Report on investigations of household travel decision making behaviour *)

by
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1 INTRODUCTION

The paper reports on a research project "An Investigation of the Travel Decision Process". The rationale for the study acknowledges Ben-Akiva's (1974) cautioning tenet that "In general, it is impossible to determine the correct specification of a model from data analysis. It should be determined from theory or *a priori* knowledge based upon experience with, and understanding of, the phenomenon to be modelled".

This statement reflects the current concern about the "behavioural realism" of alternative trip model structures, which has increased with an awareness of their limited ability to handle research problems posed by recent changes in urban passenger transport policy. Considerable discussion has surrounded questions of which travel choice models correspond more closely to consumer behaviour theory, or show better statistical fits, or are intuitively more reasonable. Here, an initial review of observed responses made by householders confronted with certain contemporary policy measures will lead to the suggestion that the shortcomings of current trip models may be less attributable to empirical features than to the way in which the concept of demand has been applied to the phenomenon of travel behaviour under these conditions.

An alternative framework for the analysis of travel behaviour is described, together with results from exploratory work using this approach towards an "understanding of the phenomenon".

Finally, implications for the development and application of planning models compatible with this characterization of travel are discussed.

2 EFFECTS OF THE NEW POLICIES UPON HOUSEHOLD TRAVEL ORGANISATION

2.1 Urban car restraint

Policy before the sixties was largely a matter of planning for peak demands on road space, and the trip model was developed to forecast the future pattern of work trips, assuming unrestrained car use, together with general conditions of *ceteris paribus*. A subsequent reappraisal of urban transport policy (eg. see OECD, 1975) emphasizes a need to reverse previous trends, using incentives to persuade the public to break existing habits, especially those relating to urban car use.

In the UK, 'new' policies have been pursued within several provincial town centres. During 1976 in Oxford, as a follow-up to a travel survey, some sixty households were interviewed in some depth, in order to assist an understanding of the effects of a comprehensive policy towards "Balanced Transport". The policy package had included escalating parking charges, extinction of on-street parking, closure of some streets, and attempts in general aimed at making public transport a more attractive alternative to the car, through disincentives toward car use.

Drawing from the report by Heggie (1976), and considering for the moment car based shopping journeys, it is apparent that effects of coercive policies, such as restraint on car use, can be both varied, and complex. Responses included the following, in order of quantitative importance:

Consolidation of shopping activities. (eg. schopping previously carried out two days per week, now combined within a single journey)

Transfer to another destination (eg. an out-of-town shopping centre. This was often accompanied by transfer of some shopping activities to another household member; eg. 'husband' carrying out specialist shopping in town during his lunch hour).

Transfer to public transport.

Transfer of journey(s) to different times of day, or different days. (eg. shopping switched to day when shops are open during early evenings)

Existing trip modelling procedures could in principle attempt to forecast changes in patterns of modal split, trip distribution and network flows that were involved. However even the most accurate forecasts would fail to account for changes in the timing of trips, and to a large extent changes in the numbers of trips implied by the evidence of what is conventionally termed trip suppression, and release of latent demand. But more significant implications for both research and policy were apparent from inspection of changes in the total daily trip patterns at the household level.

It was clear that changes in the characteristics of trips made by an individual traveller frequently affected both other trips previously made by this person, and trips made by other members of the same household. For example, car-based commuter journeys had frequently involved shopping, errands or visits being made "incidentally" during the journey home; transfer of the main journey to bus apparently then led to special journeys being generated from home during evenings or weekends. Effects upon other members of household were perhaps more complex; the release of the car by a commuter for use by the housewife in off-peak hours (in preference to use of 'park-and-ride') tended to in-

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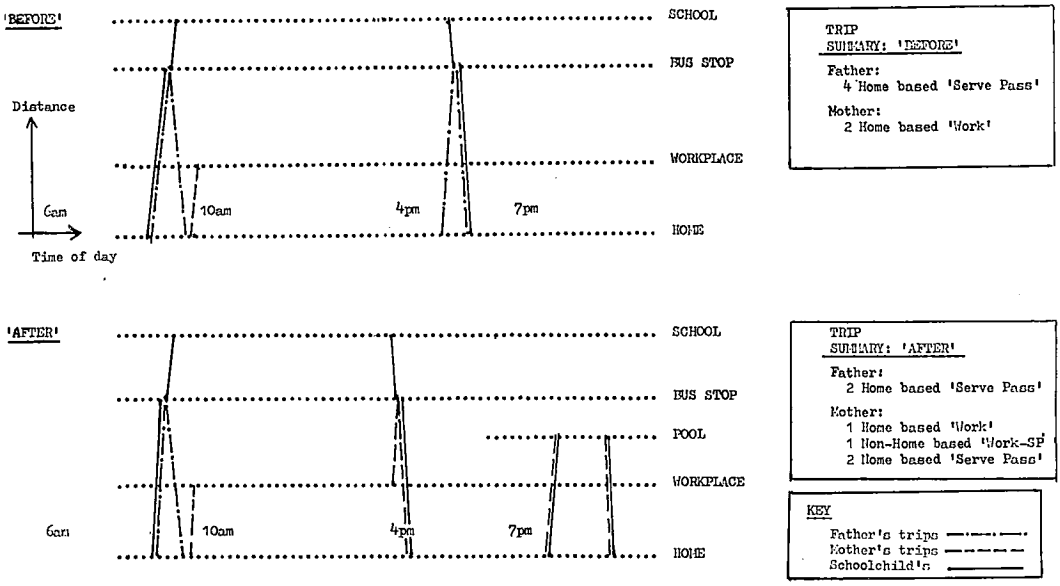


Figure 1 - Example of non-marginal adjustment to household trip pattern
Following changes to school and school bus times

volve substitution of off-peak trips from bus and walk modes. The former of course served to increase the peak loading problem for public transport operators, the latter contributed toward an upsurge in vehicular travel. Similarly, 'doubling-up' of 'serve passenger' trips was reported. For example; to replace a joint shopping activity in town accomplished in one journey, husband would drop wife in town to shop, then return home or drive elsewhere, to collect her and the shopping later in the day.

Secondary effects of policy can therefore be counter-productive if these are not anticipated at the planning stage. They may tend to offset benefits arising from the primary influence. In addition to this, traffic management schemes evidently incur important effects upon family routines, both in and out of the home; yet this is a dimension for the most part inaccessible to current evaluation methodology.

2.2 Other contemporary policy effects

Although some monitoring studies have been carried out into other contemporary policy measures, there is as yet very little detailed information available as to their precise effects. This situation may partly reflect the novelty of the policies, but is also the case that results are often treated in terms of indices, such as a fares elasticity or modal split value, which obscures the identification of response types at a disaggregate level.

Heggie (1977) reviews, in addition to work on car restraint effects, before-and-after studies of 'flexible working hours' introduction (Shapcott, Steadman 1977), and changes to school hours (Jones & Dix 1976). Both were adopted in the U.K., and both were motivated by the aim of spreading peak-hour loadings on road networks and bus systems, respectively. Noting that the 'flexi-hours' study showed that "...only a few people had deliberately altered their travel times so as to avoid the heaviest traffic", but that the opportunity to vary personal working schedules had instead "...enabled staff to get to the shops...in the centre of Reading in their lunch time...", Heggie concludes; "the stereotype of the traveller striving to avoid congested peak hour travel may be misleading. The substitute in this case was not always travel in the off-peak, but the rescheduling of another linked activity to another time of day, depending on the relationship between home, work and shopping locations, to another destination". The picture is that of the commuter minimizing journey times, perhaps, but only so far as he is allowed by routine commitments over the day, and so far as to allow occasional activities (such as personal business) to be woven into the day's schedule.

The nature of effects from the school hour changes will be described later in the paper, where it is discussed in the context of model development. However an example of one household's response is given in completion of this section (Figure 1) to illustrate a fundamental point; that an apparently marginal change invoked by policy may trigger clearly non-marginal, often dramatic changes in trips recorded before and after the event.

2.3 Implications of responses to new policies for the concept of trip demand

Examination of the foregoing responses to contemporary policy implementation points toward important shortcomings within conventional specifications of trip demand.

