchange of views on this methodology, there was a clash of opinion - on the "level of analysis" - between the supporters of a specific approach and those who favoured a general approach, but it was not so much on the criterion that views were most sharply divided (this being fairly generally accepted despite its shortcomings) but rather on the model approach.

3.3.1. Criteria for analysis

One of the main problems facing interchange planners is undoubtedly this: to reduce the generalised cost to the interchange user so that he does not opf for some other means of transport. Journey time, as shown by all behavioural surveys, is the most sensitive factor. The time element - or more precisely its cash equivalent - is the main component of the generalised cost to the interchange user. Minimisation of this cost is therefore a primary consideration for the planning, design and construction of interchanges.

As a general rule, in any operation involving interchange points (e.g. modernisation, creation of new ones) maximisation of consumer's surplus is always to some extent, an objective, and even if the operation is prompted by considerations of economic efficiency, the impact on consumer's surplus must still be borne in mind.

Since any interchange construction or modernisation project invariably has minimisation of cost, especially time cost, as an objective, the generalised cost criterion seems particularly well suited to interchange studies. It has the advantage of being fairly generally applicable to somewhat different situations. However, its use for the evaluation of interchanges presents certain difficulties and has certain limitations.

a) The difficulties

Determination of generalised cost for evaluating an interchange project or operation raises a number of problems. Some components of the generalised cost perceived by the user are not easily quantified. Thus, for instance, it is almost impossible to determine the user's "organisation costs" (see paragraph 1.3) more particularly, the cost to the user of an interchange of obtaining the information needed to proceed with his journey. Similarly, the interdependece of several factors makes it difficult to evaluate certain costs. Waiting time cannot always be quantified in terms of money in the same way. Its cash equivalent will depend on such things as comfort while waiting, the purpose of the journey, and whether there is or is not any uncertainty as to how long there is to wait (a purely psychological factor which is most difficult to quantify in terms of cash.

In order to reflect accurately what the user perceives, generalised cost should encompass all the "external" factors (i.e. noise and other disamentieis) confronting him at interchanges. To determine and evaluate these "externalities" is no easy task.

Moreover, if an interchange project is to be correctly appraised and if its worth is to be accurately measured, its benefits must also be set off against its costs. Interchanging does not have only negative aspects; for instance, it paves the way for trips which were hitherto unfeasible. To determine the effects of interchange on the consumer's surplus, account should be taken of the positive elements or "benefits" derived from it. Here again, quantification of these benefits, even their identification, presents considerable difficulties. Though all these difficulties are a serious obstacle to the use of generalised costs, it may be hoped that progress in econometrics and in behavioural studies will resolve them. The inherent limitations of the generalised cost criterion are much more troublesome.

b) Limitations

As pointed out with reference to the problem of uncertainty (see previous paragraph) the generalised cost criterion cannot easily encompass the psychological factors which have so important a bearing on the behaviour of transport users in actual practice. The significance of time or generalised cost therefore seems very limited in this respect. This explains why other frames of reference and other parameters with a much stronger "psychological" content are being used for purposes of appraisal. This approach, though still in its infancy, seems promising. Some participants indeed preferred the French word "sacrifice" (benefits foregone) to express the idea of cost in evaluations such as those concerning interchanges.

The generalised cost criterion is particularly apt when the aim is to maximise consumer's surplus and when the goal is therefore an objective of efficiency. Though this is indeed a very important objective, it is not the only one, or rather ceases to be the only one reached when consumer's surplus rises to a certain level as it does in the more developed countries. Minimisation of time or cost is not the only consideration and there is a growing demand to be able to live more "human" lives. This is a far more complex objective and the scope of the generalised cost criterion for evaluating various projects by reference to that objective seems limited. Transport policy cannot be entirely geared to maximisation of consumer's surplus. Besides this objective of efficiency, consideration must also be given to income distribution. By adopting a given transport system of transport or recommending a given interchange facility, one social group or another is advantaged in actual practice. Efficiency and income distribution can be conflicting objectives; the generalised cost criterion is of somewhat limited use for solving this problem.

When considering studies which attempt to evaluate interchange projects or operations, it is therefore important to bear in mind the difficulties and limits inherent in the nature of the generalised cost criterion. But it has to be admitted that, as things stand at present, it is one of the few operational criteria.

Results obtained with this criterion are not by any means easily applicable in all cases, however, because of the peculiarities of each study and of each of the cases dealt with. Thus, the evaluation of waiting time for commuter trips cannot be directly transposed to journeys motivated by other reasons; the latter type of journey, incidentally, has received relatively little attention in the existing studies. Similarly, it is most hazardous to use the evaluations arrived at in one city when analysing the transport system in another.

It must, however, be admitted that the biggest snag in transposing evaluations made in respect of a particular situation to a different situation is due not so much to the nature of generalised cost (this being a fairly universal criterion) as to the methods of analysis which use this instrument. This indeed explains why the advocates of the general approach based on model building were at variance with those who favoured a more empirical and pragmatic approach.

