ACTIVITY ANALYSIS AND TRAVEL DEMAND

T. P. TRUONG
Postgraduate Student
School of Economic and
  Financial Studies
Macquarie University

ABSTRACT: *Conventional transport demand models as well as disaggregate behavioural models of travel choice do not explicitly treat the demand for travel as a derived demand, although the derived nature of the travel decision has long been recognised in the transport literature. Activity-analysis brings into focus the various motivational factors and constraints, in addition to the travel characteristics, to illustrate a fact that travel decisions may be influenced by other general activity considerations.*

In particular, this paper will argue that the decisions on location, mode, route, time of day, as well as those on the type of travel (journey to work, shopping trip, leisure travel, etc.) are interrelated with other decisions on the allocation of limited individual resources among the various urban consumption activities (health, food, clothes, recreation, housing, as well as transport).

The aim of the paper is to expose the inter-dependencies between these various activities in a simplified multi-stage decision model, so as to provide a starting point for future vigorous construction of a travel demand model based on activity-analysis.

Paper for Presentation in
Session 9

ACTIVITY-ANALYSIS AND TRAVEL DEMAND

INTRODUCTION

In recent years, there has been an increasing emphasis on using time-budget studies and activity-analysis as new instruments for the study of urban growth and urban structures (Gutenschwager 1973) and the study of travel behaviour (Jones 1977). However, despite the increase in the amount of research(1), the current state of the art is still very much in an exploratory state, with emphasis being on understanding rather than on "premature quantitative model development" (Jones 1977, 18). In fact, some author is even doubtful of the appropriateness of a mathematical model in representing human activity choice (Brög 1978).

On the pioneering side, one finds several authors already proceeded with mathematical models of activity choice: Kobayashi (1976) with a queuing model of trip-linking, Hemmens (1966, n.d) with a Markov chain model, Lenntorp (1976) devised a simulation approach to study the operation of the individual's space-time constraints, and Tomlinson et. al. (1973) employed an entropy-maximising simulation model to study the distribution of activities. Even though most of the results reported so far have been encouraging, these methods are still far from being perfect and one is still a long way from having developed and perfected a general activity-choice model which can assist in the forecasting of travel demand.

The lack of an appropriate new mathematical tool, however, should not deter one from considering the conceptaul framework of activity-analysis as useful and attractive for the understanding of urban travel behaviour. Indeed, it is the contention of this paper that further advances in the area of activity-analysis need not concentrate merely in the development and refinement of new quantitative techniques, but rather it could also focus simply on integrating the activity concept into the existing frameworks of travel demand analysis. In so doing, one hopes that the derived nature of travel activities - which for so long has been recognised, but which is still widely neglected in existing travel demand literature (2)

---

1. For a survey, see Jones (1977), Ottensmann (1972) and Gutenschwager (1973).

2. What really comes out in practice is a mere introduction of a partial feedback of the transport decision on land-use pattern, and vice-versa, but not a full integration of the two types of decisions based on an activity-decision.

will be given a better recognition this time. This will help to bring into the picture new dimensions for the analysis of travel behaviour, namely the activity dimension, which will reflect the space-time constraints as well as other household constraints associated with the individual's choice of activities. This will provide a new theoretical framework for understanding travel behaviour (Jones 1977).

From a transport planner's viewpoint, the new dimension is important because it helps to broaden the scope of the planner's decision to include not only transport-related but also non-transport options(1), and in so doing, it also gives a better description of the real preferences and needs of the individuals who live within the urban environment. Without this second element, future transport plans which are based only on present needs and the expressed pattern of behaviour may continue to create further and more aggravated problems as well as solving old ones(2).

Activity-analysis offers improvement in the scope for travel demand analysis, but at the same time, it also poses difficult theoretical as well as empirical problems; how are the activity choice set and activity constraints defined? What sort of framework can handle all this? These are the question that this paper alone cannot completely answer. Instead, we will concentrate here on the following issues: an analysis of the potential benefit of activity-analysis in relation to existing transport demand models; a survey of existing concepts and theoretical frameworks leading to a model of activity demand and from there we can draw the various implications and conclusions.

POTENTIAL ADVANTAGES OF ACTIVITY-ANALYSIS

Jones (1977) summarised the potential advantages of using activity-analysis for the understanding of travel behaviour as follows:

---

1. Such as bringing opportunities to the people rather than moving the people to opportunities (Hensher 1977) through various schemes of activity decentralisation.