At the empirical level, it is observed that general and distinctly non-marginal reorganization of household trip patterns may follow 'forced' changes to specific aspects of travel, such as the timing of journeys to school, or commuter use of cars in town. Under different policy circumstances, trip patterns may alternatively be surprisingly resilient to change, so that for example opportunities to vary times of travel may be foregone despite potential advantage in travel time or 'generalized cost' savings.

Further inspection reveals the presence of strong 'linkage' effects amongst households' patterns of trips; changes to particular trips affecting not only other aspects of given individuals' trips, but also travel arrangements for other members of the same household. Such 'linkage' effects are not embodied within trip demand models; instead, elements of the pattern of trips made over the day by households tend to be isolated, and connecting events obscured.

These two observations, of the non-marginality of responses, and the importance of linkages within household trip patterns, suggest that use of any trip demand model will meet with problems in inferring future travel patterns from the basis of currently revealed demand for trips. The problems will be more or less severe depending upon the particular application, but they cannot be regarded as merely empirical, since the observations raise questions about the appropriateness of a 'consumer demand' paradigm to travel behaviour.

Trip demand models tend to implicity assume a direct demand for travel, or typically, for various types of trip classified according to purpose (work trips, shopping trips, etc.). This is despite explicit acknowledgement of the indirect nature of travel demand - viz., it is derived from demands to participate in various activities (work, shopping, etc.) which necessitate changes of location being made. The demand for almost any consumer good can of course be interpreted as indirect; the demand for overcoats indirectly reflects, perhaps, a need for warmth. Warmth is a characteristic that the consumer expects from his overcoat, and the distinction does not invalidate overcoat demand analysis since there is a sound conceptual equivalence between this, and analysis of demand for the characteristics of overcoats *per se.* The case of travel demand is less clear cut. A demand for the activity, shopping, may manifest trips to and from shops. Shopping is not however a characteristic of these trips, it is a distinct activity which under given circumstances is carried out in a way that involves a given set of trips. A change to the circumstances may, through the unexplored medium of linkages, be accompanied by changes to the number of trips made, their timing, destinations, origins, modes, and even which person is involved. It is then considerably more appropriate to postulate a demand for shopping than that for shopping trips, since to have any real value 'demand' needs to mean 'relatively stable demand', and whereas a relatively similar amount of household time and money is spent shopping 'before' and 'after', grossly different trip patterns may accompany the activity.

So whilst the failure of trip demand models to account for important linkages withing household travel behaviour may be regarded as an empirical shortcoming, which could be ameliorated by modifications to the structure of the models, to data inputs, and so on, there may alternatively be advantages in adopting some entirely different approach to the analysis of travel behaviour, in order to allow for the demonstrated nature of behavioural responses.

3. AN ALTERNATIVE FRAMEWORK FOR ANALYSIS OF TRAVEL DEMAND BEHAVIOR: EXPLORATORY FOUNDATIONS

3.1 Changing the unit of account in demand analysis

One such alternative is to change the basic unit of account, considering not trips *per se,* but the demand that is expressed over the day for participation in the basic consumer activities themselves (working, shopping, meals, school, TV, and so on) which being location-specific (to degrees) involve the additional activity of travel as a means of shifting location. From this point of view, individuals continuously devote their time to participation in activities, arrangements being subject to choice within constraints (work time and place, shop hours and locations, and so on). There will be a certain flexibility of travel arrangements within limits, whereby some household 'routine' or equilibrium of activity participation can be maintained throughout changes in immediate circumstances, including those determined by transport policy effects.

An approach using human activities as the unit of account has been described by Chapin (1974) within a general planning context, as the basis for investigating quality of life by Hägerstrand (1970), and has long been explicitly and implicitly used in sociology as a means for understanding life styles. Following seminal work by Jones (1974), work in progress at the Transport Studies Unit, Oxford has adopted a "Human Activity Framework" as the basis for "An Investigation of the Travel Decision Process".

Following sections describe research development using this alternative approach.

3.2 The character of individual behaviour in space and time

Simple plotting of individual space-time paths, using the format originating from Lund University (Hägerstrand 1970 et seq., et al) provides a useful means of representation. Using little additional data beyond that embodied in convential trip diary records (Figure 2) the 'backbone' structure of the household-day is given by the information within figure 3.

Individual paths are represented by the three traces for this household in 3(a). Oblique lines represent travel, vertical lines participation in some activity; individuals are always engaged in an activity even if it involves 'doing nothing'. The vertical cylinders represent permanent (short term) constraints; in this case the institutional constraints imposed by fixed work and school times. The local supply network of consumer facilities

	START TIME	ACTIVITY	LOCATION	MODE
	07.30	Wash, dress	Home	–
	07.50	Eat	*Home*	–
	08.10	*Travel*	–	*Car*
	08.40	*Work*	*Canal St.*	–
	12.45	Lunch	*Canal St.*	–
ACTIVITY DIARY:	13.30	*Work*	*Canal St.*	–
Full set of	*17.00*	*Travel*	–	*Car*
information.	*17.10*	*Shopping*	*George St.*	–
	17.30	*Travel*	–	*Car*
TRAVEL DIARY:	*17.55*	Prepare meal	*Home*	–
Subset of	18.20	Eat	Home	–
information	18.40	Wash, change	Home	–
which is	19.00	Watch TV	*Home*	–
underlined.	*20.00*	*Travel*	–	*Walk*
	20.10	*Drink & Social*	*"Dog & Duck"*	–
	22.40	*Travel*	–	*Walk*
	22.55	Prepare for bed	*Home*	–
	23.10	Sleep	Home	–

Figure 2 - Comparison of activity diary with travel diary

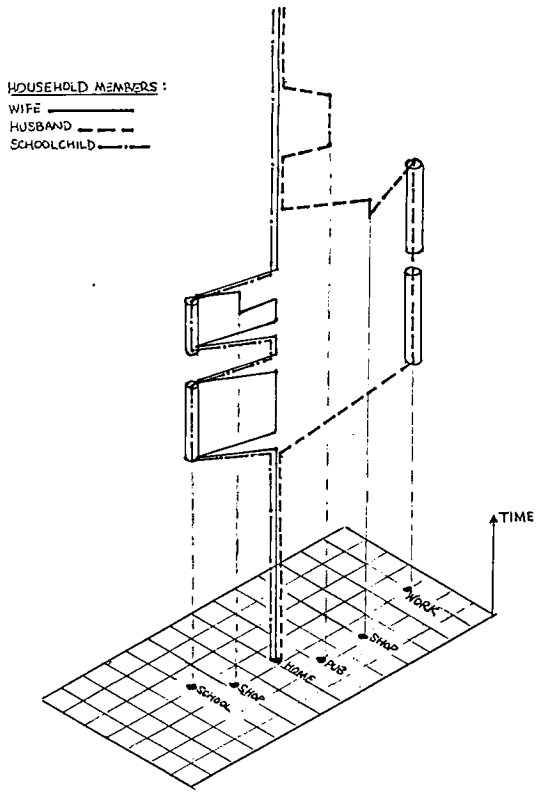


Figure 3 (a) - Space-time paths for one household
After Hagerstrand (1970)

