ECONOMIC RESEARCH CENTRE

ROUND TABLE 32

PASSENGER TRANSPORT DEMAND IN URBAN AREAS

METHODOLOGY FOR ANALYSING AND FORECASTING

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

PARIS 1976

ECONOMIC RESEARCH CENTRE

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on the following topic:

PASSENGER TRANSPORT DEMAND IN URBAN AREAS

METHODOLOGY FOR ANALYSING AND FORECASTING

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

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SUMMARY

FOREWORD

All methods for analysing or forecasting passenger transport demand in urban areas ultimately involve a model, i.e. a simplified representation of reality to help understand and predict the formation of demand. Even when the demand is analysed long before actual production of the model (in studies of behaviour for example), the findings are probably of real interest only to the extent that they can be made use of to specify, appraise or refine some element in a model. The present study therefore relates to urban transport demand modelling.

The usefulness of any model as an instrument depends on how well it works, i.e. its ability to perform as expected when in operation. This is a yardstick both for evaluating a model and also for classifying it according to the manner in which its designer has tried to make it operational. A broad classification of methodological approaches here will be found in an introductory chapter. This will enable us to classify various methods and describe various fairly distinct recent lines of approach. These lines will be discussed in a conclusion to the chapter.

Introductory Chapter

THE REQUIREMENTS FOR AN OPERATIONAL MODEL(1)

0.1 Three necessary and sufficient conditions for a model to be operational

It will be argued that for a model to be operational it must satisfy three necessary and sufficient conditions: it must be consistent, i.e. satisfy not merely a trivial condition of internal consistency (not contradict itself), but a condition of consistency with its objectives. This latter condition entails that the logical and mathematical structure of a model must be fully compatible with its theoretical aims. As one obvious example, it must contain as many independent equations as there are jointly determined variables.

It must be relevant, i.e. must conform to the realities (insofar as these can be grasped), particularly with respect to the numerical form of the equations and the causality network they represent.

It must be measurable, i.e. must only include variables or parameters which can be estimated from accessible statistical samples.

Clearly, these conditions must <u>all</u> be satisfied if the model is to be operational. If the model lacks consistency its objectives can never be achieved since it can offer no theoretical solution to the problem concerned and therefore no numerical solutions either. If a model is not relevant then its content and any results obtained from it will be meaningless, since they will not be related closely enough to reality. If the quantitative components are not measurable, it will be impossible either to verify the relevance of the model or to perform the calculations with which it would serve its purpose.

There are also three sufficient conditions for the model to be operational: if a model is consistent then it will, in theory, be able to serve its purpose. It will be able to do so in practice, too, if the quantities concerned can be measured with the statistics available. Lastly, if a model is relevant, the results it yields will truly represent reality as can be ascertained if the measurability condition is met. It will consequently be possible to make the model serve its purpose by applying it to reality.

1) This chapter draws upon the author's work on methodology developed in <u>La logique de L'investigation économétrique</u> ("The logic of investigation in econometrics") A. Bonnafous, Dunod, Paris, 1973.

So consistency, relevance and measurability do in fact constitute three necessary and sufficient conditions for an operational model, but they are not just elementary rules of proper scientific procedure: these three conditions tend naturally to conflict with one another, thus giving rise to what I shall call the modelling problem.

0.2 The Modelling Problem and ways of dealing with it

These three requirements are actually in conflict with one another, as demand models often show.

To satisfy the requirement of measurability, a model often has to be sealed down to whatever statistical categories are available (to categories for travel, for example or to social categories as defined in a census); or certain explanatory variables may have to be excluded, thus detracting from the model's consistency and even from its relevance. Conversely, trying to make it more relevant will entail introducing more variables or mechanisms, sometimes giving rise to theoretical problems that will be difficult to solve with the logical and mathematical apparatus available, and invariably raising problems of measurement. Aiming at greater theoretical power, and therefore at a different level of consistency by introducing uncertainty into the model, for example will call for further assumptions of doubtful relevance which can only be verified at the expense of a far heavier requirement for measurability.

So the complementary conditions of consistency, relevance and measurability are in conflict with one another: the better any one of them is satisfied the harder it becomes to satisfy the others. They make up a kind of "magic triangle" which constitutes the modelling problem. The reader will easily notice how any difficulty he may have encountered in implementing a demand model can always be interpreted as a conflict among these three conditions(1).

Ways of tackling the modelling problem fall largely into two categories, which will not be of interest to the same degree.

The first category can be regarded as embracing anything that can be done to make a model more operational without seriously affecting its overall structure or purpose. Difficulties in making a model operational when at least one of the three requirements cannot be properly met may arise from various kinds of incompatibility:

The purpose of the model may be incompatible with the realities of the object: a purpose such as the modelling of inter-modal choice in terms of rational decision-making, for example, may not be compatible with the reality of a process involving a very large proportion of physical or psychological captives.

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1) For a more rigorous demonstration of these contradictions see La logique de l'investigation économétrique, op. cit. page 18 and page 59.

The theoretical instruments available, especially the mathematics and statistics, may not be compatible with the realities of the object: for example, continuous functions or explanatory variables used to illustrate or account for flow levels will not be compatible with a threshold phenomenon where any mechanisms below or beyond the threshold require a very different formal approach.

There may be incompatibility between the measurability conditions and the realities of the object: for example there are some opportunity models in which the parameters can only be estimated if the probabilities that a trip for a particular reason will be made, a particular destination mode etc. will be chosen are independent; but in real life this is not necessarily so.

In all these cases, the first class of possible reactions involves making the model less detailed. The objective of the model is too ambitious, its subject is too complicated for the instruments available; so a less ambitious approach seems advisable, excluding some aspects of the process which it had originally seemed necessary to cover. The problem is solved by coarsening the model in some way; using a direct model instead of a sequential model for example, or leaving out some intermediate mechanisms of trip generation distribution, choice-of-mode etc.

The second class of reaction reflects an almost diametrically opposite attitude: since it is impossible to get a proper grasp of reality with the instruments available, those instruments had better be changed. We must innovate in the methodology. This is naturally the only aspect with which we shall be concerned in the present report. We may now describe its content and how it has been laid out in terms of the problem as formulated.

0.3 Layout of the Report

Methodological innovation as an attempt to deal with the problems of urban transport demand modelling could be broached in two ways: by reviewing and comparing earlier work, or, alternatively by looking ahead for this particular aspect of transport economics and trying to identify some very new but potentially fruitful avenues. This latter approach is perhaps more in keeping with the role of the Round Tables and is the one adopted here, though without underestimating the value of what has already been achieved. Earlier work is in fact referred to in an annex, in the form of a brief introduction to some typical models of recent years. The only models mentioned in the body of the report will be those included in the annex, to which the reader can refer for fuller design particulars(1).

1) This annex was prepared by Bernard GERARDIN, assistant lecturer at the Institute for Economic Studies at Lyons, who has adapted a systematic study of demand models, originally conducted in 1974, to the needs of the present report.

The content of the report is organised around the terms of the general modelling problem as follows: the first chapter, "towards greater relevance", aims to show how far one can go with the instruments so far available, particularly in trying to achieve relevance, and to determine the conditions for better results.

The second chapter, "towards improved measurability", offers a brief review of the usual difficulties and describes one approach currently being tried out, which seems likely to overcome them more effectively.

In the third and last chapter the question is raised of how consistency, in terms of the objectives of demand models is generally achieved. It suggests an approach in closer alignment with the expectations of present-day cities; this poses a series of problems which will have to be tackled in the very near future and are indeed already beginning to attract the attention of the specialists.

Chapitre I

TOWARDS GREATER RELEVANCE

I.1 Notes on terminology

The relevance of a model, the extent to which its mathematical structure conforms with the real demand for transport, is more than a question of statistics. After the stage of 'calibration' in which the behaviour co-efficients are matched to the statistical observations for each category of flow, most models can be rendered in a numerical form which mirrors the process as identified by the observations. It is not unusual for flows calculated with a calibrated model to differ by no more than 10 per cent at most from the flows as observed. In these cases the model designer regards his instrument as relevant.

But in the event of change in any of the factors determining demand (in the local environment, the quantity or nature of the jobs, the economic or sociological features of the population, the transport supply position etc.) the model ought to perform its real function of indicating, relevantly, the effects of such change on the composition and level of demand. Models are very seldom tested for this kind of relevance. At most, the more glaring forecasting errors are picked up after the event; but such questions as whether insufficient allowance was made for evolution in the factors determining demand, or whether the mechanisms of demand formation had not been properly perceived tend not to be raised.

Designers and, especially, users of demand models have been noticeably quick to conclude that the instruments available are inclined to be unsuitable for explaining or anticipating change. There have been a number of interesting attempts to tackle the problem.

I.2 The most significant attempts

On the whole, model designers have reacted to the problem by trying to refine the behaviour mechanisms.

With this aim in view they have introduced sequential (as opposed to direct) models, whose feature is that they break down an instance of transport demand formation into successive and separate parts:

- occurrence of the trip;
- purpose and time of day;
- destination;
- mode;
- route;

The UTP (Urban Transportation Planning Process) models provide a very good illustration of this approach, as do the growth factor models and those which can strictly be referred to as gravity models.(1)

There is a similar approach in the disaggregative (as opposed to aggregative) models now appearing: whereas an aggregative model seeks to identify the average behaviour of the user belonging to a homogeneous category (for a zone whose social and economic features are themselves homogeneous), disaggregative models are based on study of actual behaviour and analysis of psychological reactions. This category includes the models of Warner and Selnec and the CRA (Charles River Associates) suite of models(2).

In both cases, the introduction of successive categories, in the elements defining the trip (sequential models) or in the choice procedure (disaggregative models), leads to considerable problems of measurement. At a more general level it can be seen that the overall modelling problem re-appears: these methodological choices which at first sight seem relevant will also affect the consistency of the model. For the sake of measurability, it will have to be assumed that the functions relating to the different sequences and to the different elements of disaggregative models, are independent. This may be a very bold assumption and may bring up a second-order question of relevance. In any event the measurement of the parameters required for each sub-category and for each "floor" of the model, will require a substantial statistical apparatus.

Lastly, there remain some fundamental difficulties about maintaining relevance for other reasons which may now be examined.

I.3 The difficulties of relevant formalisation

In order to identify the principal methodological difficulties which cannot be overcome effectively with the instruments available, let us examine one very simple finding and then try to see how it could be allowed for in a model: in a recent study(3) of the Lyons

1) See Annex.

2) See Annex.

3) Effets de L'organisation des transports en commun sur le niveau de la demande ("Effects of the Organisation of Public Transport on the level of demand") P. Caruel, J. P. Million, Institute of Economic Studies, Lyons, July, 1974.

conurbation it was shown that under equivalent conditions for the variables determining demand between two urban zones, public transport flows were five times lower, on average, on routes served by two lines with an interchange (with higher fares and a break in the journey) than on direct routes.

Does it follow that this average ratio of 1 to 5 should be taken into account in one way or another when contemplating some change in the network - a direct route becoming a route with an interchange or vice-versa? It is arguable that were the direct route to be withdrawn, the fall in demand would indeed be of this order after a certain lapse of time. But in the case of a route with an interchange being made into a direct route, it would not be realistic to expect a fivefold increase in demand even after the service had been in operation for some years. It is well known that in a case like this, there are psychological processes of 'captivity' and behavioural inertia encouraging the private motorcar.

If it is conceded that such processes are at work - and public transport authorities have had many occasions to find that they are - then the methodological consequences ought to be drawn. At least four such consequences can be distinguished:

(1) The user's past, his experience of life in society, will powerfully affect the way he behaves. It is both necessary and difficult to identify this influence. Few models have so far taken much account of these elements, their designers ultimately assuming that they can deal with 'economic man' differentiated in terms of a few comparatively crude, <u>a priori</u> distinctions at best.

(2) The functional relationships between the variables representing demand and the explanatory variables suggest that their mechanism may be reversible; but this is not a very accurate reflection of reality. The difficulty is illustrated in the example quoted above: if we have to concede that where demand for public transport is concerned, the effect of transforming a line with an interchange into a direct line is not the converse of the effect that would have been produced by a change of the opposite kind, then we are bound to relinquish the idea that distribution among modes can be represented in terms of some functional link (an ordinary preference curve or function, for example).

(3) More generally, the stimulus/response pattern no longer seems sufficiently relevant where user behaviour is concerned. It is implicit in every attempt to apply modelling to urban transport demand but perhaps the time has come. 60 years after J. B. Watson imposed it upon the psychologists and half a century after it was proved inadequate by Wolfgang Köhler, to challenge its validity in this field. This view, that one should try to go beyond the stimulus/response pattern, can be seen in the approach in which the

user's objective universe of choice is distinguished from a subjective universe of choice(1).

(4) Urban transport demand has more than one dimension. The usual models reflect this multi-dimensionality by taking account of the characteristics of supply, of the zones in which traffic is generated and received, of user groups etc. Current methodology involves a deductive kind of operation: relationships between dependent variates and independent variables are postulated, then compared with statistical samples; today however there is a technique available, data analysis, with which a multi-purpose sample (from a household survey for example) can be made to yield the components of a model. This has proved its worth in other areas of demand analysis: marketting has made more spectacular progress than transport economics as a result of systematically utilising such methods.

Many other difficulties in implementing relevant models could certainly be mentioned. We have tried to pick out the ones which appear to be crucial and to suggest some methodological approaches which are so far comparatively unexplored. Some of these will be referred to in the final paragraphs of this chapter.

I.4 Demonstration projects

Economists have long recognised that their field differed from the experimental disciplines because of the difficulty of conducting a controlled experiment in economics, i.e. an experiment in which a controlled sequence of operations with detectable and measurable effects can be initiated.

Controlled testing is however possible in some cases. In marketing, for example, such tests are called demonstration projects. They involve simulating a product launch in a restricted area with a number of experimental precautions. This kind of exercise could be applied in the field of urban transport and was indeed mentioned at the 19th E.C.M.T. Round Table in connection with the problem of the role played by the various factors in demand(2). But for such an exercise to be fruitful it needs simultaneously to satisfy at least three conditions which have never so far been altogether met:

(1) Full statistics must clearly be available on the demand levels before and after implementation of the project. The usual practice is to take advantage of improvements in transport supply to

1) This distinction was suggested in Contribution à une psychosociologie des comportements urbains. Choix du moyen de transport. ("Contribution to a psychosociology of urban behaviour. Choice of transport mode") G. Mercadal, Paris, Ministry of Equipment and Housing, Copedith 1970.

2) "Influence of cost, quality and organisation of terminal transport and interchanges on the choice of passenger transport mode". P. H. Collins, D. J. Wagon, Report of the 19th Round Table of the E.C.M.T., 1973.

find out more about the mechanisms which determine demand. This being a secondary objective in comparison with the main purpose of the operation, there is a tendency to be behindhand in setting up the arrangements for observation. For example, in a study to assess the effect of a traffic plan on the numbers shopping in central Lyons(1), the only data available had been gathered retrospectively and were therefore somewhat poor.