3.3.2. The model-building approach

In the introductory report, especially in Chapter 4, models are recommended as a general approach for studying the interchange problems in urban and suburban areas. This technique of analysis was discussed at length by the participants in the Round Table and gave rise to a number of criticisms which fall under two heads:

- those which were not basically levelled at the actual technique of analysis recommended in the report but to the type of model shown in Chapter 4 of the report;
- those which underlined the weaknesses and limitations of models as such for the purpose under review. Objections in this latter category came from and ultimately drew a clear dividing line between the advocates of a general approach and those who supported a pragmatic approach.

a) The form of models

The participants in the Round Table all agreed on the unsuitability of "all-or-nothing" model building procedures. It was necessary to go beyond these over-simple procedures and develop "probabilistic" models which are more flexible and realistic.

It should also be emphasized that gravity models are not the only ones available for covering trip origin and, more generally, trip distribution. Other types and forms of models have now been developed for this purpose. Recent studies in the United States have shown that these new models are far more effective than the gravity models used hitherto. This is undoubtedly a most interesting and promising avenue for research.

The transportation model shown in Section 4.2 of the introductory report gave rise to lively discussion. The "phased" model structure - a legacy of highway engineering studies - was criticised as far too rigid. In the real world (in contrast to what "phased" models seem to suggest) users do not make a series of successive choices unlinked with each other. The various phases interact. For instance, users do not first choose a particular mode and then a particular route, but a combination based on the routes and modes available.

On these grounds, some of the supporters of the model-building approach suggested that interchanges problems should be studied on the basis of more flexible models capable of encompassing all the independent determinants of the user's choice.

Other participants, however, argued that one of the principal merits of the model-building approach was that models had a "pedagogic" content. Those based on generalised cost or time had an "information" function; they helped "to put ideas across". The political decision-maker, for whom models were intended, must be given help and enlightenment on the action to take. Over complicated models lost their briefing value and were most commonly "non-operational" because of the insuperable difficulties in getting them into final shape. It was better to sketch out and simplify a problem rather than run into endless snags. Straight forward conclusions were needed if political decision-makers were to take notice of them. This being so, some participants in favour of the model-building approach considered that, despite its shortcomings and its over-simplification, the conventional "phased" model structure taken over from highway engineering should be kept for interchange studies.

Some participants commented that this discussion on the form of models was pointless. All the studies showed that there the various models were similar in many respects and that those used for some studies had produced much the same results. The true problem was that though these results were similar they all differed from reality. It was in the light of this finding that the majority of participants in the Round Table drew attention to the difficulties and shortcomings that any analysis based on models, whatever their form, would encounter in the present state of the art.

b) Difficulties of an analysis based on models

The "model" approach to the analysis of transport problems, including interchanges, raises four types of difficulty:

The relativity of models. Most of the participants considered it impossible, especially in the present stage of knowledge, to define once and for all a general approach and the methodology covering all interchange problems. Models could not be transposed; a model designed for one city cannot be applied, unaltered, to any other city. And the same of course applies to results obtained through the models. Thus, ways of life vary considerably from city to city; the subjective value which users attach to the various elements of an interchange is not everywhere the same. It was also pointed out that the choice of a model depends on the modal split and that this varies according to the zone concerned. All this means that models have only very relative value and accounts to the present unreliability of any approach based on models.

Unreliability of models. The reliability of models for the study of transport problems is very doubtful even in the case of the simplest models. "Phased" conventional models, for instance, are by no means safely dependable for the study of "microscopic" problems such as interchanges as this is a far more unstable context than that of highway engineering to which these models were first applied. "Phased" conventional models were recently used in a French study designed to forecast parking capacity requirements. The degree of reliability of that approach proved inadequate. When determining the size of car parks, especially in connection with a park and ride system, the econometrician is confronted with several degrees of freedom: all may depend, for instance, on the operation of the rail transport system, the design of the distributor network in the city centre (a change in this respect involves changes in user behaviour at peripheral points) parking facilities in the city centre (demand can be completely altered by changes in parking charges). For all these reasons, models, whatever their form, are almost incapable of interpreting new situations. Because of constant changes in the socio-economic environment, results obtained from a model-based approach, in the present state of the art, are bound to be very uncertain and subject to qualifications, especially as all models are very incomplete.

The incomplete character of models. During the discussion on the form of models, the advocates of a model-based approach themselves pointed out the deficiencies of phased models. The participants in the Round Table considered that if models were to reflect reality correctly, they must take into account the inter-relationships and interaction between variables and the feedback effects between the model components. Theoretically, this is not inconceivable but it is not feasible in practice, at least as things stand at present, because it involves the use of models so complicated as to be unworkable. As practical considerations in model design are paramount, it has to be admitted that, at the present stage of research, any model-based approach is inevitably inadequate. It is indeed well-nigh impossible to design models that are both comprehensive and practicable, that is, capable of reproducing clearly and accurately the reality of transport phenomena and, in particular, those relating to interchange. To design such models is all the more difficult in that the construction of simple models involves considerable snags.

