THE STRUCTURE OF JOURNEYS AND NATURE OF TRAVEL PATTERNS

D.A. HENSHER

ABSTRACT: The aim of this paper is to investigate at a conceptual
level, with a limited amount of empirical evidence, the
likely consequences on our present planning methodologies
of taking into account the true structure of all journeys.
A particular concern is the influence of changes in land
use configurations on the structure of journeys and the
probable policy implications. A consideration of journey
structure appears to offer one potentially promising
procedure for relating land use and transport plans in
a way that yields more realistic insights and policy in
the urban areas. The paper concludes with some suggestions
for the way ahead.

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INTRODUCTION

Whenever the nature of travel is discussed, the notion of derived demand is introduced to emphasise the point that travel is, with few exceptions, required not for its own sake but as a means to an end. However, having made reference to this notion, transport planners readily apply very crude measures to "allow" for the derived nature of travel, measures which do not appear to reflect the true role of the configuration of land uses (which are associated with non-travel activities) in structuring the pattern of travel. The influence of land use configurations (LUC's) is very apparent in the structure of journeys, a structure which has been oversimplified for modelling convenience. The essence of this simplification is a two-trip journey with a single purpose; for example the journey to and from a single work-place. Such a journey structure does not typify all travel; and given our limited empirical evidence (Daws and McCulloch 1974, Patricios 1975, Hanson 1975, Downes and Wroot 1974) we can suggest that at least 30 per cent of all urban travel involves journeys that entail more than two trips of which more than a single purpose is not uncommon. The aim of this paper is to investigate at a conceptual level, with a limited amount of empirical evidence, the likely consequences on our present planning methodologies of taking into account the true structure of all journeys. A particular concern is the influence of changes in LUC's on the structure of journeys and the probable policy implications. A consideration of journey structure appears to offer one potentially promising procedure for relating land use and transport plans in a way that yields more realistic insights and policy in the urban arena. The paper concludes with some suggestions for the way ahead.

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It is appropriate to begin with a brief discussion of the state-of-the-art in studies concerned with "multi-trip journeys" (MTJ) and "multi-purpose journeys" (MPJ); and the types of approaches and methods that we might pursue in a search for improved understanding of the nature of travel and structure of journeys, which have not strictly been concerned in the past with MTJ's and MPJ's. Jones has provided an extensive review of the literature specifically concerned with the analysis and modelling of MTJ's and MPJ's. In general the contributions to date have either been concerned with description of travel diary data in order to indicate the extent of such journeys (e.g. Daws and McCulloch 1974, Bruce and Jones 1975, Bentley, Bruce and Jones 1975, Downes and Wroot 1974) or methods of modelling aspatially such journeys, given that they occur (e.g., Vidakovic 1972, Gilbert, Peterson and Schofer 1972, Horton and Wagner 1969, Sasaki 1972, Nystuen 1967). While these studies are valuable contributions to an important neglected area, they are deficient in one major way - the general lack of any theoretical framework to assist in understanding the causal processes that produce such journey structures. A behavioural framework is required, both at the micro (individuals) and macro (spatial aggregate of persons and land uses) levels, which will provide the necessary mechanism for generating testable hypotheses.

The existing transport research does not offer any appropriate general procedure within which MTJ's and MPJ's might be incorporated. Two basic approaches have been pursued in an independent manner in the search for a spatial travel choice model. The first is commonly labelled "conditional spatial choice process", illustrated by route choice models that allocate trips to points or areas within urban areas. Disaggregate probabilistic utility models or Wilson entropy models belong in this category. They analyse the decision process of

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a group in selecting one of a set of destinations in time period t, given that an activity or activity combination is to be undertaken. This ignores time variations in trips by individuals or groups to an alternative, consequent on trip purpose sequencing and trip purpose changes over time. We do not have any procedure for identifying the likelihood of particular activity sequences. The second approach is called the "activity sequencing process", and is essentially concerned with trip linkages over time. The studies of Vidakovic, Sasaki, Horton and Wagner already mentioned above belong in this category. Such procedures using Markov models of land use linkages during trips ignore the problem of predicting which of the particular locations of a land use activity will be chosen, given that an activity is selected.

The appropriate framework should in an explicit manner emphasise the non-travel activities, as the fundamental influence on the structure of journeys, and the transport factors which influence the individual's transport behaviour (frequency, destination, mode, route, timing) in a given and/or changing LUC. It thus seems desirable to replace a transport framework with an activity framework in order to capture the more realistic emphasis (see Jones 1974). It does not seem possible to modify the contents of our present urban transport planning framework in order to allow for the LUC; rather we must begin with a set of behavioural hypotheses (or assumptions) and develop an alternative framework (from the ground up) which will assist in our understanding of the nature of travel and structure of journeys. Boulanger (1971) seems to be hinting at this point.

The space-time budget approach (Chapin 1974, Cullen and Phelps 1975) appears to encompass the joint requirements of spatial travel choice modelling referred to above, although

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within a more appropriate activity framework. To date, however, this work has not produced a well articulated conceptual framework.

Even though LUC's are arrived at over long periods of time, it is also important that we attempt to identify the extent to which the individual's pattern of activities (which includes his journey structures) are determined over the longer time period (and thus routinisation or habit predominate for the majority of his travel activities in the short-run) or whether careful evaluation of alternative activities and hence journey structures prevails resulting in a fresh decision each time an action takes place. If the former is the case, then we must be very careful in inferring "too much" from cross-sectional revealed behaviour data at one time point (regardless of whether such data is for a single day or a complete week) but rather qualify our basic activity data with a series of attitudinal perspectives in order to reflect the extent of long-run decision and short-run routinisation:

> "everyday behaviour is not fully intelligible,
> either at objective or at subjective levels,
> without recourse to information about the
> attitudes and premeditations of the actor"
> (Cullen and Phelps 1975, p. 7).

The point being made is that the structure of journeys is likely to be better understood in a long-run behavioural context if we can provide evidence that the structure of any activity (including travel) is conditional predominantly by experiences accumulated over a relatively long time horizon, and that what we observe happening today (both LUC's and journey structures) is better explained by the identification of long-run determinants of activity configuration.

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The macro-approach which emphasises configuration in terms of spatial aggregates (e.g. persons per zone, trips per corridor, shops per acre, etc.) is, given the present state-of-the-art, more immediately suited to this new orientation, except for its general lack of a behavioural unit of account when "understanding" as distinct from "describing" is required. It seems appropriate to discuss MTJ's and MPJ's at both the micro and macro levels, but that more emphasis at this early stage should be given to a micro-behavioural framework. The remaining sections of this paper reflect this bias. Like the recent contributions in behavioural disaggregate travel demand modelling, the individual as a member of an explicitly accountable group of persons undertaking activities is the basic unit of analysis, and it is our task to understand the ingredients that result in his particular journey structures. From this knowledge we should be able to build up a macro-behavioural framework to depict overall urban activities and journey structures likely to be associated with alternative LUC's. In addition we will have a basis for assessing the likely extent of journey restructuring as a result of either a land use and/or transport policy. It is argued that without the solid micro-behavioural foundations, we would not be able to satisfactorily predict a resultant macro-behavioural configuration in advance of change.