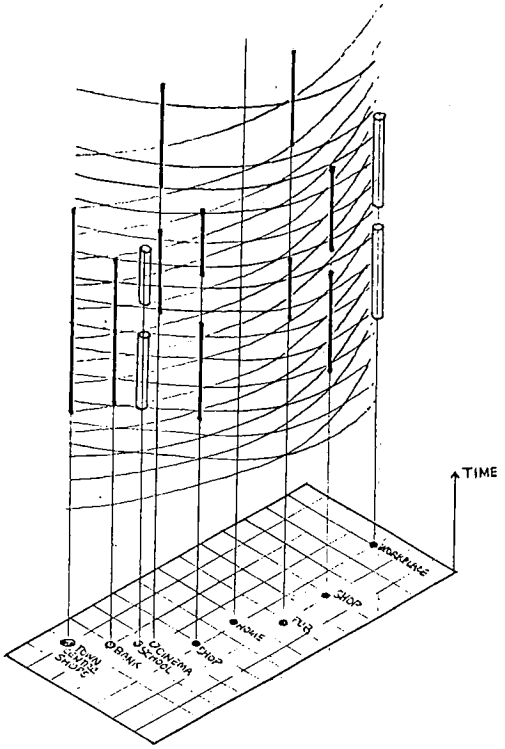
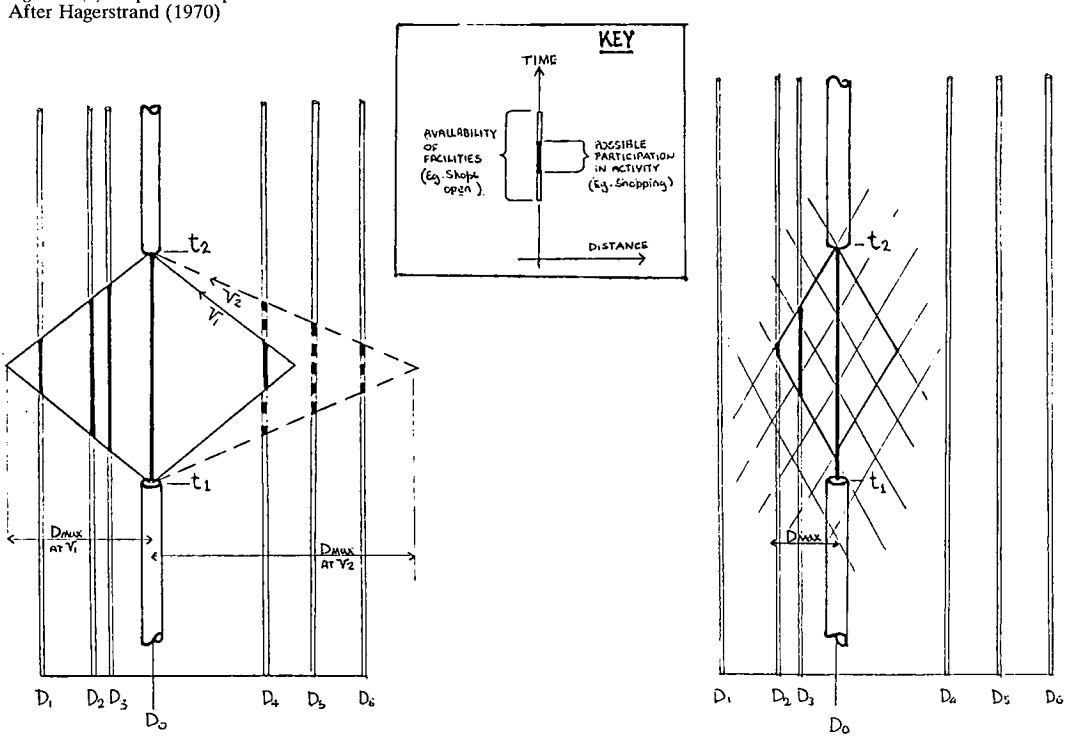


Figure 3(b) - Space-time distribution of facilities and local public transport



Figures 4 - Physical constraints on action within a 'window' of free time

4(a): Given unrestrained car use After Hagerstrand (1970) 4(b): Within a bus network

and public transport is schematized in 3(b); this defines all possibilities for public transport use.

During periods of free time, when there is a choice of activity, the nature of the feasible choice set can be inferred from; the length of the block of free time available, the current location, the location and temporal availability of local facilities, and the transport possibilities, Hägerstrand illustrates the effect of these constraints with the concept of time-space prisms; figure 4(a).

Here, the individual has a block of free time (t_2-t_1), which he can fully devote to a chosen activity at his existing location (D_0) or use some of this time to travel to other locations (D_1-D_n) offering alternative activity facilities. The edge of the prism represents his maximum range ($D_{max} = V_1(t_2-t_1)/2$) using all his time travelling. Increased speed (V_2), or extra facilities within the prism, increase the choice set. The operation of the bus schedule is more constraining (Figure 4b); comparatively few alternative facilities are available.

The choice within these constraints is either intralocational (choice of activity only, location given) or translocational (choice of activity and of destination). The latter would involve a trade-off situation between benefits expected from possible activities, costs of participation among alternative activities, and costs of (return) travel. Since some activity is always being performed, trade-offs must always be involved (for example within a given free-time period, the choice might be between watching TV at home, seeing a film at a local cinema, and seeing part of the film at a more distant cinema).

3.3 Additional constraints upon choice and action

In addition to constraints upon choice and action in space-time imposed by its physical dimensions and by particular configurations of land use, and also by institutional commitments (such as work or school) and physiological necessities (sleeping), the interview surveys identified a considerably larger set of effective constraints generally shared amongst the sample.

Individuals tend to experience a range of quite varied demands on time resources, the more so when functioning in a (family) group which establishes a routine and defines role commitments for its members; being at home "...because I know the dinner is waiting". "...the children will be getting back from school". ". . .my wife needs the car". . . .and so on. The family not only demands the use of individual time, it also tends to regulate when things are done; a "rhythm of urban activities" (Shapcott and Steadman, 1976) is maintained. Whether internal constraints such as these are regarded as determined by personal preference (Chapin 1974) or social commitment (Hägerstrand 1970) does not of course affect the reality of their operations.

Within the common constraints imposed by needs to attend work or school, to observe shop or cinema hours, to spend time sleeping, and preparing and eating meals, and to follow certain sequences of activity (eat and dress before going out), respondents were expected to display considerable variety both day-to-day, and amongst themselves. However, the synchronisation of joint activities (eating together, staying in together in preference to going out independently), through a tendency towards routinization ("you know where you are, then...") acted as a self-imposed constraint. Preconditions for certain optional activities were frequently, as a result, highly time-specific. The coincidence of, for example, 'free' blocks of time in both husband and wife's schedule, availability of the car, and sufficient block of shop opening time, was often restricted to Saturdays only - an extension of shopping hours would increase the choice set in a predictable way.

Cost constraints operate too, but in a different way. Conceptually, there is a total cost attached to each alternative activity within the choice domain, which includes costs both of participation (cinema ticket) and any travel. Costs are subject to budget constraints. But money, unlike time, can be saved and transferred from one activity to another. Time can be transferred between activities within a given block of uncommitted time, but not beyond it, and the day has to be regarded as a series of separate and constrained time periods. It is unrealistic to regard time as a continuous variable in the functional sense, and this has serious implications both for trip demand models and for evaluations of travel time savings.

An illustration of the extent to which constraints determine the travel decision process is provided by the following 'example'. This is based upon the individual diary given in figure 2.

External constraints (figure 5a) comprise the spatial pattern of land use and the transport characteristics (assumed to comprise walk and car only for simplicity); these have a temporal dimension too since time is taken travelling between locations. Institutional constraints are as per 5b; and some additional time is allocated to physiological constraints; 5c. Internal constraints arising from obligations to joint activities with other household members are ignored.

The broad structure of the day along the time dimension is sketched out in figure 6. Note that from these basic but realistic assumptions, nearly three quarters of the day is taken up with committed activities; this excludes necessary travel time. Three 'windows' of possible choice appear. Firstly, after rising and before work, but the location (home) is effectively fixed. Secondly, during the lunchbreak, if he chooses to spend 15 minutes eating his essential shopping activity is impossible, because travel time plus shopping time exceeds available time. Shopping must instead be done in the free 'window' after work; and of the two shopping locations the more distant is infeasible since this closes at his time of earlies arrival (see figure 7).

Given the needs of this individual, and the constraints affecting him, nearly 80% of his weekday is determined by external factors; and the individual has no choice about the timing, destination, purpose or mode used for the three trips made. Clearly, changes to the pattern of constraints, such as changes to work or shop hours, land use configuration, or network travel times would allow (or force) behaviour to vary in certain respects, which would be predictable.

