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Behavioural models and spatial planning: some methodological considerations and empirical tests

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Abstract. This paper is concerned with the relevance of various geographic models of spatial shopping and residential choice behaviour to physical planning. It is argued that models relying on areal aggregation and overt spatial interaction patterns generally do not satisfy a number of methodological requirements considered extremely relevant in an applied context. In addition, it is argued that behavioural models provide a potentially more valuable approach for predicting consumer response to policy decisions with regard to spatial structure. Empirical evidence substantiating the claim that consumer evaluations bear some systematic relationship with objective attributes of spatial alternatives and overt choice behaviour is provided in the context of spatial shopping behaviour and residential choice behaviour.

Introduction

Since 1965 a substantial number of articles have emerged in geography and regional science which are concerned with developing and testing models to explain aggregate spatial-interaction patterns. Although clear differences in terms of specification and calibration between these models prevail, they may be classified into two general approaches. First, there are the gravity, spatial-interaction, and entropy-maximising models. Basically, these models assume that aggregate spatial choice patterns can be predicted from the attractivities of the alternatives and distance decay effects. In addition, they assume that observed interaction patterns may be used as input data to calibrate the model and make conditional forecasts of the likely effects of changes in attractivities and distance decay to consumer choice behaviour. Second, there are the lesser developed behavioural models. These share with the first class of models the assumption that consumer choice behaviour is contingent on the attraction of a number of alternative choices and distance separations. However, unlike the first class of models, the behavioural models predict choice behaviour by reference to individual's preferences, valuations, attitudes, perceptions, and/or judgments, which are generally measured with questionnaires or in laboratory experiments.

The present paper examines the relevance of both approaches to physical planning. Specifically, it discusses some methodological issues involved in applying these approaches to predict consumer reactions to changes in spatial structure in the context of residential choice behaviour and spatial shopping behaviour. The central thesis is that behavioural models offer a potentially more valuable approach to predict the likely effects of physical planning schemes as compared with the gravity-type approaches. The second part of this paper reviews some of the authors' recent research findings to substantiate the claim that consumers' evaluations bear systematic relationships with overt behaviour and with the physical attributes of spatial alternatives.

The appropriateness of the approaches to physical planning

To assess the appropriateness of the approaches to physical planning it is first necessary to define the essential characteristics of physical planning on the basis of which the approaches may be evaluated. Physical planning is basically concerned with the

location, intensity, and amount of land development for various space-demanding activities. This task represents not a goal in itself; land-use plans are the result of a more general planning process aimed at fulfilling objectives of economic and social well-being. Physical planning is also essentially future-oriented. It is concerned with the needs of space-using functions in the foreseeable future. Both characteristics necessitate the use of research. That is, research is needed to evaluate alternative planning programs in terms of fulfilling their underlying objectives; it is also required to forecast the future state of the system under investigation. If model building is to contribute to the solving of physical planning problems, at least two conditions should therefore be satisfied; generalisability of the results of a model and the inclusion of policy-sensitive independent variables. Generalisability in general refers to the fact that behaviour in one area can be predicted from observed patterns in another area. Generalisability thus refers to the condition that results pertaining to one group of respondents in one particular study area can be used validly to predict the behaviour of another group of respondents in a fundamentally different study area, and possibly in a totally different time period. The term refers to the condition that the structure and parameters of the model may be used to predict future behaviour in a different spatiotemporal setting. Parameter estimates should be independent of initial conditions.

Generalisability therefore involves three interrelated and overlapping issues: first, generalisation of the results pertaining to one group of respondents to another group of respondents; second, generalisation of the results to a future point in time; and third, generalisation of the results to a totally different region, as will often be the case in the context of physical planning, where there are major changes within the study area itself. The first issue largely seems to be a matter of suitable sampling design and therefore refers to a technical matter. The second issue, however, has some strong conceptual implications and essentially refers to the temporal stability of the phenomena being studied. The third issue has both some conceptual and technical implications and primarily is concerned with the process of model specification and parameter estimation. Two modelling approaches previously mentioned are now discussed on these dimensions.

