

A NEW LOOK AT MULTI-MODAL MODELLING

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1 INTRODUCTION

1.1 Background

In May 2000 the Department of the Environment, Transport and the Regions commissioned a consortium of consultants - David Simmonds Consultancy, MVA, John Bates Services, and the University of Leeds Institute for Transport Studies (ITS) - to carry out a wide-ranging review of future needs for multi-modal passenger modelling and of how these needs may be met. This paper is an outline of the work done in that study¹. Note that the study was specifically about passenger transport, not freight, and that it concentrated on the modelling of travel itself rather than related determinants such as car ownership.

1.2 Project structure

The Brief specified three parts to the study:

- an assessment of future modelling requirements, taking account (for example) of changes in policy issues, in appraisal and in decision-making;
- a review of current and emerging possibilities; and
- an assessment of possibilities against requirements, taking account of practical issues (such as data needs), leading to recommendations.

The review of future modelling requirements was initiated by the preparation of working papers dealing with national and long-distance transport planning issues; regional and conurbation issues; and local and rural issues. These were discussed at a seminar in September 2000 with participants representing the full range of interests in transport planning. The issues were then reviewed and condensed into a Requirements Report which was finalised in January 2001. The main findings on Requirements are outlined in section 0.

In parallel with this, we sought to identify modelling methods and techniques which might be brought into practice both in the near and in the more distant future. The underlying assumption was that advances in practice over the next few years will be based upon methods and techniques which are already the subject of initial, "leading-edge" applications or at least of applied research projects, whilst later advances may be based on ideas which are not yet

recognized as deserving such heavy investment. We therefore attempted to identify and to review (with the help of specialists in different approaches) in some detail the present frontiers of modelling, whilst looking more briefly for other possibilities which may represent the next frontier. Our findings are summarised in section 0.

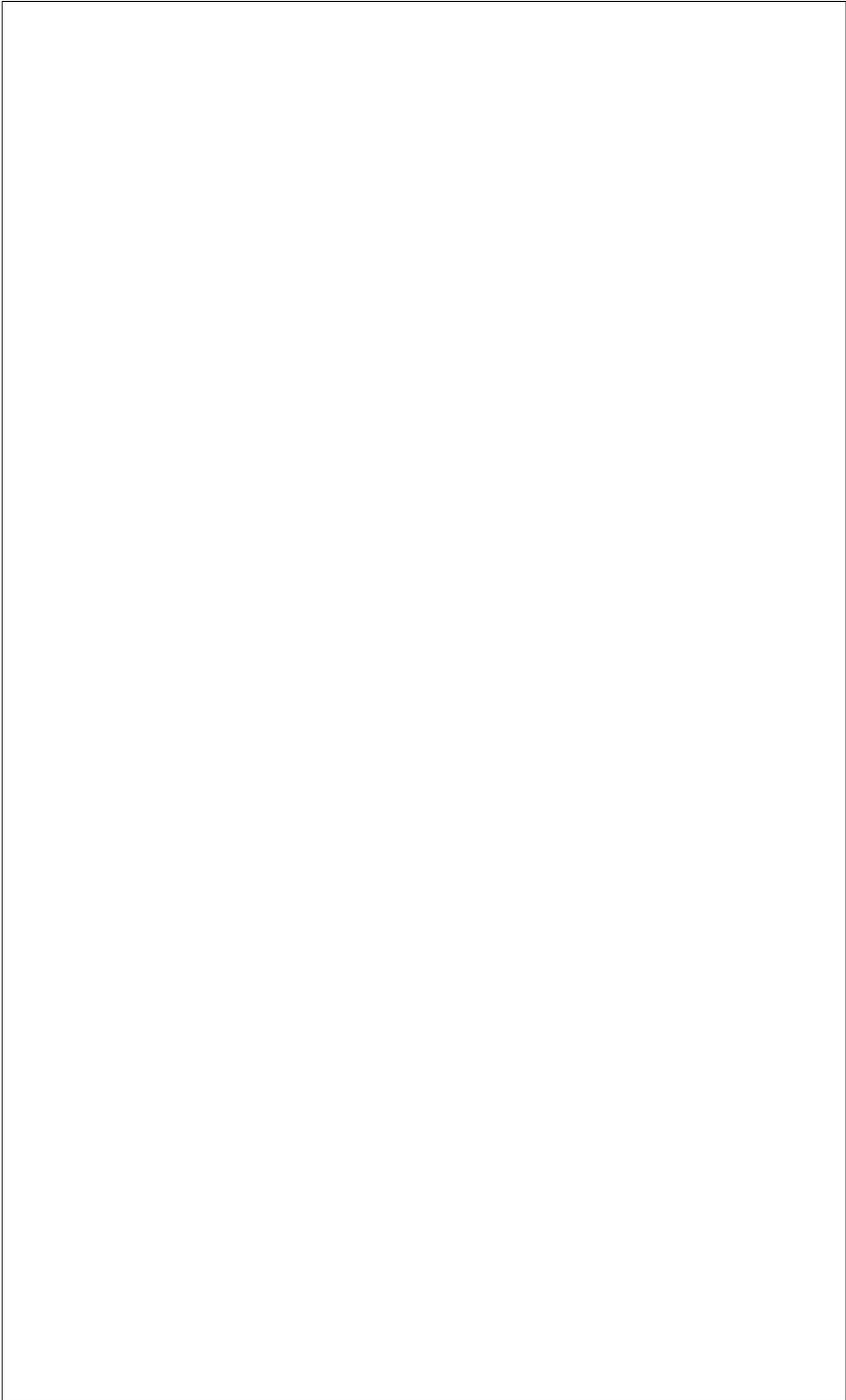
The final stage of the project was to consider whether or how the modelling possibilities could meet the requirements, and hence to make proposals and recommendations as to the future development of transport modelling and related activities. Our analysis is summarised in section 0 and our conclusions in section 0.