3.4 Interview surveys: procedures

Initial interview surveys (Dix 1975) were concerned to identify the forces that regulate ongoing patterns of household travel, and which apparently constrain the freedom of travel choice. The concern, as throughout, was with short-term adaptations, that is, residential and employment location decisions are taken as given. In a pre-pilot survey, protracted unstructured interview sessions were carried out among less than thirty multiperson households resident in a commuter village near Oxford. A number of alternative discussion frameworks were introduced into the interviews, the general theme being the conscious planning of travel arrangements. It was found that an interview framework in which household members discussed their sequence of activities over a weekday, and described variations to the plan occurring over the week and longer (including contingencies such as temporary car loss) performed better than one in which attention was implicitly restricted to trips; in the latter, short, incidental, optional and non-vehicular tra-

vel was not readily recalled, and explanations were markedly acausal in content. Experience from these interviews was consolidated by:

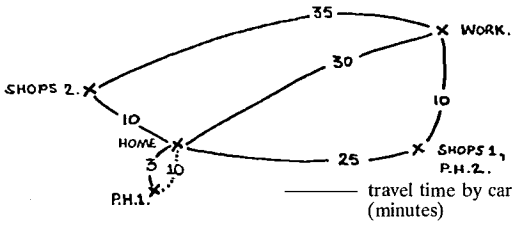
A pilot survey, which involved all household members from a sample of sixty-six households in Abingdon (Oxfordshire) in personal completion of continuous records of activities carried out over seven days, noting times, locations and travel modes. Unstructured interviews were carried out subsequently.

Following progressive inplementation of policies restraining the use of cars in Oxford, residents were interviewed in depth. (This survey was referred to in the Introduction).

During the most recent and main survey, 1,200 seven-day, activity travel diaries were collected in Banbury, together with full landuse information (including temporal availability of consumer facilities). Diary data is currently at the coding stage, and an additional fifty household follow-up interviews have been completed.

GENERAL CONSTRAINTS ON ACTION

A. *Geographical*



B. *Institutional*

Work hours:	08:45 – 12:45; 13:30 – 17:00
Shop hours:	09:30 – 17:30
Pub hours:	18:00 – 22:30

C. *Physiological and Domestic*

Sleep	At least 8 hours
Meals	3 times a day (minimum 15 minutes plus preparation
Personal care	20 minutes morning; 15 minutes evening
Shopping	20 minutes

No household constraints

Figure 5 - General constraints on action

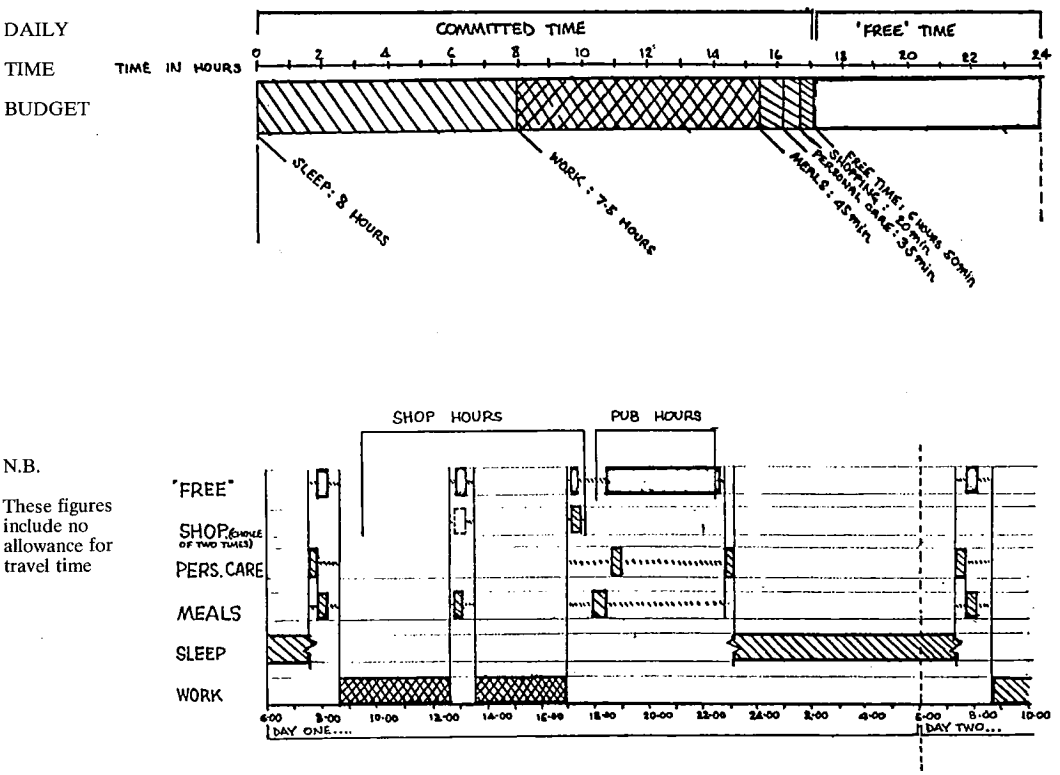


Figure 6 - Temporal scope for arrangement of activities

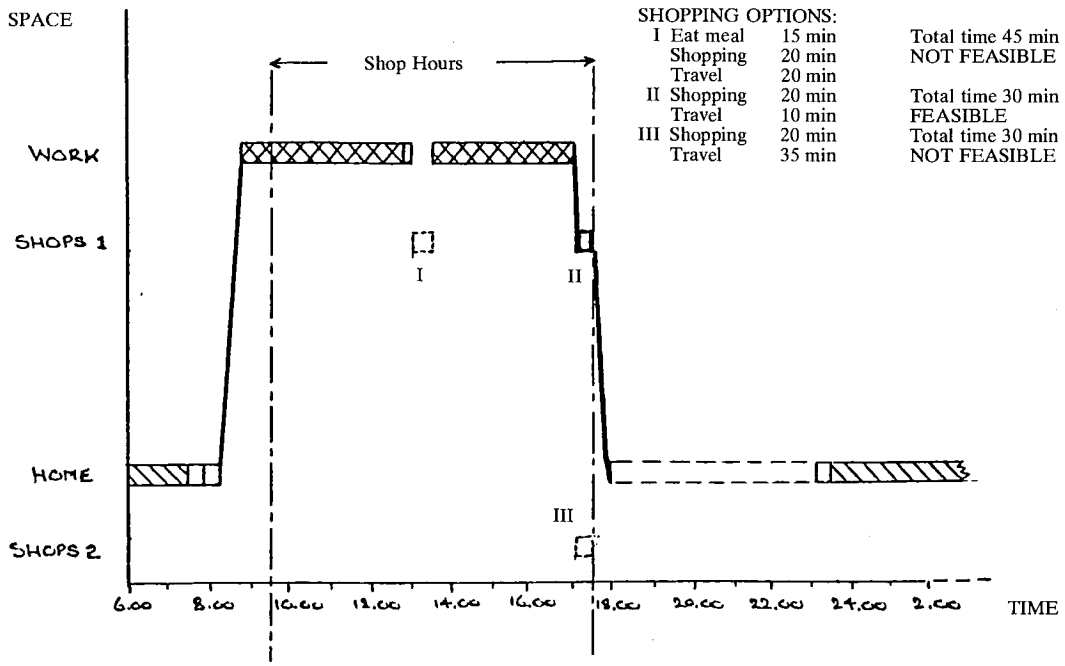


Figure 7 - Space-time constraints on action

3.5 The character of preferences and constraints among different types of household

An attempt will be made here to summarise, from the qualitative and quantitative information collected over the course of the investigation, salient differences within the population in terms of travel behaviour but also, more importantly, characteristic differences in preferences and constraints that seem to be causally related to the way travel is organized by identifiably different types of household.

The description is qualitative, tentative and incomplete. It may also only be general to the population of a medium-sized provincial town in the UK. For a somewhat fuller discussion, the reader should refer to Heggie (1977)

Household structure

One of the most striking features about travel behaviour is the apparent importance of stage in the family life cycle. Not only do family circumstances impose constraints on behaviour (eg. families with small children find travelling more difficult than families without), they also impose extra demands on time (eg. children need to be fed and attended to) and create complex problems of inter-personal synchronisation.