2. A classic example is the attempt to provide for future transport demand by building more roads to accommodate more cars. In some instances, this may create further problems because the building of roads displaces more people and activities, and the people will in turn require to be accommodated for in the roads.

ACTIVITY ANALYSIS AND TRAVEL DEMAND

(1) Activity-analysis explicitly recognises travel demand as a derived demand.

(2) Travel linkages are easily incorporated in an activity framework.

(3) Non-travel implications of transport policies as well as travel implications of non-transport policies may be easily assessed in an activity framework.

(4) This will facilitate qualitative as well as quantitative assessment of the role of transport in the people's everyday life and hence give the transport plan a wider perspective.

Starting with the issue of 'derived demand', traditional transport modelling techniques (four-step approach, gravity models) recognise that travel is derived from the forces of interaction between population distribution and opportunity (or activity) distribution. However, the 'theories' are no more than an analogue of the physical law of gravity, and as such, they offer no real insight into the understanding of the way people behave (the choices they make or the constraints they are facing). Given a transport, land-use system structure and the population distribution, one can then predict an aggregate pattern of travel movement, but one cannot infer from this what pattern of movement the individual would prefer or how he would react in the face of future system changes. One can say that the aggregate pattern is derived from the supply side, a situation whereby an individual has to make a decision when the system of constraints has already been in operation, and one in which the individual has no real choice. What one really needs to look at is the travel behaviour derived from the demand side, i.e. derived from the demand for various activities which are in accordance with the individual's preferences and needs, subject of course to the society's economic and institutional constraints.

Disaggregate behavioural models have corrected for this by focussing on the individual's choice process and then try to infer from it the aggregate result for the system as a whole. But then the principal concern here is only with the travel decision alone, and as a result, important factors which are of direct relevance to the travel decision but which do not come under the heading of

'travel characteristics' are not considered(1). With the importance of non-work travel as well as of travel linkages now recognised (see Jones 1975), Morris et. al. 1978)one cannot view the nature of travel activities in a simplified manner as before, ie. where all the relevant decision factors are reduced to an 'uninteresting' set of travel costs and travel time which in many cases may not be significantly different for alternative decisions.

When one recognises that travel decisions are usually linked with other activity decisions, then one can see that transport policies and non-transport implications are necessarily linked. As Ellegard et. al. (1950, 50) pointed out: "It would of course be an exaggeration to say that the transport apparatus is a motive force in social development. On the other hand, every choice of system has a way of fostering certain development trends and inhibiting others".

Apart from the changes brought about by conscious policies, people's preferences and life-style may also change over time or changes with technoligical development. The improvement in the electronic means of communication and exchange may lead to a reorganisation of activities so as to reduce the need for certain types of travel activities and increase the incidence of others. A technological development in the area of mass transport may induce certain locational and activity reorganisation so that the future pattern of travel demand may greatly differ from the exist- ing reliance on the private means of transport. In other words, a car is as much a means of transport as a means to a certain activity life-style, so that one cannot study transport demand without reference to the people's activity organisation and life-style. Indeed, it was primarily a concern with the quality of life issue that originally led modern urban planners (Chapin 1971, Hagerstrand 1970) to the study of activity organisations and patterns, and perhaps this should remain as one of the principal concerns of activity-analysis.

---

1. To take as an example, the choice between alternative modes is not conditioned by travel cost and travel time alone, or the level of comfort, convenience, etc.... but may also depend upon a set of household constraint characteristics (Hensher 1978) such as how to fit in with other activities and other members of the household, etc...

ACTIVITY CHOICES AND CONSTRAINTS

The two main concepts that relate to activity-demand are activity choices and activity constraints. The former can be said to come from the work of Chapin (1968) and the latter from the work of Hägerstrand (1973).

