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FORECASTING NON-HOME-BASED TRIPS AS COMPONENTS OF A TOUR MODEL

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This paper presents a method for the forecasting of non-home-based trips within the framework of a disaggregate travel demand model. Although primary concern is focused on the practical and implementational aspects of modelling trip chains, we also review a number of issues and trade-offs that led to the particular implementation selected (and the approximations made in the process) against the background of the ongoing development of transportation demand models. In particular attention is given to the level of detail and accuracy in the representation of behaviour, computational complexity, efficiency of estimation, and ease of implementation and operation.

1. APPROACHES TO TRAVEL DEMAND MODELLING

The state of practice in travel demand models has evolved steadily if slowly over the past 20 years (see Ben-Akiva (1992)) and recently activity-based approaches to transport analysis are receiving more attention. Jones (1995) highlights two paradigm shifts in this development: the first from vehicle flows to person trips, the second from trips to activities. The basic concept that travel demand itself is derived from the demand for goods, services etc. (in short: their activities) has been noted earlier by (e.g.) Jones (1983), Antonisse *et al.* (1986) and Cascetta (1992).

In the light of the first paradigm shift from emphasis on vehicle flows towards emphasis on person trips with vehicle flows as a derived quantity, a resulting shift in modelling methodology (e.g. introduction of mode choice) and the associated data requirements as described by Jones (1995) can be seen as a natural development. With the person-based approach came a demand for evaluation of policies that acted directly on people's behaviour, which encouraged a shift towards disaggregate travel demand modelling (Ben-Akiva *et al.*, 1977, Daly, 1982).

An increase in the modelling of causal relationships underlying travel behaviour itself can be seen as a common thread in much of the model evolution in the past 20 years. Behavioural analysis has provided insights into travel behaviour in terms of simple properties of the underlying activity pattern.

A discussion is under way on how best to incorporate these insights into practical travel demand models. In principle two approaches are possible: a more fundamental, *ab initio*, approach in which one tries to build travel models from the bottom up on basis of individual activities (e.g. through micro-simulation), and a more evolutionary approach, in which daily activity-patterns are incorporated into the framework of conventional disaggregate modelling, as represented in Ben-Akiva and Bowman (1995). An example of a more fundamental approach towards travel demand modelling on the basis of activity analysis, which may lead one to the use micro-simulation of individuals' daily activity pattern as a means for modelling travel behaviour, can be found in Ettema *et al.* (1995).

However, in agreement with the statement by Jones (1995) that "*As with the first paradigm shift, in many areas activity-based approaches offer an additional layer and an enrichment of the traditional framework rather then a straight replacement*", the authors contend that there is a continuum between the paradigm of trip-based modelling and the ab initio approach of activity-based modelling, and that evolution along this scale can be seen in a number of operational travel demand models.

The first step along the spectrum from trip-based to activity-based modelling is taken by the introduction into the models of the concept of the "tour", i.e. the total travel required to take part in an activity, extending from the trip, the one-way movement from (e.g.) home to activity site, which does not incorporate the need to return. Further steps are the introduction of timing constraints, household interactions and the integration of a wider range of decisions, all of which have now been incorporated into at least one practical planning model (for Stockholm, Algers *et al.*, 1995) which is discussed in more detail below.

Considerable steps have thus already been made in introducing elements of the activity approach into practical modelling. In this paper we focus on the first of these, the treatment of tours, and in particular on the way in which non-home-based trips can be handled in a much improved way within the tour framework.

2. THE TOUR BASIS FOR TRAVEL DEMAND MODELLING

It has long been acknowledged in transportation analysis that the analysis of travellers' behaviour can be improved by taking the basic unit of travel as a 'tour' - a round journey beginning and ending at home - rather than as a 'trip'. The immediate advantage of this approach is that, viewing travel in units of tours rather than trips, it is possible to maintain coherence in the modelling of mode choice, destination choice and time of travel. This improvement alone would be sufficient to justify the tour approach, but two important further advantages are also gained.

- First, in recent years research on travel behaviour has come to focus more and more on the 'derived demand' nature of travel and hence on the out-of-home activities that are the underlying cause of journeys. Since the tour is the basic unit of travel required to take part in an out-of-home activity, the representation of travel as tours gives a much better linkage to activity modelling than would be possible with a trip-based model.