(2) As mentioned above, there are a great many factors at play in determining demand; this always makes it difficult to isolate the effect of variations in supply and particularly to show where those factors are exerting pressure on the mechanism. This is a well known difficulty in experimental sciences; it particularly affects the biologist who is equipped with the statistical methodology of the "lattice design" to deal with it. This methodology, or at least this methodological approach is especially necessary in determining the categories of user and of trip with which the accompanying surveys are to deal.

(3) A set of findings from a demonstration project is only of interest to the extent that it can be generalised. Comparisons are therefore necessary among a number of experiments; in theory, experiments conducted in different towns should share a common observational methodology; user and trip categories, in particular, should be identical. Only then can findings of general application be distinguished from those actually due to local conditions not properly allowed for.

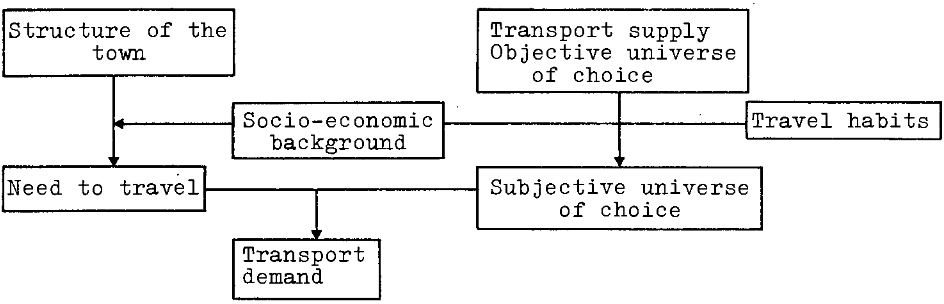
But demonstration projects, whatever the precautions, can never throw up all the questions which ought to appear in a broader conceptualisation of the problem.

I.5 A broader and more comprehensive conceptualisation

The difficulties of maintaining relevance when formalising, referred to in paragraph I.3 **suggests that the conceptual framework** within which urban transport demand formation is studied and analysed needs widening. We have observed for example the need to distinguish between the user's subjective universe of choice and the objective universe, to make allowance for the many aspects of the social and economic background transcending any simple distinction between social and occupational classes, the need to allow for an individual's past attitudes, etc.

1) Les conséquences du plan de circulation sur le niveau des activités commerciales de Lyon ("The consequences of a traffic plan on retail business levels in Lyons"). A. Bonnafous, H. Castinel, F. Darsy. Cahier de l'institut des Etudes Economiques de Lyon (Nouvelle série) No. 4, April 1974.

All this must be organised within some kind of conceptual framework or there will be an accumulation of disorderly and half-finished research findings. This would not be the right place for a definitive conceptual framework and we shall not endeavour to suggest one. The pattern below is offered merely as an example, a quick illustration to show how such a framework could help.



This picture of the mechanism of urban transport demand formation would certainly need to be completed. It does however provide a list of concepts (boxes) to be defined before any attempt to investigate the overall problem, while the investigation itself can be organised in terms of the relationships to be clarified (arrows).

Insofar as a transport demand study requires one or more surveys, themselves entailing appropriate processing methods, the investigation can be regarded as consisting of three stages:

- the definition of a conceptual framework;
- the definition of the content of the necessary statistics;
- the definition of a methodology for processing the statistical data.

This would appear to be the right scientific approach except that (the second and third stages are interdependent, and that any given processing technique may impose constraints on the statistical content). Yet there are many instances of studies and research projects failing to observe this approach; there may be no attempt whatever at conceptualisation, the data may have been gathered at too early a stage, or the statistical methodology may be unsuited in some way to the problem concerned.

This latter point should be emphasized because the chief difficulty in trying to identify meaningful relationships lies in the fact that demand formation is determined by a number of conditions. These combined influences cannot be studied separately. For example, in analysing the move from objective to subjective universe of choice it is not possible to assume 'other things being equal' with respect to the social and economic background or travel habits. On the contrary, the fact that all other things are not equal elsewhere must be used to attempt a simultaneous synthesis (in the etymological sense of "bringing together") of a maximum of elements likely to exercise any effects. The methods for doing this are available today, as has already been mentioned and it should be possible with their help to achieve a decisive step forward in the study or urban transport behaviour.

These methods of data analysis will be discussed in the next chapter as they have the advantage of making a useful contribution to the problems of measurement.

Chapter II

IMPROVING MEASURABILITY

II.1 The usual difficulties in measuring

There are two major classes of difficulty to be distinguished in the measurement of demand model parameters. The first relates to the statistical material available, which does not necessarily match the structure of the model. It is not unusual to have to rely on no more than origin/destination statistics in public transport, and flow statistics in private transport, to estimate all the parameters of a model. They usually can be calculated on this basis, but evidence for the relevance of the model as designed will then be very slender. More generally, any model built from statistics gathered independently of its structure will always raise insuperable problems of measurement.

It is therefore necessary to have statistics available which suit the needs of the model, i.e. a "household survey" with which trips can be reconstituted (with all their characteristics included in the model), usually for the day preceding the day of the survey. We need not go into the technical difficulties of the household survey: in defining what is strictly to count as a trip, devising exclusive and exhaustive categories for purposes, places of origin and destination, in dividing the area into zones, in cross-checks, sample stratification, etc. These difficulties have been overcome and the knowledge exists nowadays to set up fully operational indexes(1).

When the difficulty about the source of statistics can be solved, there remains a second class of difficulty which derives more closely from the general modelling problem dilema. It is the disaggregative, sequential type of model(2) which goes furthest in the pursuit of relevance, but thereby raises difficult problems about measurement. As an illustration, let us take a simplified stochastic presentation. Suppose that the choice made by an individual in any given category is the outcome of a composite of probabilities each

1) One example would be the latest household surveys carried out by the Service des Etudes Techniques des Routes et Autoroutes (SETRA, 46 avenue Aristide Briand, 92223 Bagneux).

2) See Annex.

reflecting one feature of the choice: the probability that he will make the trip (event 1), that he will be making it for a particular purpose (event 2), that any given place will be the destination (event 3), that he will choose a particular time (event 4), and a particular mode (event 5); then the probability of the composite event which consists of his making the trip in all these circumstances can be expressed:

$$P_1 \times P_{2/1} \times P_{3/1,2} \times P_{4/1,2,3} \times P_{/5/1,2,3,4}$$

For example, "$P_{4/1,2,3}$" will be the probability of the trips taking place within a given segment of time, knowing that the events "decision to make the trip", "to make it for a particular reason", "choice of a particular destination" have already occurred. There is an obvious difficulty about estimating all these probabilities: if a proper household survey has been conducted, covering 4,000 households for example, it will have yielded a full description of more than 40,000 trips(1). Suppose the events the survey covers respectively involve:

event 1: 2 possibilities (the trip is or is not made)
event 2: 4 possibilities (reason)
event 3: 100 possibilities (destination)
event 4: 6 possibilities (time segment)
event 5: 4 possibilities (mode).

There will be 19,200 different composite events to be taken into consideration for each category of individual originally decided upon. Even if these possibilities are pruned, by eliminating those whose probability is negligible, there is an insuperable difficulty about calculation, even though the statistical material is good.

The measurability requirement can only be met by modifying the consistency of the model, at the risk of prejudicing the relevance requirement, by assuming that the composite probabilities, or at least some of them, are independent. So this problem about measurement is another indication of how difficult it is to represent the process in its full complexity.

Given this difficulty, the only reasonable approach is to break down the complex process of demand formation into categories of individuals whose behaviour is sufficiently homogeneous to be represented in a relevant way without raising insuperable difficulties of measurement. The next step, then, is to "stratify" the users.

1) The latest household surveys carried out by SETRA at Grenoble, Nice and Rouen show an average of more than 10 trips per household per day including those made on foot.

II.2 Solving the problem by stratifying users

Stratification means dividing up the universe of users in such a way that the model's parameters can be calculated in terms of the characteristics of each sub-set while respecting the original objectives of the exercise.

It could be decided for example to classify users by area of residence in one of three categories (centre, inner ring, outer ring); by socio-occupational category, perhaps with three main categories; and by size of household, in one of three classes of household size. On these assumptions, the criteria will intersect in such a way as to distinguish 36 different "strata" of user who can be expected to behave homogeneously enough for relevant modelling to be possible without an insuperable measurement problem. For example, it should in principle be possible to fit the mode assignment curves much more accurately for each of these categories than it would be for the whole population; the same should also apply, in principle, to the other elements of the model.

There do however seem to be two shortcomings in the usual way of applying this stratification procedure:

(1) The criteria determining the stratification are doubtless chosen on the basis of the model designer's experience and there is a good chance that the groups they define will be reasonably homogeneous in terms of the mechanisms governing their demand for transport. But there is no indication that his criteria will be optimal in terms of maximising the degree of homogeneity they yield: they will have been selected a priori, regardless of any information that might be available, for example, from a household survey.

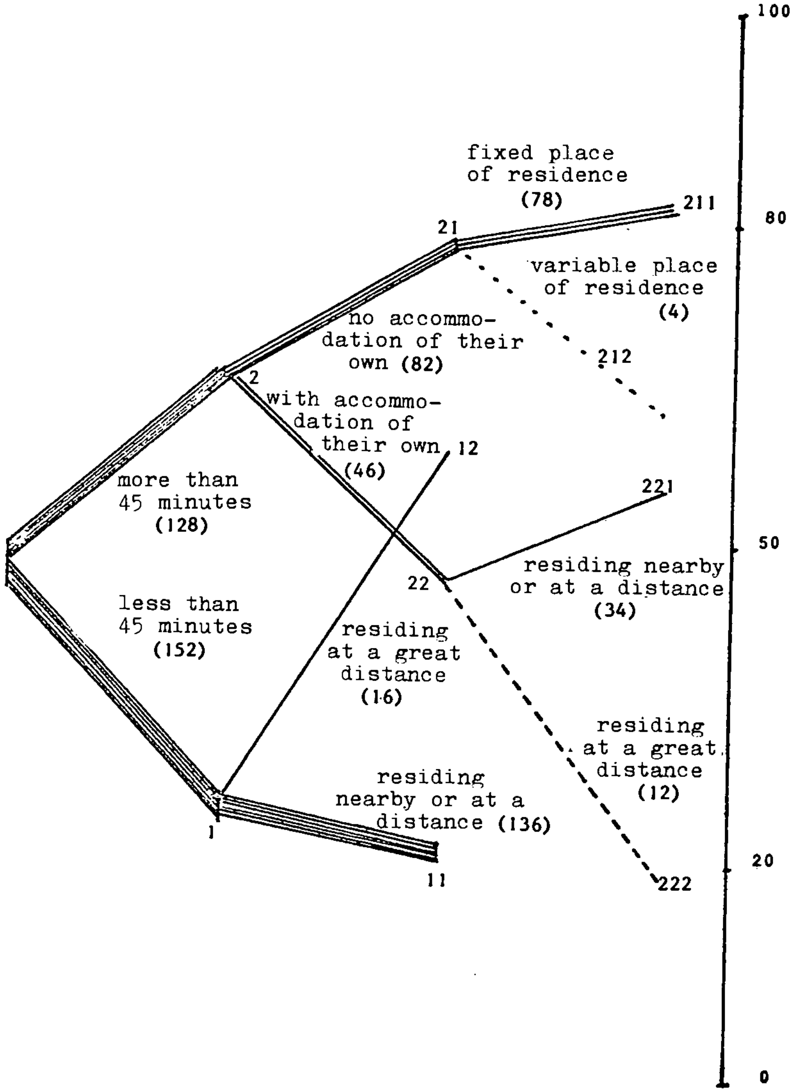
(2) Although the numerical values for the parameters are made to differ for each of the groups thus formed, the mathematical structure of the model is generally identical for all of them. But there is no reason to suppose that the realities of the process can necessarily be formalised in the same way irrespective of the group considered.

The remainder of this chapter will be devoted to discussing an avenue of research which constitutes a new methodology for uban transport demand analysis, and offers some prospect of making good these shortcomings.

Before starting to discuss this, we should note that the typology method is not very well suited to the problem. It would consist in this case of consolidating the individuals according to type of behaviour(1) defined by proximities calculated on the basis of a set

1) This method was introduced in an entirely different context by A. BONNAFOUS, F. PLASSARD and D. SOUM in the report of the 25th Round Table of the E.C.M.T. (March 1974).

USE OF BUS



100
80
50
20
0
fixed place of residence (78)
211
21
variable place of residence (4)
no accommodation of their own (82)
212
2
with accommodation of their own (46)
12
more than 45 minutes (128)
221
residing nearby or at a distance (34)
22
less than 45 minutes (152)
residing at a great distance (16)
residing at a great distance (12)
residing nearby or at a distance (136)
1
11
222

of variables characterising such behaviour. But this method does not lend itself well to the manipulation of qualitative criteria (social categories, household structure, zone of habitat, etc.) and it would not in any case make good the second of the shortcomings mentioned above, i.e. show what structure of the model would be suitable for each of the types obtained.

II.3 Stratification by the segmentation method

In introducing this method we shall consider an example rather than the theoretical basis(1) which will be cursorily described in the following paragraph.

The diagram below shows the outcome of an exercise in segmentation, in this case an experimental segmentation covering a sample of 280 students at the Bron-Parilly campus (on the outskirts of Lyons) following a small-scale survey to determine for each individual:

- his mode of transport between home and campus
- the location of the home
- family situation
- type of accommodation (with parents, in a hostel, etc.)
- the duration of the journey from home to campus

The feature of interest was the use made of buses. The vertical axis shows bus utilisation as a percentage for each group represented by the extremity of a segment. Segment 211 for example represents a subset of 78 students (the numbers being indicated between brackets) of which 80 per cent use the bus (percentage read off from the vertical axis), defined by the conjunction of three criteria: journey time in excess of 45 minutes, living with family or in student hostel, fixed place of residence.

The most important aspect of the outcome represented by this diagram is that 226 of the 280 respondents can be classified within sub-sets in which the percentages using buses vary from under 20 per cent to over 80 per cent. So these subsets are homogeneous with respect to choice of mode. Similarly, on the basis of a fuller sample surveying a larger population and with more variables, it would be possible to investigate a series of processes such as rates of generation, captivity per mode, choice of mode, etc.(2).

1) A full account is contained in "Analyse de la demande de transports urbains par segmentation d'un échantillon d'usagers" ("Analysis of urban transport demand by the segmentation of a sample of users"). D. Soum, Rivista Internazionale di Economia dei Trasporti. Vol. II, n° 2, August, 1975.

2) Some experiments of this kind are suggested in L'étude des déplacements des habitants des grands ensembles de Lyon. ("Study of trips by inhabitants of the major residential areas of Lyons"). D. Patier-Marque, D. Soum, 1973. Cahier No. 1 de l'I.E.E. de Lyon. Nouvelle série.