2 MODELLING REQUIREMENTS

Our analysis took the approach of

- assessing future changes in the decision-making context;
- determining the requirements of the process of strategy formulation;
- assessing the needs of each group of stakeholders; and thus
- specifying the requirements for models and data.

Figure 1 provides a flowchart which summarises this approach in terms of the stages in the decision-making process. Through this analysis we identified a large number of potential model development requirements, and proposed a list of the top twenty, as shown in Table 1. They are listed not in order of priority, but in the logical sequence of Figure 1; numbers in Figure 1 relate to these 20 requirements. Some appear at more than one point in the flowchart, reflecting their contributions to a number of elements of the decision-making process. For each, Table 1 provides an initial assessment of the importance of the need in the contexts in which it is required (very high; high; medium), and of the range of application contexts (broad; moderate; narrow).



Requirement		Importance	Range of application
1	Models need to incorporate land use-transport interactions	high	moderate
2	Models need to reflect choices between telecommunications and travel	medium	moderate
3	Models need to reflect a wider range of user responses, including vehicle ownership, trip frequency and length, trip timing and chaining	very high	broad
4	Models need to be able to reflect the changes in travel which users make in response to life cycle, location and other external factors	very high	broad
5	Models need to be able to predict the stream of changes over time, rather than simply conditions in a horizon year	high	broad
6	Models need to be able to represent the demand and supply impacts of a much wider range of policy measures, including land use, attitudinal and information measures, and those affecting cycling, walking and parking	very high	broad
7	Models need to reflect the response of the private sector in influencing public transport supply and performance; track-based systems in particular need to be better represented	high	moderate
8	Models need to represent the causal chains which lead to changes in demand, supply and performance, and to do so through increased use of feedback loops within and between the demand and supply sides of the model	very high	broad
9	Models need to predict the indirect influences of transport on social, health and economic impacts	high	broad
10	More complex models are needed for conurbation, regional, corridor and potentially national application, including greater spatial, temporal and person type differentiation	high	narrow
11	Models need to be able to generate appraisal indicators relevant to sustainability, social, health and economic impacts	very high	broad
12	Models need to be able to assess impacts on quality and reliability and, particularly for the private sector, the reliability and risk associated with the recommended decisions	high	moderate