Chapin considered that activity systems or patterns are the main determinant of urban structure and urban growth, in contrast to the traditional concept of the city which considered only the physical attributes as important. Chapin developed the idea from Mitchell and Rapkin (1954) who can be considered as the first transport planners to look into urban activities systems[1]. However, while Mitchell and Rapkin considered activities as responsible for the level of traffic demand, Chapin considered only the land-use aspects of activity patterns[2]. There can be two types of activity patterns in the Chapin framework: short term (e.g. daily) activity patterns and long term (e.g. life-cycle) activity patterns. The two are inter-related, with the first having a direct influence on the second, and with the second having a direct bearing on the process of urban growth. For example, daily activity patterns influence the decision on household locations, which in turn has an impact on the pattern of land-use. The "agents" that are responsible for the activity decisions are of three main categories: the firms, the institutions, and the individuals. For the individuals, the decision process is explained by the following "schema": motivation   choice   activities. Obviously, there is nothing "new" in this schema, as the transport planners have already been familiar with the "choice scheme" of the disaggregate behavioural models, where each transport decision (e.g. mode choice) is explained in terms of the level of the utility (motivation) of a set of attributes (households, locational, transport). What is important and

---

1. "It is obvious that the transportation systems should be planned as a whole in order to serve the city's many activities with the greatest possible efficiency. These activities include the production and distribution of goods, the rendering of services to business and to individuals, the advancement of cultural, civic, and political interests, and the daily living and working routines of people". (Mitchell and Rapkin 1954, 6).

2. "Just as the analysis of movement systems ... has become the basis for transportation planning, the study of activity systems serves a corresponding purpose in land-use planning". (Chapin 1965, 224).

useful in Chapin's framework is a supporting evidence about the increasing recognition of the role of the individual's preferences in the determination of the systems outcomes.

In contrast to Chapin, Hägerstrand (1973) emphasised the role of space-time constraints in determining the activity patterns of the individuals. These constraints relate, not only to the physical distribution of activity, locations and population (land-use structre), and to the level of transport services, but also on the social and institutional structure. Within this system of constraints, the individual is allowed a certain amount of "freedom of action"(1) which can only be changed through the social and institutional rearrangement of activities and through improved level of transport services. Here comes the role of the transport planners: to guarantee to provide a minimum amount of "freedom of action" to all individuals in the urban environment who may differ in their activity patterns as well as accessibility to the various means of transport(2).

There are more constraints to activities than just space-time or institutional constraints as envisaged by Hägerstrand, for example, the constraints due to socio-economic characteristics of the individual or due to the interdependencies between the individual and other members of the household (Hensher 1978). These so-called "household constraints", together with the space-time and system constraints, define a set of activity constraints that delimit the choices of the individual.

As Jones (1977) pointed out: choices and con-straints together define a powerful framework for under-standing the travel behaviour of the individuals. In the

---

1. Hägerstrand defined the individual's "freedom of action" as the total number of possible combinations or permu-tations of activities that he can carry out given a land-use structure and a level of transport service. It is thus a kind of "accessibility measure" and in fact a better measure than the conventional ones because here it relates to a whole program of activities rather than just a single activity.

2. An example of this minimum level is given in Ellegård et. al. (1975, 56). Here, considering one individual who has access to a private means of transport, and another who has to use public transport, the aim of the transport planner is to provide a level of public trans-port services such that the latter can carry out at least the same activity program as the former, although not necessarily in so many different ways.

language of the economists, the former relates to the demand, whereas the latter is a characteristic of the supply. Both elements are interdependent and jointly they produce the activity outcome, i.e. the travel behaviour.

PREVIOUS MODELS OF ACTIVITY ANALYSIS

Hemmens (1966, n.d) using a Markov-chain simulation model and various other statistical correlation analysis tried to establish a relationship between the pattern of activity occurrences and various household (socio-economic) and space-time (time of day, duration of activities, free time availabke, relative accessibility to activity location, etc...) characteristics. The results reported were "essentially negative" in the sense that "the propositions or factors related to activity choice are generally upheld in the statistical analysis, but the results are not good enough to support further modelling work or to develop simpler, more parsimonious propositions. The statistical associations are weak and the web of relationship is complex" (Hemmens n.d, 3).