In order to appreciate how far a method of this kind may avoid the two disadvantages of the usual stratification procedures, it is necessary to refer to some of the details of the methodology which produced these results.

II.4 The segmentation procedure

The segmentation algorithm is as follows:

1. A double-entry table is constructed for the variable to be explained against all the other variables in the sample which are likely to be independent.
2. Selection of the independent variables most closely linked to the dependent variable (on the basis for example of a chi-squared test).
3. In the doube-entry table linking the variable to be explained and the variables selected, choice of a dichotomy for this to give the most significant two by two table (on the basis of the chi-squared test for example).
4. Division of the sample into two subsets in accordance with this dichotomy.
5. Perform the operation described in figure 1 for each of the subsets and continue until the subset obtained reaches a predetermined significant percentage of the variable to be explained or contains only negligible numbers of respondents.

In the example above, double-entry tables were set up as shown here between use of bus and the variables available.

Journey time	0-5	5-10	10-15	.....	75-90
Using bus					
Not using bus					

Out of all these tables, the one chosen related to journey time; the time categories were divided into two groups under and over 45 minutes; the sample could then be divided into two subsets and the same procedure was carried out on each of them, continuing in the same way until the results shown in the diagram were obtained.

So this method has two advantages: on the one hand it puts the emphasis on identifying homogeneous behaviour in the groups it forms and the stratification criteria it offers encourage such homogeneity. In this way, it avoids the disadvantage of predetermined stratification. Secondly, the method shows which variables should be used to define the strata so that for each stratum formed, it indicates variables which ought not to be neglected in a demand formation model - thus giving the designer a chance to adopt whatever form of model will be best suited to the particular mechanisms of each stratum.

The segmentation method is therefore a useful approach in solving the difficulty of measurement by stratification, while avoiding the two disadvantages referred to in paragraph II.2. This method however, derives from work on market research and is meant for analysing demand - it was never designed to produce the elements for an urban transport demand model. No method wholly suited to this latter purpose is yet available. In the last paragraph of this chapter we shall try to say something about the form such a method might take.

II.5 One avenue of research

The segmentation method can be used to calculate the value of a variable representing some aspect of a trip. If a whole series of trip characteristics is processed in the same way, a number of facts will accumulate about a total of two sets of modalities: one set providing the basis on which any trip can be defined (purpose, time segment, mode etc.), and another set of modalities by which a user can be described (place of residence, social class, age, household structure, position in the home, etc.). If this could be pursued far enough to yield a perfect representation (clearly an impossible extreme) of passenger transport demand formation, there would be corresponding stratifications of trips and users in such a way that for each type of trip there would be one and only one corresponding type of user, and vice-versa.

The hypothetical pattern to which this would lead would therefore be a table with two dimensions for the two sets of types. The only numbers that would not be zero would be those lying along the diagonal.

Types of user

Types of trips					
	n_1	0	0		
	0	n_2	0		
	0	0	n_3		

The method remaining to be devised, to provide not a perfect table but a table close to this configuration, might be a double segmentation method, one for the "trip" modalities the other for "user" modalities but with both segmentation procedures necessarily being dependent. This problem can be left for the reader to think about.

The available methods do meanwhile offer considerable scope for devising a form of stratification to facilitate measurement and also to impose a certain degree of order upon the apparent complexity, as was suggested in the previous chapter when the need for multi-dimensional methods of investigation was argued.

Chapter III

TOWARDS A DIFFERENT KIND OF CONSISTENCY

III.1 The problem of evaluating strategy

The methods we have so far discussed are for use in analysing and forecasting urban transport demand; this, of course, forms part of a broader framework of urban transport strategy. We have not yet considered how far the consistency in the instruments we use ought perhaps to be subordinated to the requirements of this broader objective. The present chapter seeks to go some way in answering this question. We shall start by raising the problem of evaluating a strategy, i.e. a co-ordinated set of investment, fare structure, regulation and organisation measures for an urban transport system.

Among the various points of view from which a strategy can be evaluated we shall be looking only from the standpoint of the user, as the technique adopted for identifying this point of view may have an effect upon the demand model whereas other standpoints - costs, nuisance, the view of the transport companies, etc. will certainly have much less of an effect.

To assess the advantages to a user from any particular transport initiative, the conventional criterion is user surplus. This criterion seems to owe its continuing popularity not so much to force of habit as to its theoretical justification in economics: we know that the variation in user surplus is one of the constituents of variation in collective utility following any change in transport supply. This concept of surplus does however rest on a number of assumptions - including the very restrictive one of an optimal distribution of income. Ignoring the theoretical basis, this assumption can be interpreted very directly: it means that the variation in user surplus, considered as a whole, is only really significant if the categories of user benefiting from the variation are indifferent. This can be conceded in cost benefit analysis to compare two projects whose beneficiaries belong to the same social class. In a context of alternative strategies, very much broader than that of alternative projects, it is quite likely that the various options will not benefit the same social classes; the physical distribution of their effects will probably be very different.

It follows that when strategies are being evaluated, user surplus can only be regarded as a proper criterion if it is broken down firstly by zone within the urban area considered, and secondly by the social classes occupying the area concerned. A surplus variation ΔS in a strategy should therefore be replaced by breaking down the surplus in terms of its elements ΔS_{ij} which represent the proportion of ΔS accruing to users living in zone i and belonging to social class j. So a table such as the example below:

social class

			j			
...	...	...	...	...	...	...
Zone i			ΔS_{ij}			ΔS_{i}
...	...	...	...	...	...	...
			$\Delta S_{.j}$			ΔS

$$\Delta S_{i.} = \sum_j \Delta S_{ij}$$

$$\Delta S_{.j} = \sum_i \Delta S_{ij}$$

$$\Delta S = \sum_i \Delta S_{i.}$$

$$= \sum_j \Delta S_{.j}$$

should be worked out so that as well as the overall variation in the surplus, two equally important components can be assessed: firstly, the preventive effects of the strategy with respect to disequilibrium in the degree to which spatial transport requirements are satisfied (these corrective effects can be identified through the configuration of the last column of the table), and secondly, the redistributive effects of the strategy with respect to those social classes which do not deserve equal attention (such redistributive effects can be evaluated through the configuration of the bottom line of the table).

This approach raises two series of problems which will be examined successively in the next two paragraphs: first, problems of implementing the table and their implications for the demand model; second, problems of interpreting the table, which may give rise to a further dilemma.

III.2 Implementation problems and their implications for demand models

These problems will be discussed in terms of three definitions which remain to be given: definitions for the lines and columns of the table, and the precise definition of the terms ΔS_{ij}.

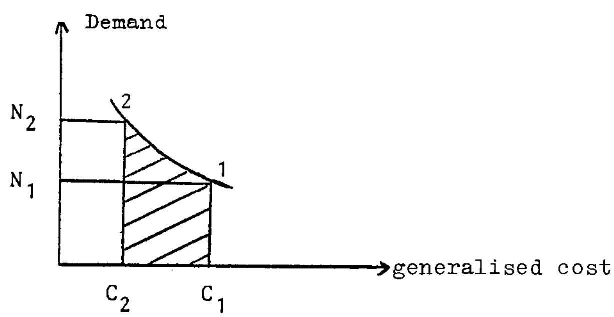
1) Definition of the zones: for the purpose of analysing and forecasting demand, the conurbation is divided up into a pattern of zones determined in such a way that the heavier the flow of urban transport the more accurately it can be measured. A pattern chosen to pick out the poorly served zones and highlight their lack of accessibility in comparison with the zones, served best would probably be distinctly different. Such a pattern would in particular have to be more detailed than the first for urban zones at a distance from the major public transport routes. To make a surface breakdown possible in respect of these routes, the kind of zoning pattern usually adopted for demand models will generally need to be subdivided.

2) Definition of the social classes: the purpose of breaking down the surface by zone is to display the corrective effects of a strategy in respect of spatial disequilibrium in the satisfaction of travel needs, whereas the purpose of the breakdown by social class is very different. In this case it is to see what redistributive effects a strategy will exert with respect to features suggesting that the distribution of income is not optimal. The important categories will therefore be income categories.

It is therefore important that such categories should be able to be reconstituted on the basis of the stratification of the model mentioned in the chapter above; which must contain a sufficient number of income categories.

3) Definition of elementary surplus variations: It is the precise definition of the terms ΔS_{ij} which poses the most difficult theoretical problems. Only two of the most important of these will be referred to here.

In the first place, the surplus variation between two situations, represented on the graph below, is defined in relation to a demand function. To construct this function in the most relevant way possible, it is defined in relation to a generalised cost. The many difficulties involved in this concept are well known: a monetary equivalent of time, taking account of frequencies, comfort, safety, etc. These many difficulties revive the debate between the



two views of monetary equivalence: the view which adopts monetary equivalence corresponding to user behaviour, as illustrated for example in the Beesley method of measuring the value of time, and the view which puts forward monetary equivalence in terms of explicit policy preferences. The first view is naturally the one adopted for the generalised costs intervening in a demand model, as such a model would otherwise have very little chance of being relevant. But in setting up our table, the second view would have the advantage of involving indicators corresponding to policy preferences. Such preferences should indeed be integrated in a methodology for strategy evaluation. They can also however be introduced at the stage of interpreting the table if it has been constructed in terms of the first view. We have no decisive argument to suggest coming down on one or other side here.

Secondly, it should be noted that the 'surplus' concept is based on the assumption that there is a law of demand. It is therefore necessary to consider situations one and two at the same date. The second poses very little problem: that is the situation to be created by the strategy being considered. But there is no obvious way of defining the first situation. One could imagine a number of ways of giving concrete form to this reference situation: the situation brought about by supply of transport identical (at the horizon of the strategy) to the present supply, the situation characterised by generalised costs, at the horizon of the strategy, identical to the present generalised costs etc. Each of the solutions imaginable for this reference situation will of course have its own consequences upon the values contained in the tables and cannot, therefore, be neutral in the evaluation method. Here again we will avoid passing judgement one way or another, as at the time of preparing the present report there has not yet been sufficient reflection on the theory.

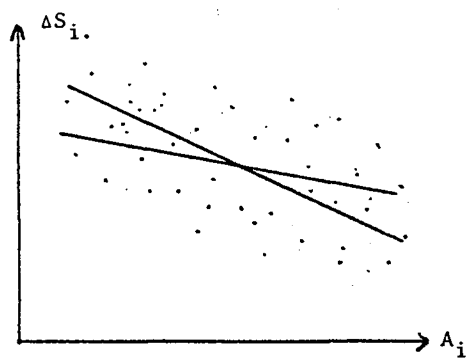
In all cases, it will be necessary for the model to supply elements with which to calculate the term ΔS_{ij} for each of the boxes in the table and in particular, the demand levels N_1 and N_2. Assuming that all these difficulties have been overcome, the essential problem is still that of how to interpret the table.

III.3 Interpretation of the table

Interpretation of the table is ultimately a matter of interpreting the margins from which the redistributive and corrective effects of a strategy are to be evaluated. For the redistributive effects there is no serious problem: insofar as the surplus is distributed according to social classes picked out in terms of income, each component of the surplus $\Delta S_{.j}$ can be regarded as 'enriching' social class j (which would moreover be more in keeping with the first of the two views of the generalised cost referred to above).

From this the redistributive virtues of the strategy will be easily detectable in terms of the relative values of the ΔS_j benefiting the different social classes.

Interpretation of the column ΔS_i is a more awkward matter. This is a vector and we should immediately note that it contains a great many components. If the number of zones were too low, it would not be possible ultimately to allow for those areas which are inadequately served. Let us therefore imagine that the vector includes about 100 components. To interpret it, each of these components must be related to the present situation of the zone and specifically, to a measurement of the satisfaction of the travel needs of that zone's inhabitants. It will therefore be helpful to define an indicator of accessibility A_i for each zone i. Let us assume that this problem has been solved, though we shall look at it again in the next paragraph as it is an important one. Supposing that the A_i indicators



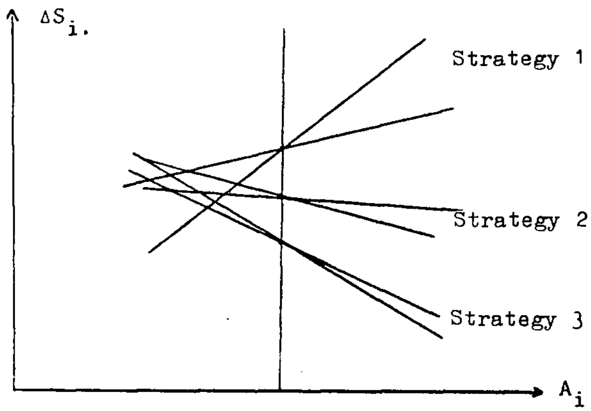
available have cardinal properties(1). Under these conditions, each zone i can be represented by a point with respect to two axes and the sum total of all zones represented by a cloud of dots. The shape of this cloud will be a starting point in assessing the corrective effects of a strategy: the greater the tendency for high-surplus points to represent low accessibility zones the more corrective it will be, and vice-versa. It is therefore important that the cloud should show a falling trend and do so with a certain degree of regularity. This trend and its regularity can be illustrated, for example, by the two least squares regression lines(2), for ΔS_i on A_i and for A_i on ΔS_i. The higher the coefficient of correlation between the variables, the tighter the pencil thus formed is known to be. A broad pencil on the other hand shows that the correlation is not regular and that there are many points which would conflict with any negative correlation between surplus and supply indicators.

1) This means that the difference between two indicators is meaningful. The problem would not be much more difficult to solve if the accessibility indicators had only ordinal properties.

2) In these regressions, each dot will represent the number of inhabitants of the zone concerned.

In this way, a number of strategies can be weighed against one another by showing them in the form of their respective pencils. The diagram below provides a convenient, simultaneous presentation of three criteria for strategy appraisal:

- the ordinate of the centre of the pencil, or the centre of gravity of the cloud, which represents the global value of the surplus i.e. the conventional criterion;
- the slope of the pencil which represents the corrective feature of the strategy;
- the breadth of the pencil; a large angle shows that the corrective aspect is not regular and that there are many exceptions to be registered.



There are three elements here corresponding to three numerical values, which are clearly easier to consolidate for a multicriterion assessment than a vector of 100 or so components, but they can be formulated only if an indicator for accessibility has been defined beforehand. The right definition for such an indicator will not, however, be self-evident.

III.4 Indicators for accessibility

Although these are sometimes called supply indicators, there are at least three good reasons for studying them in the context of transport demand analysis: firstly, the mathematical structures of the indicators hitherto suggested are close to the demand model structures. Secondly, as has just been mentioned in analysing and forecasting demand for the purposes of urban transport strategy, indicators for accessibility are needed at the final, appraisal stage of the strategy. Last and most important of all, such indicators raise the problem of an operational definition for transport need, a concept closely bound up with that of demand.