  Research on activity patterns, for example as described in the papers presented at the recent conference in Eindhoven ("Activity Based Approaches: Activity scheduling and the analysis of activity patterns", Eindhoven, The Netherlands, May 25-28, 1995), stresses the need to take account of a number of interactions and constraints within households and in time and space which are simply not possible in a person-trip approach but which become much more tractable when a household-tour approach is taken.

- Second, non-home-based trips can form an important means of gaining access to activities, a fact that is fully recognised by the activity research. In a model in which tours are treated in full, it is possible to represent non-home-based travel in a coherent and behaviourally acceptable way. That is, the requirement to make a non-home-based trip can be set in the context of the conditions under which it is made, in particular the activities undertaken at both origin and destination, and set against the alternative means of meeting the requirement, generally the making of a separate home-based tour.

Thus the use of the tour approach is not only advantageous in increasing the coherence and internal logic of the modelling, but also offers theoretical advantages and improved quality for the modelling of non-home-based trips.

This paper develops an approach to modelling non-home-based trips which is consistent with an activity-oriented approach and provides technical means for handling more complex tours which should be helpful in activity modelling. Rather than contributing to research on activity modelling, however, the main aim of the paper is to improve the practical treatment of complex tours within the disaggregate modelling framework.

Analysis of actual travel patterns shows that an important minority of the tours that are made have more than one destination. That is, in most cases travellers visit just one destination (work, shop or whatever) before returning home, but that in an important number of cases more than one destination is visited (e.g. shopping after work) before returning home; in studies of some areas (larger cities, perhaps) more than half of the tours are observed to visit more than one destination. Apart from the need to model all these trips accurately for their own sake, policy makers are often concerned that specific policies under consideration may substantially affect the balance between home-based and non-home-based travel.

A straightforward approach to the modelling of complex tours is offered by the 'primary destination' method (Weisbrod and Daly, 1979). In this approach, the destinations that are visited on each tour are ranked in 'importance', the most important being termed the 'primary' destination, the others 'secondary', 'tertiary', etc.. This ranking can be done on the basis of a number of criteria (see Antonisse *et al.*, 1986), of which the most satisfactory seems to be the 'activity time', roughly the time spent by the traveller at each destination. An arbitrary hierarchy of activities, with work ranked highest (compulsory activities ranked higher than discretionary, see Cascetta (1992)), gives approximately the same results.

The primary destination approach gives a rational basis for travel demand modelling and this advantage clearly outweighs the suggestion of arbitrariness that is inevitably associated with a method of this kind. The alternative would be to give all destinations equal importance, which is intuitively implausible and much more complicated.

The modelling issues concerned with non-home-based trips can be treated consistently in the primary destination framework. Timing, mode and destination choice for secondary (and subsequent) destinations are then all related to the decisions taken for the primary destination. The decision to visit a secondary destination, i.e. to make a *detour*, is related to the accessibility of secondary destinations (given the paths followed to reach the primary destination), set against the accessibility of alternative destinations for the same activity that can be reached by making an additional primary tour. Scheduling is also treated relative to the timing of the primary activity.

The estimation of models describing the choices involved is difficult but can be achieved with modern methods (see Algers *et al.*, 1989, 1992, Ben-Akiva and Bowman, 1995). The calculation of the accessibility for the three relevant trips (to and from the secondary destination less the direct trip that does not need to be made) is a complicated exercise in transport network analysis, but once this has been done the model estimation itself is reasonably simple.

The problems of using the model for forecasting are also difficult and quite different in nature to those of model estimation. The relevant accessibilities need to be calculated in this case also, but there is an additional problem arising from the fact that three locations need to be considered. Unless special approaches are adopted, these three locations can cause the need for calculations to be required of the order of n^3 (n is the number of zones). Methods for dealing with this issue are described below.

3. APPROACHES IN PRACTICAL DISAGGREGATE MODELS

The improvements that can be made in modelling by the adoption of the tour approach can be seen by comparing model systems that are used in practice. For illustrative purposes, we compare two models that have been set up on the basis of disaggregate modelling techniques: the trip-based 'MTC' model of the San Francisco Bay Area, which was one of the first practical disaggregate model systems, and the tour-based 'SIMS' model of Stockholm, which has only recently been implemented.