Kobayashi (1976) using a queuing optimization model attempted to describe the trip-linking activities of the individuals within the urban and suburban areas and came up with encouraging results. Given a total time duration for each round trip, together with the "physical factors of the area, that is, the time required for both transportation and activities", the model can then predict the optimal number of visits to various destinations, i.e. the type of activity-linkages. The model, however, is not a true demand model because it only generates the expected number of visits per round trip, but not the total number of trips per day. In principle, the total number of trips can be deduced, by dividing the total time available by the total transport and activities time, however, this is not completely satisfactory, as the total time available needs to be treated as an endogenous variable as well, i.e. something which is related to the activity program and to the level of transport services. Furthermore, since "demographical parameters" of the inhabitants and the "social characteristics of the area" are not directly represented but only indirectly through the length of the activity time and by way of the choice of destination places, much of the explanation power of the model is thus lost. One needs to know how activity time and destination choice are really related to individuals' socio-economic characteristics or to the characteristics of the urban environment.

In contrast to the above models which handle Chapin's choices, the simulation models of Tomlinson et.al. (1973) and Lenntorp (1976) are concerned only with the working of the constraints system. Tomlinson et. al. used an entropy-maximising simulation model to find out the daily distribution of individuals (students) to various locations and activities given a set of space-time activity constraints. The model yields aggregate result for the system as a whole but no individual pattern of activities. Even though Jones (1977) pointed out, that this was due not to any theoretical short-coming but simply because the data was inadequate, one thing is obvious from the model, and that is, it is not designed to handle individuals' choices as "ho personal motives are attributed to an individual behaviour" (Tomlinson et. al. 1973, 233). In a similar way, Lenntorp's (1976) model was not concerned with how an individual would choose among the various alternative activity programs. All that the model was concerned with is the range of alternatives, or the individual's "freedom of action" defined in terms of the travel possibilities, given a land-use structure and level of transport services. The simulation approach has the advantage of being able to handle space-time constraints dynamically, but it lacks a "behavioural content" in the sense that it cannot predict how the demand (the individuals) would react to changes in the condition of the supply (the constraints). For example, would the individual make more trips if given more "freedom of action"? How would he change his activity and travel pattern if certain constraint changes? The attempt to answer the second type of question is given in Jones' (1977) Household Activity-Travel Similator. Here the emphasis is simply on understanding the travel behaviour and exploring the patterns. The curcial question, however, is whether one can come up with strong testable hypothesis to explain the travel patterns themselves, and to date this has not been established.

Hensher (1978) attempted a diff erent approach; here the concept of activity constraint is integrated into the travel (mode choice) decision itself. The method used was probabilistic individual choice modelling. The utility function of the mode choice decision is expanded to include not only travel characteristics but also household constraints characteristics describing the interdependencies between the travel activites and other activities, as well as between the individual's activities and those of other members of the household. A similar approach is observed in McCarthy's (1977) model. Here the mode choice decision is expanded to include factors relating to residential location decision. In adopting this type of approach, one can retain the basic

structure of the conventional model and all that is required is to integrate the activity dimension into the various stages of the travel decision. In so doing, the derived nature of the travel decision will come out clearly without too much effort on the restructuring of the existing models. Indeed, such an approach will be adopted in this paper.

TOWARDS A MODEL OF ACTIVITY CHOICE

Theoretical Issues and General Framework

As behavioural models of travel choice normally have to face with the theoretical issue of whether travel decisions are sequential or simultaneous, so do models of activity choice.

The basic setback of a simultaneous model is that there will be too many interrelated factors to be handled at any one time. This setback is even more grave in a situation of activity choice, since an activity decision necessarily involves more factors than a simple travel decision. Take for example, the decision regarding mode choice, within the framework of activity-analysis, this may involve factors such as the type of travel activity undertaken, the time of day, in addition to the usual travel characteristics of the alternative modes. A sequential model has the advantage of having to cope with only a few parameters at a time, consequently, it is more manageable.

Sequential decision, however, does not imply separability of decision in time. It only means that at a given point in time (perhaps during a given day, or week, or month), the decisions are arrived at through several sub-optimization processes, each drawing on the results of the previous sub-process, but all of the decisions are to apply for that given point of time. The only reason why decisions are optimized in sequences or steps is that there appear to be subsets of variables, each of which can be treated as a single composite commodity, so there is no need to consider all the individual variables all at once. In an economic context, sequentiality of decisions implies a utility function which is separable, and separability of the utility function "implies such a budgeting procedure in which the decision to commit a sum of money [and/or a given amount of time] to a particular purpose is taken, not on the basis of individual goods on which it is to be spent, but rather on a notion of the general level of those prices" (Hansen 1974, 201, words in brackets added).