It has already been suggested that a zone's accessibility indicator should show the extent to which its inhabitants' travel needs are satisfied. There are two ways in which one could set about studying such need: within a conceptual framework, in which the components of the need can be grasped objectively, or else by proceeding normatively, deducing travel needs from a predetermined model of urban life designed beforehand. Those who have so far worked on accessibility indicators, such as G. Koenig(1) have taken the first approach. The second approach has not yet so far, to the author's knowledge, been taken in any published work. But to the extent that it is clearly unrealistic for the urban transport policy-maker to ignore the implications of what he is doing upon the life styles of future generations, this second approach is the one which needs to be adopted.

This chapter can therefore be closed by raising one more question and more specifically by adding one more to the avenues for research already suggested here.

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CONCLUSION

This report has had the specific objective of going beyond the kind of problem too often brought up when urban transport demand is under consideration, and to challenge the limits which those problems are recognised to impose by those whose task it is to deal with them. The fact is that the policy-maker faces fresh demands; there is a need for better forecasting and consequently for better understanding of a process whose manifold socio-economic aspects are seldom considered comprehensively, a need to make full use of the great potential in the new methods of data analysis to impose some degree of order upon this complexity; and to put the investigation of transport policy back to a standpoint from which the fast-rising expectations of the city-dweller can be kept in view.

This will inevitably have brought up fewer answers than questions but these, too, may also have their place among the contributions to Round Table.

Annex

SUMMARY PRESENTATION OF VARIOUS DEMAND MODELS

I. MODELS REFERRED TO WITH BIBLIOGRAPHICAL REFERENCES

I.1 Sequential aggregative models

1. Generation

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4. Assignment

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I.2 Direct aggregative models

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I.3 Sequential disaggregative models

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"Stochastic choice of mode in urban travel: a study in binary choice". Northwestern University Press, 1962.
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I.4 Direct disaggregative models

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I.5 General

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- Cahier de l'IAURP No. 4-5; 17-18 and No. 28.
- M. BARBIER and F. MELLET.
  "Determination of elasticities of demand for the various means of urban passenger transport."
  13th E.C.M.T. Round Table (28th-30th April, 1971).
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  "Some problems with urban transportation planning models".
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  Special Report 143 Highway Research Board 1973.

II. PROPOSAL FOR CLASSIFICATION INTO FOUR TYPES

II.1 Study of the taking of the decision

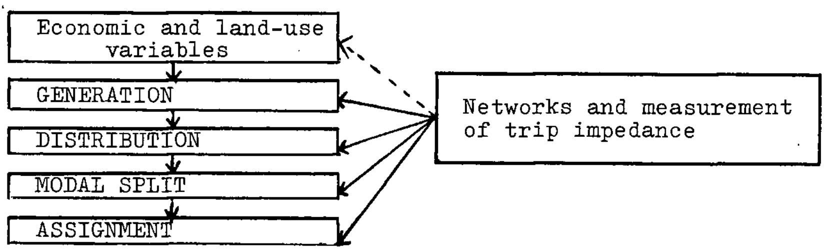
Each trip is the outcome of choices about:

- Whether or not to make the trip
- The purpose and time of the trip
- The destination
- The mode of transport used
- The route chosen.

These choices may be made simultaneously or successively. If they are made simultaneously, they can be dealt with by direct models integrating all factors in this decision within the same equation.

If they are made successively, sequential models are needed, the choices being interlocked.

The conventional decision chain can be represented as follows:



It may happen that constraints at assignment level modifies certain choices made previously.

Any corrections are made when the model is calibrated and adjusted.

II.2 Trip analysis

The trips can be modelled in several ways. The usual comparison is between aggregative and disaggregative models.

1. Aggregative models

In these models the data are aggregative by consolidating trips according to zone of origin and of destination. These zones will have been formed by dividing up the area, sometimes intelligently but usually in an arbitrary way based on no objective criteria.

This means that in the study of modal split, aggregative models implicitly assume that the split function will be uniquely dependent on the averages of the independent variables for each zone. Yet the distribution of these characteristics inside each zone should clearly be taken into account as well. Aggregative models provide no way of analysing the characteristics of the transport system inside a zone. This becomes a particular problem when it is desired to predict, on the basis of the analysis, what effect a modification in transport supply will have upon demand.

2. Disaggregative models

Some authors have recently tackled these difficulties by developing probablistic models, as disaggregative as possible, showing individual attitudes towards their choices. These have several advantages:

- The precise value of the different characteristics of the transport system enables them to be accurately adjusted;
- They take account of the psychological reactions of the user, which are often the determining factor .

Such individual forms of behaviour can be consolidated either by:

- Taking account only of the characteristics of the system being considered as independent variables. The number of combinations is limited by the data processing capacity available.
- By making assumptions as the shape of the functions and adjusting these with the help of coefficients.

II.3 Types of model

From these four different approaches analysed in the preceding paragraphs and introduced in paragraph I.2 of the report there correspond four types of model:

- Sequential aggregative models
- Direct aggregative models
- Sequential disaggregative models
- Direct disaggregative models.

We may now briefly consider the main elements of the most representative examples of each of these types of model.

III. SUMMARY PRESENTATION OF VARIOUS MODELS

III.1 Sequential aggregative models

This is the conventional structure for analytical models in the urban transportation planning process. It has five phases:

- Generation, the calculation of the number of trips made by a person in a household
- The spatial distribution of the trips
- The user's choice of mode
- Assignment over the network
- Time distribution of trips (rush hours).

Each of these phases is determined by the result of its predecessor and each has prompted the construction of mathematical models of varying degrees of sophistication.

II.1.1 Generation

The method currently used is the regression technique. If T_i^n represents trips for purpose n originating in zone i and T_j^n represents those whose destination is zone j, then:

$$T_i^n = k_i^n + \sum_{h=1}^{m} k_{ih}^n \, S_{ih}$$

$$T_j^n = k'^n_i + \sum_{h=1}^{m} k'^n_{ih} \, A_{jh}$$

Where S represents the socio-economic variables, A represents the activity variables and k_i^n, k'^n_i, k_{ih}^n, k'^n_{ih} are the coefficients of regression.

The socio-economic variables most often used are:
- Average yearly income, rates of car ownership
- Number of persons in the household.

The activity variables:
- Spatial distribution of jobs
- Area occupied by the various activities.

These models do not take account of transport costs nor of the accessibility of the various zones, which is tantamount to assuming that trip elasticity relative to costs is nil. Furthermore, the independent variables used in the regression are often interdependent. In this case the regression is, strictly speaking, no longer linear.

A much more sophisticated aggregative generation model (though this, too, does not include costs) has been suggested by Adib KANAFANI (see paragraph IV). In this model it is implicitly assumed that a group of persons with similar socio-economic characteristics will behave in the same kind of way with respect to trip generation. KANAFANI seeks to define density functions within these socio-economic groups. These functions are obtained by integrating the conditional probabilities of trip generation, knowing the characteristics of the individuals making the trips.

III.1.2 Distribution

Four types of distribution model can be distinguished:

1) Growth factor models
2) Gravity models
3) Opportunity models
4) A preferential **equilibrium model** - SEMA.

1. <u>Growth factor models</u>

These models do no more than extrapolate future situations on the basis of present flows. They have two important defects:

1. They do not take any direct account of the existing transport network (except by the exchanges resulting from it).
2. Inter-zonal flows which are nil at the present time are eliminated at period t.

The general formula for these models is:

$$T_{ij}^{t} = \Phi(T_{ij}^{o}, F_i, F_j, F)$$

T_{ij}^{t} is the number of trips between i and j projected to time t.

T_{ij}^{o} is the present number of trips.

F_i and F_j are the growth factors for zones i and j respectively.

F is the growth factor of the town.
The factors F, F_i and F_j are defined by

$$F = \frac{T^t}{T^o} \quad F_i = \frac{T_i^t}{T_i^o} \quad F_j = \frac{T_j^t}{T_j^o} \quad T^t = \sum_{i=1}^{n} T_i^t$$

T_i^o and T_i^t are the number of departure or arrival points for the trips in zones i at the present time at time t.

These models can only be used for the short-term, i.e. when there will be no important changes in the transport system during the period considered.

2. <u>Gravity models</u>

The trips depend on the respective weights of the business and residential zones or more generally, of the zones of generation and of attraction.

The "distance" between these zones is represented by an impedance function which decreases with the cost of transport.

Hence the expression T_{ij}:

$$T_{ij} = A_i\, B_j\, O_i\, D_j\, f\,(c_{ij})$$

O_i: number of trip origins for zone i

D_j: number of destinations in zone j

c_{ij}: generalised costs of the trip between i and j

A_i, B_j: parameters depending upon the characteristics of these zones of generation and of attraction.

These models assume that the n-2 other zones do not intervene in T_{ij}.

WILSON has endeavoured to refine this model by introducing the theory of entropy maximisation (see paragraph IV).

3. Opportunity models

These are micro-economic models designed to reconstitute the choice by the individual of a zone of destination, making it possible to study the modality and the accessibility of the various zones. The calculation for this model is developed in paragraph IV.

4. The SEMA preferential equilibrium model

This is derived from gravity models and distinguishes between three types of user:

- those who choose their place of work on the basis of their place of residence.
- those who conversely choose their place of residence on the basis of their place of work.
- those who choose both independently, at random.

Some of the components of this model are described in paragraph IV.

III.1.3 Modal split

There has been much research into choice of transport mode. The early studies, mainly in the United States, concentrated very closely on the problem of the car and sought to do no more than to link the rate of utilisation for a given mode of transport for the conurbation as a whole, to such global characteristics as: size, density, car ownership. Costs were only indirectly and very roughly taken into account. The models were then refined, introducing time and costs directly. It was desired to calculate the fractions corresponding to each mode as a function of these times and costs.

$$p^{n}_{ijk} = \frac{T^{n}_{ijk}}{T_{ijk}} = f^{r}_{nk}\left(\frac{tija}{tijt}, \frac{cija}{cijt}\right)$$

where f^{r}_{nk} expresses households according to income group and car ownership, r gives fractions of users of the modes k for the reason n. tija, tijt are transport times by car (a) or by public transport (t). The same applies to costs cija and cijt. Times are subdivided into:

- time taken to reach the point of departure for the mode concerned
- waiting time
- travelling time

- time spent looking for somewhere to park (car)
- terminal journey time
- time spent interchanging

Each of these times is weighted by a discomfort factor. The factors given by M. BARBIER and F. MELLET in the report of the 13th E.C.M.T. Round Table are:

travelling time:	1
waiting time:	3
interchange time:	2
terminal leg time:	1.75

These models were improved by the introduction of L_{ijk} representing the level of service each mode k available between i and j, leading to the more general formula:

$$T_{ijk}^{n} = f_{nk} \quad (T_{ij}^{n}, L_{ijk}, S_{i}, A_{j})$$

III.1.4 Distribution over the network

The final stage of the process is to distribute flows optimally over the network.

Various methods of greater and less refinement have been devised. Most of them rely upon the theory of graphs and the various algorithms deriving from this. The network is made up of modes corresponding to the centre of each zone, and of branches representing each possible itinerary for each of the modes concerned. Each branch is weighted according to the value of its impedance function, which takes account of the quality of service (travelling, waiting, interchange time, costs, comfort, etc.). A shortest road algorithm is then applied (using the Kirby, Moore or "once-through" methods) to determine the optimal route between two modes.

The model can be refined by introducing capacity restrictions on certain itineraries; making it possible to take account of the existing possibilities and, using an iterative process, to load the sections until the network reaches a state of equilibrium. Methods of this kind have been used to study the American motorway network, and by organisations such as the RATP in public transport.

III.2 Direct aggregative models

These provide origins, destinations and transport modes in a single equation.

Originally developed for inter-city travel over quite extensive areas in the United States, they have recently been applied to urban zones.

Three types of model can be distinguished:

1) specific mode choice
2) "abstract" mode choice
3) modal split.

They involve very heavy mathematical formalisation which does not lead to greater degrees of relevance.

1. Specific mode choice models

These modals take account of the transport modes available in the system and they require data collection on a substantial scale.

They are of the form:

$$T^{n}_{ijk} = f^{k}_{n} (L_{ijk}, S_{i}, S_{j}, A_{i}, A_{j})$$

The form of equation f^{k}_{n} depends on the mode k (specific mode choice equations).

These type of model has three variants. The mathematical formulation of the equation can be either:

- a product
- a sum of logarithms
- a product of exponentials

- product

This model has been applied in studying inter-city travel within the Boston-Washington corridor. It takes account of population P_i, average incomes Y_i, and of the costs and travel times for the various modes.

$$T^{n}_{ijk} = \alpha o \; P_{i}^{\alpha_1} \; P_{j}^{\alpha_2} \; Y_{i}^{\alpha_3} \; Y_{j}^{\alpha_4} \; \Pi_{k} \, (C_{ijk}^{\alpha_5} \; , \; t_{ijk}^{\alpha_6})$$

Coefficients αo, α_1 ... α_6 enable the model to be adjusted. They are dependent upon purpose n and mode k.

- sum of logarithms

This variant of the preceding model has been used to study homework travel in a metropolitan area. The socio-economic and occupational variables are:

- number of workers in the zone of origin,
- jobs in the destination zone
- average incomes in the zone of origin
- car ownership in the zone of origin

The conventional variables for level of service (time, direct and indirect costs) are also incorporated. The mathematical expression deriving from this is somewhat complex.

$$T^{n}_{ijk} = M^{n}_{k} (S_{io}, A_{jo}) \left[\sum_{k} \sum_{l} a^{n}_{kl} \, L_{ijkl} + \sum_{k} \sum_{l} b^{n}_{kl} \log L_{ijkl} + \sum_{l} c^{n}_{kl} \, S_{l} + \sum_{l} d^{n}_{kl} \log S_{l} \right]$$

where M^{n}_{k} is a constant corresponding to mode k and to purpose n. S_{io}, A_{jo}, and S_l are socio-economic and occupational variables L_{ijkl} are level of service variables, a, b, c, and d are coefficients for adjustment.

- product of exponentials

This final variant provides a way of modelling trips for shopping and homework travel by public transport in a large conurbation.

The activity variables taken into account are:

- number of households in zone of origin
- number of persons per household
- average income
- car ownership
- density of trading employment in the zone of destination; giving the expression:

$$T^n_{ijk} = M^n_k \Pi_{k,l} L^{a^n_{kl}}_{ijkl} \cdot e^{b^n_{kl} L_{ijkl}} \cdot \Pi_{kl} S_l^{c^n_{kl}} \cdot e^{d^n_{kl} S_{kl}}$$

2. "Abstract" mode choice models

With technological innovation, new modes of transport are currently being developed and these ought to be included in demand models.

One approach to this is to design models for "abstract" modes, i.e. modes defined solely in terms of service characteristics.