The follwing groups seem to represent the main stages in the family life-cycle in an English Provincial town:

Group I: Young adults, whether married or not, without children.

Group II: Families with dependent children, the youngest aged 7 yrs or less.

Group III: Families with dependent children, the youngest aged 12 yrs or less.

Group IV: Families with dependent children, the youngest aged 13 yrs or more.

Group V: Family of adults, all of working age.

Group VI: Elderly

Each group exhibits fairly distinct travel characteristics. They differ markedly between groups and are reasonably consistent within them. Even Group I, which includes both married and unmarried adults, seems to be fairly homogeneous, since the main and most significant change in life-cycle is associated with the arrival of small children. The most difficult division is between Groups III and IV. It is determined by the age at which the youngest child becomes relatively independent. It varies considerably between families, but seems to lie - with some exceptions - between the ages of 10 and 13.

The principal feature of Group I is that they engage in a great deal of discretionary travel. Persons living in or near the neighbourhood in which they grew up have fairly localised travel patterns. People living 'away from home', on the other hand, usually have quite elaborate travel patterns, reflecting the incidence of journeys designed to maintain extended family and friendship ties. This travel (or its end object) is highly valued and does not represent journeys which the individual, or family, would readily give up.

Group II are greatly affected by the presence of dependent children. This takes a variety of forms, but is usually perceived in terms of the physical encumberance itself; less flexibility in the venue and timing of meals; the need to synchronise family activities more closely; together with the increased time needed to prepare food, wash clothes and perform a variety of new household chores. Up to the age of about 5 the child usually has to accompany its mother on most, if not all, journeys and is physically dependent on her. This dependence, which still applies at weekends and during school holidays with older children, continues to be important until the youngest child reaches the age of about 7 years.

Group III are less affected by the physical difficulties associated with small children. Most parents are nevertheless unwilling to leave children of this age at home by themselves, so that they still tend to accompany - and to hamper - adult travel. The most significant phenomenon encountered in this sub-group, relates to the way in which the children stimulate discretionary travel. There

is a widespread feeling in this sub-group that free time should be used to ". . .take the children somewhere nice". Indeed, this becomes a minor preoccupation with most of the group who rationalise it in terms of being ". . .part of the children's education". It is thus seen as an essential means of broadening the children's learning experience during these particularly formative years. This period is also the time when children's group activities start becoming important with football, swimming, brownies, guides, scouts, etc., as important focal points. This becomes a further motive for engaging in discretionary travel.

The difference in travel patterns between Group III and IV is quite marked. By the time the youngest child reaches the age of about 12, the children (if there are more than one) are becoming relatively independent and both (a) wish to do their 'own thing' and (b) are able to do so because they can make many journeys on their own. The net effect is that parents seem to make fewer discretionary or child-based journeys and do not replace them by many new journeys of their own. Most parents are not willing to leave adolescent children at home by themselves and this restricts discretionary travel during the week, while at weekends the motive for (and child's desire to participate in) quasi-eductional travel is geatly diminished. The adults in such households nevertheless do seem to start recreating a life of their own. This often manifest itself as a desire, on the part of the housewife, to take a temporary job.

Although Group V forms a fairly distinctive category, it is also a little anomalous. Its members are in a state of transition since, although the standard UK Census definition [1] of a household still applies, the unit is really a twin household accompanied by multiple adult employment: one is a potential candidate for Group VI)the elderly); the other is an embryonic 'new' household awaiting reclassification in Group I. The characteristics of this Group are nevertheless not simply an amalgam of Groups I and VI. The embryonic household (the potential member of Group I) faces different constraints and has access to more communal resources while it remains in Group V. Commitments to other household members are also stronger, eg. some discretionary activities are still done on a 'family' basis, while claims on the use of the car are far stronger. A single adult living at home, exercising some claims on use of the family car, will thus make many more car-based discretionary journeys than a comparable Group I household without ready access to the family car.

The parent adults in Group V likewise seem to be more mobile than their counterparts in Group IV. There seems to be a higher incidence of adult group involvement, eg. in P.T.A. activities, church organisations, organised sport, recreation clubs, etc., and this usually involves increased discretionary journeys. Because they are frequently done in groups, however, there tends to be a great deal of car-sharing and use of chartered coaches.

Group VI again exhibits distinctive characteristics; the most obvious being the absence of the work journey. An additional - and quite striking - feature is the generally lower level of travel activity in general. The elderly do not engage in very much discretionary travel, even when they do own a car. Travel involves physical effort and is often thought of as confusing.

Another distinctive feature, is the gradual transformation of the household from an origin of journeys to a destination for them. They may not make many journeys themselves, but this does not mean that they are necessarily deprived of the activity underlying these journeys. The activity goes to them, instead of them going to it.

Stage in the family life cycle is thus an important determinant of travel patterns. Indeed, it seems to be even more important than household income. Income may have some effect (at least within each life-cycle group), but does not seem to be of primary importance. It is the characteristics associated with a progression through the family life-cycle that seem to exert the predominant effect.

Household characteristics

The characteristics of the household, particularly its level of mobility, are another important determinant of travel behaviour. They are a function of a number of factors including car-ownership, the incidence of neighbourhood car-sharing, the ownership of driving licenses, and access to public transport facilities.

The principal differences between car-owning and non-car-owning households lies (a) in the wider range of choice, in both home and workplace locations, available to the former (this usually results in a more complicated work journey) and (b) in the enhanced opportunities they enjoy for discretionary travel, particularly in life-cycle Group III. Non-car-owners are generally constrained to live, work and shop in a more limited physical environment. They are also usually members of life-cycle Groups I and IV; if not they tend to live in areas (particularly when they belong to Groups II and III) where most facilities are accessible on foort.

Neighbourhood car sharing is also associated with stage in the family life-cycle. Passenger journeys made in other people's car represent a large and rapidly expanding mode of travel (in the 1965 National Travel Survey [Dept. of Environment 1967] roughly 25 per cent of passenger journeys by car or van were made in other people's cars). The incidence of this phenomenon varies considerably between the different life cycle groups. It seems to be lowest in Groups II and IV, whilst in Group III it practically explodes. This is the time when children start participating in group activities which, for boys, include such things as: football (watching or playing), fishing, swimming and cubs/scouts. For girls, it includes: brownies/guides, swimming, music and ballet. Typically, one parent in a neighbourhood group provides transport for all the children participating in the activity (whether they come from car-owning households or not). At times the arrangement is formalised and a car-sharing rota is agreed; at others it is more spontaneous and does not necessarily involve a balanced sharing arrangement. Some parents may always take certain children to a common group activity. Car pooling for work also seems to start during this period, although this might reflect the increased demands on use-of-the car associated with the above child journeys. In a sense car sharing relaxes a constraint enabling a joint family asset - the car - to meet increased household demands.

The pattern of licence holding, which affects (or reflects) claims on use of the car, is also importantly dependent on stage in the family life-cycle. Most adult males nowadays acquire a driving licence as soon as possible after reaching the qualifying age. The same pattern is not repeated amongst adult females and a significant proportion do not initially acquire a licence. Once married and bringing up children the mother without a licence furthermore exhibits little desire to acquire a licence, while those with licences do not seem to drive very much. This only lasts until the youngest child reaches the age of about 7 or 8 years. The mothers - or a significant proportion of them - do then acquire a desire to drive and the incidence of driving licences seems to increase. This should be not suprise, since stage in the family

life-cycle affects both 'needs' (the move from Group II to Group III coincides with an increase in serve passenger trips) as well as affecting household constraints. It would indeed be surprising if licence holding was not correlated with stage in the family life-cycle.

Access to public transport affects the household in an indirect way. Most non-car-owning households seem to live in areas where most of the necessities of life (shops, work, civic amenities, etc.) are readily accessible on foot, by bicycle, or by means of public transport. They live relatively self-contained lives and often form part of a tightly knit neighbourhood community. Car owning households, on the other hand, generally live in areas that are less accessible and use a combination of car/public transport/cycle/walk to accomplish a much more elaborate set of household activities. Although public transport is not often used, it usually fills a vital gap without which claims on use of the car would become so great that the singel-car owning household would either (a) have to acquire a second car (if they could afford one), or (b) would have to move house to a more accessible place.