Separable utility functions have been used to study travel-activity demand. Kraft and Kraft (1975, 1976) used an S_1-branch utility tree and an S_2-branch block-additive utility function to study the demand for intercity travel in terms of the transport characteristics (cost, comfort and

convenience) of the four transport modes (airplane, auto-
mobile, bus and train).

The analysis of demand in terms of abstract trans-
port characteristics rather than in terms of actual physical
commodities also represent a new development within the
micro-economic framework of consumer theory. More specifi-
cally, this is a Lancastrian approach (Lancaster 1966),
which assumes that individuals do not demand commodities
(or activities) for their own sakes but rather to obtain
the characteristics that these commodities provide (1).
Using the Lancastrian approach, one can handle the question
of technological development, quality changes, future
characteristics, etc., in a more natural and easy manner.
These issues are important especially in the area of
activity-demand, because here qualitive aspects are as
important as quantitative aspects.

The adoption of a separable utility function and
the use of a Lancastrian-characteristics approach allows
one to specify a model of activity demand in several stages
as follows:

- In the first stage, the individual allocates his
total expenditures (money, and/or time) to various groups
of consumption activities (food, clothing, entertainment,
housing, transport, etc.)

- In the second stage, the allocated budgets are then
distributed among the various sub-groups of each group.
For example if one is concerned with the "transport" group,
the sub-groups may be defined as various types of transport
activities such as journeys to work, shopping travel,
leisure travel, as well as related consumption activities
like car purchasing, car maintenance and insurance, etc.

- In the third and final stage, activities within
each sub-group (such as journeys to work) will then be
allocated among the various destinations, modes, routes,
and perhaps even times of the day or week.

The specification of such a simplified multi-stage
model of activity demand has been based on the empirical
evidences reported, relating to travel and general consump-
tion expenditures. Jones (1977) reported studies which

---

1. If there is only one "characteristic" associated with
   a single commodity, then the characteristic is identical
   with the commodity itself.

pointed to a constant budget of time and money being spent on various travel activities. Mogridge (1977) reported a certain degree of substitutibility between car usage expenditure and car purchase expenditure, leaving the total level of car travel expenditure relatively stable. Schou (1978) reported studies which showed that certain types of travel activities (shopping and other non-work travel) are more sensitive to price changes than other type (such as work travel). All of these questions can be analysed within the theoretical framework of our simplified model.

It must also be stressed, however, that such a simplified model of activity-choice cannot be specified any more rigorously without further testing of the validity of the underlying separable utility hypotheses. One can also conduct parallel investigation into the nature of the individual's decision structure, the type of characteristics or factors influencing the decision at every stage. For this purpose, the type of techniques, such as those described by Louviere et. al. (1977) for the understanding and measurement of behaviour and judgement, may prove to be most helpful. In the absence of further empirical evidences, however, our simplified multi-stage activity model can be used to describe the general features of a model of activity-analysis.

A Mathematical Description of the Model in Details

Let: $Y_1, \ldots, Y_n$ be the real expenditure levels for consumption activities of group 1 through n

$P_1, \ldots, P_n$ be the corresponding general price levels of these groups.

Y be the total expenditure or income

$U(Y_1, \ldots, Y_n)$ be the utility (or preference) function of the individual

then, the problem for the first stage is:

$$\text{Max} \quad U(Y_1, \ldots, Y_n) \tag{1}$$

$$\text{s. t.} \quad \sum_{i=1}^{n} P_i Y_i = Y \tag{2}$$

347

the solution to this problem will yield the optimal demand function for various commodity groups as follows:

$$Y_i = F_i (Y, P_1, \ldots, P_n) \qquad (3)$$

One can experiment with various forms of the utility function which correspond to the various forms of the demand function. For example, the simplest additive utility function

$$U = \prod_{i=1}^{n} Y_i^{a_i}$$

will yield the simplest demand function

$$Y_i = b_i \frac{C}{P_i} \quad \text{where} \quad \sum_{i=1}^{n} b_i = 1$$

or, if the utility is of the Klein-Rubin form:

$$U = \sum_{i=1}^{n} b_i \log (y_i - a_i)$$

then the demand function will take the linear-expenditure form:

$$Y_i = P_i y_i = a_i P_i + b_i (Y - \sum_{j=1}^{n} a_j P_j)$$

The estimation of these demand equations will give the expected levels of expenditure for each commodity group by the individuals of a particular socio-economic group.