Requirement		Importance	Range of application
13	Models need to be able to represent the distributional impacts of strategies and measures on all impact groups of interest	very high	broad
14	Models need to be able to present outputs at greater levels of spatial and temporal detail	high	moderate
15	Models need to enable performance to be assessed accurately against specified targets and standards	high	broad
16	Models need to generate output data of much greater output quality to facilitate interaction with decision-makers and stakeholders	very high	broad
17	There is a case for developing interactive decision-making models and decision support tools	medium	moderate
18	There may also be a need for models which assist in option generation and optimisation	medium	narrow
19	Public participation in decision-making should be used as an additional source of model enhancements and data provision	high	moderate
20	More and higher quality data is needed for model development, calibration and validation, particularly for demand responses, and greater use should be made of monitoring programmes and innovative data capture methods	very high	wide

Table 1 Main Requirements

Note that the order reflects the logic of the analysis, *not* an assessment of priority.

3 MODELLING POSSIBILITIES

3.1 Scope and approach

The Modelling Possibilities Review sought to consider

- the development of modelling techniques (from theory to workable techniques – not the commercial supply of software)
- the supply of data
- the possibilities for computation
- the availability of personnel able to develop and use models.

In order to make progress, we had to adopt some classification of alternative methodologies. There are two dimensions which can usefully be distinguished. The first is *the conceptual approach*, or what it is that a modeller is trying to do: this is what really differentiates one methodology from another. The other dimension is *the range of techniques* which are used within the methodology. Typically, the techniques which may be applied have wider relevance, both within transport studies and in other fields. We therefore envisage a cross-classification of methodologies in which the techniques are ways of implementing the conceptual approach.

3.2 The mainstream approach

The “classic” approach to transport modelling is that of the “four stage model”. We see this as part of a wider “mainstream” methodology, central to transport modelling since its emergence in the late 1950s, which includes many variations both of approach and technique. Our approach here is first to discuss this “mainstream” methodology, and then to identify and contrast alternative approaches, noting the “leading-edge” work in each area.

The characteristics of the *mainstream methodology* imply a model with:

- a *zonal* basis, thus implying some level of spatial aggregation;
- demand measured by *trips* or *tours*, more or less segmented;
- a *static* or *cross-sectional* structure (all demand and supply variables related to the same point in time);
- a structured set of *travel choices* usually corresponding to those of the four-stage model, but not necessarily applied that way, eg they may be structured into a variety of simultaneous hierarchical models; and
- a requirement in principle to iterate to *equilibrium*, more or less completely achieved in practice.

Although, as noted, the zonal basis requires a level of aggregation, this does not rule out the possibility of the *estimation* of the models being on an entirely disaggregate basis, nor of the forecast matrices being produced by essentially “micro” techniques such as sample enumeration.

With this kind of definition, much of what are often independently classified as “disaggregate” or “discrete choice” models can be viewed as an enhancement of the four stage model, rather than as a departure from it, and to that extent, part of the “mainstream”.

The more developed four stage models accept the need to distinguish between different times of the day (eg peak vs off-peak), and although the modelling problems remain significant, the addition of a “fifth stage” to allow for **choice** of time period does not seem to be a difference in the essential concept. We have therefore included time of day choice in the mainstream classification.

The borderline might be considered to be the treatment of “trip linking”. The original four stage models were firmly rooted in the assumption of independence between different trips made by the same traveller. More developed versions allow some interdependence between outward and return journeys for the same purpose. This is very close to the “primary destination” tour approach of the earlier “disaggregate” models.

However, the emergence of more explicit trip linking methodologies, dealing more effectively with non-home-based movements, as well as the allowance for interactions between persons within the same household, does seem to be a significant departure from the four stage approach, and moves towards some of the characteristics of *activity-based models*. This was the first of the alternative approaches we identified where we judged that substantial progress has already been achieved. The others were:

- dynamic modelling; and
- some forms of land-use/transport modelling.

These approaches are briefly discussed in the following three Sections. We then consider some other approaches that have been proposed, and go on to discuss *techniques*.