SOME BASIC CONCEPTS

Having stated the broad orientation of this paper, it is appropriate to digress briefly and define explicitly the notion of a multi-trip journey, since this is a key construct in the discussion. The definition used by Jones (1975a., p.1) is adopted:

"A multi-trip journey may be defined as a travel

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> sequence which commences at the traveller's
> home and involves at least two trips (i.e. it
> comprises three or more trips in all). A trip
> in turn is defined as a one-way movement from
> an origin to a fundamental destination for a
> single purpose and may comprise a number of
> stages corresponding to the use of a sequence
> of modes (e.g. walk-bus-train-walk)."

A non-home based trip can be accommodated within this definition
if it forms part of a MTJ. The connection depends on the
extent to which activities are sequenced and structured over
a sufficiently long period of time to encompass the non-home
based trip in a journey that commenced from home. This should
not be taken to imply that the house location is the only prime
determinant of activity sequencing in time and space, but
rather that the home place is the major location from which
the traveller commences his routinised day (Cullen and Phelps
1975) or makes his decisions on his daily activity structure,
and major constraint on the overall structure of journeys
(Hanson 1975). The workplace also performs a conditioning
function; Hanson has shown with Swedish data that 44 per cent
of stops at non-home places were made while on the work journey.
When seen in this context the work journey still has a pre-
dominant place in transport research, on an argument that is
independent of the traditional justification in terms of
peakedness, congestion and determinants of road capacity.
Hanson has also shown that the workplace is an important
organisational node in the household's travel pattern, with
57 per cent of households making more stops on work journeys
than on non-work journeys; and a few making as many as four
work journey-associated stops for every stop on a non-work
journey. Thus a case could be made for separating out journey-
structure on an initial classification rule related to a

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hierarchy of dominant journey purposes; since there is evidence
to suggest that a dominance hypothesis does impose important
constraints on the spatial and temporal sequential structure
of travel and non-travel activities. The mere reference to
the "work journey" implies a dominance hypothesis.

The concept of a "stop" has been freely used without
definition. This is a difficult issue, since we have to
decide on the extent to which a particular stop changes the
essential structure of a journey, both spatially and temporally.
While we can suggest two types of stops: "fundamental" and
"incidental", the difficulty comes when allocating stops to
this binary classification scheme. Does stopping at a garage
to obtain petrol qualify as a fundamental or incidental stop?
The procedure adopted here is that a stop is incidental if it
does not alter the spatial and temporal structure of the travel
and non-travel activities in a non-marginal way. This introduces
the further problem of a marginal adjustment; and we have
opted to define a marginal temporal adjustment as one entailing
less than 5 minutes in "detour and stop time"; and a marginal
spatial adjustment as one entailing less than 1 mile (or 1
kilometre) in "detour space". This reflects the logical units
of account used in the individual's action "space". "Detour
time" and "detour space" are new constructs, requiring a
knowledge of the expected temporal and spatial structure of a
journey just prior to and subsequent to each stop; in addition
to the temporal and spatial structure if no such stop were to
occur. The subsequent temporal and spatial arrangement has
to be related to the subsequent fundamental destination (assuming
no additional intervening incidental stop). An example will
clarify this point (Table 1). It is assumed that such stops
have a negligible influence on the structure of journeys and
activities, and should be removed from the data at an early

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stage. However, it is worthwhile noting the extent of incidental stops, since we might obtain ancillary information of relevance in other contexts (for example, the placement of a newspaper boy at traffic lights rather than in the shopping centre).

Journey Structure	home place ... work place (shop)	home place ... work place (shop)
	a b c shop	a b c d shop
Time (minutes)	2 12 9 2	16 .16 .08 9 3
Space (miles)	.05 3.0 2.0 -	.06 .06 .03 2.0 -
Detour time	16 - 9 = 7	12.32 - 9.08 = 3.24
Detour space	3.5 - 2.0 = 1.5	2.12 - 2.03 = 0.09
Type of stop	fundamental	incidental

Table 1: Illustrative Difference Between a Fundamental Stop and an Incidental Stop. (Not to Scale.)

To complete the definitional digression, an illustration of a set of daily activities undertaken by an individual from the Watford sample (original travel diary; see Daws and McCulloch 1974) will clarify the essential difference between the true structure of daily travel and that adopted in the existing modelling structure (Table 2). The prime difference is that when the true structure of travel is modelled we maintain the sequence of journey purpose and direction of travel; two very important requirements in any behavioural approach to under-standing the relationship between transport and LUC's. The

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existing modelling procedure, summarised in Table 2(b) eliminates
these two requirements. Hence, we need to reinstate these
requirements in order to progress; and it seems that the study
of MTJ's and MPJ's is a central concern in the reformulation of
our models.

So far we have pointed out the structural difference
between the actual and modelled journeys. However, it should be
mentioned that we should be able to, within a conceptual and
modelling framework, predict the extent to which MTJ's and MPJ's
are undertaken in contrast to single trip and single purpose
journeys. This will require a knowledge of the factors influ-
encing the structure of journeys, which are likely to be those
factors associated with LUC's, the individual and his household,
travel behaviour, and travel opportunities. Bruce and Jones
(1975) provide a useful summary of the likely influences
(Table 3). The available empirical evidence does suggest that
the incidence of MTJ's and MPJ's is on the increase, and hence
we should have a procedure for identifying the circumstances
under which they might occur; for it will have important policy
implications.

To conclude with a simplified example; at present
an individual undertakes the daily activities in a manner shown
in Figure 1(a). His total travel time and cost are respectively
90 minutes and 70 pence; and the journey to and from work in
1(a) is by public transport because of demands on the car by
housewife for day usage. The individual now has use of the car
for journey to and from work because his wife (the ex-housewife)
now has to go to work full-time. As a result of this new house-
hold circumstance, the individual decides to go straight from
work by car to the shops instead of returning home initially for
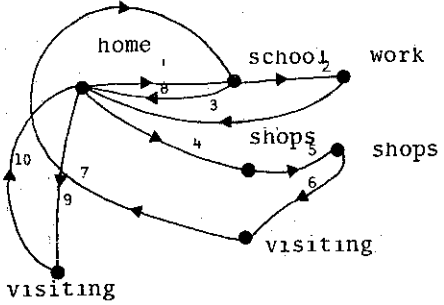the car. The result is a saving of 20 minutes and 20 pence,

(a) Actual Structure of Daily Travel Activities	(b) Modelled (at present) Structure of Daily Travel Activities

(a) Actual Structure of Daily Travel Activities

Summary:

3 journeys:

    (i) multi-purpose, multi-trip
        (3 trips, 1 school, 1 work)

    (ii) multi-purpose, multi-trip
        (5 trips, 2 shops, 1 visit,
                    1 school)

    (iii) single purpose, two-trip
        (2 trips, 1 visit)

(b) Modelled (at present) Structure of Daily Travel Activities

home X_____X school   1 home based trip production

school X_____X work   1 non-home based trip production (school)

work X_____X home   1 trip attraction (work)

home X_____X shops   1 home-based trip production (shops)

shops X_____X shops   1 non-home based trip production (shops)

shops X_____X visiting   1 non-home based trip production (shops)

visiting X_____X school   1 non-home based trip production (visiting)

school X_____X home   1 trip attraction (school)

home X_____X visiting   1 home-based trip production (visit)

visiting X_____X home   1 trip attraction (visiting)

Summary: 3 home-based trip productions, 4 non-home based trip productions, 3 trip attractions.