Generalisation of the results of a model to another group of respondents, but within the same study area and at the same point in time, only presupposes a suitable sampling design. Within a particular study area a number of consumer types, which may be defined on the basis of their decisionmaking characteristics, may be identified. If generalisation is needed, it seems therefore necessary that the sample gives a good representation of the consumer types which occur in the population. Thus, a random and sufficiently large sample design is needed to generalise the results of a model which pertain to one group of respondents to another group of respondents, providing both these groups have similar decisionmaking profiles. Because the decisionmaking process of individuals may be governed to some degree by spatial factors, the sample should also be random in a spatial sense.

Temporal stability of the phenomena being studied relates to the fact that model calibration is dependent upon observations at one point in time. Evidently, if models are used for conditional forecasting a necessary condition to yield meaningful results is that the observed relationships between environmental factors and behaviour can be taken to apply in future time periods. That is, stability of behaviour patterns presupposes stability of antecedent conditions. Models of residential choice behaviour relying upon observed spatial-interaction patterns for calibration such as maximum-entropy formulations of the Lowry model (for example, Senior and Wilson, 1973; Putman, 1977a; 1977b; 1978; Putman and Ducca, 1978a; 1978b), linear programming models (for example, Hårsman and Snickars, 1975; Wheaton, 1974),

syntheses of these approaches (Anas, 1973; 1975; Senior and Wilson, 1974; Williams and Senior, 1978), semi-Markov models (for example, Ginsberg, 1971; 1972a; 1972b; 1973; 1978; 1979), and developments at UCLA (Clark and Huff, 1977; Huff and Clark, 1978; Clark et al, 1979; Huff, 1979; Smith et al, 1979; Smith and Mertz, 1980) appear not to satisfy this condition. Observable intraurban migration patterns are not only, nor mainly, the result of household's preferences, housing demand, and housing supply but are also the result of constraints deriving from personal, environmental, and social factors. In addition, the effect of each of these factors on observable residential choice patterns cannot readily be determined. Since it is well-known that these antecedent conditions may change dramatically even within the period of a few years, it is hazardous to use observable residential choice patterns for prediction. The effects of imperfections in the urban housing market on market choice cannot readily be assessed, and Menchik (1972) therefore also opts for using questionnaires to elicit residential preferences. The underlying contention is that household's preferences and evaluations are relatively stable and well-defined for various life-cycles and income groups unless major cultural boundaries are crossed. At least the rate of change in preferences and evaluations will be much slower as compared with the rate of change in environmental and social constraints. Hence, one should attempt to measure separately housing demand and supply. It is supposed that these preferences and evaluations can be measured properly. Recent research findings tend to support these assumptions (Veldhuisen, 1979b; Veldhuisen and Timmermans, 1981a; 1981b).

An implication of this line of reasoning is that only discretionary behaviour may be modelled adequately on the basis of overt spatial interaction patterns (see also Pirie, 1976). Unlike residential choice behaviour, spatial shopping behaviour may be considered as a form of discretionary behaviour. Although it is accepted that spatial shopping behaviour may be influenced by search and learning, imperfect information and uncertainty (MacLennan and Williams, 1979), it is argued nevertheless that these factors are relatively unimportant in influencing consumer shopping behaviour (see also Timmermans and Rushton, 1979). Consequently, models relying upon revealed choice behaviour for calibration (for example, Pipkin, 1977; Smith et al, 1977; Pankhurst and Roe, 1978; Recker and Kostyniuk, 1978; Hay and Johnston, 1979; Hubbard, 1979) reasonably satisfy the condition of temporal stability. It may even be argued that these models have the potential advantage that they model revealed behaviour whereas they do not share the difficulties of measurement, questionnaire design, and administration so typical for models relying on expressed preferences. Revealed preference models do not have to demonstrate that expressed preference bears some systematic relationship with overt behaviour.

As has been noted, generalisability refers to the condition that results pertaining to one group of respondents in one particular study area can be used validly to predict the behaviour of another group of respondents in a fundamentally different study area, possibly in a totally different time period. The term refers to the condition that the structure and parameters of the model may be used validly to predict future behaviour in a different spatiotemporal setting. Thus generalisability involves the question of whether results obtained by modelling one particular set of spatial alternatives with specific characteristics may be transferred to different sets of spatial alternatives.