3.1 The MTC Model

This model is presented in CSA (1980) and is used as an example by Ben-Akiva and Lerman (1985), who present a summary of it. More recently the model has undergone major recalibration and maintenance, as described by Kollo and Purvis (1989). In this way it reflects the experience with the original model, and provides some insight into the direction in which the model has been taken.

The MTC model system is a disaggregate travel demand forecasting system for home-work trips, home-based social/recreational trips, and home-based shopping trips. The structure of the model system is based on a three-stage choice hierarchy. At the top of the hierarchy are the slowest changing aspects: the 'urban development decisions' which determine the location of jobs and housing. In the middle are the 'mobility decisions' which comprise: number of workers per household, location of workplace, residential location, car ownership, and travel mode to work. The lowest level in the hierarchy consists of choices made on a daily basis, such as frequency, destination and mode for non-work trips. The output of the models consists of tables summarising the choices made, and in particular trip tables for home-based work, shopping, and recreation trips, and non home-based work trips. Business trips are not modelled separately but are included in the work trips.

Although the emphasis of the MTC model is clearly on home based trips, the interest in this article is in its non-home-based component. In the original design, Non-home based trips were modelled through two logit models, one predicting the choice of *origin* for non-home-based trips to a given destination, the other predicting the choice of *destination* for non-home-based trips from a given origin. In each case a 'zero' choice was used to represent a direct connection from or to home.

These models were applied after the work-based trip models to ensure that the decision makers are individuals who are already assigned a trip by one of the higher-level models. Although in principle with this structure separate models can be estimated and applied for all trip purposes, CSA (1980) mentions non-home based models for work trips only. There were separate NHB models for transit and car modes, based on the choices made in the work trip model.

The models were estimated and validated first on disaggregate data, using all known characteristics of the households. Subsequently, aggregate versions of the models were derived, segmenting the population by three levels of car ownership and by income, estimating average values of the other socio-economic variables for each segment. The aggregate versions were used for detailed forecasting. The variables appearing in the models were employment density, distance, travel time and travel cost.

As described by Kollo and Purvis (1989), the model system was updated and recalibrated in using the 1980 Census and the 1981 Household Travel Survey. In this update, for simplicity the NHB models were changed from the logit models described above to linear models for NHB trip generation and attraction, a gravity model for trip distribution and a logit model for mode choice. It appears that the sophisticated original design proved too complicated in practice.

It is also interesting to note that Kollo and Purvis draw a distinction between the development of the individual models and that of the model system, and that software preparation is mentioned as a separate step in the development process. The structure of the model system was kept intact, but the mathematical form of some of the models was changed e.g. from logit to gravity-type models. The six steps in the overall system development process were: specification, estimation, disaggregate validation, market segmentation, software preparation, aggregate base year validation. Some tests caused a back-up of several steps in the specification / estimation / implementation / validation chain. The step of market segmentation was used to avoid excessive averaging when aggregating the models.

3.2 The SIMS Model

The SIMS travel demand model for Stockholm County features an unusually complete treatment of the integration between travel frequency, mode-choice and destination choice models, trip chaining. Further important aspects of the system are detailed household interactions and a highly segmented representation of the population (Algers *et al.* (1989, 1992, 1995)).

The model system contains a separate model for each of six main travel purposes: (commuting, going to school, business travel, shopping (two submodels), social visits and service & recreation travel (four submodels)). Here we concentrate on the Business travel submodel, since the explicit treatment of trip chains is most clearly modelled here, without the complication of car allocation and travel group formation that occur in other purposes. It is applied to the population of people eligible for making business trips living in each zone (i.e. employed people), giving the expected number of travellers by travel frequency, trip type, travel mode, and destination. The model is a nested logit model which gives joint probabilities for trip frequency, trip type, mode and destination. The model has a structure as illustrated in Figure 1.