One can also follow a different line. For example, if one is interested in finding out how the individual evaluates his welfare position corresponding to a particular level of expenditure (i.e. his preferences rather than his actual behaviour) then one can adopt the method developed by Van Praag (1968). Here, it is a return to the cardinal utility concept in the sense that the individual is assumed to indicate, not only a preference ordering for the various welfare positions, but also to assign a unique welfare measure to each position. The measure, however, depends on the choice of the commodity-space, consequently, it is not a unique cardinal utility measure in the classical sense, but only a relative one, a neo-cardinal measure as called by Van Praag (1968).

ACTIVITY ANALYSIS AND TRAVEL DEMAND

In this approach, one first establishes the conditions under which the commodity-space (or the characteristics-space, if one adopts the Lancastrian approach) can be (approximately) represented by the expenditure-space. That is to say, the conditions under which there is a one-to-one correspondence between the amount of money (or time) spent on a commodity group and the combination of commodities (or characteristics) thereby obtained. The welfare evaluation can now be expressed in terms of the expenditure level. There is a similarity between the expenditure-space and the random variable space, and between the welfare measure $W(y_i)$ and the probability distribution function of the "random variable" y_i. Indeed, Van Praag (1968) made use of the similarity in the structures of the two concepts to apply the results of probability theory into the welfare area and established the following result: under certain conditions, the welfare measure $W(y_i)$ can be approximated by a log-normal distribution function[1]

$$W(y_i) = \Lambda(y_i; \mu_i, \sigma_i)$$

where μ_i and σ_i are the parameters of this distribution which can be estimated from the individual data (see Van Praag 1971). The meaning of μ_i and σ_i can be expressed as follows: $\mu_i = \log \overline{y_i}$ measures the logarithmic level of the expenditure at which the welfare measure is 0.5, i.e. half-way between zero satisfaction (W=o) and total satisfaction (W-1). μ_i can be described as the preference-parameter(1) of the individual the larger the value, the higher will be the level of expenditure for which W=0.5. σ_i describes the welfare sensitivity of the individual. Since a large value of σ_i will mean that the welfare measure is sensitive to changes in the expenditure level y_i.

The parameters μ_i and σ_i can be estimated for each individual. They are observed (Herwaarden et. al. 1977) to vary with income level and family size as well as other socio-economic characteristics of the individual groups. One can calculate the average values of $\overline{\mu_i}$ and $\overline{\sigma_i}$ for a particular socio-economic group and then compare the "average preferred level of expenditure", defined as $\overline{y_i} = \log_e(\overline{\mu_i})$, with the actual level of expenditure estimated from the demand equation (3) to have an idea of the extent to which an individual is "better off" or "worse off" as compared to the average position of the group. This extent can be measured by:

---

1. Van Praag (1971) called this terms the "want-parameter" of the individual.

$$W(y_i) - W(\overline{y_i})$$

and is a _cardinal_ measure which can serve the purpose of comparison between individuals.

After the total budget has been allocated to various commodity groups, one can then proceed to investigate how the individual allocates the group-budget among the various sub-groups of activities. Consider, for example, the 'transport' group. Let Y^o be the allocated travel expenditure (it might be the _preferred_ level or the actual average level) T^o be the _allocated_ time budget (which can be measured in the same way as Y^o). The individual is concerned with allocating Y^o, T^o among the various activity sub-groups:

Y_w, Y_s, Y_c denoting expenditures for work-travel (w), shopping travel (s) and car purchase (c).

t_w, t_s denoting time expenditures for working and shopping travel.

We assume that the individual will allocate his time and money according to the following DeSerpa-type (DeSerpa 1971) model:

Max $U(x_i, t_i, Y_c)$ $i = (w, s)$

s.t.

$$\sum_i c_i x_i \leq Y^o - Y_c$$

$$\sum_i t_i = T^o$$

$$t_i \geq b_i x_i$$

Here x_i denoted the level of trips (travel demand) for activity purpose i, and c_i is the cost of one trip for this particular type of travel. The solution of the model yields the travel demand for various activity purposes. This can be considered to be equivalent to the _generation_ step of the conventional transport approach.