Models relying on revealed behaviour clearly have the disadvantage of restricting themselves to the domain of experience. Revealed behaviour, by definition, concerns the choice of actual spatial alternatives. Since this set of alternatives is only one subset from among all possible sets of spatial alternatives (and hence the parameters of the model are not based on novel alternatives), these models involve the problem

of extrapolating the results of the model beyond the actual types of spatial alternatives observed. On the contrary, laboratory experiments and questionnaires permit the varying of the levels of the stimuli in every possible way even to the point of specifying spatial alternatives beyond the domain of experience. Therefore, in theory at least, the results of laboratory experiments and questionnaires are transferable to real-world situations which previously did not exist. The problem, however, is that one will have to demonstrate that subjects view the hypothetical choice of alternatives as real-world phenomena and that these alternatives can provide reliable information. That is, if the results of laboratory experiments and questionnaires are to be used to predict real-world choice behaviour it has to be demonstrated that these results bear some systematic relationship with overt choice behaviour. Recently, a large amount of empirical evidence supporting this assumption has been accumulated in a variety of spatial contexts (Lieber, 1978; 1979; Louviere and Wilson, 1978; Louviere et al, 1980).

Generalisability implies that the parameters of the model be independent of any spatiotemporal structure. During the last few years several authors have argued or demonstrated that the parameters of gravity and entropy-maximising models are dependent upon the spatial structure of the study area (Curry, 1972; Johnston, 1973; 1975; 1976; Cliff et al, 1974; 1975; 1976; Olsson, 1975; Curry et al, 1975; Sheppard et al, 1976; Sheppard, 1979; Veldhuisen and Timmermans, 1979; Fotheringham and Webber, 1980; Griffith and Jones, 1980). Distance decay effects reflect both the influence of map pattern and the actual willingness to travel of individuals. For the moment there are no generally accepted ways of separating the effect of these two sources from observed interaction patterns, except perhaps for Rushton's preference scaling model (Rushton, 1969; Girt, 1976; Timmermans, 1979). The preference scaling approach may yield accurate preference estimates providing the study is carefully designed. Especially it is important to design a purposeful sample which enables estimation of the preference function throughout its range. If these conditions are reasonably satisfied, some evidence exists that preference structures derived from the spatial choice behaviour of one group of respondents in one particular study area can be used successfully to predict the spatial choice behaviour of a totally different group of respondents in a completely different environmental setting (Timmermans, 1981b). If one uses behavioural models relying on laboratory experiments or questionnaires in which distance is considered as a negative stimulus entering an individual's decisionmaking process rather than as a variable increasing or decreasing the likelihood of an interaction, parameter estimates will be independent of spatial structure because the hypothetical spatial alternatives may be anywhere. The advantage of behavioural models is that preferences, evaluations, or judgments are distinguished from opportunities. In other words, behavioural models are relatively independent of any spatial structure compared to the models relying on areal aggregation and aggregate spatial-interaction patterns. Consequently, the level of generalisability of behavioural models is potentially high whereas, strictly speaking, gravity-type models can only be used validly to make conditional forecasts if the spatial structure of the study area will remain unchanged. However, environmental planning programmes are generally directed at changing the spatial structure of the study area and, hence, it is methodologically unjustified to use the parameters of gravity-type models for forecasting.

A further problem militating against the generalisability of the results of gravity-type models concerns the way in which these models are calibrated. As Louviere (1979) has noted, a necessary condition for generalisability seems to be that the set of observations are balanced; that is, that one has an approximately equal number of observations at every level of the attributes of the spatial alternatives and similarly

even joint distributions. However, since gravity-type models are calibrated on the basis of real-world data this will almost certainly not be the case. Consequently, the parameters of the model will be weighted more according to certain observations. Again, because environmental planning programmes are generally directed at changing these real-world distributions and these changes will affect the estimated parameters, it is difficult to see how gravity-type models can yield parameter estimates which can be used validly to predict the likely effects of policy decisions on overt behaviour.