The various levels of the model are connected by logsum variables[1] that capture the attractiveness of the nest in the choice tree that they represent. For this reason the model is applied by calculating the utilities from the bottom up. First the utilities of each destination are calculated for each of the possible paths from the top of the tree downward, then the logsums of the destination-choice layer are evaluated, which give

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the logsums needed in the evaluation of the mode-choice utilities. This is done independently for each of the population segments (person types).

In the components of SIMS that deal with other travel purposes, additional features are incorporated such as car allocation, which is modelled as dependent on the accessibility of the workplaces with and without the car, and travel group selection, which again is modelled on the relative accessibilities of destinations to workers and non-workers, conditional on car availability etc.. Several of these sophistications seem to be new in practical forecasting models, but the model estimation shows that they are significant in explaining the choices that were observed (Algers *et al.* 1989, 1992).

There are substantial similarities between MTC and SIMS, e.g. the use of logsums to link the various submodels, the fact that car ownership is endogenous in both, and the enforcement of mode consistency in non-home-based travel. However, a number of key advances have been incorporated in SIMS:

- tour modelling instead of trip modelling, with all the associated benefits of this change
- separate modelling of the primary destination
- a more detailed treatment of household interactions; however, the MTC model predicts the *number* of workers in the household, while SIMS models the frequency of work tours for employed persons; MTC treats ‘primary’ and ‘secondary’ workers differently, while SIMS models the joint work choices of the first two persons in the household and models subsequent persons’ work travel differently;
- more detailed definition of purposes, much more segmentation by person types and a more detailed zoning system;
- the distinction between primary and secondary destinations and the modelling of the choice between chained and secondary tours; SIMS also extends non-home-based modelling to all secondary purposes on work tours, MTC appears to allow only business purposes.

Several of these advances have become possible because of the improvement in the computer power : price ratio over the last few years. Others were necessary because of the nature of the travel choice situations in Stockholm, where public transport and slow modes are important for travel in the city and because of the complicated interactions that arise from the high rate of female employment.

In the SIMS business model, the segmentation takes account of licence holding by the individual, car competition in the household (for licence holders only) - taking three levels: no car; conditional car availability; free car availability - sex and whether a lease car is owned (a common means of ownership in Sweden for car used for work). A total of 20 segments is thus used in most of the business models. In the frequency model only, the type of occupation and the employment location type give an additional 21 segments, making 420 in total.

In the MTC model, trip chaining is modelled as having a stationary Markov chain structure (stationary transition matrix, no memory). As observed in Kitamura (1983), the implicit assumption that the same transition matrix applies to all transitions (NHB tours) is too restrictive for a rigorous modelling of behaviour. We note that the purpose of separate legs within a tour may vary (as in Home-Work-Business-Shopping-Home tours), but also that the total distance travelled and the total amount of time spent may influence the transition probabilities in the consecutive legs of the trip-chain. In the SIMS model, NHB tours are modelled for business, shopping, and recreational trips separately, and frequency is modelled together with mode and destination choice pertaining to that frequency.

The benefit of the tour formulation is, apart from the improved model coherence, that the model can represent the need to visit a business destination by (a) undertaking a new home-based tour; or (b) by a tour from work, returning to the workplace afterwards; or (c) by making a *detour* on the way to or from the workplace. The model, integrating destination, mode and tour type choice can be estimated as conditional on the home and workplace of each employee: this process is in principle reasonably straightforward once the complicated network processing problems have been solved. However, it was necessary because of the size of the model to undertake the estimation of the entire structure sequentially in parts, as explained by Algers *et al.* (1989, 1992); the more advanced computer hardware and software now available would allow this decision to be reconsidered in a future model system.

These two model systems indicate how it is possible to estimate either trip-based or tour-based models with a coherent treatment of NHB trip-making, albeit in these two cases limited to detours on the work journey. The implementation of a model with NHB trips, however, poses new and different problems.

4. MODEL STRUCTURE AND IMPLEMENTATION

The primary destination approach, outlined in Section 2, supposes that there exists a hierarchy among the activities in which an individual or household participates - and hence among the destinations visited - such that decisions made concerning activities and destinations 'lower' in the hierarchy can be considered to be conditional on the decisions taken concerning 'higher' activities and destinations. This hierarchy is most clear and acceptable for combinations like work and shopping, but offers a method of approach to more general combinations of activity and travel.