The travel demand for a particular activity purpose (x_i) will then be allocated to the various times of day (t), destinations (d), modes (m), and routes (r), according to the following model of the third stage:

ACTIVITY ANALYSIS AND TRAVEL DEMAND

Max $\qquad U(x^i_{tdmr})$

s.t.

$$\sum_{tdmr}\sum\sum\sum x^i_{tdmr} = x_i$$

An example of the type of models which correspond to our third stage sub-model is Beckmann and Golob (1974), Hensher (1978).

Implications for travel-linkages.

As indicated in the beginning, one of the principal concerns of activity-analysis is how to model activity-linkages. Even though our model does not handle activity-linkages explicitly, one can investigate this type of problem indirectly by prior specification of the various patterns of activity-linkages and label them as various travel activity sub-groups. Thus, the individual will allocate his time and money for activity-linkages when he compares the cost, as well as other characteristics, of this type of activities, with other single-purpose travel activities.

Implications for value of travel time.

The implications for value of travel time (VOT) measurement is evident in the sub-models of every stage of our model. In stage one, for example, if one can establish the parameters of the individual's welfare function $W(Y°, T°)$ in which both the time for travel and travel expenditure are evaluated jointly by the individual according a log-normal function:

$$W(Y°, T°) = \Lambda(\underline{Z}; \underline{\mu}, \underline{\Sigma})$$

where

$$\underline{z} = \begin{bmatrix} Y \\ T \end{bmatrix} \quad \underline{\mu} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \quad \text{and } \underline{\Sigma} = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{12} & \sigma_{22} \end{bmatrix}$$

then the <u>value of travel time in general</u> can be derived as

$$VOT \doteqdot \frac{\lambda}{\mu} \quad \text{where} \quad \lambda = \frac{\partial W}{\partial Y°}$$

$$\mu = \frac{\partial W}{\partial T°}$$

351

Stage two establishes the value of travel time associated with different activity purposes (travel sub-groups) and stage three can establish the value of time for various modes, time of day, etc.

CONCLUSION

Activity decision is necessarily complex, so that to capture all the relevant features of an activity choice which has a bearing on the travel demand, one has to resort to a simple specification of a multi-stage activity decision structure. At every stage of the decision, one tries to identify not only the factors relating to transport – land-use characteristics, but also other factors relating to the constraints arising out of a general pattern of activities, and not just travel activities. In doing so, one emphasises the derived nature of the travel demand. Travel, and activities in general, is a product of individual choice and urban technological constraints. In concentrating on analysing activities, one hopes to strike a balance between traditional transport demand models which favour the urban constraints and the disaggregate behavioural approach which has favoured only individual choice.

REFERENCES

Beckmann, M.J. and Golob, T.F. (1974). "Traveller Decisions and Traffic Flows: A behavioural theory of network equilibrium". In D.J. Buckley (ed.) Transportation Theory and Traffic Flows. (Reed, Sydney).

Brög, W. (1978) "Behaviour as a result of individual decision in social situations". Paper presented at the Research Conference "Mobility in Urban Life", Arc-et-Senans (France).

Chapin, F.S., Jr. (1965) Urban Land Use Planning, Second Edition, Urbana, Ill., University of Illinois Press.

Chapin, F.S., Jr. (1968) "Activity Systems and Urban Structure: a Working Schema", Journal of the American Institute of Planners, Vol. 34, No. 1, pp. 11 - 18.

Chapin, F.S., Jr. (1971) "Free time activities and quality of urban life", Journal of the American Institute of Planners, Vol. 37, No. 6, pp. 411-417.

DeSerpa, A.C. (1971). "A Theory of the economics of time", The Economic Journal, Vol. 81, No. 324, pp. 828-846.

Ellegård, Hägerstrand, T. and Lenntorp, B. (1975) Activity organisation and the generation of daily travel - Two future alternatives, Department of Social and Economic Geography, Research Notice 23, Lunds University.

Gütenschwager, G.A. (1973) "The Time-budget-Activity Systems Perspective in Urban Research and Planning", Journal of the American Institute of Planners, Vol. 39, No. 6, pp. 378-387.

Hägerstrand, T. (1970) "What about people in Regional Science?" Regional Science Association Papers, Vol. XXIV, pp. 7-21.