3.3 Alternative (i): activity modelling

The first major category which we have recognised as distinct from the “mainstream” approaches is that based on activities rather than travel demand *per se*. This is an alternative modelling stream of considerably long standing: however, it is only very recently that it has been viewed as a *potentially* alternative to the mainstream for practical analysis. This reflects the more demanding data requirements of activity modelling, but also a failure to follow through the network *supply* implications of the predicted travel demand.

The hallmark of activity analysis is the assumption that the use of time in classifiable activities, potentially in different places, is the underlying motivation for travel and must be treated explicitly. There now appear to be model structures which start from an activity perspective but mesh more directly with the traditional description of transport networks – in this respect, the Portland (Oregon) work seems to be the most highly developed. An important ingredient here is the microsimulation component.

Because of the interest in time allocation to activities, models of *duration* are often required. This is an area of some interest in its own right, and its transport interests extend beyond activity analysis² (for example, into car replacement decisions).

3.4 Alternative (ii): dynamic modelling

The next major category which we recognise as distinct is that which takes a dynamic viewpoint of the evolution of travel demand rather than taking a cross-sectional static equilibrium perspective. This is also an alternative of long

standing, but one which has produced a less cohesive corpus of work than activity analysis.

The term “dynamic” can be applied to any inter-temporal dependence where outcomes at each point in time depend on the consequences of earlier outcomes or decisions. It can include dynamic assignment dealing with the build-up and dispersal of queues on the network, and the “within-day” temporal dependencies of the activity analysis framework, such as (at simplest) the constraint that return journeys can only take place after the outward journey etc. However, the main aspect of dynamic modelling in which we are interested involves the concept of learning or adaptive processes. At one level, it may be sufficient to allow for a “history” on the part of the “stimulus” (cost) variables, as opposed to assuming instantaneous responses. More ambitiously, there may be an attempt to understand the adaptive process.

Clearly, the analysis of these processes is facilitated by a) longitudinal data, and b) explicit recognition of changes over time in modelling, including techniques such as duration modelling. As usual, therefore, there are data and estimation implications from pursuing a particular modelling methodology, though our approach is to regard these as variations of technique rather than concept.

3.5 Alternative (iii): land-use/transport modelling

Our initial view was that we were concerned in this study only with those aspects of land-use/transport modelling which offer alternative approaches to modelling transport demand. This would mean that our interest was limited to those components of certain land-use models which either

- generate transport demands, or
- represent other transport-related effects such as car-ownership,

in ways which are different from the approaches listed above³. However, in consideration of modelling requirements, and particularly in consultation, it became evident that there concerns about transport modelling include a range of issues which clearly fall into the scope of land-use/transport interaction modelling. We have therefore taken this into account in our analysis and recommendations, without going into detail of how the land-use elements of such modelling should be developed to meet these requirements.

3.6 Other alternatives

While the three identified approaches seem to us the most developed alternatives, many other possibilities have been proposed .

The first area to note is that of alternatives to the standard econometric approach to the representation of decision-making. This includes various “rule-based” perspectives and other “non-compensatory” models. It is not clear how far any of these differ from the standard approach *in practice*, even if their conceptual foundations appear to be different.

Two other areas of work which should probably be classified as “techniques” rather than “approaches” are the related fields of cellular automata modelling and agent-based modelling. Agent-based modelling has been used to represent traffic dynamics and pedestrian flows (Batty, 1999). At present it would appear (a) that applications are most likely to be for physically small systems (such as a building or an intersection), and (b) if it becomes more widely applicable, it most likely to constitute a particular technique for applying short-term dynamic models.

The Systems Dynamics approach has aroused periodic interest ever since the pioneering urban work by Forrester (1969). It tends to put the focus on representation of the performance of the system as whole, rather than on understanding the decisions of the actors whose behaviour determines that performance. It is thus at odds with the majority of research and modelling which seeks to focus on actors’ behaviour.⁴ Many of the desirable characteristics of Systems Dynamics, such complex feedbacks over time through multiple linkages, are being achieved in other, more behaviourally-based models.