Difficulties of model design. To construct a model, sufficient statistical data must first be available. The Round Table expressed its surprise at the scarcity of information available on interchanges, and, more particularly, on the general influence of the various types of interchanges. Before contemplating improvements in model design, more knowledge is needed on the effects of interchanges; the "econometric" stage should, in particular, be preceded by a "psychological" stage. Only when this information is available will it be possible to build interchange models and overcome the difficulties mentioned in the foregoing paragraphs. In the present state of the art, model building of this kind is pointless and discussions on the form of models serve no purpose.

To obtain the data required for model building, studies of user behaviour and needs must be conducted methodically as practical tests are well-nigh out of the question (the infrastructures being so unwieldy, practical experiments would be very costly). Such studies are of considerable complexity as it is most difficult to gauge the reaction of the "potential" users of the system to be introduced or modernised. Moreover, a knowledge of the socio-occupational groups using the system is most important for model-building, but their contours are not easily apprehended as they vary according to the considered zone. Only empirical studies can help the quest for such information to start with. Thus, there are considerable difficulties even as regards the prerequisites and data needed for model building. The difficulties are obviously no less great at the design and construction stage.

For a model to be operational it must fulfill three conditions(1):

- it must be coherent;
- it must be relevant, that is, capable of interpreting reality. Its logical and mathematical structure must match the realities of the situation it is intended to apprehend;
- it must be quantifiable, that is, capable of generating other figures from the quantified data fed into it, and it must be able to put an estimate on all the magnitudes (variables or parameters) used in its construction.

In the light of these considerations, it has to be admitted that, in the present state of the art, interchange models do not comply with the last two conditions shown above (a discussion of the condition of "coherence" would be outside the scope of this report). The majority of participants accordingly considered that for the time being, and doubtless for a long time to come, interchange problems would have to be studied by more or less empirical means. Having regard to the scarcity of information in this field, interchanges should be investigated case by case, within a limited geographical area, and demonstration projects should be worked out for each case. Information collected in this way could in due course provide the basis for a general approach to interchange problems.

4. CONCLUSION: FUTURE RESEARCH

The participants in the Round Table judged it appropriate, by way of conclusion, to list the lines of research on interchanges which deserve further enquiry. They accordingly outlined what might be termed a study programme, based on the views set out above, which lays most emphasis, at least in the

1) Bonnafous, A., "La Logique de l'Investigation économétrique," ed. Dunod, 1973.

early stages, on studies pragmatic enough to make some progress in a still somewhat ill-explored area and doubtless eventually come to the general approach, based on models, which cannot be envisaged at present.

The scarcity of knowledge on the impact of interchanges makes it imperative to have precise data on this subject. The participants in the Round Table suggested that surveys, even of fairly limited scope, case studies and demonstration projects be undertaken in this field. However, because of the high cost of these investigations they considered that the objectives of the surveys should be clearly defined and, if possible, harmonized. In order to extract the utmost information from these pragmatic studies and ensure that it will be comparable, the participants suggested that the surveys should be based on the same techniques and methods and that their dates should be co-ordinated.

The surveys should cover, as a first step, basic behavioual patterns from a physical angle only. As things stand at present, the collection of data must in fact be restricted to the quantitative implications of interchange and the behaviour of users at interchange points in actual practice. As regards priorities, the evaluation of consumers' surplus and the determination of the value of time for transport users are of secondary importance for the time being. By means of surveys and pragmatic studies, efforts should first be directed at measuring physical elasticities. These first, purely quantitative, investigations should also be used for determining the optimum size of samples for studies on interchanges. This is an area of research which needs to be explored. When the information relating to the effects of interchanges on transport demand has been obtained, it will then be possible to consider more general behavioural studies.

The few studies conducted so far show that the factor to which travellers are the most sensitive is time. Consequently, when more general behavioural studies are undertaken the best strategy would certainly be to focus research on that factor to start with. It is indeed important to find out, for instance, why more weight is attached to waiting time than to in-vehicle time. The scope of these behavioural studies will have to be gradually be expanded; in this way it will be possible, in particular, gradually to formulate what can truly be described as demand functions and to develop the new techniques for investigating demand which are so badly needed at present.

As regards transport supply, a similar procedure should be adopted. Initially, a fairly pragmatic approach will have to suffice. For each problem, the various feasible solutions must be examined and cost studies carried out in each case. Evidently, the results of these studies will not be the same. They will vary from city to city and from case to case.

At a later stage, to match the formulation of demand functions based on careful and comprehensive behavioural studies, it will be necessary to formulate cost functions on the supply side. These cost functions will be particularly relevant to the study of new transport technologies and the interchanges connected to them.

Only when these demand and cost functions have been worked out will cost-benefit analysis of interchange phenomena be really feasible and will it be possible to construct models providing for a more general approach to interchange problems. But this last stage still seems a fairly long way off.

One last point which the participants in the 19th Round Table were anxious to make was that in order to carry out successfully a study programme of the kind outlined above, it was necessary to set up, and finance, multi-disciplinary research groups. Besides economic considerations, sociological, psychological and ecological factors must be taken into account when a general methodology for the study of transport interchange phenomena is developed. Failing this, the move from a pragmatic approach to a general model-based approach cannot be made on sound principles.

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