Pioneers here were QUANDT and BAUMOL (1966). in the context of an inter-city study. They arrived at a formulation of the type:

$$T_{ijk} = ao(P_i P_j)^{\alpha_1} (Y_i Y_j)^{\alpha_2} (c\overset{*}{i}j)^{\alpha_3} (t\overset{*}{i}j)^{\alpha_4} (f\overset{*}{i}j)^{\alpha_5} \left(\frac{cijk}{c\overset{*}{i}j}\right)^{\alpha_6} \left(\frac{tijk}{t\overset{*}{i}j}\right)^{\alpha_7} \left(\frac{fijk}{f\overset{*}{i}k}\right)^{\alpha_8}$$

where Tijk represents the volume of traffic between cities i and j in both directions by mode k and:

Pi Pj: population

Yi, Yj: incomes

cijk: generalised cost of travel by mode k

$c\overset{*}{i}k$: generalised cost of travel by the best mode

tijk: generalised travel time by mode k

$t\overset{*}{i}j$: generalised travel time by the best mode

fijk: frequency of service for public transport modes k

$f\overset{*}{i}jk$: best frequency...

Purpose of travel does not enter into this formulation.

This work was then taken on by MONSOD, MAC LYNN and CHESLOW in the form of linear models.

KAN HUA YOUNG, however, has worked on non-linear abstract mode choice models.

The models can be synthesised in the expression

$T^n_{ijk} = f^n(L_{ijk}, S_i, S_j, A_i, A_j)$

3. Modal split models

These models include two distinct functions: one predicts the overall volume of trips between i and j, while the other is concerned with the distribution of such trips.

This leads to the expression:

$$T^{n}_{ijk} = f^{n}(A_i, A_j, Y_i, Y_j, L_{ijk}) \frac{gk\ (L_{ijk})}{\sum_k gk\ (L_{ijk})}$$

MAC LYNN used an approach of this kind in his model for analysing inter-city travel.

He eventually arrived at the functions:

$$f = ao\ P_i^{\alpha_1}\ P_j^{\alpha_2}\ Y_i^{\alpha_3}\ Y_j^{\alpha_4}\ \left(\sum_{k=1}^{n} fk\right)^{\alpha_5}$$

$$\text{and } fk = bo\ C_{ijk}^{b_1}\ t_{ijk}^{b_2}\ f_{ijk}^{b_3}$$

coefficients b_o, b_1, b_2 and b_3 depending on the mode.

III.3 Sequential disaggregative models

Most of the research so far has been in the direction of a closer approach to the ways in which choice is exercised by the individual.

Early studies in this field dealt with the choice of mode. This was a binary choice between no more than two competing modes. More recently, multiple choice models have been described in some published work.

Four types of approach are discussed here:

1. The WARNER model, modal split, binary choice
2. The IAURP model
3. The SELNEC model
4. The CRA (Charles River Associates) series of models.

1. The WARNER model

This seeks to determine the influence of a number of factors on binary choices by users between modes of urban transport.

Estimating the probability that an individual will choose one of two possible modes makes it possible to quantify the effect of small variations in important factors affecting his decision. Independent variables are price, time, income, distance and age.

The data are based on a household survey conducted by Chicago Area Transportation Study.

The principle is to determine a function of the variables describing an observation.

Warner associated this function with a law of probability of belonging to the group choosing one of the modes. In this sense, it could be said that the choice attitude is described probabilistically.

There are several ways in which an argument which is a function of the independent variables can be associated with a probability law.

1. discriminant approach

The function is the discriminant linear form obtained by maximising the ratio of the variance between the groups of individuals and the total variance.

2. the regression approach

The function is the regression relation calculated from the independent variables for choice of mode expressed in binary form.

3. maximum likelihood

The linear form is obtained by maximising an expression of likelihood for a group of users. In all three methods, the probability law is of the form:

$$\frac{e^t}{1 + e^t}$$

2. IAURP model

The IAURP has designed a model of the Warner type in which the probability that a user will choose a particular mode is shown directly, as:

$$P(Z) = \frac{e^{az + b}}{1 + e^{az + b}}$$

where Z is a linear function of the characteristics of the relation considered for two modes.

$$Z = \alpha \Delta C + \beta \Delta T + \gamma$$

where $\Delta C = C_1 - C_2$ = difference in the cost of the two modes and $\Delta T = T_1 - T_2$ = difference in the time required for the two modes. It can be used to estimate the value of time (by the BEESLEY method) and to calculate elasticities. The amount of variance accounted for is however low. It is often necessary to resort to a specific survey to study the motivations of users in a particular sector.

One example is "Etude du choix du mode de transport par les habitants de quelques quartiers de Marseille" ("A study of the choice of transport mode by residents of various districts of Marseilles"), IRT-CERAU 1970. When comparison of the time cost elements yields convincing results, rules for distribution can be inferred.

3. The SELNEC model

This model utilises the results of the Wilson entropy maximising method (see paragraph IV) and distinguishes two types of person (car owners and others).

Other models of the same kind have been designed by EDENS, KALDER and HYMAN.

4. <u>CRA series of models</u>

The CRA has developed a suite of disaggregative models to match the succession of choices made by the user:

- reason for travelling?
- when?
- at what time of day?
- by which mode?

These models have to be adjusted in the reverse order:

- <u>choice of mode</u>

The model is based on a binary choice, between public transport or car. It yields the following result:

$$\frac{P^n_{ija}}{1 - P^n_{ija}} = \exp\left[k^n_o + \sum_l k^n_l \left(L_{ijal} - L_{ijtl}\right) + \sum_l k'^n_l \, S_{il}\right]$$

where P^n_{ija} is the probability of the trips for purpose n by household i to destination j by car rather than by public transport.

L_{ijal} = variables for the level of service applying to the car.

L_{ijtl} = variables for the level of service applying to the public transport facilities.

- <u>distribution by time of day</u>

This has only been studied in connection with travel for the purpose of shopping, distinguishing between rush hours and ordinary periods. The user has a binary choice, between:

1) travelling in any direction during non-peak periods;
2) travelling during peak periods, but only in certain uncongested directions.

- <u>choice of destination</u>

This model takes account of the different destinations possible for shopping.

In the equation:

$$\frac{P_{ij}}{P_{im}} = \exp\left[a_1 \left(C_{ij} - C_{im}\right) + a_2 \left(A_j - A_m\right) + a_3\left(C_{ij}.S_i - C_{im}.S_i\right)\right]$$

P_{ij} and P_{im} are the proportions of shopping journeys by household i to destinations j and m.

A_j and A_m are the variables for activities at destinations j and m.

- <u>trip frequencies</u>

Shopping is the only purpose taken into account. The model provides for only a binary choice, between zero trips and one shopping trip per day. In view of probabilities P_{ij} and C_{ij}, the total cost of shopping trips by household i can be deduced by summation.

$$C_i = \sum_j C_{ij} P_{ij}$$

In the same way when instances of A_j are weighted by probabilities P_{ij}, a mean characterising the shopping possibilities for household i in the system can be obtained.

$$O_i = \sum_j A_j P_{ij}$$

This gives a probability of P_i that a household i will make one trip for shopping per day.

$$\frac{P_i}{1-P_i} = \exp(a_1 C_i + a_2 O_i + a_3 Y_i)$$

III.4 Direct disaggregative models

BEN AKIVA of MIT has developed and adapted a direct disaggregative model for shopping trips. This model does not cover either the opportunity of such trips nor the way in which they are distributed by time of day. In mathematical structure it is comparable to the sequential disaggregative model equations.

The activity variables used are:

- the number of jobs in whole and retail shops in destination zone j
- an indicator for car use
- income brackets.

The variables for level of service distinguish costs directly paid by the user, indirect costs, time spent outside and inside the vehicle (both for cars and public transport). Comparison is possible between the proportions of trips P_{ijk} and $P_{ij'k'}$ by household i to two competing destinations (j and j') using two competing modes k and k'. It is possible for k and k' and j and j' to represent the same mode or the same destination, but never simultaneously.

$$P_{ijk} = \exp\Big[\big(\sum_l a_l (A_{jl} - A_{j'l}) + \sum_l b_l (M^1_{kl} - M^1_{k'l}) + \sum_l c_l Y_i (M^2_{kl} - M^2_{k'l}) + \sum_l d_l (L^1_{ijkl} - L^1_{ijk'l}) + \sum_l \frac{e_l}{Y_i} (L^2_{ijkl} - L^2_{ij'k'l})\Big]$$

where M^1_{kl}, $M^1_{k'l}$, M^2_{kl}, $M^2_{k'l}$ are modal variables.

IV. SPECIAL STUDY OF VARIOUS MODELS

The models described in this paragraph exemplify four interesting approaches to the general modelling problem.

IV.1. The KANAFANI aggregative generation model

The relationship between a household's propensity to generate trips and its characteristics qua household can be expressed in the form of a probability density, which is a function of the average number of daily trips generated by a household s.

$$P\ (Y/X_1,\ X_2,\ X_3 \ldots\ X_n) = \Phi(Y;\ X_1,\ X_2 \ldots\ X_n)$$

where P is the conditional probability of making Y trips per day given the n independent variables $X_1 \ldots X_n$ describing the household. The function Φ is constant in time, but may have a different form depending upon the purposes of the trips. Conditional probability P can be extended to a group of families with similar characteristics $X_1 - X_n$. It is possible to define a combined density function for these variables $b\ (X_1,\ X_2 \ldots\ X_n)$ expressing the dependency relationships among variables $X_1,\ X_2 \ldots\ X_n$. Integrating each of these variables gives:

$$P\ (Y) = \iiint_{X_1 X_2 X_n} \Phi(Y,\ X_1,\ X_2\ \ldots\ X_n)\ b\ (X_1,\ X_2,\ \ldots\ X_n)\ dX_1,\ dX_2\ \ldots\ dX_n$$

The number T of trips in any zone is such that its mathematical expectation $E(T) = NE(Y)$

where N is the total number of households in the zone.

From this the variance of T can be calculated:

$$\text{Var } T = N^2 \left[\sum_y Y^2\ P(Y) - \sum_y Y\ P(Y)^2 \right]$$

The distribution function for a random variable can be described in terms of a small number of parameters.

The generation model consequently becomes a function of these parameters and of the coefficients of correlation between the variables $X_1 \ldots X_n$.

It overcomes two of the major defects of conventional regression models.

1) Aggegative of the households is no longer arbitrary
2) Interdependence of the variables is allowed for.

IV.2 Entropy maximisation method

With this technique, developed by WILSON, we can go on from the Newtonian gravity model to a dynamic model the construction of which is analogous to Shannon's information theory.

It starts with a matrix (T_{ij}) representing trips by T users in n zones and assumes that all micro-states are equally probable. The number of ways in which these micro-states can be arranged is:

$$W = \Sigma W\ (T_{ij}) = \frac{T!}{(T_{11})\ !(T-T_{11})\ !} \cdot \frac{(T-T_{11})\ !}{T_{12}!(T-T_{11}-T_{12})!} \ \frac{x \ldots\ldots}{x \ldots\ldots}$$

$$W = \frac{T!}{\prod_{ij}(T_{ij})\ !}$$

WILSON actually regards a table (T_{ij}) as the outcome of every individual's own experience. The probability of obtaining any one table (T_{ij}) is therefore proportional to the number of ways of obtaining it for all the combinations to which it could give rise at the level of the individual. He then looks for the most probable solution compatible with the constraints at the boundaries and the further constraint of costs.

$$\sum_i \sum_j C_{ij} T_{ij} = C$$

which states that the sum of the costs over each relation is constant. The boundary conditions are:

$$\sum_j T_{ij} = P_i$$

$$\sum_i T_{ij} = P_j$$

$$T = \sum_i P_i = \sum_j P_j$$

The probability of each arrangement is

$$\log W = \log \frac{T}{\prod_{ij} (T_{ij})!}$$

The most probable solution will be the one which maximises log W under the constraints referred to.
Using Lagrange multipliers, an expression similar to that of the generalised gravity model can be obtained:

$$T_{ij} = A_i B_j O_i D_j \exp(-\Delta' c_{ij})$$

In fact, the multiplier M can be written:

$$M = \log W (T_{ij}) + \sum_i \Delta i (P_i - \sum_j T_{ij}) + \sum_j \Delta j (P_j - \sum_i T_{ij})$$
$$+ \Delta' (C - \sum_i \sum_j C_{ij} T_{ij})$$

M can be maximised by cancelling $\frac{\delta M}{\delta T_{ij}} = 0$

$$\frac{\delta M}{\delta T_{ij}} = -\log T_{ij} - \Delta i - \Delta j - \Delta' cij = 0$$

Hence $T_{ij} = \exp(-\Delta i - \Delta j - \Delta' cij)$

$$\sum_j T_{ij} = P_i = e^{-\Delta i} \sum_j \exp(-\Delta j - \Delta' cij)$$

$$A_i = e^{-\Delta i} = \frac{Pi}{\sum_j \exp(-\Delta j - \Delta' cij)}$$

Similarly

$$\sum_i T_{ij} = P_j = e^{-\Delta j} \sum_i e^{(-\Delta i - \Delta' cij)}$$

$$B_j = e^{-\Delta j} = \frac{Pj}{\sum_i \exp(-\Delta i - \Delta' cij)}$$

The ratios $P_{ij} = \frac{T_{ij}}{T}$ can be defined to express the proportion of trips between i and j. Then, by applying Stirling's formula we find

$$\log W = - T \sum_{ij} P_{ij} \log P_{ij}$$

In Shannon's information theory this expresses the entropy and is noted as S. Hence, by analogy, our use here of the expression "maximisation of entropy".

IV.3 Opportunity models

Opportunity models seek to reconstitute the choice of an individual in a destination zone j. It is assumed that the user goes to the nearest destination to his zone of origin that will satisfy his trip purpose.

dp is the probability that a trip will terminate in an elementary zone j comprises dv destinations.

This probability is equal to the product of the probability that there will be an acceptable destination in this zone and the probability 1 - p that there will be no nearer acceptable destination.

$$dp = (1-p)\ L\ dv$$

which, when integrated over the region confirmed, yields:

$$P = 1 - k\ e^{-Lv}$$

If no destination is possible P = 0. Hence k = 1.

$$P = 1 - e^{-Lv}$$

Trips starting from zone i, housing Gi travellers towards zone j, are:

$$T_{ij} = Gi\ T_{ij} = Gi\ \left[P(V+V_j)-P(V)\right]$$

where V_j represents the number of possible destinations in zone space j and V is the number of destinations closer to zone space i than the destinations V_j.

Hence: $T_{ij} = G_i\ e^{-Lv}\ (1-e^{-Lvj})$

Mobilities and flows can be reconstituted more faithfully with the opportunity model than with the gravity model, because the former includes trips taking place within a zone. Transport costs, however, are only reflected at second hand in the order of proximity of the destination zones.

Any homogenous improvement or deterioration in transport conditions which does not affect the orders of proximity of the zones will not appear in this model.