In this context, the key decision made by the individual or household is whether a particular activity will be carried out by generating a new home-based trip or whether it can be accommodated as a detour on a tour made for another purpose. From a behavioural viewpoint, this decision incorporates the essential trade-off between the time saving of the detour against the flexibility of making the second tour at a time, by a mode and perhaps by a person that the household may prefer. From a policy standpoint, the aggregate of these decisions by many households embodies the concern that policy options may have consequences in affecting the number, mode and location of non-home-based trips that could invalidate less sophisticated forecasting.

Given the need to visit two destinations, the choice to be made by the traveller, as illustrated in Figure 2, is whether to travel

a) Home-based: home - primary - home, home - secondary - home (4 trips) or

b) Chained: home - primary - secondary - home (3 trips) or

c) Work-based: home - primary - secondary - primary - home (also 4 trips).

It will almost always be the case that the second of these is significantly shorter (less travel disutility) than the others. The direction of travel, i.e. whether the secondary destination is visited before or after the primary, is less central to determining the travel disutility. More important is to impose the relevant time and mode constraints, e.g. it may not be possible to go home from work and still get to the shop before it closes, or the secondary destination may not be accessible by public transport, making it necessary to return home to pick up the car if public transport was used to get to the primary destination. Thus the central issue is to set the differences in travel disutility between the three options against their convenience within the traveller's daily schedule.

Once this key decision can be modelled, practical models can be developed that take account of variation in the hierarchy of activities, the detail in which constraints are represented and the number of destinations modelled in a single tour (primary, secondary, tertiary, etc.). Other decisions such as the choice among the alternative secondary destinations, the choice of mode and time of travel can be based on the same information.

As illustrated in Section 3, it is possible to estimate models that take account of the possibility of organising travel in different ways to visit the destinations required. Both the MTC and SIMS models represent the option of non-home-based travel, SIMS integrating it more coherently in the overall travel and activity pattern of the traveller's day. The model estimation shows the significance of the links between non-home-based and home-based travel. However, the implementation of models of this type presents difficulties concerned with the number of calculations that must be made. In particular, the treatment of NHB travel and the number of person types need attention to avoid excessive calculation.

4.1 Travel Disutility for Secondary Destinations

Figure 2 illustrates the three basic patterns by which a secondary destination can be visited. The travel disutility of the first of these, involving a new home-based tour, can be derived as two *independent* calculations, home-primary and home-secondary, with the number of calculations being of the order of $2n^2$ (if n is the number of zones); this is because the location of the primary destination does not affect the accessibility of the secondary destination. Similarly, the last pattern, in which outbound and return trips are made from and to the primary destination to visit the secondary, can also be calculated with $2n^2$ steps, because the location of the home does not affect the accessibility of the secondary destination from the primary. However, the middle pattern, with a 'Chained' tour, requires in principle n^3 calculations. When n is large, and in SIMS it is about 800, the number of calculations to evaluate this model in full would be excessive.

One approach to dealing with this problem is to approximate the impact of one of the locations on the choice of secondary destination and the other aspects (mode, time, etc.) concerned with that journey. Only in this way can the dimension of the calculation be reduced from n^3 to kn^2 (with a reasonable constant k). An alternative is to work with a high level of sampling. While sampling is a good approach for some types of policy analysis, policies for which a traffic assignment is needed, i.e. where link flows or congestion assessments are required, will require complete matrices and sampling must accordingly be restricted. For example in the SIMS model, stratified samples of about 25% are used for both primary and secondary destinations, leaving matrices that are adequately ‘full’ for assignments but not in itself reducing the ‘n^3’ problem enough to run in a reasonable time.

The approach that is adopted for the SIMS implementation, therefore, and which would also be suitable for other models of this type, is to base the choice of secondary destination for tours of more than two trips on the accessibility from the primary destination only. The loss caused by this approximation is that the effect in practice that secondary destinations will be chosen that are ‘on the way home’ will not be represented in the model, secondary destinations will be predicted that are centred around the primary destination rather than lying between there and home. This approximation means that the implementation of secondary destination choice (and of mode, time,..) are very similar in SIMS to the implementation in MTC.