Table 2 (a,b) The Real & Modelled Structures of Travel

INDIVIDUAL FACTORS	GROUP FACTORS	OPPORTUNITIES FOR TRAVEL	LOCATION OF FACILITIES	TRAVEL BEHAVIOUR
Primary needs - food sleep social etc.	Household size & composition	Mobility	Places	Mode
		Travel urgency	Types	Time
Secondary needs - leisure passenger serving, etc.	Family cycle stage	Modes available Activity interchange-ability	Variety with-in types Centrality	Day of week Route
	Social class			Distance
	Census data at area level etc		Accessi-bility	
Age				
Sex Marital status Working status Education level Role in group etc.		Opportuni-ties for continued travel Travel decision-making	Cost of use	Cost of travel Travel in groups
Time budgets - work hours leisure flexibility freedom			Conducive-ness to activity linkages	Trip pleasure per se Destina-tions visited per week
			Number of visits	Activity linkages
Facility pref-erence & images				
Perceived options				
Lunch options				
Need to search				
Habit formation				
Wealth & life-style				
Journey planning ability				
Multi-purpose journey motivation & satisfactions				

Table 3. Types of influences

and a new journey structure (Figure 1b) - i.e. initially we
have two single purpose two-trip journeys and a single purpose
three-trip journey; now we have one single purpose two-trip
journey and a multi-purpose four-trip journey. The traditional
choice (demand or usage) models based on narrow simplified
assumptions would not have been able to predict this new
structure, nor the change in generalised cost. It would most
likely have predicted a change in generalised cost associated
only with change of mode for the single purpose two-trip work
journey. In addition, the restructured journeys are likely to
result in changes in the amount of time at the destinations
and homeplace; which would not also be properly modelled to
reflect the true role of the activity at the destination.
Thinking in terms of the activities will force both researcher
and practitioner to rethink common concepts such as "quality
of service" and "net benefit". We are now ready to begin
setting out some basic assumptions for a revised approach to
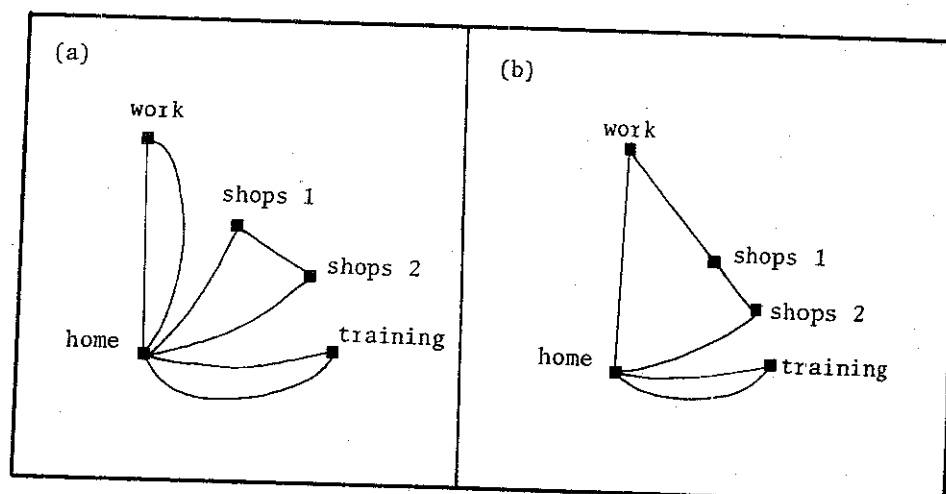studying travel behaviour in an activity framework.

Figure 1: Alternative Travel Contexts

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TOWARDS A REFORMULATED APPROACH - SOME MICRO FOUNDATIONS

Research and application in a number of subject areas can be drawn on in setting out the main assumptions underlying the reformulation of the approach to studying the nature of travel. The key topic areas include disaggregate behavioural modelling, activity sequencing modelling, space-time budget research (including travel diaries), and general theories of human behaviour. The emphasis is on a knowledge of the way individuals, as members of households, form and reinforce behavioural patterns of travel and non-travel activities in time and space. Equally relevant, but not discussed here, is a knowledge of the way the suppliers and regulators of facilities arrive at decisions (Rimmer 1976), and the interaction between the demanders and suppliers (Gaudry 1973).

Foundation 1

The derived nature of travel is allowed for by replacing the travel framework with an activity framework (AF). This alternative approach emphasises an understanding of why an individual does or does not include a particular activity node in his "action time-space" choice set and why the individual chooses or does not choose a particular activity node (given its inclusion in the action time-space choice set) in the allocation of his time and space budgets. Travel becomes one of the important considerations, but not the framework within which we have to study and model "our decisions". Urban transport plans (UTP's) are replaced by urban activity plan (UAP's); and the concern is with understanding and modelling the probability of choosing a particular activity, located in time and space, given the individual's money, time and space budgets. A space budget is a notion related to the individual's total

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action space, and does not have useful meaning if seen any other way. An activity node can be described as a point on a hyper-surface which is defined in terms of a space time coordinate (grid) reference and an index or function representing the probability of a person locating himself there and undertaking activities over a period of time. This central aspect of an activity framework is illustrated in Figure 2. It will become increasingly feasible to adopt a coordinate grid system for spatial modelling (the U.S.A. Census of 1980 is to do just