It has been developed to distinguish alternating flows - mainly homework - from other kinds of travel (such as for shopping or recreation).

SALENIUS has described an opportunity model whose calculation of the probability that a given traveller will terminate his journey at a given destination makes allowance for other travellers bound for the same destination.

Other opportunity models include work by the Penn Jersey Transportation Study on competitive opportunity models, though it has not so far been possible to put these into application.

IV.4 The SEMA preferential equilibrium model

This is a gravity type of model with the special feature that it can distinguish three types of user:

- Those who first select their place of residence and then choose among the various possible places of work (these are α proportion).
- Those who have selected their place of work and then choose their place of residence (β).
- Thirdly, those whose choices of place of residence and where to work are not interrelated (γ).

It is assumed that the number of residents in employment and the number of jobs is known for each of the zones.

Ai is the number of residents in zone space i.

Ej is the number of jobs in zone j.

The region is assumed to be closed

$$\sum_i A_i = \sum_j E_j = N$$

so that all residents forming part of the labour force are assumed to have a job and all jobs are assumed to be filled and not vaçant.

T_{ij} (α), T_{ij} (β) and T_{ij} (γ) are trips between space i and space j made by users in the α, β and γ categories defined above.

Category α obeys a gravity law

$$T_{ij}(\alpha) = \alpha A_i \cdot \frac{E_j}{(C_{ij})^\lambda} \left[\frac{1}{\sum_j \left(\frac{E_j}{C_{ij}^\lambda}\right)}\right] \quad \text{avec} \quad \sum_j T_{ij} (\alpha) = \alpha Ai$$

This also gives $\sum_i T_{ij} (\alpha) = \alpha E'j \neq \alpha Ej$

Individuals in category β follow a gravity law in choosing their place of residence on the basis of their place of work.

$$T_{ij} \quad (\beta) = \beta E_j \cdot \frac{A_i}{(C_{ij})^\lambda} \left[\frac{1}{\sum_i \left(\frac{A_i}{C_{ij}^\lambda}\right)}\right]$$

$$\sum_i T_{ij} = \beta Ej \qquad \sum_j T_{ij} = \beta A' i \neq \beta Ai$$

Category γ chooses place of work and place of residence at random.

$$T_{ij}\ (\gamma) = \gamma \frac{Ai\ Ej}{N}$$

$$\sum_i T_{ij}\ (\gamma) = \gamma Ej \qquad \sum_j T_{ij}\ (\gamma) = \gamma Ai$$

This yields : $\sum_i T_{ij} = \sum_i T_{ij}\ (\alpha) + \sum_i T_{ij}\ (\beta) + \sum_i T_{ij}\ (\gamma)$

$$= \alpha E'j + \beta Ej + \gamma Ej$$

$$= \alpha E'j + (1-\alpha)\ \ Ej$$

$$\sum_i T_{ij} = Ej + \alpha(E'j - Ej)$$

The discrepancies $\alpha(E'j-Ej)$ in relationship to the marginal constraint are uniquely a function of α.

These can be called merely by allocating them proportionally among the populations $\alpha(Ej-E'j)\ \frac{Ai}{N}$

We in fact have $\Sigma(E'j-Ej) = 0$

In the same way: $\sum_j T_{ij} = \sum_j T_{ij}\ (\alpha) + \sum_j T_{ij}\ (\beta) + \sum_j T_{ij}\ (\gamma)$

$$= \alpha Ai + \beta A'i + \gamma Ai$$

$$= (1-\beta)\ Ai + \beta A'i$$

$$\sum_j T_{ij} = Ai + \beta(A'i-Ai)$$

A similar process for the β category leads to the ultimate formulation:

$$T_{ij} = \frac{\alpha A_i E_j}{(C_{ij})^\lambda} \left[\frac{1}{\sum_j \left(\frac{E_j}{C_{ij}{}^\lambda}\right)}\right] + \alpha\left(E_j - E'_j\right)\frac{A_i}{N} + \frac{\beta A_i E_j}{(C_{ij})^\lambda} \left[\frac{1}{\sum_i \left(\frac{A_i}{C_{ij}{}^\lambda}\right)}\right]$$

$$+ \beta\left(A_i - A'_i\right)\frac{E_j}{N} + \gamma\frac{A_i E_j}{N}$$

This model has been adapted by the IAURP, when it yielded the following values:

$\alpha = 0.7$

$\beta = 0$

$\lambda = 0.3$

$\nu = 2.5$

According to SEMA, category ν correspondents to members of the labour force who choose their places of residence and work at random. This does not correspond with reality as observed by motivational surveys. The assumption that a category ν exists in a city of average size must be treated with caution in the case of a conurbation of the size of Paris. Furthermore, the method of fitting at the boundaries obtained without iteration, though rather convenient at first sight, becomes much more laborious due to the occurrence of negative T_{ij} flows which have to be cancelled while still respecting the conditions at the boundaries, which involves lengthy manual calculations.

SUMMARY OF DISCUSSION

INTRODUCTION

To be effective, methods of analysing and forecasting transport demand must, as pointed out in the introductory report, satisfy three requirements. These requirements, relevance, measurability and consistency - which prove more or less contradictory when analysed - constitute three necessary and sufficient conditions for operationality and were therefore particularly useful as focal points for the Round Table discussion. In this way, too, all the problems of demand analysis and forecasting could be covered while avoiding the pitfalls of the "survey" which, in view of the wealth of literature on the subject, would inevitably have been very incomplete.

I. THE RELEVANCE REQUIREMENT

Discussion of the relevance criterion dealt mainly with three points:

- term (long, short etc.) of the analysis;
- form of models;
- orientation of research.

The examination of these three questions showed how very closely inter-related they are.

I.1 Term of the analysis

- Up to now, the emphasis has been on long-term investment, and models have been constructed accordingly. But it is becoming increasingly clear that long-term forecasting models have serious shortcomings; as matters now stand it is impossible, in particular, to establish reliable long-term forecasts for behaviour patterns. As a result, awareness is growing of the danger of trying to make once-for-all decisions on long-term plans and investments. What is required is flexible investment programming reviewed at regular intervals; for investment, therefore, a continuous and adaptive planning process with decisions at regular intervals needs to be introduced.

- In econometrics, this mistrust of long-term forecasting has led to a reaction in favour of the short-term, concentrating on such issues as congestion, pollution, etc. There has consequently been an increasing trend to work on the basis of demand as expressed by the market, and to use simple, very short-term econometric simulations.
- This type of simulation can certainly yield very valuable results, but should not be allowed to obscure the <u>danger of relying on very short-term models in the absence of any long-term data</u>. It is very difficult, for example, to establish a reasonable forecast in connection with the introduction of parking meters if no information is available about the future of the urban fabric concerned. Similarly, in a continuing and adaptive planning process, periodical decisions - even those of a short-term character - must unquestionably affect, and be affected by, the long-term.

  So, it is clearly essential, even within a short-term economic approach, to have some degree of long-term perspective, so that at least the main long-term consequences of short-term decisions can be identified. It would be wrong, however, to expect too much in the way of long-term predictions. In the present state of knowledge, no model can be expected to provide accurate long-term forecasts. This being the case, relevant analysis means building explanatory long-term models in the form of <u>models which define what is not possible</u>, and which identify the unachievable and those situations where blockages will occur. The best approach here would probably be to write scenarios indicating, for each short-term option, the long-term options it would leave open and those it would rule out.

<u>Conclusion</u>

In the interests of relevance, and especially of providing some kind of background for the short-term work which can only be encouraged by our present inadequate state of knowledge, forecasters should give priority to the analysis - with scenarios and definitions of the "not-possible" - of the long-term consequences of measures which will increasingly have to be taken at intervals as part of a continuing, adaptive form of planning.

I.2 <u>The form of models</u>

With this approach to the short-term/long-term question in order to ensure the relevance of demand analysis, models should be so constructed as to provide the most adequate possible picture of reality.

In this field, however, recent research shows some measure of suspicion towards:

- global, generalised models;
- sequential models.

a) Non-relevance of global, generalised models

The attempt to establish global models, automatically applicable to well-defined types of situation, seems open to criticism on a number of counts.

- Highly detailed global models are cumbersome and in particular, very expensive to construct. As the Round Table pointed out, the cost of a model conditions its utility.
- Highly detailed global models suggest the presence of a more or less conscious assumption that there are well-defined situations which can fairly easily be classified into categories, and that there can be generally-applicable models capable of representing these situations and then producing forecasts. This oversimplification explains the setbacks of recent years in research based mainly on the development of highly sophisticated global models. The real world exhibits a whole range of analytically intricate situations. These situations have to be understood before one can try to make forecasts. Many wrong forecasts are actually due not so much to inadequate forecasting of factors determining demand as to the failure to analyse the demand-formation mechanisms properly in the first place. Every dynamic modelling approach must start, therefore, with a searching analysis of the situation, which will always be complex and in a state of flux. More generally speaking, recent methodological approaches show that there is a need for some distinction between a model's explanatory power and its predicting power; at present, the two often tend to be combined in the presentation of models and this has led to a good deal of trouble; it is especially dangerous to use a model for forecasting when even its explanatory power is not beyond doubt. However, while the distinction between explanatory model and forecasting model is generally very useful in macro-economic analysis, it would be fair to say that in the case of transport the explanatory side is vital; any forecasting model in this area simply must possess explanatory capability. In transport demand research, then, there is nothing for it but to try to identify specific behaviour patterns.
- While the point of departure for the design of demand models should be a searching analysis of the situation and of specific behaviour patterns, they should also be designed with an

eye to their purposes and aims. The form the model takes will vary according to its purpose; one obvious consideration, for example, is the level envisaged for the model - national, regional or local.

Conclusion

Examination of the most recent research discloses a need for the development of highly specific, and often, therefore, very fractional models, based on the thorough analysis of situations and behaviour patterns and tailored to suit the objectives in mind.

b) The shortcomings of sequential models

There has been a striking failure of confidence in chains of models of the UTPP type where each model is calibrated separately.

- In the first place, one is dealing with a hierarchy of interdependent and often simultaneous decisions.
- For certain trips, especially for non-work purposes, the following decisions will generally be made simultaneously: the decision to travel, the choice of mode, choice of route, etc.
- Furthermore, choice of mode for such trips will in fact be a composite choice largely dependent on that generally used for travelling to work, the level of car ownership in the household, residential location, etc.
- Similarly, there are obvious links between choice of mode for trips from home to work and decisions about the purchase of a motor car, area of residence, job, etc.
  More broadly, the traveller's range of choice will be very much a function of his cultural and national background, social category, etc.
- It should also be remembered that the frequency and term of these hierarchically-ordered, interdependent and often simultaneous decisions vary. Since the term of choice may vary so much, it is clearly essential to distinguish very short-term decisions whose frequency is very great from medium or long-term decisions with a very different frequency.
  Thus, whereas for "shopping" and "leisure" trips, simultaneous and interdependent choices (whether and where to go and what mode to use, etc.) will usually be made every day, the choice of mode for commuting will cover a far greater span of time. Choices relating to car ownership and residential location will occur even less frequently and affect an even longer period.
- Another type of interdependence which has not yet been considered sufficiently in sequential models is the influence of

transport supply upon modal choice. The fact is that many demand forecasts being used as the basis for decisions on transport supply are liable to materialise simply through the process of supply determining demand. In this case, demand forecasting must lose much of its significance. Lastly, at every timescale level (short, medium or long-term) decisions interact upon one another, both:

- vertically: the long-term reacts upon the short-term;
- horizontally: in the case of a "shopping" trip, the decision to go out and the choice of mode and destination will be interdependent and simultaneous; in the same way, the decision to purchase a car and to use it for particular types of trip will be closely interlinked. So there is a complete hierarchy of interdependent decisions specific to an individual's culture, social category, etc., and a coincidence of choices, neither of which can be reflected in sequential global models.

Conclusion

It will be apparent from the foregoing that models are needed dealing specifically with simultaneous choices and with the time aspects of supply and demand, and designed to allow for the interdependence of decisions and the special features of each choice situation. To be relevant, such models must be compatible with the life-style, time-scale and spectrum of choice, which will all vary considerably from one context to another. This means that before any demand model can be constructed a thorough analysis will be needed to distinguish various patterns of behaviour and to investigate decision-making mechanisms among the different user groups.

Analysis of forecasting techniques makes it clear that the current problem in transport demand forecasting is a question less of modelling technology than of relevance. The answer is to make a slight shift in research.

I.3 Research orientation

In the present state of research, modelling technology poses no real difficulties; the real problem is to identify the relevant variables (and the links between those variables) and to determine the model's objectives (social objectives, local, regional, or national scale, etc.). In the Round Table discussions, however, the emphasis was largely on the first question as this has special implications for the future trend of economic research. The meeting sought to define a number of possible avenues for research, so that it could be relevant, and lead to models fully capable of performing their task - which, in the first instance, is to enable instrumental variables to be identified.

a) To determine the relevant variables it will be desirable, bearing in mind the emphasis attached above to the explanatory power of transport models, to conduct in depth behaviour studies. Analysis of individual patterns of behaviour will be an essential stage in improving these models:

- Here it might be as well to begin in a somewhat pragmatic way by focussing on the effect of changes in transport supply upon behaviour patterns. This less ambitious direction for research would also be justified by a growing awareness of the limited availability of resources; priority will probably go increasingly to making better use of existing facilities, and this never requires such a major demand-forecasting study as the large-scale investment project. If research does move more in this direction, there will inevitably be direct implications for the way it is organised. It must be admitted that by not properly analysing changes in transport supply, data of high quality are currently being allowed to go to waste; it would be desirable in future for studies to be carried out before, during and after every change in transport supply in order to find out which variables really affect behaviour.
- While it is essential to ascertain the variables to which demand is sensitive, it is also vital to identify those with no impact on user behaviour. In particular, it would be most useful to identify variables which are generally regarded as important by decision-makers but in fact have no real effect.
- Having isolated relevant and non-relevant variables it would then be desirable to determine behaviour patterns for the various types of user, and identify groups of individuals whose behaviour is homogeneous in a given context. This type of research would be of particular value in assisting policy-makers to identify target groups with well defined behaviour patterns on which they can act effectively; it would then be easier to fix the exact limitations of any policy measure in terms of efficiency.
- User behaviour should be analysed not only from the "modal choice" aspect but in terms of the whole range of substitution possibilities outside the transport sector - substitution of trips by location, for example - which can be represented in the form of conditional probabilities.

b) In the interests of greater efficiency in future transport demand research, behaviour studies should be supplemented by attitude surveys - attitudes towards comfort, for example; hitherto there has been too great a tendency to neglect qualitative aspects of travel and especially the ways in which these are perceived psychologically. Behaviour is the outcome of a series of constraints modifying the user's universe of choice. So in parallel with studies on behaviour and attitudes, material, temporal, informational and emotional constraints should be carefully analysed, since these, like habits and prejudices, limit the user's range of choice.