The recent SACTRA Report “Transport and the Economy” (SACTRA, 1999) recommended more research into “Computable General Equilibrium” (CGE) models for understanding the “total economic impacts of transport schemes”. CGE models recognise the existence of imperfect competition, and non-constant returns to scale. To **some** extent they can be seen as an alternative to Land-Use Transport Interaction (LUTI) models. However, CGE is, at least in its current applications, a highly “macro” level system-wide approach, operating at the level of individual countries or, at best, regions. It is unlikely to be a practical tool for forecasting the spatially detailed effects of particular policies.

Approaches based on travel time budgets have had a chequered history. We remain unconvinced by most of the applications in this area. Time budgets may be valuable as constraints on models, but seem insufficient as a basis for models in their own right. (Total time budgets are of course central to activity modelling.) We take a similarly cautious view of the more recent concept of an Energy Expenditure Budget, based upon the physical energy expended by the traveller.

The generic use of microsimulation has made significant advances of late. Although this is sometimes put forward as a modelling approach in its own right, it is more productive, in our view, to see it as a *technique*. Nonetheless, it has considerable flexibility, which gives it great appeal. In the first place, it is well adapted to the “rule-based” concepts just referred to, while it can also be used as a device to make headway with analytically intractable calculations (such as multiple integrals). It also has the apparent ability to mimic “real life” behaviour, which makes it an appealing research and presentational tool.

3.7 Conclusions on possibilities

Looking first at the range of possibilities, we have not identified any distinct “new wave” outside the existing approaches discussed above. Our assessment is that most advances are taking place either within those four existing *approaches*,

which we have examined in some detail, or in the realms of *techniques* which can be employed in implementing those approaches. In some cases, the advances are not so much new ideas as older ideas that have finally become feasible owing to increased computing power.

We noted at the outset that our emphasis would be on travel modelling rather than on “background” variables such as car ownership, in particular, or population and employment characteristics. Although these merit attention in their own right, especially in relation to continuing use of the mainstream approach, they are being increasingly dealt with within some of the wider alternative approaches. Indeed, there is evidence that the states of the art in each of the approaches are converging and tending towards a more “holistic” account of all aspects of the transport system within a general socio-economic context.

Whilst this convergence of different approaches is encouraging, we have some concern about the complexity which may result. There is a need to consider the principle of *parsimony*, and find the appropriate balance between oversimplicity and excessive complexity, bearing in mind the requirements for the state of practice (as opposed to state of the art).

There is also a long-standing issue relating to model *validation*, which interacts with principle of parsimony. While ever-increasing complexity may seem to be justified in the name of a more realistic description, it is *potentially* in opposition to the kind of confidence-building that depends on

- a) a comprehensible model structure and
- b) some demonstration that the model’s predictions accord with actual outturns.

On the other hand, too parsimonious a model may be unable either to represent travellers’ decisions or the policies to be tested.

4 ASSESSING POSSIBILITIES AGAINST REQUIREMENTS

4.1 Appropriate modelling approaches for different requirements

We begin by considering the applicability of different modelling approaches to meeting the range of requirements, then move on to techniques for implementing these approaches. We are not at this stage considering priorities or how the different approaches might be brought into modelling practice.

Some of the characteristics of *dynamic modelling* are needed to improve the representation of the ways in which users make travel decisions – in particular to deal with

- the need to produce streams of changes rather than horizon year forecasts (5)⁵
- the facts that people make decisions on the basis of expectations rather than perfect knowledge (6)

- the potential value of representing feedback loops as real responses to information over time (an extension of the last point) rather than as an abstract process of iteration to equilibrium (8)
- the phenomenon that people in apparently similar situations make different travel choices (4).

An issue related to dynamic modelling is the possible desirability of moving away from models which iterate to equilibrium towards models in which repeated sets of calculations represent real processes of change over time. One view is that many of the decisions in urban transport are made so frequently that it is reasonable to assume that the equilibrium pattern of travel is being reached given the current pattern of land-uses and the current transport supply. The contrary view is that given significant imperfections in information, and variations in travel outcomes from day to day, it *is* necessary to consider the day-to-day dynamics even of apparently “regular” travel patterns such as the weekday morning peak. This view would suggest that the efforts currently put into iterate-to-convergence methods to represent a “typical workday” might be better devoted to representing (say) a sequence of workdays.