It is thus clear that household characteristics have an important effect on travel behaviour. They are nevertheless not entirely independent of stage in the family life-cycle. A number are importantly dependent on it and change - in a quite discrete way - from one stage in the life-cycle to another. Even levels of car ownership are affected by it, although this is an extremely complex phenomenon since some households seem to substitute 'locational' mobility (ie. the choice of where to live), for household mobility (ie. whether or not to own a car).

3.6 Conclusions from exploratory study using the human activity framework

Preceding sections attempted to show how the approach adopted provides a coherent framework within which both quantitative and qualitative information can be integrated towards an understanding of travel behaviour.

The classification of households' preferences for activities by their lifecycle stages, and the description of observed within-group differences associated with additional characteristics such as car and licence ownership, suggests a functional basis for the segmentation of the population. Such a classification may be more appropriate to policy-oriented research than a segmentation carried out with respect to recorded trip-making characteristics. This is because the former is conceptually closer to 'need' for travel than the latter, which is restricted to considering revealed preferences for trips (which may themselves be unstable with respect to the same policy changes that the models may be required to consider). The activity-based classifications has in addition the useful property of closer correspondence to groups that are distinguished in everyday life.

Differences within the population are however subject to those general constraints upon action that were indicated earlier; individual preferences operate within these limits. Furthermore, the general stability of activity time-budgets is indicated by studies carried out internationally (amongst developed countries) which have shown remarkable similarities in terms of time allocated daily to different types of activity (Szalai 1972) despite considerable differences between social, racial, cultural and infrastructural characteristics.

The concern with constraints, largely ignored in the consumer travel choice framework, secures the useful operational advantage that inclusion of additional information reduces the choice set at each decision point. This property of convergence contrasts with the escalation problem reported in connection with trip model developments; Ben-Akiva (1974) notes that "because of the large number of alternative trips that a traveller (now) faces (in these terms) . . . a simultaneous model can become very complex". In fact household data requirements for the sorts of model described in the following section are little more than those represented by conventional trip diaries; these latter merely happen to be poorly utilized within trip models.

In summary of this descriptive section, it is suggested that explicit consideration of travel as a means of shifting location, in order for participation in activities within space and time, provides a framework offering important conceptual advantages to policy-oriented research. Travel becomes responsive to changes in demand for the activities themselves, whilst the influences of transport supply conditions are themselves explicit. Thus, problems attached to notions of 'trip suppression' or 'latent demand for travel' do not arise, since the question of whether a trip is made is respecified as a trade-off between activity participation in alternative locations. A more realistic basis is also provided for considering questions such as 'travel need', 'minimum transport provision', 'personal mobility', and others, since need is specified in terms of need to be able to participate in certain activities. Appraisal of the opportunities for such participation must then take into account effects of landuse configuration, temporal availability of facilities and transport supply upon possible journey structures, and additionally, non-travel alternatives (such as mobile shop, libraries and deliveries) may be considered.

4. MODEL DEVELOPMENT

4.1 Types of model

Consideration of this characterisation of travel behaviour suggests that a range of models may more appropriately accommodate policy-oriented research needs than a single formulation.

In the first instance, certain mathematical programming approaches lend themselves to the approach, although initially, simplifying assumptions become necessary, so that a fully satisfactory application is regarded as a longer term outcome of the project.

A different alternative is to forego attempts to capture the individual's decision process extrinsically, instead using the individual to participate directly in the predictive exercise. The TSU 'Household Activity-Travel Simulator' realises this concept.

Finally a number of hybrid models can be envisaged, whereby a qualitative understanding of constraints upon action can be used to specify boundary conditions, within which econometric models might then be applied.

The first two developments will be described, beginning with 'HATS'.

4.2 The T.S.U. 'household activity-travel simulator'

The rationale behind HATS [2] is that a sampled group of households, or specifically, their predispositions towards travel decisions, become a functional part of the 'model', replacing any extrinsic system of mathematical proxies.

A number of planning techniques have adopted a similar tactic; for example the Community Priority Evaluator (Hoinville and Prescott-Clarke, 1974) and various Interactive Graphics techniques (egs. Arnstein & Winder, 1975; Rapp et al, 1976) all include the individual in their operational modelling procedures. Their applications are of course different from those of HATS, but a common principle is that a given stimulus provokes a set of tentative responses by the participating individual; a system of logical constraints disallows infeasible

responses, and a means of representation feeds back the implications of each response to the participant who then evaluates and decides between alternatives.

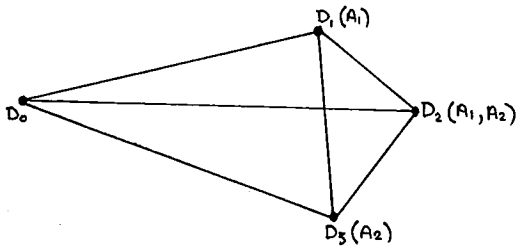
Procedure

The HATS equipment, as used by rural Oxfordshire householders to explore responses to changed local school and school bus times before the event, is depicted in Figure 9 and 10. Each household member initially assembled a physical representation of activities and travel over a former termtime day which has previously been recorded on a diary. Figure 11 illustrates how combinations of the 'components' of the day (ten non-travel activity types, each colour-coded, and six alternative modes of travel) are assembled into the given board to provide a record of which activities were performed over the day, where, when, and using which travel links. This assembly is however designed to be readily manipulable, and in the next stage of procedure the necessary changes in external constraints (in this case, changes in times spent at school) are recreated on 'affected' individuals' boards. The immediate result is that the conflict between routines 'before' and the changed commitments 'after' appear as visible inconsistencies on the boards (egs. 'gaps' appear within the day, former transport connections fail to connect, individuals appear in two places at once, and so on; see Figure 12). An iterative process then begins, as household members acting both individually and jointly explore their own spontaneous adaptations and what these mean in practice; they reorganize the pattern to produce logically consistent results. The need to account for activities continuously over the day imposes a 'closed system' characteristic, so that reper-

GIVEN:

(1) A home location, D .

(2) A set of non-home locations, D_1 - D_n; each catering for any or all of the non-home activity categories, A_1 - A ; for example . . .

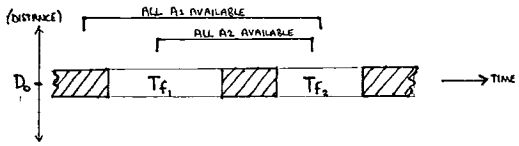


(3) Other network information (see text)

AND GIVEN ALSO:

(4) Constraints on individual schedules (eg. at home) such that the day comprises blocks of free time T_{f1} T_{f1} . . .

(5) Constraints on availability of non-home facilities, for example . . . . . .



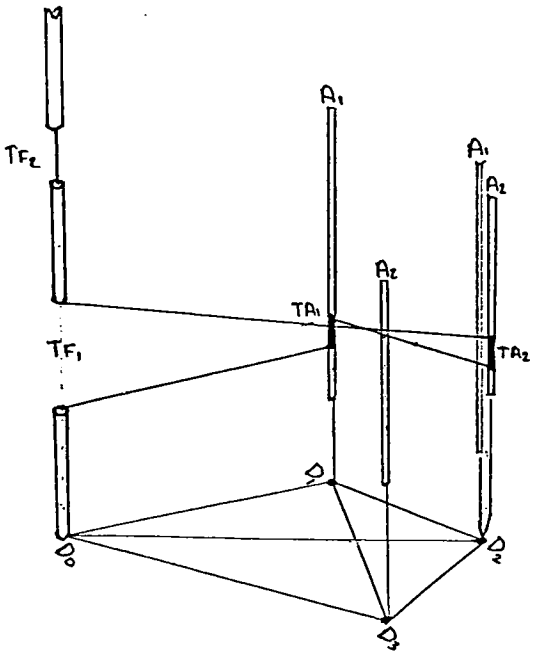
Allocate non-home activities (compulsory, and intitially fixed in duration (T_{A1} - T_{An}) to the supply network, using any or all free time periods (T_f) so as to . . .