Time (96 units : 01 to 96) i.e. 15 mins. interval

6 pm
— 68
12 pm
— 36
6 am

an urban area or an individual's perceived action space

Example: Sp has coordinates 00 00 00 00 to represent base location in a North (N), South (S), East (E), West (W) grid system. Each square is 10 units. Suppose an individual has 2 activity locations to choose from A and B, referenced spatially as 25000500 and 28000014. The individual lives at H, reference 45000010. The times of the day that an individual could choose to go to either A or B are between 36 and 68 (i.e. shop business hours). Hence our basic activity referencing in space and time is 25000500t, 28000014t, t=36,37......,68. If i=4, and j=A,B, then we need a function to indicate the probability of individual choosing one of j, given i and t. This is our time-space referencing; now we have to identify the travel & non-travel influences
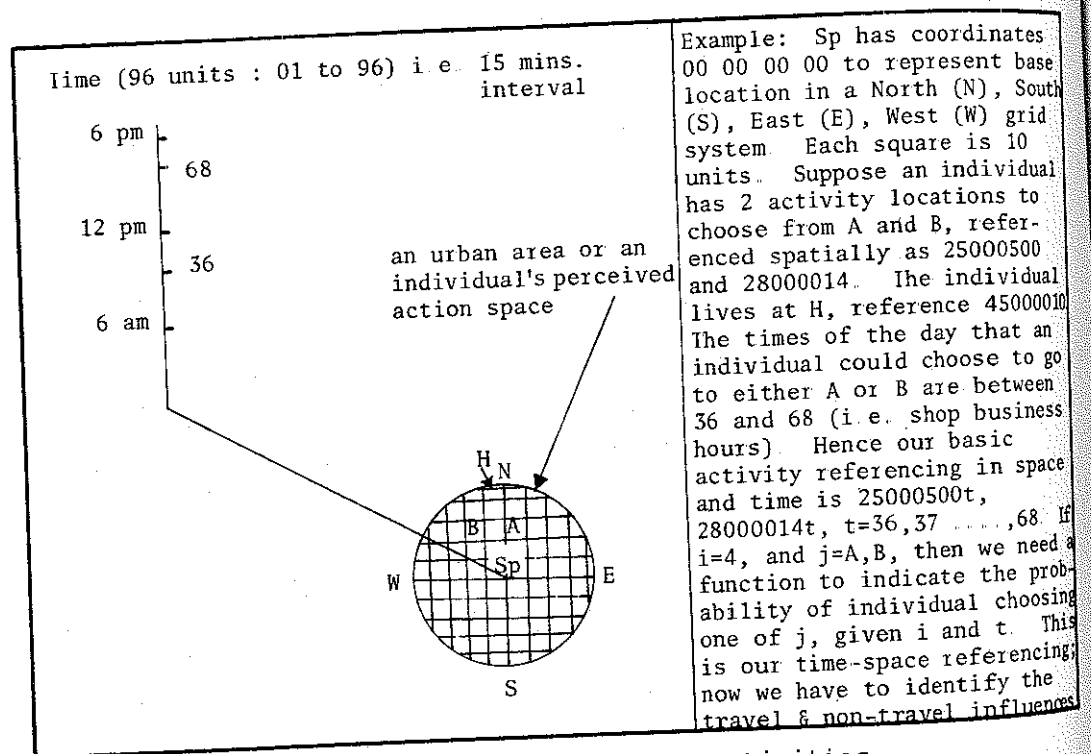
Figure 2 : Space-Time & Activities

that) which will overcome the major deficiencies of both aggregate and disaggregate (travel) modelling; and then we can (with computer assistance) digitise a complete urban area, with respect to the complete set of facilities (private residences,

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shops, transport interchanges, business, workplaces,etc.,) in terms of location and any time conditions (e.g., shopping hours, transport facility hours). This requires more detailed thought, but must be a fundamental part of a reformulated approach.

Foundation 2

The behavioural assumptions vary between the short-run and the long-run; and it is necessary to be quite explicit as to the nature and differences of assumptions. There appears to be a generally unclear statement in the transport literature. Within the activity framework, certain behavioural phenomena need to be made explicit in a short-run long-run context:

(i) the formation and evolution of structures and forms
All beings or things are forms or structures endowed with a degree of stability, and they are contained within a spatial and temporal framework. These objects or things have boundaries, implying a discontinuity, yet all our models are based on differential calculus which presupposes continuity. Unfor-tunately, the structure and form of activities is full of discontinuities (a planner's and mathematician's nightmare), making our modelling task difficult. Until such times as we have mastered the concepts and objects basic to both differential topology and classical mechanics we must do our best with con-tinuous functions. One general approach is to modify (convert) our theories of discontinuity into continuous operational functions by the use of attitudinal information from carefully worded "attitudinal" questions in order to "connect" the com-ponent influences (Hensher 1976a) in a continuous fashion. For example, "routinisation" (Cullen and Phelps 1975) or habit (Hensher 1975, 1976a) have been suggested as major influences on short-run behaviour of individuals in both travel and non-travel activity contexts.

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It is difficult to model the short-run behaviour of individuals in a continuous function which displays the "alternatives" available to the individual since the intervening influence of habit makes any inference based on system factors about changing the chosen alternative unrealistic (Hensher 1975) until the true relationship between the chosen alternative and other alternatives (each carrying non-uniform weights) is established properly. The entire area of discontinuity is partly reflected in the notion of "constraint". There are only 24 hours a day, 7 days a week, a multitude of activities that are committed for survival in the present society, etc., and hence inflexibility and routinisation enters forcibly into the determinants of action space and choice (see Table 4):

> "The overall picture is one of a dominant and inflexible pattern of routine domestic and paid work, punctuated by equally inflexible and equally routine meals and personal chores. More flexible punctuations include spur of the moment shopping trips and the whole pattern relaxes considerably, though by no means entirely, as the evening is given over to social and leisure pursuits, sometimes routine, sometimes deliberately arranged and sometimes just filling in time." (Cullen and Phelps 1974 pp. 71-71).

In contrast to the short-run situation above, where discontinuity is generally more prevalent, in the longer term the continuity assumption is more valid. The problem lies, however, in utilising cross-sectional data reflecting present day-to-day activities to model long-run behaviour. The economic theories of characteristics associated with goods, popularised by Lancaster, are misleading in this respect. In applying his models to the consumption of time in an activity, rather than simply to the consumption of unique goods. Lancaster is not

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	Arranged (%)	Planned (%)	Routine (%)	Unex-pected (%)	Time Filling (%)	Spur of Moment (%)	No. of Activities Performed
Work	4	2	79	3	1	0	338
Domestic	4	4	80	5	1	5	506
Child Care ...	2	3	86	4	2	2	195
Shopping	16	17	33	11	3	19	93
Personal	2	1	91	2	1	3	891
Adult Education	0	9	82	0	0	9	11
Social	21	3	47	14	6	9	185
Active Leisure	24	2	45	7	12	10	42
Passive Leisure	4	4	66	2	17	6	321

Table 4 : Activity Classification by Premeditation
Source: (Cullen & Phelps 1974 p. 31)

explicit about the time dimension; falling into the trap of
assuming that because the outcomes of choices are only really
observable at the day-to-day level, this must also be the level
at which the choices are occurring. Cullen and Phelps have
evidence to suggest that only 10 per cent of the average
working day is characterised by very recent deliberations.
Thus, in essence we have long-run choice and short-run
routinisation. A difficulty here is in determining the point
at which routinisation moves into choice (Hensher 1975). This
has important implications for journey structuring, for unless
we can explicitly model the role of routinisation, then we have
no basis for indicating that our predictions of short-run change
are reliable. There clearly is a value attached to habit,
equally as much as a value attached to other more generally

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accepted influences on activity formation.