Some of the characteristics of *activity modelling* are needed to deal with the ways in which non-transport factors condition short-term response to transport change. These factors include in particular

- constraints on the scope to substitute modes with different characteristics for one another (eg cycling for car) (3 and 6);
- constraints on the scope to substitute telecommunications for travel (2);
- the determinants of trip chaining (3), particularly in complex settings where many alternative destinations are available (10).

Some of the characteristics (or potential characteristics) of *land-use/transport interaction modelling* are needed to deal with longer-term “non-transport” responses. This relates to

- the explicit interest in land-use/transport interaction (1, and also 5 and 8 in so far as feedback loops and time-lagged responses extend outside the “transport” system) and to the distribution and levels of economic and social effects which are part of “land-use” in its widest sense (9 and 11),
- the interest in using land-use policy to influence transport (6) - which should include analysis of the other impacts of land-use policies, rather than simply assuming that they will have the intended effects
- the requirement for additional detail about households, their members and their locational and other “land-use” decisions as the basis for forecasting their transport demands (4) at the required levels of segmentation (13).
- parking as a land-use (for example, the fact that the supply of parking may be influenced by the competition for land from other uses) (7)

- relocation of activities (especially by changing the nature and/or intensity of use of existing buildings) in major cities and conurbations where the scope for such change is high (10)

Broadly speaking, this suggests dynamic modelling tending to replace mainstream transport modelling, with activity modelling tending to intervene between transport modelling and land-use modelling. This can perhaps be illustrated by Figure 1:

Present	Proposed
Transport modelling (static)	Transport modelling (dynamic)
	Activity modelling
Land-use modelling (dynamic)	
	Land-use modelling (dynamic)

Figure 1 Existing and proposed relationships of models

We therefore concluded that to satisfy the methodological implications of the Requirements, it would be desirable to extend transport modelling towards, or integrate it further with, all three of the alternative approaches which we identified in the Possibilities Report. The convergence of “mainstream” modelling with aspects of the other approaches suggests that the state-of-the-art is already moving in this direction. The idea that extensions in just one direction would suffice, or that everything necessary can readily be done within the existing mainstream, cannot be supported. This is not to suggest that transport modelling practice should immediately try to incorporate all the ideas mentioned above. Different advances will be most appropriate to different circumstances, and numerous implications need to be considered. We concentrate here on the implications for modelling techniques.

4.2 Implications for techniques

A major theme in the Requirements is the need for greater segmentation and for increases in the representation of inter-personal and inter-household variations and linkages. The usual response to this is it should be dealt with by disaggregate modelling. It is useful to be clear about the thinking behind this.

There are two distinct tasks relating to segmentation. One is to forecast the *size and characteristics* of the segments. The other is to *evaluate the demand response* for each segment. Segments may be distinguished because they face different transport supply characteristics (inherently or because of actual or potential policy measures), because their demand responses are different, or because they are of particular importance in policy appraisal. In many cases, segments imply cross-classifications (eg working status by income).

In aggregate models, the “natural” representation of travel is on a matrix basis, and each additional segment requires its own set of matrices. The aggregate approach assumes that the size and necessary (average) characteristics of each segment are forecastable and that the demand function can be readily calculated for each segment. In extending the segmentation, however, even moderate levels of complexity (cross-classification) quickly raise the possibility of ending up with far more categories than travellers. The question then arises of whether it is either efficient or plausible to represent all the feasible combinations of traveller characteristics if the result is that most matrix cells represent only fractions of travellers.

The argument for the disaggregate modelling approach of *sample enumeration* is that it is better to work with (say) a 1% sample, and to be able to model many segments within the smaller number of characteristic combinations that such a sample will display, rather than being limited to the much smaller number of categories that are considered practical in conventional “aggregate” models. It may also be possible to work directly with continuous variables rather than with segment averages, eg to use the income of each sampled traveller rather than the average income of a segment.