(a) Statisfy the criteria (see text)

(b) Minimize travel time, and maximize free time at D_0 (see text)

Fig. 8(a) – Basis of mathematical programming formulation

(i) One possible solution, and a certain journey structure



(ii), (iii), (iv); Variations to journey structure resulting from other possible solutions.

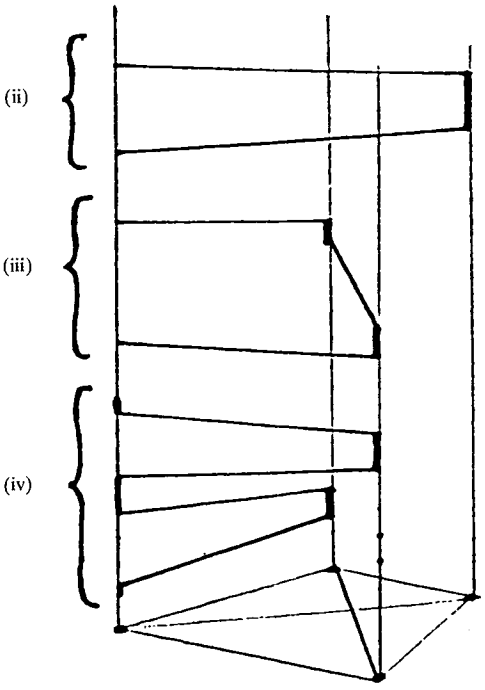


Fig. 8(b) – Forms of solution to simple case of programming application

cussions of a possible primary response are made explicit. The household evaluates alternative possibilities in their own terms; deciding which is most 'convenient', or 'fair' or 'economic', or whatever criterion is normally adopted by the household, before determining the most likely response. The number of alternative feasible outcomes is in practice usually small, which itself reflects the nature of constraints normally operating on a household's day. The whole process, which typically involves an hour's interview time, involves considerable discussion and bargaining, which may be tape recorded for subsequent analysis. The end product is a new set of physical activity-travel diaries, to be coded and translated into the same format as the original diaries for purposes of analysis.

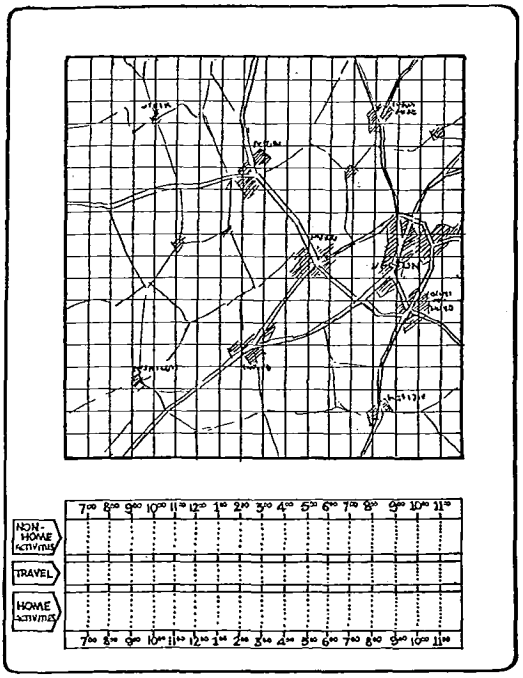


Figure 9 - A 'HATS' board

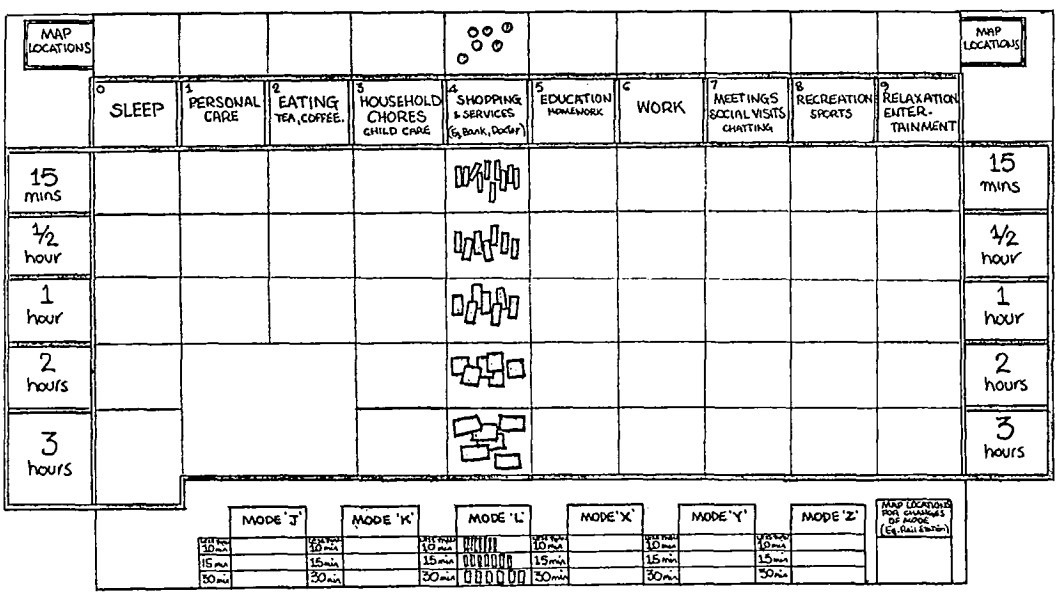


Figure 10 – Household activity-travel simulator components display box

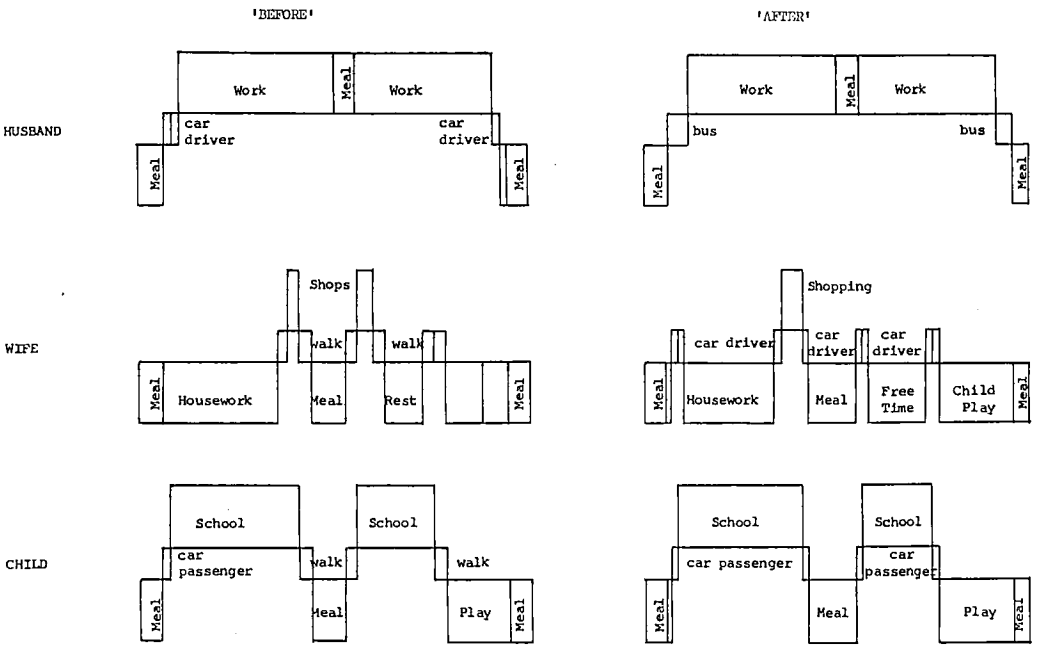
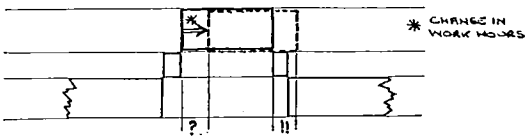


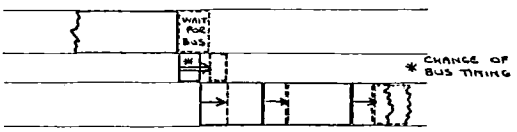
Figure 11 - 'HATS' representations of a household activity-travel pattern, 'before' and 'after' a 'policy change'

THE USE OF 'HATS'...