(ii) hierarchy of activities

This issue is in some ways the closest discussed here to the
aspect of modelling a system in which MTJ's and MPJ's perform
an important role. There is a growing body of literature on
the hierarchy of travel decisions (e.g. Brand and Manheim 1973,
Charles River Associates 1972, Richards and Akiva 1975, Hensher
1976c, Wilson 1972) yet an apparent dearth of material on the
likely hierarchy of activity decisions. As indicated earlier,
the activity framework provides a more realistic basis for
emphasising the role of MTJ's and MPJ's, and thus we will out-
line the beginnings of a possible hierarchy of activity decisions
as a way of highlighting the "location" of the travel decision
(and its associated hierarchy) and the relationship between
travel and non-travel decisions. Hagerstrand (1970; 1973) has
recently provided an important beginning in this entire area.
His contribution centres on the relationship between behaviour
and constraints and is concerned to ensure the accountability
of place-use and time-use concomitantly; on the assumption
that in most cases the justification of movement is in what
the person wants (or has) to do when he is not moving. In
structuring a framework within which the nature of activities
can be investigated, a number of assumptions are required.
There are at least five basic assumptions which appear consistent
with the present state of activity formation:

> (i)   there is a minimum of time that an individual
>   believes should or has to be allocated to a
>   particular activity.

> (ii) a timing constraint prevails, restricting certain
>   activities to particular hours of the day (e.g.,
>   shop business hours, theatre hours).

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(iii)   across the population there are varying degrees
         of flexibility with respect to start time, finish
         time, and total time involved in a particular
         activity.

(iv)   there is likely to be a constant travel time
         budget, which has arisen out of an individual's
         decision process in allocating his "flexible time".

(v)   there are dominant activities in the sense that
         they constrain the extent to which simultaneous
         decisions occur.

Taken together these assumptions reinforce the existence of
routinisation in the short-run and a limited amount of flexi-
bility. Let us expand on these five assumptions as a way of
identifying a hierarchy of activities and a possible modelling
strategy. The first assumption can best be discussed in the
context of a "typical" daily activity time profile, illustrated
in Figure 3 (Hargerstrand 1974). The example is of a full-time
worker, which is in many ways the most simplified of all the
activity structures of members of a household (Dix 1975).