The model of choice of tour type can be applied using accessibilities based on the ‘biased’ secondary destination choice. This is because the *additional* disutility of the detour to the secondary destination is

$$HP + PS + SH - (HP + PH) \quad = \quad PS + (SH - PH)$$

and the average values of SH and PH (averaged over all destinations S and P) are approximately equal. A constant correction is entered into this model to account for the impact on average accessibility of the destination choice bias. A further correction is needed for the same reason to the overall frequency model. Neither of these corrections is difficult to calculate.

The advantage of SIMS with respect to MTC is that the *estimation* of the model takes account of all components of the tour. The estimated model can be used with a high level of sampling when policies are to be investigated that do not require a full assignment. Moreover, the choice between the various types of tour is based on measures of overall accessibility that do take account of the complete tour.

The destination probability matrix from the work model is used to estimate the expected utility from of making a NHB tour when calculating the utility of prospective NHB business tours. In this way the entire travel pattern is taken into consideration. In contrast, in the original formulation of the MTC model, two separate models are used to calculate expected origin and expected destination of NHB trips, without retaining origin information.

4.2 Segmentation

A further difficulty in achieving a reasonable run time is that the model was estimated on a survey dataset containing a large amount of information on location of home and work, household composition, car ownership level, sex, profession (e.g. legal, financial, ..., other), activity at work place (building, medical, construction, transport, trading), whether they had lease-cars, and the type of their recent trip (home-based, work-based, chained) etc.. Many of these attributes proved to be significant in affecting the travellers’ choices.

It was not feasible to include all of the decision-maker’s attributes in the segmentation, since that would have led to a very large number of segments, many of them without representation in the base sample. Nor was it possible to base the model on a detailed sample, again because the run time would have been excessive. Further, not all the attributes found to have significant explanatory power are also available in the datasets on which the model is to be applied. This difficulty was partly circumvented by using two different segmentations in the model: one for the frequency model, and another for the trip-type, and mode-destination choice. The segmentation used for the model for each purpose was also unique to that purpose. The distribution of the population over the reduced segmentations was estimated on basis of other characteristics that were available. In e.g. the commuting model, certain external effects (such as the time of the year, average income, etc.) could not be incorporated into the segmentation but had to be brought in either as extra model parameter, or as average per segment. Similar, but much more extensive averaging was used in the MTC model as described above.

5. PROGRAMMING ISSUES

The demand model for Business trips has been implemented in FORTRAN-77, containing 8900 lines of code divided over 50 subroutines. The implementation was done very carefully to minimise the calculations required, increasing the complexity of the program but making very large reductions in time. The final run time is about 60 min. on a 66-Mhz. 80486-based PC. An indication of the amount of data processed is given by the following statistics (see also Algers *et al.*, 1995 for more recent applications experience).

Table : Amount of input data processed for Business model

Data Function	Data Type	Size (Mb.)
Input	zonal data	0.6
	L.O.S. data	21.0
	population data	2.0
	O-D probabilities from work model	2.7
In-core	assorted arrays	3.5
Temporary	scratch space on disk	122.0
Output (per scenario)	9 Tour matrices (one for each mode/trip-type)	12.0
	aggregated table	0.5

With respect to the implementation, the computational environment is usually unnoticed until it becomes a limiting factor (e.g. insufficient core memory, limited on-line storage for data and results, poor development environments, and slow turnaround time). Such constraints significantly increase the development cost since they may require workarounds and trade-offs between e.g. speed of computation, memory requirements and ease of programming. At the time of implementation (1992) the available PC's were only just able to cope with the requirements of the model implementation (i.e. 3.5 Mb. of core memory).

The run-time for this particular model is largely spent on the treatment of chained trips, which requires calculation, storage and retrieval of 122 Mb of travel disutilities. The latest generation of computers reduces the computation time, but the data storage requirement remains significant. Despite the simplifications in the treatment of secondary destinations and segmentation, the model still poses a significant computational burden. On the other hand, despite the degree of sophistication embodied in the model, its computational performance compares well with other large-scale models. Detailed attention was also paid to the programming of the models.