..reveals the emergence of unaccounted for periods of time and the impossibility of being in two places at once:



..shows the repercussions of a change in activity-travel pattern throughout the day:



..and makes explicit the activity trade-offs that lead to trip generation or suppression:

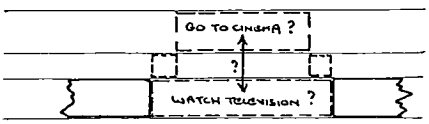


Figure 12 - Logical checks embodied in 'HATS' procedure

Applications

Potential applications of HATS are numerous, the chief limitations on use being: (a) Surveys are necessarily limited in scale to sample sizes typical of depth interview surveys (which in some situations HATS would advantageously replace). (b) Long-term responses to policy are beyond reach, since reliance is upon current knowledge of alternatives, and therefore results of job or residential relocation cannot be anticipated. (c) A financial budget is not explicit. It is implicit to the judgement of alternatives by participants, but money cost changes are not represented physically as are time changes. HATS development is intended to incorporate cost constraints, but the present version would not be suitable for studies of, for example, marginal changes to fares levels.

Within these limitations, HATS can offer hypotheses within areas of policy planning and evaluation that are beyond the scope of current trip models. Its present form was developed specifically for one such application; the school hour changes study.

Some summary results from this study will be presented here, to illustrate the nature of behaviour changes that can be successfully predicted by use of this 'model'. Predictions were gathered from 34 Oxfordshire households with children in attendance at Burford School, prior to introduction of a policy of staggering school transport arrangements, whereby Burford's times were advanced half an hour in the morning, and bus schedules were made more efficient. Predictions were subsequently confirmed by a postal questionnaire survey following the change itself (the only cases where predictions were not borne out involved apparent deviations of actual bus operation from the intended service schedules).

Forms of output

Firstly, HATS was able to expose linkage effects

within individual trip patterns. All school journeys involved changes of timing; for the majority of families, children's arrival home up to an hour earlier led to two kinds of increased trip making. These were in connection with late afternoon activities formerly confined to weekends (mainly social and shopping) or more frequently, evening social and leisure activities. The factor facilitating these arrangements was not a sudden availability of transport, but simply the appearance of a sufficiently 'long' free time 'window' (due to homework being cleared early). This demonstrates the dependence of 'trip generation' upon the temporal scope for return travel *and* activity participation within alternative (non-home) locations.

Secondly, linkage effects between household members' travel arrangements were exposed by HATS, allowing successful predictions of repercussion throughout the entrie household's trip pattern. Examples included cases where earlier return home enabled the family to combine meeting children at the bus stop with another travel generating activity, 'saving' a journey in each case; one household decided to abandon chauffering children to two different schools because the phasing would now rule out a round trip, hence children were transferred to buses; and others involved re-routing of a regular journey to work including a chauffeur-to-school role. Cases such as these demonstrate how the concept of 'convenience' of transport (which was raised again and again by participants) is a question of interface between transport supply, and committed household activities both outside and inside home, rather than being an attribute of transport supply *per se* as it is sometimes represented.

A third area in which HATS was able to operate was that of the evaluation of changes incurred to routines within the home. This aspect is dealt with comprehensively in Jones and Dix (1977); a generalization to be noted here being that apparently minor alterations to an in-home schedule (such as a working wife's extra half hour to clear up from the family breakfast before leaving for work) were often considered to represent extremely important benefits from policy. The contrast between the delight expressed towards 'relief of pressure' on normally 'tight schedules', especially associated with 'packing everyone off in the morning', and on the other hand, the potential concern over children returning home before the wife, illustrates that time savings are valued, not absolutely, but in terms of their results. It is their distribution that is important, in a way that has clear objective correlates in analyses of activity diary data.

This outline of results from the trial using HATS shows how results can be expressed at several levels. Forecasts of trip pattern reorganizations can be provided by simple extraction of 'before' and 'after' trip data in conventional terms. Comparison of activity patterns allows for redistributed time savings to be assessed in aggregate between activity groupings, providing a rigorous behavioural basis for valuation of these. In principal, marginal time utilities between activities may also be investigated. Finally, qualitative records of discussion and bargaining provide substantial data for both the investigation of rules by which decisions are made, and the sensitive evaluation of effects from policy changes.

4.3 Applications of mathematical programming

The simplest from of programming model derives from an interest in analysing the possible effects of different landuse configurations upon journey structures. Specific interest is on the timing and sequencing of trips, and the likelihood of multipurpose and multi-trip journeys given different patterns of spatial distribution of (in the simple case) local shops and services, and a 'housewife-shopper' with commitments to being 'home' during fixed periods of the day. Specification of different schedules of in-home commitment will simulate characteristic constraints within households of different type, and different home locations selected within the main survey area will simulate characteristically different spatial configurations of local shopping and service facilities with respect to the 'home', base.

The simple problem is set in these terms:
A one-person-day is specified in which given time periods are committed either to 'in-home activities' or 'free time'. A set of non-home activities is also given; each is compulsory and is of specified duration. These latter must be assigned to any of a set of given non-home locations, at any time and in any sequence, provided that (a) the location provides facilities for the activity and (b) these facilities are 'open' for use at the time. Travel and non-home activities must be carried out during a 'free time window' and time for these may be taken from any or all windows. A travel time matrix is constructed, initially, for one mode only. The problem is to establish the optimum timing and route which (a) satisfies the given criteria, (b) minimizes travel time and (c) maximizes continuous free time at home. The problem is set out and explained by Figure 8.

Development into a more sophisticated and general activity-travel model (see Jones and Dempster 1977) will follow in stages, and involves creation of a more detailed supply network, together with more detailed and flexible specifications of 'given' activities over the day. The main data base is to be used as a means of providing data on these input variables, and also for checking results against recorded journey structures as the specification is changed, in a hypothetico-deductive fashion.

Network improvements are to include real times of availability of all facilities; generalized cost matrices for 'all' models by time of day, and attraction ratings across facilities.

Uset representation will also become more realistic by stages. Still at the individual user level, other commitments are specified (work, school, 'logical' sequences). A specification of activity needs for a given type of multi-person household follows, commitments remaining fixed in time, but with joint participation for certain activities appearing as an additional constraint. A move from a given day to a longer period, allowing substitution of activities between different days, would be a further refinement. Ultimately, time duration for certain committed activities would become variable, within limits; this requires both a move towards procedures using optimal control theory, and a specification of marginal utilities of time transfer between certain activities. The use of 'HATS' within semi-experimental situations can, in principle, fulfil the latter requirement.

Objective functions are crucial; experience shows that the nature of these should vary according to the household 'type', and an interesting possibility to be tested is the use of a constant travel time budget in this sense (cf. Zahavi, 1973; Bullock et al, 1974; Goodwin, 1975).

5 CONCLUSIONS

Studies of human activity within the travel research context are in their very early stages, and substantial conceptual and empirical problems remain to be re-

solved.

Although the potential benefits of such an approach have yet to be widely demonstrated, it would nevertheless appear to offer considerable conceptual advantages over the trip demand framework, and its field of application may be considerably greater.

Further research is to concentrate upon development of increasingly appropriate mathematical models, but the qualitative understanding of the phenomenon of travel behaviour suggests that less formal approaches, including the variants of 'HATS', may have an assured role both for pragmatic planning; and for 'pure' research. In certain applications 'HATS' can produce information about primary and secondary impacts of policy, that can be expected to be both more complete and more reliable than the most accurate output of current 'behavioural' trip models.

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FOOTNOTES

1. The 'household' includes one or more people sharing common housekeeping

2. The apparatus carries a preliminary patent no.45,433/76 lodged in the names of P. M. Jones and M. C. Dix.