In Figure 3, it can be seen that a person requires a minimum
amount of sleep (for example 6 hours) and has to work a given
number of hours (for example 7 hours). The actual time he
has to go to bed, rise, be at work and complete work is
variable within a limited time band (assumption (ii)), which
can be represented by some distribution function; for example,
the majority of individuals begin work between 7 a.m. and
10 a.m., and sleep until between 5 a.m. and 8 a.m. Although
this variability might appear to be large across the entire
population, for a particular individual it is likely to be

```
                                     000

                                     sleep (minimum)

                      B₁ ┤           0600
                         *
                       / │               flexible (sleep, preparation,
                      B   │                        work, travel)
                       2 ┤           0900

     complex
     decision
     periods &
     boundary        ┐       B₃ ┤   1230  flexible (work, eat, shop, other)
     determination   ┘           *    1330
                              B₄
                                     work

                            B₅ ┤     1700
                              \
                                         flexible (work, eat, shop,
                                                 sleep, travel, other)
                               *

                         ┤┄┄┄ 2400
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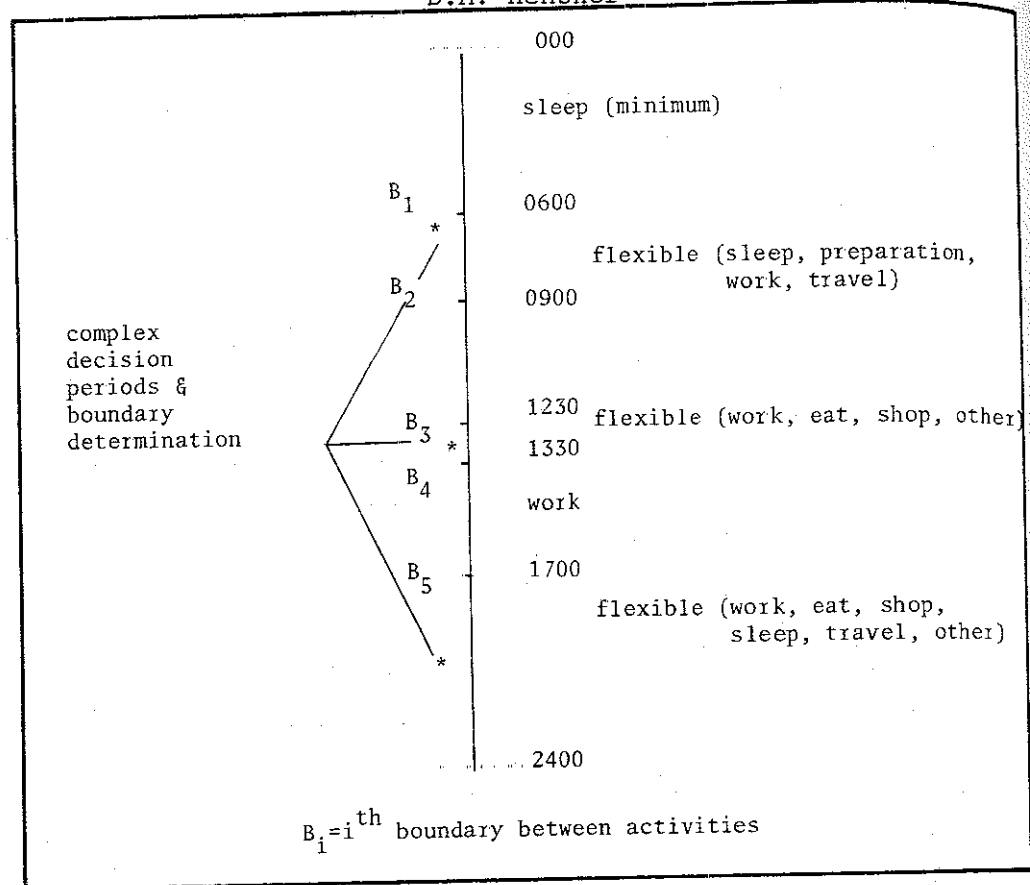
B$_i$=ith boundary between activities

Figure 3 : A Daily Activity Time Profile

considerably less variable. It is this reduced variance that is relevant in structuring a (short-run) framework for individual activity (and travel) behaviour. When supply timing constraints are considered, we find a reduced level of flexibility in the timing of activities, and in general an even greater degree of inflexibility in substitution between activities within a given time band (e.g. between 6 a.m. and 9 a.m.). It is this latter restriction (associated with assumed predetermined boundary points) which has contributed towards the constancy in the weekly travel time budget for an individual, and across all individuals (assumption (iv)). When we allow for the minimum amount of time required to prepare for travel and work and to

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have breakfast, there is a limited amount of short-run flexi-
bility in the amount of time that can be allocated to travel
to work; which is again consistent with the routinisation
hypothesis. Zahavi (1974, 1975, U.S.A.), Bullock et al (1974,
U.K.) and Goodwin (1975, U.K.) have evidence to suggest a
constant weekly travel time budget for a household; and some
evidence suggests that the travel time budget tends to increase
with distance of residential location from the city centre
(Zahavi 1974, p.18). Bullock et al (1974) and Tomlinson et al
(1973) suggest that it is possible to regard the time budget
as largely independent of the location of facilities in any
particular case. However, do people living further away from
the centre of a city undertake relatively more MTJ's and MPJ's?
We have no evidence at present since the known empirical work
into MTJ's and MPJ's is based on a relatively small study area.
The issue of substitution of timing of activities and hence
the resultant implication on journey structure is clearly also
influenced by the time constraint associated with the boundary
points. Difficulties in identifying the "time-ties" have been
outlined by Hedges (1974). Although in the case of work there
is generally no difficulty, what of a mother meeting a young
child from school? It may not be easy for an interviewer to
establish whether the mother's presence at the school premises
at 3.30 p.m. is obligatory, because of the subjective nature of
the 'tie'. Shopping is another difficulty, where the activity
itself may be obligatory, but the location and/or timing may
not be. Hedges found few examples of hard and fast ties, and
beyond these -

> "a large grey area in which activities had ties
> of varying strengths" (Hedges 1974, p.38).

Hence, to allow for this problem of flexible boundary points,
we need to complement the time budget data with measures of
the degree of obligation that an activity occurs at a particular

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time and place, and model this continuum of degrees of time-space obligation.

Thus far, we have indicated the need to identify and model (probabilistically) the determinants of the time-space boundary points, these influences being implicit in the five assumptions. This seems a useful reference point. Data would be required on the factors that influence the beginning and finishing times of activities. Such data would reflect a hierarchy of activities structure, and hence the basis for identifying the appropriate structure. Essentially, do individuals make simultaneous or sequential choices? (assumption (v)). Unlike the argument for simultaneity within the context of travel (i.e., with respect to the various travel choice acts) it is highly unlikely that all decisions on all activities are made simultaneously. That is, the decisions to get up at 6 a.m., travel to a particular workplace location at a particular time of day, live in a particular house location, go visiting and shopping on way home after work instead of initially travelling home, etc. Rather some sequencing, related partially to dominance of activities occurs. An empirical investigation centred around the issue of boundary points might produce a relationship between activities for one individual within a short-run context such as that shown in Figure 4.

In the short-run, although residential and workplace location are fixed, and the location of schools, hospitals, shops, etc., the individual can and does have the opportunity to rearrange his activities and thus restructure his journeys. Many of the potential influences indicated in the chart are variable in the short-run (e.g., amount of time required to travel to work). Another important aspect of this approach is that we are attempting to place travel in a more realistic activity framework in which the boundary points themselves are critical
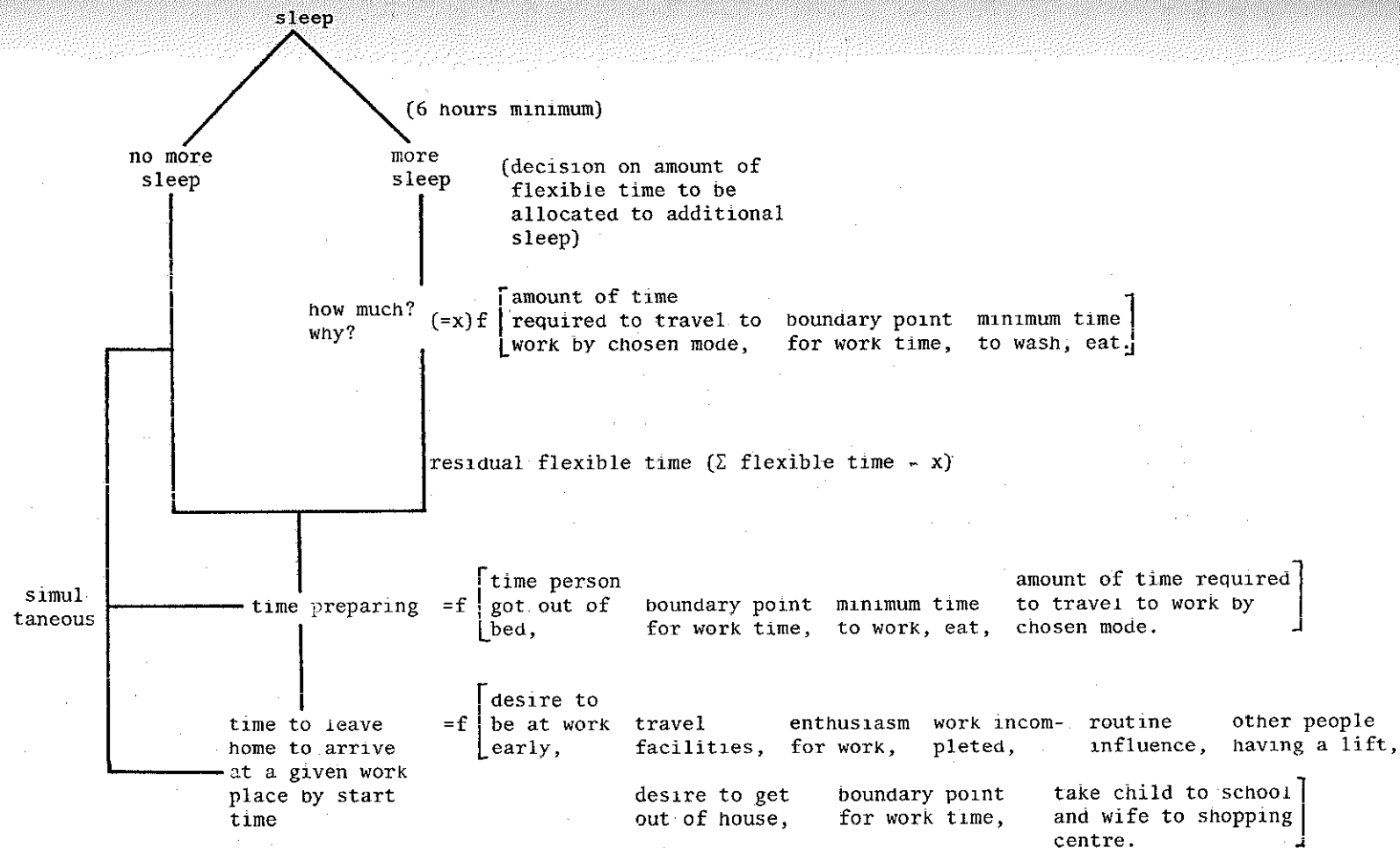
sleep

(6 hours minimum)

no more
sleep

more
sleep

(decision on amount of
flexible time to be
allocated to additional
sleep)

how much?
why?

$(=x)f$ $\begin{bmatrix} \text{amount of time} & & \\ \text{required to travel to} & \text{boundary point} & \text{minimum time} \\ \text{work by chosen mode,} & \text{for work time,} & \text{to wash, eat.} \end{bmatrix}$

residual flexible time (Σ flexible time - x)

simul
taneous

time preparing $=f \begin{bmatrix} \text{time person} & & & \text{amount of time required} \\ \text{got out of} & \text{boundary point} & \text{minimum time} & \text{to travel to work by} \\ \text{bed,} & \text{for work time,} & \text{to work, eat,} & \text{chosen mode.} \end{bmatrix}$

time to leave
home to arrive
at a given work
place by start
time

$=f \begin{bmatrix} \text{desire to} & & & & & \\ \text{be at work} & \text{travel} & \text{enthusiasm} & \text{work incom-} & \text{routine} & \text{other people} \\ \text{early,} & \text{facilities,} & \text{for work,} & \text{pleted,} & \text{influence,} & \text{having a lift,} \end{bmatrix}$