6. CONCLUSIONS

In this article we have identified both a number of opportunities and difficulties in modelling NHB trips. The opportunities lie in the fact that it is possible (and practical) to incorporate fairly elaborate modelling of activity-based aspects such as trip-chaining, household interaction, effect of level of service on trip frequency, into conventional disaggregate travel demand models. The difficulty is that implementation of the resulting model systems requires somewhat more implementation effort then is the norm. Obviously the implementation effort is one of the factors that determine which models are practical enough to be 'state of practice' rather than 'state of the art'.

Because of the importance of the behavioural complexities addressed by SIMS and similar models, it would be valuable to draw lessons from the work reported that could reduce the effort required for a similar study in the future.

One of the lessons learned is that it is absolutely necessary to have a completely unambiguous and explicit model specification at the time of implementation. Care must be taken with respect to data availability when the model is to be applied. Much can be gained in this respect by ensuring good communication between the model estimation team and those making the implementation.

A very pragmatic aspect to be considered is the allocation of resources: for some applications (e.g. research settings, one-off studies) no resources are available to custom-code the model system. In such cases a model-estimation package which can apply the estimated model without any further coding being required (e.g. HCG's ALOGIT package) is recommended. Custom-coding the model can then be reserved to those occasions, such as in Stockholm, where a prediction system is needed for routine use, and model turn-around time is a major issue.

In some cases it may even be advantageous to try to define model specifications to reduce implementation problems.

Further developments in modelling, implementation procedures, and computer software and hardware are needed. Meanwhile, the methods described in this paper offer the means to incorporate several important aspects of travel behaviour into practical model systems.

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Figure 1: **Model Structure for Business Travel Model**

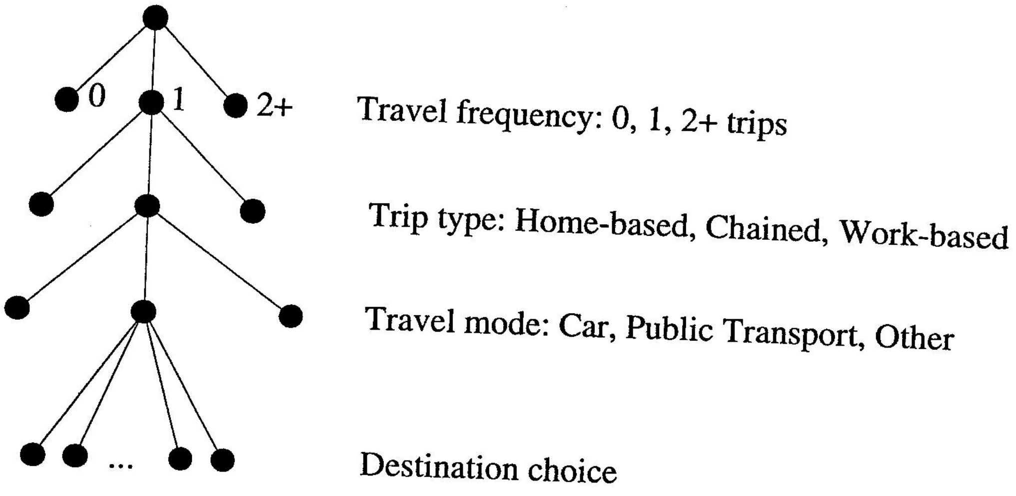
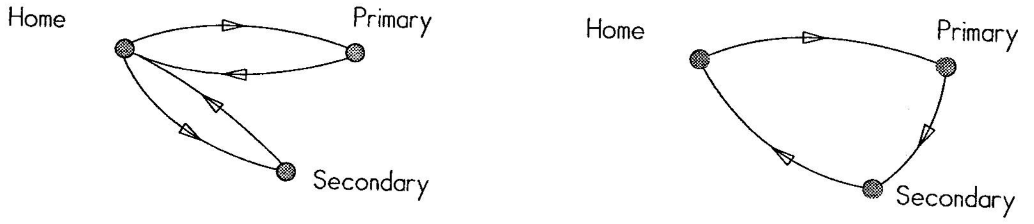


Figure 2: **Tour Type Decision**



Home-based: Two separate tours

Chained: Detour to secondary destination

Work-based: Tour with NHB tour