In practice, however, those variables which elasticity calculations have shown to be significant are very much the same as those shown to exert the greatest influence, by attitude surveys but the intensity of that influence varies according to the context of the decision, which is why conventional regression models lack relevance; in a constantly changing context, user choices are highly specific, and may not coincide precisely with regression or optimisation curves.

It is clearly essential therefore to include an analysis of the environmental context in a study of demand determinants.

c) On the whole, there has been too much emphasis up to now on personal behaviour patterns. The result has been to ignore the social aspirations of the individual and in particular, the fact that individuals act as members of groups (family, society, etc.). Similarly, recent surveys have over-neglected the influence exerted by urban structures on personal mobility, especially through the individual's subjective universe of choice.

The behaviour of transport users should be studied in its social context and the framework of the analysis should therefore be enlarged. Attitude surveys, for example, should not be confined to such simple issues as sensitivity to comfort; it would be particularly interesting to analyse more general attitudes such as the attitudes toward making journeys themselves. Combining this type of analysis with a study of constraints should give a clearer picture of the user's subjective universe of choice. More generally speaking, for further advances in research, and to gain significant insight, analysts must try to achieve some kind of a theoretical framework which would enable them to provide a detailed explanation of the context in which behaviour occurs; from this point of view, such structures as that of Hagerstrand's space-time model(1) seem to offer a valuable approach.

d) The studies mentioned above should all be supplemented by the formulation of models for activities in which transport demand could be studied as a derived phenomenon. The activities diagram

1) See, in particular, "The Impact of Transport on the Quality of Life", T. Hagerstrand, Fifth International Symposium on the Theory and Practice in Transport Economics, Athens 1973 - ECMT.

approach - and here it would be most constructive to examine every function that consumes an individual's time - and, generally speaking, all studies upstream of behaviour analysis, showing how demand for transport is only a derived form of demand, the outcome of one structure of activity, constitute highly promising research avenues which would be well worth developing. For it is important to understand why particular constraints or psychological attitudes arise, before examining how they affect user behaviour. In this field moreover, a sociological analysis should be made of the concept of need - a non-operational concept. The "need" to travel is, as a first approximation, a derived need; one possible research avenue would be to go more deeply into the concept of how and why wants arise; for these are explanatory components well upstream of behaviour and have so far been overneglected in the models, to the detriment of the latters' relevance.

Conclusion

The Round Table discussions showed that there is a need for a measure of balance between traditional econometric approaches and analysis based on social psychology. In this the Round Table was in full agreement with participants at a research seminar held at the same period by the French Transport Research Institute. The conclusions of that seminar(1) fully reflect the view emerging at the ECMT Round Table.

"In approaches based on social psychology the tendency is for personal mobility to be viewed in relation to all the components of everyday life; this means taking social structures into consideration when trying to understand what people do. Transport is only one aspect of such research, as mobility is also studied for the light it can shed on social habits, this being the other aspect of such research.

- Econometric approaches can definitely be of value by helping to define orders of magnitude for some variables, and identifying those relationships which may be of use in predicting behaviour. But it is important to remember that correlation does not necessarily imply an explanatory relationship.
- A last point is that the social psychology and econometric approaches are not necessarily in conflict. Apart from their complementary nature as research methods, there is very clearly a place for social psychology studies applying quantitative statistical methods."

1) X. Godard. Séminaire de recherche sur la mobilité en zone urbaine ("Research seminar on mobility in urban areas") in the IRT information bulletin Recherche - Transports, No. 14, April 1976.

Only by achieving a better balance between the traditional econometric approach and analyses based on social psychology can we hope to arrive at a practical understanding of user behaviour and (an important aspect) produce findings accessible to decision-makers. The fact is that a purely econometric view of consumer behaviour is very limited; in particular, it assumes that the individual is aware of all the choices on offer, is never influenced by the past or the future, etc. This does not mean that the approach should be abandoned altogether; in any case, in the short term, before the necessary progress has been made in psychological studies, we shall have to make do with the econometric approach. These remain fairly satisfactory - despite their shortcomings - in forecasting for quite short periods, as is shown by the agreement between elasticity calculations and attitude surveys. At the same time, though, a start should be made with intensive psychological research, in taking behaviour analysis as its point of departure, in order to provide a clearer view of users' primal needs and of the influence of constraints and the environment as a whole. For this, many more case studies will be needed, and in particular, other sciences and methodologies - social psychology, psychometrics, anthropology, etc. will have to be brought to bear upon the study of behaviour. This will lead on to new-generation models - which will be partial, not global - calling on all the refinements of econometric analysis but capable, in particular, of indicating experimentation processes and changes in individual preferences over time.

If demand research is directed along these lines, analysis must ultimately lead to the multidisciplinary approach. It is essential that transport economists and analysts should turn towards other fields, some of them remote, such as anthropology or marketing. The need here is to organise a systematic exchange of research information and to exploit the "living memory" of scientists although it must be admitted that the techniques for such a multidisciplinary approach are still largely wanting.

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The Round Table's review of the relevance of transport demand analysis and forecasting methods showed that a very noticeable change has occurred during recent years in the behaviour of transport economics specialists. Making models less ambitious in scope, and more specific in content and taking a more psychological, sociological and qualitative approach to transport economics, their concern for greater analytical relevance represents a profound and wide-ranging challenge to present-day methods.

II. THE MEASURABILITY REQUIREMENT

To solve the problems of measurement arising when models are used to analyse and forecast transport demand, it is clearly essential to break down the complex entity of demand formation into categories of individuals with homogeneous behaviour. In this way, relevance can be maintained with some hope of achieving a form of representation which does not create insuperable measurement difficulties.

Breaking down the demand phenomenon in this way raises at least two problems:

- The choice of method: the Round Table, like the introductory report, considered that "stratification" techniques were probably the most appropriate ways of dealing with the measurability requirements.
- Choice of criteria for stratification: in breaking down demand it would seem desirable to move away, as far as possible, from the system of predefined criteria in favour of some more inductive type of method. For it seems possible, whilst not justifying a totally inductive approach, that some elements of the model might be identified in the statistical material itself.

II.1 Choice of breakdown method

Stratification techniques were put forward both by the introductory report and by Round Table participants; despite clear limitations, they offer a number of undeniable advantages.

a) The advantages of stratification

Stratification, as shown in the most recent tests - the British application of the University of Michigan findings for example - is a technique for forming homogeneous groups which makes it possible, particularly when largely inductive methods such as segmentation are utilised, to identify the more important explanatory variables and thus specify the form of a model. Thus:

- Stratification makes for a more refined analysis by concentrating on a well-defined stratum, and increases the effectiveness of policy measures by enabling policy-makers to pinpoint specific people with specific needs and adjust their policies accordingly; up to now there has been too great a tendency to base everything on averages.
- It lowers data-collection costs; with stratification the necessary data need only be gathered for very precise segments, and this avoids the collection of irrelevant data and lightens the statistical processing load.

- Stratification techniques highlight explanatory values and target groups, thus freeing the researcher from unwieldy models or a succession of unduly specialised models, enabling him to aim at a simple, much less cumbersome type of model.
- The biggest advantage of the stratification technique is that it takes qualitative elements into account which are difficult to embody in purely quantitative or binary variables. In this respect the typology method too is ill-suited to the manipulation of qualitative criteria.
- The advantage offered by stratification techniques as opposed to traditional methods is also very marked in another field. Clearly, no one system of equations can be conceived to cover all behaviour patterns, since the realities of the process concerned cannot usually be embodied in the same formalisation irrespective of the particular group being considered. Yet conventional approaches assume that one system of mathematical formalisation can be applied to the behaviour of all individuals. The stratification methods, particularly when they draw upon sufficiently inductive techniques such as segmentation, do not suffer from this defect; by determining the variables defining each stratum, they show which variables must not be neglected, for the stratum so constituted, in an explanatory model of demand formation - thus enabling the researcher to find the design of model best suited to the stratum's own mechanisms. Certainly when particular components are lacking, conventional reliance on binary variables is an excellent way of increasing the number of degrees of freedom; but care must be taken that there should be no correlation among them; in fact, the result of using such variables is to restrict the number of behaviour structures that can be included in the model and, in particular, to prevent any change in the mathematical form of the model - whereas the mathematical structure of the various types of behaviour will be logistic for some segments and linear for others... so it would be fair to say that binary variables are somewhat lacking in practicability compared with stratification techniques, and cannot easily be given any policy content.

b) The limits of stratification

Stratification, in spite of its advantages, is not the complete answer.

- Stratification methods are still insufficiently developed. Techniques like segmentation are still largely experimental. The ideal situation would be for the extremities of the segments to approximate to 100 per cent and 0 per cent -

perfectly homogeneous subsets; as yet, however, stratification methods do not have this objective in view, seeking merely to maximise information. It would therefore be desirable to guide such work more firmly towards this goal, using additional stratification to reprocess intermediate segments. In the field of transport demand analysis and forecasting, researchers should endeavour to achieve cross-tabulated typologies or double segmentations, so that trip stratification can be made to correspond with user stratification in such a way that each trip corresponds to one - and only one - type of user, and vice versa.

- Like all disaggregated models, stratification, particularly when a segmentation process is used, raises serious <u>problems of aggregation</u> (aggregation by zone, for example,..) when it is desired to move from the explanatory to the <u>forecasting</u> stage. The more disaggregation and stratification, the greater the explanatory quality of the model - but the greater the difficulty in forecasting which requires everything to be combined, reconstituted and reaggregated. From this standpoint, though stratification makes it easier to understand behaviour patterns, it does not necessarily lead to better forecasting. Without dwelling again on the importance of the explanatory analytical phase, we would make two points about this difficulty: it should encourage work on the refinement of methods for stratifying and then reconstituting the various segments of population and it brings us back to the problem of any model - the more or less contradictory requirements referred to in the introduction.

<u>Conclusion</u>

In the present state of research it is impossible to choose among the various stratification methodologies, many of which are still experimental. Such methods as segmentation and analysis of data do not yet have the technological strength of traditional procedures relying on non-stratification techniques and are too novel for any conclusion as to their superiority. Because of their advantages, however, they represent a highly promising new avenue of research and deserve to be pursued in greater depth; in particular, they are an instance of the development of a more inductive type of procedure, as favoured by the Round Table, affording an interesting approach to the problem of choosing criteria for stratification.

II.2 The determination of criteria for stratification and for the selection of relevant variables

The criteria selected for stratification are usually chosen on the basis of the model constructor's experience; in other words they are selected on an a priori basis, taking no account of the information available; there is therefore nothing to suggest that such criteria will be optimal in terms of homogeneity obtained.

In this situation, research is needed to develop methods of a more inductive nature, i.e. methods which will themselves, by analysing available information, deliver criteria likely to yield homogeneity of behaviour within the groups formed. Work along these lines is all the more necessary in that stratification criteria, as the Round Table emphasized, are essentially a function of the problem being studied and segmentation cannot be unique or unilateral: depending on the problem and the situation, no one segment will necessarily be usable. Research should therefore be encouraged into such matters as the segmentation process and data analysis, as worthwhile steps towards a more inductive approach at the level of stratification criteria selection.

It would however be unrealistic to stake all on the inductive approach. It is never really possible to eliminate the "a priori" altogether. Whatever method may be adopted, some theoretical element is essential; some theory is needed - even if only an intuitive one - for the variables on which information is to be collected. Without some a priori assumptions about which variables are probably relevant to segmentation, it is impossible to set effectually about gathering the data required and analysing the statistics.

Here too, the Round Table emphasized the need for development, especially in the short-term, of effective data banks for transport demand analysis. At some time in the future, it will certainly be necessary to build up direct access data banks which can themselves generate stratification once models for optimal data selection have been developed. But until research has reached that stage, it would be unrealistic to try to establish effective data banks if nothing is known about the models being used or the aims of their users. Some minimum basis of assumption is therefore necessary for the introduction of such data banks, which can then be used to try to isolate the most significant variables using such instruments as the χ^2 texts, the concepts of entropy and factorial analysis.

In the short-term, however, the main need is not so much for some more or less intuitive underlying theory so that data are not selected at random, but for the avoidance of technocratic bias in the choice of which variables to study. For the development of effective data banks, as touchstones for relevance in analysis, there will be a need in the near future for procedures enabling users to be involved in the choice of variables and criteria for selection.

These data banks, to be effective, should not be restricted to "transport" data but should cover a wider field (socio-economic and qualitative variables relating to users, modes and route, with account also being taken of location aspects). Such data banks should also be capable of recording the characteristics not only of choices actually made, but of those not made.

Conclusion

Clearly it will not be possible for a long time to do without assumption altogether and to give up traditional methods in choosing criteria for the selection of relevant variables. But to satisfy the measurability requirement in demand forecasting models, it would now seem desirable to steer research towards the more inductive stratification techniques. Whatever method is eventually adopted, however, there will have to be some underlying theoretical element; what makes the inductive stratification techniques look so promising is that for them, this underlying theoretical element ceases to have the same commanding position as it does in the traditional approaches, since some of the model's components can be arrived at by statistical data processing whereas the form of traditional models is wholly governed by the theoretical element.

III. THE CONSISTENCY REQUIREMENT

For a model to be really consistent, not only must it be internally consistent or non-contradictory but it must also be consistent with its objective. Methods of analysing and forecasting demand must in fact be seen in the broader perspective of urban transport strategy. The consistency of these methods must therefore be compatible with the requirements of this broader objective.

Economic growth has brought considerable changes in transport policies. With the disappearance of scarcity situations, objectives have broadened. In urban transport today, thinking is in terms of strategy; the object is no longer to select the best project in terms of return on investment based on cost/benefit analysis, but to choose the most effective strategy. This raises the new problem of comparing strategies, which could hardly be solved by exclusive reliance on instruments for calculating return on investment.

The question of consistency in models in fact leads on to the general problem of strategy evaluation and what methods should be used for this; the methods adopted must have implications for the demand model developed. When the Round Table discussed the consistency requirement, it therefore did so in terms of identifying an appropriate instrument for comparing strategies.

There are various instruments for assessing the effects of a strategy from the user's viewpoint - the only one considered here in view of its very direct influence on the form of model used. Three types of appraisal were particularly considered by the Round Table:

- The first uses a traditional yardstick - the surplus notion. With this, global effects can be assessed in the form of the advantages a particular transport measure brings to users. It is, however, too general and seems only worth considering if broken down by geographical area and social category. Participants felt that, in addition to the global variation in surplus, it was necessary to be able to assess.
- Effects related to the degree to which spatial transport needs were satisfied, i.e. the corrective spatial effects; accessibility indicators would appear to be suitable for measuring such effects whose value ought not to be overlooked;
- The redistributive effects on the different social categories. Here economics seem somewhat inadequate; other disciplines will doubtless be needed to design a suitable instrument.