$\begin{bmatrix} \text{desire to get} & \text{boundary point} & \text{take child to school} \\ \text{out of house,} & \text{for work time,} & \text{and wife to shopping} \\ & & \text{centre.} \end{bmatrix}$

Figure 4 : Relationship Between Activities

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influences on the nature of travel and structure of journeys, and which must be modelled explicit. Present urban transport models take the boundary points as exogeneous variables rather than prime endogeneous determinants on such travel choices as the selection of a particular mode or route or frequency of travel. Once again we face the problem of discontinuity (exemplified by boundary points). It is this problem that has given rise to a limited set of (transport-type) policy options emanating from current models. The hierarchy indicated above has been arrived at by reversing the order of emphasis to highlight the timing of an activity. The timing of travel is a function of both travel and non-travel influences; the travel influences in the short-run being the modes available and the routes available for certain dominance journey purposes (e.g., work); and for other purposes being both of these influences plus available frequencies and destinations. Since our example suggests a simultaneous modelling of the allocation of flexible time between sleep, prepare and travel, it does not seem plausible to model choice of travel mode for the trip to work in isolation, as is commonly the situation. The latter implies a sequential structure in which time has already been allocated to sleep and preparation, and that the choice of mode is independently assessed and the travel time budget given. In addition, according to the sequential model any policy change (e.g., reduction in bus fares) should not have any effect on the reallocation of the flexible time. In fact, if a switch to the bus also entailed a new travel time outlay in excess of the travel time budget, then our sequential model could not accurately predict the real outcome. Once again, boundary points are central to the determination of the extent of simultaneity or sequencing.

The simultaneous model would be

$$P \text{ (sleep, prepare, travel)} = P(s) \cdot P(p/s) \cdot P(t/s,p)$$
$$\quad\quad (s) \quad\quad (p) \quad\quad\quad (t)$$

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and the sequential model of two possible forms depending on
whether each activity is assumed to be completely independent
or interdependent with a hierarchy:*

    (a) independent   :   P(s), P(p), P(t)

    (b) interdependent   :   P(t), P(s/t), P(p/t,s)

To conclude this section and to clarify the importance of a
need to research the short-run and long-run hierarchy of travel
and non-travel activities, information is required not simply
on the factors affecting particular travel choice acts (e.g.
mode choice) but also on the factors that influence the spatial
and temporal structure of travel. Does a person perceive charac-
teristics of travel or the specific form of travel as important
to the decision process? (Fried and Havens 1974, Dix 1975).
This approach helps in determining the extent to which various
travel choice acts are in fact relevant issues. For various
situations, for example, choice of mode may not be a relevant
issue at all (Boulanger 1971, Hensher 1974); but rather choice
of journey structure for a given mode.

(iii) land use configuration

The activity framework must be able to represent the role of
existing LUC's in structuring present journeys. How do we
"integrate" land use and travel? Initially, we must identify
the "action space" (after Wolpert) defined to designate the
spatial framework of behaviour which guides decisions relative
to desires and needs. As a starting point, we should thus
collect data from individuals on the various activity locations
(plus nature of activity) that an individual visits regularly
and those he considers in his relevant action set but does not
visit (for a number of identifiable reasons). Then information
is required on the present structure of journeys to and from

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*P(A) is the probability that a random event, A, occurs.
P(A/B) is the probability of event A occurring when it is
known that event B occurs. This is the conditional prob-
ability of event A for given event B.

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the activity locations. LUC can be expressed initially in a
distance or generalised cost matrix of every activity location
in the action space by each other activity location, for each
mode (in case of generalised cost). This matrix is then
related to the present structure of journeys: no. of n trip
journeys per person = f(   ). If a person has for one week
(say) two 2-trip journeys and three 3-trip journeys we have 5
observations for that one person, with values of 2,2,3,3,3.
There is a separate model for each of the journey structures.
An alternative dependent variable might be the proportion of
total journeys that are MTJ's. The independent variable could
be measured in a number of ways, although the most appealing
initially is the ratio of

$$\frac{\text{distance if 2-trip journeys}}{\text{distance when n-trip journeys}}$$

For a 2-trip journey, the ratio will be unity, using this as
a norm. This procedure does reflect the spatial separation of
activity locations. The higher the ratio, the less dispersed
are activity locations. We can produce probability models of
a person undertaking a particular journey structure given a
particular LUC (measured in terms of distances between activity
locations). Additional variables could be added to reflect the
proximity of the key activity nodes (home and workplaces) to
schools, shops, etc. If land use facilities are close together
a person could visit each one after another. If facilities
are not close together, the individual may still want to visit
one activity location after another, if they are all closer to
each other than each is to the home or workplace. Thus the
extent of MTJ's and MPJ's must, amongst other considerations,
be related to the distance or generalised cost between pairs
of fundamental destinations relative to the distance or general-
ised cost between each fundamental destination and home or
workplace. The distribution of activity locations around the

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home and workplaces is a key consideration. The availability
of various means of transport in accessing activity locations
and the generalised cost associated with available means of
transport are further variables which have an influence on the
extent of MTJ's and MPJ's, although they are not strictly
related to the issue of LUC.

Since a basic requirement of this approach is a knowledge of
the individual's action space, we should attempt to identify
the determinants of the action space as a way of assessing how
such space (which contains relevant activity locations) is
affected by any changes in the individual's position. One
useful way is to measure action space in terms of the number
of fundamental destinations visited per week as a function of
such potential influences as car availability, car ownership,