Hägerstrand, T. (1973) "The Impact of Transport on the quality of life", Fifth International Symposium on Theory and Practice in Transport Economics, Vol. 1, Topic 5, European Conference of Ministers of Transport, Athens.

Hansen, S. (1974) "A Survey of Traffice Models with emphasis on behavioural assumptions" in Sven Erlander (ed.) Optimising Bus Systems in Urban Areas, Linköping University.

Hemmens, G.C. (1966) The Structure of Urban Activity Linkages, Center for Urban and Regional Studies, Chapel Hill, North Carolina.

Hemmens, G.C. (n.d) *Simulation of Urban Activity Patterns*, Center for Urban and Regional Studies, Chapel Hill, North Carolina.

Hensher, D.A. (1977) *Formulating an Urban Passenger Transport Policy: A re-appraisal of some elements - Accessibility, Energy and Urban Form*, Research Paper 151 School of Economic and Financial Studies, Macquarie University.

Hensher, D.A. (1978) *Interdependencies of travel decisions, other activities and household members in the frequency, timing and mode of travel to the shops: empirical evidence*, Research Paper 168, School of Economic and Financial Studies, Macquarie University.

Jones, P.M. (1975) "The Analysis and Modelling of Multi-trip Journeys", Working Paper No. 6, Transport Studies Units, University of Oxford.

Jones, P.M. (1977), "New Approaches to Understanding Travel Behaviour: The Human Activity Approach". Paper presented to Third International Conference on Behavioural Travel Modelling, Tanunda, South Australia.

Kobayashi, K. (1976) "An Activity Model: A Demand Model for Transportation". *Transportation Research*, Vol. 10, pp. 105-110.

Kraft, A. and Kraft, J. (1975) "Specification of commodity subsets for separable utility functions". *Applied Economics*, Vol. 7, pp. 225-240.

Kraft, A. and Kraft, J. (1976) "Mode Choice characteristics as determinants of interurban Transport Demand", *Transportation Research*, Vol. 10, pp. 31-35.

Lancaster, K. (1966) "A New Approach to Consumer Theory", *Journal of Political Economy*, Vol. 74, pp. 132-157

Lenntorp, B. (1976) *A Time-Space structured study of the travel possibilities of the public transport passenger*, Department of Social and Economic Geography, Paper No. 24, Lunds University, Sweden.

Louviere, J.J., Wilson, E.M., and Piccolo, J.M. (1977) "Psychological Modelling and Measurement in Travel Demand: A State-of-the-Art Review with Applications". Paper presented to Third International Conference on Behavioural Travel Modelling, Tanunda, South Australia.

McCarthy, P.S. (1977) "Residential Location and the Journey to Work", Journal of Transport Economics and Policy, Vol. XI, No. 2, pp. 169-184.

Mitchell, R.B. and Rapkin, C. (1954) Urban Traffic - A A Function of Land Use, Columbia University Press, N.Y.

Mogridge, M.J.M. (1977) "An Analysis of Household Expenditures 1971-75", PTRC, July.

Morris, J.M., Dumble, P.L., and Wigan, M.R. (1978) Accessibility Indicators for Transport Planning, ARRB Internal Report AIR 1058-3.

Morris, J.M., and Wigan, M.R. (1978) Transport Planning; A Family Expenditure Perspective, ARRB Research Report ARR No. 71.

Ottensmann, J.R. (1972) Systems of Urban Activities and Time: An Interpretative Review of the Literature, Center for Urban and Regional Studies, University of North Carolina, Chapel Hill, N.C.

Schou, K. (1978) "Energy and Transport: Strategies for Energy Conservation in Urban Passenger Transport". School of Economic and Financial Studies, Research Paper No. 170, Macquarie University, Sydney.

Tomlinson, J., Bullock, N., Dickens, P., Steadman, P., and Taylor, E. (1973) "A Model of Students' Daily Activity Patterns", Environment and Planning A, Vol. 5, pp. 231-266.

Van Herwaarden, F., Kapteyn, A., and Van Praag, B. (1977) "Twelve Thousand Individual Welfare Functions", European Economic Review, Vol. 9, pp. 283-300.

Van Praag, B. (1968) Individual Welfare Functions and Consumer Behaviour, North Holland, Amsterdam.

Van Praag, G. (1971) "The welfare function of income in Belgium: An empirical investigation", European Economic Review, Vol. 11, pp. 337-369.