III.1 A global yardstick: user surplus

This concept, previously applied in the narrower framework of project evaluation, should be examined to see how far it may be helpful at strategy level.

Conventional user surplus calculation definitely has a certain usefulness; but in view of the weaknesses inherent in the way it is calculated it should be used cautiously for evaluating transport strategies, in full awareness of its limitations.

a) Why it is worthwhile to calculate user surplus

The reason is not that the result can be regarded as final or decisive, but because of its essential part in the decision-making process. A decision-maker does not always think in terms of monetary units. What he really takes into account in making his decision, is a whole range of factors.

User surplus simply has the advantage that to some extent it gives explicit form to the implicit aggregation process decision-makers always go through. It provides policy-makers with a preliminary assessment, often a fairly rough one, which has the advantage of being in concrete form precisely when they may be in no position to grasp all the facts of the problem.

As part of the decision process, the calculation of user surplus is definitely useful and undeniably constitutes one basis of comparison (though not necessarily the only or most decisive one) which policy-makers evaluating transport strategies should consider.

b) Weaknesses in the calculation of user surplus

The calculation of user surplus for the evaluation of certain transport decisions presents definite weaknesses which may seriously compromise the result.

- The generally-recognised properties of user surplus are based on a number of highly restrictive assumptions. Apart from the optimal distribution of income assumption to which reference is usually made, there is the fact that so many assumptions have to be made in calculations for unprofitable services that it is reasonable to doubt the real significance of the results of global surplus calculation.
- Apart from the assumptions, there are calculating difficulties, not least that of determining the potential users for whom the surplus has to be evaluated.
- Doubts as to the value of user surplus in the evaluation of transport strategies also arise from the fact that an instrument of this kind always embodies some implicit weightings. Some authorities think it would be better to let the trade-offs be clearly visible through simple procedures, rather than give the impression of an unequivocal result in terms of some precise monetary calculation; nothing is more dangerous than the illusion of precision.

Conclusion: the limitations of user surplus in the evaluation of transport strategies.

Because of the weaknesses outlined, the surplus notion should be used with great care. Before making any such calculation, the weaknesses of the procedure, the assumptions and the weightings adopted should all be brought into the open.

At all events, user surplus should be regarded only as one of a number of criteria to be taken into account in strategy evaluation. All decisions are in fact multi-criterion decisions and the calculation of user surplus, though informative, should never be the decisive factor. As decisions become more complex and involve more implications (and this applies to strategic decisions) the importance of user surplus calculation diminishes within the increasingly elaborate multi-criterion analysis, in which decision-makers, not economists, have to decide the weightings.

It follows that user surplus is much more useful for comparing two projects in the same field than two options of very different kinds; and precisely because of its inherent assumptions about income distribution, it is more suitable for assessing two projects whose beneficiaries are in the same social category than for two strategies affecting different categories of user. However, as for comparisons of closely related decisions, more simple and more effective criteria are available at user level: intermediate analyses, lying between the comparison of complex strategies and that of very close decisions, seem to constitute the ideal field for analysis in terms of surplus.

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As an aggregated yardstick, user surplus does have certain shortcomings; but in transport strategy evaluation, the problem of aggregation or disaggregation ultimately arises in relation less to such things as cost, time, pros and cons, etc. than to the question of the areas or people to receive the benefits identified. Unlike same-kind projects, alternative strategies necessarily imply different beneficiaries. A breakdown by social category is therefore necessary and for that user surplus does not constitute a usable concept. As a criterion for appraisal, user surplus completely disregards the observable disparities between different points of space in terms of satisfying travel needs.

Economists, recognising this inadequacy but anxious to bring more consistency into their analysis, have looked for measuring techniques sensitive both to a transport strategy's corrective effects with regard to space, and to its redistributive effects with regard to incomes. The Round Table wound up its discussion on consistency in transport demand analysis and forecasting methods with an examination of these two types of indicator.

III.2 Measurement of geographical corrective effects

In recent years instruments called "accessibility indicators" have been developed to measure the possible effects of a transport decision on accessibility in different areas. Bearing in mind the considerable differences in destination accessibility implied by the needs and life styles of our society, there is no doubt that such techniques can help to increase the sensitivity of urban transport strategy evaluation. Given the limitations of user surplus, they certainly meet a need felt by all transport analysts. In spite of their advantages, however, accessibility indicators do present a number of important difficulties in their definition and construction.

a) Definition

With accessibility indicators, as with every new instrument, the first problem is terminology. The Round Table discussions showed a need, in the first place, for common definitions, because different schools of thought are using the term to mean very different things.

That is only to be expected so long as there are numerous approaches to the mathematical formalisation of accessibility itself, in the form of isochrones or of gravitational accessibility with a hyperbolic, exponentially decreasing or gaussian function.(1)

The concept of accessibility indicators thus needs to be more closely defined. It should be seen as an indicator for judging how activities are distributed within an agglomeration and what quality of service is being provided by the corresponding transport system. Accessibility itself can be defined as "a local measurement of ease of access from one geographical point to one or more others for reasons associated with a need, by one mode or a combination of modes of transport".(2)

When constructing accessibility indicators, therefore, account should always be taken of two contradictory elements:

- a 'resistance' element, limiting accessibility, which must be incorporated, implicitly or explicitly, in any mathematical formulations, namely time and space (i.e. distance);
- a motor element relating to that to which access is desired, i.e. attraction potential. This motivation is necessarily part of an activity system whose geographical distribution will have to be identified.

This would appear to be the ideal definition for constructing accessibility indicators, but many operational difficulties arise.

b) Difficulties of construction

The actual formulation of an accessibility indicator raises a series of problems and satisfactory solutions have not yet been found to all of them; this considerably limits the operational usefulness of such indicators.

- Level of aggregation. An accessibility indicator should be clear and understandable, but the more it takes into account, the more difficult it becomes to interpret. With too general a frame of reference, it loses much of its meaning for policy-makers and may even become dangerous. If accessibility is aggregated too much, it in fact becomes inappropriate for forecasting demand on an individual basis. Relatively intensive disaggregation by household, reason, trip period, etc. therefore becomes advisable. This is all the more necessary in that, as with demand elasticity calculations, it is essential to distinguish between short-term and long-term accessibility, in which structural effects such as changes in the urban fabric

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1) Cf, inter alia: Gérard Bien "Une application du concept d'accessibilité à l'étude des réseaux de transports collectifs". Institut de Recherche des Transports - June 1974.

2) A. Bonnafous - B. Gerardin "Les indicateurs sociaux d'offre de transport et le point de vue des usagers dans l'evaluation d'une stratégie". Rivista Internazionale di Economia dei Trasporti. Vol. II No. 3 - December 1975.

itself may come into play.(1) The measurement of accessibility again emphasizes the importance of a fine breakdown of the market. In particular, highly detailed disaggregation would appear essential for each zone. This poses a difficult problem.

- Zoning. Clearly, accessibility indicators have to be calculated for a fixed and definite pattern of zones. A change in any of the boundaries will mean a change in the value of the indicator. But established methods are liable to produce zones of very heterogeneous composition and it might well be wondered whether instead of a geographical basis, the analyst would not do better to concentrate on groups of households with typical characteristics, and to identify those with real accessibility problems. In fact, this difficulty should not be exaggerated; experience shows that there is some degree of correlation between location and social status. It is fairly easy to arrive at reasonably homogeneous socio-economic zones if the sub-divisions are fine enough and with twofold disaggregations - zonal and social - where necessary.

- Construction of a demand function. Producing an accessibility indicator involves constructing a demand function (a resistance function which will act as a weighting factor) and determining behavioural resistance to movement. Thus accessibility indicators in no way mask the problem of defining a demand function, any more than this problem can be solved by overall user surplus. In fact, the same limitation occurs with accessibility indicators as with demand distribution models, since time is generalised, all-mode time and embraces the whole context. Any change in supply(2) will involve some change in trip distribution, altering the shape of the all-mode curve and thus making it impossible to compare accessibility indicators validly. To solve this problem, a non-standardized approach is needed in the construction of accessibility indicators, and less of the pragmatism inherent in the use of the demand distribution function as a weighting factor. The weighting for the "motor" element in accessibility

1) In this connection the Round Table emphasized something that is too often overlooked, namely that the combined long-term effects of changes in transport networks or in the urban fabric must always be taken into account in evaluating a strategy or analysing transport demand. Measures can sometimes produce long-term effects that are the opposite of their expected short-term effects; a policy designed to restrain car usage, for example, is liable to have undesirable long-term effects from this point of view by generating changes in the urban fabric.

2) The Round Table also felt that on the whole, not enough account is taken of supply models. This is because analysts are not yet able to make demand models sensitive enough to changes in supply, and are therefore obliged to compare highly contrasting supply situations. This is undoubtedly an avenue for further research if urban transport analysis and forecasting are to be made more sophisticated.

indicators should, in fact, be based more on the lifestyle intended for the city, and therefore be less subject to change with every change in supply; this allowance for target lifestyle should be introduced, in particular, at the level of people's reasons for travelling.

- The reference element. Of a similar kind is one of the most difficult problems in the construction of an accessibility indicator, namely the definition of the reference situation against which a transport strategy is to be assessed from the accessibility standpoint. This reference element, by which the accessibility of the various zones is to be judged, is all the harder to specify because the urban structure concerned obviously makes it impossible for all zones to be equally accessible. One possible way of dealing with this problem is to compare the situation which would be created by the strategy to be assessed with the situation that would result from some more or less arbitrarily defined "floor" strategy. The disadvantage of such a yardstick is obvious: the outcome will depend very much on the characteristics of the "floor" strategy adopted. In fact, the definition of a reference element against which to assess strategies leads on to a problem of choice and trade-off - mainly shouldered by the decision-maker - to which no satisfactory answer(1) has yet been found in the construction of accessibility indicators. It also raises the question of whether accessibility indicators can reflect the extent to which a situation is changing.

- Dynamic evaluation. The fact that accessibility indicators possess no cardinal virtue is certainly their most important limitation on their use. While accessibility indicators do make it possible to qualify a situation and describe the differences between zones at some given point in time, their physical nature, and the lack of any satisfactory monetary equivalence, rule out any dynamic appraisal of the situation, or any comparison between situations in terms of time. In the absence of any monetary quantification of accessibility, it is in fact "impossible to use (such indicators) as a basis for relating the advantages of a strategy to its cost, which rules out any meaningful economic balance sheet. Furthermore, neither the indicators obtained nor their variations lend themselves to any global appraisal on which an interpretation can be based: for example, the information that average accessibility has increased by 4 per cent does not add very much in comparison with our usual resources of representation".(2) The scope for this type of assessment is therefore considerably limited and, in that sense, user surplus is clearly more operational as an instrument.

1) For attempts to define a "floor" strategy see: A. Bonnafous, B. Gérardin, op. cit.

2) A. Bonnafous, B. Gérardin, op. cit.

While accessibility indicators do not suffer from the disadvantage of user surplus (namely that no account is taken of the corrective effects of a strategy), they have the defect, unlike user surplus, of defying expression in monetary terms or providing any economic measurement of benefits to users. The respective disadvantages of the two instruments, and the incomplete nature of the information they provide, suggest that they might well be used to complement each other in transport strategy assessment. In that case care would be needed to ensure consistency between the elements involved in calculating user surplus and in measuring accessibility. The geographic categories taken for a model are usually defined in such a way as to provide a convenient perception of demand. They are not necessarily the most suitable for analysing corrective effects and it is to be feared that for some time to come, model effectiveness will take precedence over strategy evaluation objectives.

Conclusion

There are therefore many difficulties in formulating accessibility indicators - not all of them specific to this particular instrument. For example, the well-known problems about distinguishing short-term from structural effects, choosing criteria for segmentation and determining the relevant variables, crop up again in the working out of these indicators; and as with other more conventional techniques, the only way to find out what factors the user perceives as restraints on travel is to have travelling behaviour analysed psychologically and sociologically.

Nevertheless, in spite of these limitations, accessibility indicators do provide strategy evaluation with the additional refinement of what might be called a metastatic accessibility balance sheet. Such a balance sheet would certainly contribute a further comparative criterion, supplementing the information available from the global surplus calculation, to the policy-maker's multi-criterion decision process.

III.3 Measurement of redistributive effects

Just as it is not acceptable to ignore the corrective effects to geographical inequality, it would also be wrong to disregard the redistributive effects of meeting transport requirements. This, in fact, is one of the crucial questions, particularly where the decision or policy-maker is concerned, since the latter are constantly having to weigh up efficiency against redistributive effects and growth against the distribution of the effects of growth, and this makes them very sensitive to the repercussions of any transport strategy on the distribution of incomes and on the different social categories.

In spite of all the work done on such instruments as surplus(1) (attempts at breakdown) and on concepts such as entropy, (before-and-after analysis) it would not seem possible to measure all the redistributive effects and express them by a single figure; there is clearly no question of adding them together. Even before such yardsticks as surplus or entropy can be applied, the difficulties of actually pinning down such redistributive effects - especially in all their qualitative aspects - and defining distinctions between the social categories concerned, are such as to cast the greatest doubts on the possibility of quantifying them.

Here, then, it would probably be fair to say that in this field, which no transport strategy assessment can afford to ignore, the most that can be done is to identify a few redistributive effects by means of crude social indicators, and to describe them, giving decision-makers an indication of the various likely effects (with all their risks and uncertainties) and of the variants in these effects according to the options open to them. The consideration of redistributive effects is one sphere where econometrics should not be applied - the problem being basically a political one.

Conclusion

Though it may have little to do with economics, a simple description of redistributive effects is still of vital use to the decision-maker. It is just as necessary for evaluation as global user surplus or the accessibility indicator - and the more strategic the decision, the more criteria should enter into its assessment.

GENERAL CONCLUSION

Research on demand analysis and forecasting has developed considerably - often at a breathless pace - during recent years and the time has perhaps come to step back and review progress. The Round Table, having considered research development and its weaknesses, was able to outline a framework for future research on urban transport demand and to define the broad directions it should take including:

- the need to draw upon a variety of techniques in demand models and research - including those of disciplines outside economics - and in particular, to combine the approaches of econometrics and social psychology;
- the need at assessment level to abandon attempts to express findings as a single figure, and to think instead in terms of

1) It goes without saying that surplus can be used for this type of evaluation only to the extent that there is a demand function, i.e. a reaction to cost.

multi-criterion analysis; the main object being to identify the trade-off and to clarify the options confronting decision-makers;

- most important of all, the need for findings to be presented intelligibly, and in such a way that everyone can understand them. All the participants agreed that this had been too greatly neglected in the past, the tendency being to consider only the internal use of models and to underestimate the importance of their external presentation, particularly vis-à-vis decision-makers. Some priority should be given to techniques for making scientific work more accessible, such as interactive supply models with graphic illustrations. And in this connection, if transport analysts concerned themselves more with social psychology and less with quantification - as in the interests of greater relevance they ought - they could do much to make demand studies more comprehensible to decision-makers.

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