structure of household, income, etc. By this method, we have
an idea of action space, its determinants, and the influence
of LUC (within the action space) on the structure of journeys.

Although there is little empirical evidence at present, it is
reasonable to assume that changes in LUC do have an effect on
the structure of journeys and thus the nature of travel. For
example, a new regional shopping centre close to a major work-
place location could be expected to influence the timing and
sequencing of journeys. One possibility is that after work the
main worker meets his wife and does the weekly shopping, and
they both return home; in contrast to the previous situation
of he returning home from work and going shopping with his wife
elsewhere (Figure 5). Three 2-trip journeys (treating the wife's
journey separately) have been replaced with one 3-trip journey
(worker) and one 2-trip journey (wife). What sort of model can
predict this outcome? A model that responds positively to this
question will be a fundamental contribution to the debate. Some
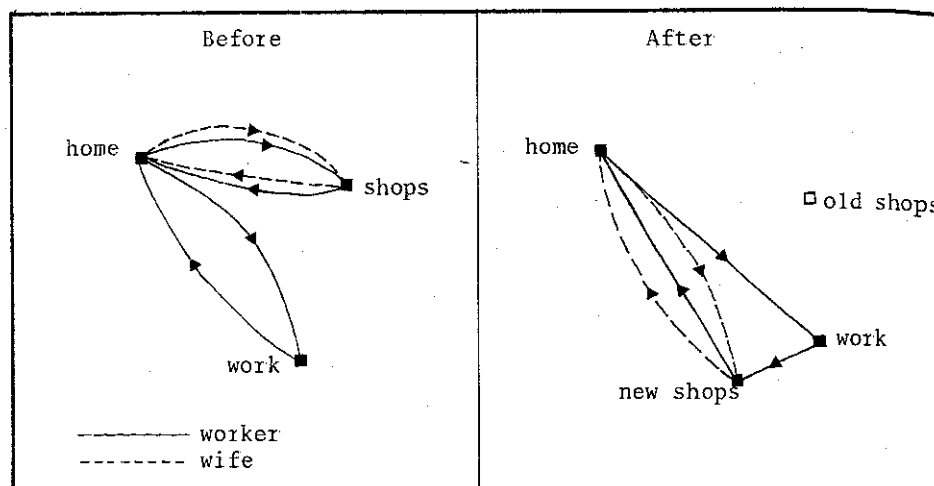
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Figure 5 : Effect of Journey Structure of Change
in LUC

suggestions can be made. The model proposed above is of value
only in seeing if there is any variation in journey structure
as a result of variations in LUC's. It is not able to predict
the likely restructuring of a journey as a result of a change
in land use since it only contains a simple distance ratio to
represent the physical effect of LUC. Hence we now require a
more general model in which the present LUC is an input. Two
functions might be required:

P_r(undertaking a journey) = f (....   )

P_r(continuing a journey/undertaken) = f (LUC, routine
                                        influences,

                                availability of mode,

                                number of commitments
                                (i.e. No. of times a
                                week person has to
                                undertake activity
                                type i,)

                                duration of
                                activities, ...)

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This could be a binary (limited) dependent variable, equal to
one for a two-trip journey and zero for a multi-trip journey.
The binary logit transformation function can then be used to
estimate the model.

It is the LUC in the second function which is modified. It is
defined initially (until research has identified the important
determinants) in terms of the distance ratio as modified by the
additional activity location creating new distance ratio pairs.
All new combinations must be included, and the model should
predict the probability of the individual continuing the
journey (i.e., going to new shops in contrast to going home).
The inclusion of LUC in the broader model has placed in per-
spective (vis-a-vis other variables) its role in influencing
the structure of journeys. Quite clearly, other influences
must be considered such as the attractiveness of the facilities
at the new location compared to those at the present activity
location (e.g., see Stopher, Watson and Blin 1974), the boundary
points which constrain the amount of time available within
which activities can be reallocated, the availability of
modes at the new times of the day, the non-distance related
travel influences, etc. Once again, some basic research is
required to identify the independent variables for the two
functions.

Further, pre-estimation classification by socio-economic
characteristics might be undertaken to identify any relation-
ship between the extent of MTJ's and MPJ's and socio-economic
characteristics of the individual and his household (Hensher
1976b). Categories, with respect to the issue, can be produced
which are conceptually homogeneous (all the phenomena in it
are comparable), mutually exclusive (the answers are non-
overlapping) and collectively exhaustive (they together include
the whole situation).

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CONCLUDING COMMENTS

The topic of this paper is not an easy one to come to grips with because of its complexity and the dearth of work in the area of behavioural approaches to modelling the real structure of journeys. Hence, the arguments are sometimes incomplete. It was considered desirable to attempt to bring together some of the basic arguments that have been developed in separate areas of research (in particular time-budget work, disaggregate behavioural travel demand modelling and general theories of human behaviour) in order to highlight the key components of a more integrated and realistic approach to investigating individual (and subsequently group) behaviour in an activity framework, within which the structures of journeys are fundamentally interwoven. Any model should allow for change in the number of trips per journey and the number of purposes per journey. Generally, none of the empirical research has been concerned with collecting data primarily to identify, understand and model journey structures at a behaviourally responsive level. The majority of the research concentrates on modelling known aggregate trip linkages.

The time budget and travel diary approach, together with necessary complementary information on the extent of planning of activities, obligation of allocated time, habit, and dominance of activities, can help to develop hypotheses that are more appropriate for modelling the nature of travel than existing approaches. The work of Cullen and Phelps supports the notions theoretically proposed by many that the present disaggregate behavioural choice models do not adequately represent the true behavioural situation an individual faces (especially in the short-run) since he does not consider himself in a choice situation on a daily basis. The work of Burnett (1974) comes close to the spirit of this paper, where

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she is concerned with the choice of alternative destinations, although she does not allow for the possibility of alternative journey structures.

Within an activity framework in which boundary points are endogeneous variables, new possibilities for policy are more evident. For example, small changes in shop opening hours and work hours could help to relieve problems of traffic congestion which had hitherto been considered soluble only by the construction of more transport infrastructure or other direct means (e.g., road pricing, banning vehicles in certain areas). Staggered working hours, however, may adversely affect those establishments that are heavily linked to the work trip unless longer business hours are adopted (Hanson 1975). Hanson suggested that car pooling has a constraining influence on a person's ability to undertake additional trips for non-work purposes on the way home from work.

The immediate task is to investigate the arguments of this paper in an empirical context, as a useful way of identifying the main determinants of the structure of journeys. Only then will we be in a better position to suggest more positive guidelines for direction for future research.

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