Before continuing to discuss the implications of greater segmentation in disaggregate modelling methods, it is important to note that the ability of disaggregate models to handle explicitly greater complexity in traveller and supply characteristics is to a considerable extent dependent on doing less of the time-consuming things that conventional aggregate models do, such as capacity restraint and subsequent feedback. When these procedures are included in disaggregate models, they are often done at an aggregate level, after the disaggregate-level results have been summed into conventional matrices, with less iteration from (say) capacity restraint to modal choice.

Clearly the greater level of segmentation typically offered by disaggregate modelling increases the challenge of forecasting segment sizes and characteristics. A typical procedure is to derive the “future sample” of travellers by estimating and applying growth factors for each segment. There is an issue about attributes used in the demand model which are not explicitly forecast, but whose distribution is merely *implicit* in the base year sample⁶. Here a change in critical characteristics could be brought about in the forecasting process without ever being directly considered. In general, the need for more detailed forecasting of segment sizes and characteristics may be regarded as a desirable clarification of the effects underlying travel demand change, or as an added risk of error.

Disaggregate modelling methods include both conventional “econometric” [probabilistic] methods and microsimulation. They have similar requirements for forecasting of traveller characteristics, but microsimulation also allows for situations where the probability of choosing any one travel alternative is mathematically intractable (the classic case being where the model adopted involves multiple integrals). It may provide a means of exploring (by repeated runs) the uncertainty inherent in a given model. It may lend itself to explicit representation of the “search” process by which the decision-maker identifies and obtains information about available alternatives. Less formal reasons for using microsimulation may also apply: for example, a requirement to have output in terms of discrete units assigned to each alternative for use in subsequent processing - which might be another microsimulation model, but might also be a dynamic graphic output routine.

State-of-the-art models such as that for Stockholm show the sophistication it is possible to achieve in a highly-elaborate application of the well-established discrete choice approach applied to disaggregate data and to a variety of conventional and unconventional variables. The same model could be built in microsimulation form, but it is not obvious that this would be advantageous, and there would be some disadvantages - for example, it would be highly inefficient simply to replicate a logit model by microsimulation. However, if we were to move away from compensatory models⁷ towards non-compensatory ones (including models in which people may be ignorant of certain alternatives) then the benefits of working with established discrete choice techniques may be reduced and microsimulation may offer greater advantages.

A special case of the earlier arguments about segmentation arises in meeting the requirement for finer spatial detail, whether this is necessary in itself (see Requirement 14) or a means of improving the performance of models in other ways. Beyond a certain level of detail it becomes unreasonable or meaningless to work with conventional zonal averages and probabilities, and more appealing to work in terms of individual units (this is a special case of the argument about segmentation, above). Microsimulation produces meaningful-looking results even at the finest level: for example, each simulation shows each individual traveller in the sample choosing one particular mode and destination rather than distributing herself in small fractions over many alternatives.

The disadvantage is that each simulation is one outcome from the distribution of outcomes that successive simulations will produce for the same input conditions. To establish statistically reliable results of what is likely to happen for small areas, rather than a single illustration of what could happen, it will be necessary *either*

- to carry out many simulations and to consider describe the distribution of the results, *or*
- to apply other techniques for reducing variation between runs – which exist, but need to be investigated.

We agree with Miller (1997, p169) that the properties and potential problems of microsimulation models in transport have received surprisingly little attention. We also have some concern that microsimulation's ability to support dynamic graphics of short-term behaviour such as traffic flows may in practice distract attention away from broader issues (such as modal shares) which are graphically less exciting.

Overall, we conclude that

- the methodological developments identified in the previous section are likely to be disaggregate in technique;
- microsimulation methods *may* be appropriate;
- the implications of using disaggregate, sample-based models in either conventional probabilistic or in microsimulation forms will need to be examined carefully and compared with the implications of attempting to build equivalent aggregate models.

5 CONCLUSIONS AND RECOMMENDATIONS

Our main conclusions were as follows.

Transport modelling needs to adopt some of the methods or characteristics of *dynamic modelling*, with reference to both short-term and longer-term responses.

It also needs to adopt some of the methods or characteristics of *activity modelling*, in order better to understand and represent the constraints acting on travel choices, and on choices between travel and telecommunication.

Greater use needs to be made of *land-use modelling and land-use/transport interaction modelling*, to examine the wider implications of transport change and to provide increased detail (for example, of population segments) as inputs to transport modelling.

Future models are likely to be increasingly based upon samples of individual households, persons and trips, and research is needed into the *relative advantages of disaggregate modelling versus microsimulation*.

There is a general need for greater *segmentation* of transport models, by person type and by travel purpose.

There is also a general need to improve the representation of *quality variables*, especially those describing the quality of public transport, and to improve the ability to predict how quality will change as a result of policy measures or other changes, taking account of the division of public transport supply between different companies. The latter is part of the wider and highly significant need to *improve modelling of the supply* of public transport, of car parking, and possibly of other modes such as taxis and hire cars.

There is a need to understand better how detailed design and other changes affect the attractiveness of *walking and cycling* relative to other modes, including

their attraction as exercise or recreation; agent-based modelling may have a role to play here.

Greater attention needs to be given to ensure that maximum use can be made of *data*, and to develop methods of creating appropriate synthetic data for new forms of models.

Models should offer better facilities for the use of *graphics* to check and present inputs and outputs and to explain the results obtained, either directly within the model or through efficient and reliable interfaces to standard software with graphics and mapping capabilities.

The idea of *simplified or reduced models* for high-speed and/or “public” operation should remain under review, but with regard for the possible conflict between simplified and standard models.

Methods of appraisal should be developed which reflect the advances in understanding and prediction achieved in new models.

Any programme of model development should include provision to *train new modelling researchers*, and will need to be followed by a programme to *retrain existing modellers in new methods*.

Model development work should involve continuing testing of the benefits of alternative methods in terms of *parsimony, convincingness and usefulness for policy analysis*.

Consideration should be given to the economies and greater consistency that could result from building models with *greater versatility* in policy analysis, rather than undertaking separate analyses of different policy issues.

Efforts to develop new models to meet the requirements *should not be limited* by consideration of how readily they could be used in wider practice or by any restriction on how far they can diverge from current modelling approaches.

Further thought should be given to

- the kinds of *programme or project arrangements* in which model advance might best be pursued, and
- the possibility of *a national travel/activity survey* as a common resource for such work.

Consultation on the ideas and recommendations discussed in this project is essential⁸.

6 DISCLAIMER

The work described in this paper was carried out by a consortium of consultants directed by David Simmonds Consultancy under contract to the Secretary of State for the Environment, Transport and the Regions. The views expressed are those of the authors and not necessarily those of the Secretary of State or his successors.

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NOTES

¹ The three Reports (Requirements; Possibilities; Conclusions/Recommendations), and the earlier Working Papers on requirements, are all available in .PDF format from www.davidsimmonds.com

² Note that “duration” may refer to anything from the length of time spent by an individual on one activity in one continuous period at one place (probably hours, maybe only minutes) to the length of time that a household resides in the same house (probably years and possibly decades).

³ For discussion of how transport demands are generated in LUTI models, see the discussion of interaction-location and location-interaction models in the DETR’s *Guidance on Methodology for Multi-Modal Studies* (Volume 2, page B9).

⁴ Hence the definition given in the *New Fontana Dictionary of Modern Thought* (1999): “Systems dynamics is ... a style of model-building in which large structures are built which make little use of empirical evidence or previous knowledge of the subject”.

⁵ Figures in brackets refer to the Requirements listed in Table 1.

⁶ For example, given appropriate data, it is theoretically and practically attractive to use travel-group size and composition as explanatory variables in disaggregate modelling of leisure travel, but not at all easy to forecast future changes in group sizes and compositions.

⁷ ie those in which a highly undesirable level of one characteristic of an alternative can always be balanced by a highly desirable level of another characteristic

⁸ Plans for consultation are being formulated at the time of writing (June 2001) and will be announced via www.davidsimmonds.com and elsewhere.