The second condition—the availability of policy-sensitive independent variables—will be self-explanatory. This condition poses a number of problems both for the gravity-type models and the behavioural models. In the case of shopping models, consumer shopping patterns are usually explained by some measure of the attractiveness of the shopping zones (for example, floor-space) and some measure of distance decay. Similarly, many gravity-type models explain residential choice behaviour by reference to the distribution of employment and some measure of distance decay. Hence, these models use surrogate variables to explain overt spatial choice patterns. The problem is, however, that one does not know the form of the relationship between these surrogate variables and the variables actually influencing spatial choice behaviour. If these relationships are nonlinear, as might be expected, how can one assume that manipulating the surrogate variables will have the desired policy effect on consumer behaviour? Expressed in different terms, this means that, if the relationships are nonlinear, changes in the surrogate variables will not result in one-to-one changes in terms of consumer responses, and hence the predictions of the model may be inferior compared with models incorporating nonlinear relationships.

Apart from the problem of using surrogate variables, there is also the problem of the number of variables. When using models for description, one may wish to use as small a number of independent variables as possible to account for the variability of the dependent variable. If one uses a model in the context of physical planning, however, the prime objective will be to predict the likely effects of all variables which are considered relevant to a particular planning task. Usually, this will involve more than two variables, which in turn may lead to severe data-gathering problems and also to estimation problems due to possible near-multicollinearity among the independent variables (Timmermans, 1981a). In theory at least, behavioural models do not share these problems. A fairly large number of variables may be included in questionnaires. In addition, independent parameter estimates may be obtained by assessing the relationship between consumer evaluations and manipulable attributes of spatial alternatives. However, behavioural models share with the gravity-type models the problem whether equations can be developed solely on the basis of policy-sensitive factors, or whether other influential factors should be included. For example, a number of empirical studies (Hudson, 1976; Potter, 1979; Schuler, 1979; Timmermans, 1980) have suggested that price and product quality are very influential variables in consumer shopping behaviour. These factors, however, cannot be manipulated within environmental planning programmes. Consequently, a behavioural model which does not include these variables may be inferior both from a theoretical and from a practical point of view. On the other hand, it is not readily evident how such factors may be included anyway when using the model for prediction, unless very simple assumptions are made.

In conclusion, models relying on overt aggregate spatial-interaction patterns, with the possible exception of the preference-scaling model in the context of shopping behaviour, suffer from a number of methodological issues which restrict their potential contribution to the solving of physical planning problems. The reason is that these models primarily give a description of interaction patterns; they cannot be interpreted in terms of causal relationships. Of course, several authors have provided *ex post*

rationalisations of the gravity model, linking the structure of the model to a set of assumptions regarding the decisionmaking of individuals. Examples include the derivation of gravity-type models from deterministic utility theory, random utility theory, and psychological choice theories (for example, Choukron, 1975; Golob and Beckmann, 1971; Golob et al, 1973; Hyman, 1977; Niedercorn and Bechdolt, 1969; Nijkamp, 1975; Smith, 1975; 1976; White, 1976). However, these developments were criticised by Sheppard (1978) and Williams (1977); utility functions may vary considerably among individuals, with the assumptions involved being rather unrealistic and often not substantiated by empirical research findings. Nonrational behaviour, imperfect information, constraints, and perception are often not included in the specification of gravity-type models.

The failure of these models is that they do not capture the mechanisms that give rise to observable aggregate interaction patterns. On this point we agree with the reasoning of Sayer (1976; 1979a; 1979b). However, unlike Sayer we believe that some of these mechanisms may be captured by behavioural models, at least for less complex types of spatial behaviour and decisionmaking. Gravity-type models suffer from the fact that they are not explicitly developed for application in the context of physical planning. Consequently, methodologically relevant issues such as the generalisability of their results, the stability of their results, and multiattribute extensions, have received only minor attention. At present, gravity-type models may only be used validly to predict consumer response to policy decisions of the antecedent conditions of the behaviour and decisionmaking under investigation remain unchanged. However, in practice this will rarely be the case, especially because policy decisions generally aim at changing these antecedent conditions. We have been arguing that behavioural models offer a potentially valuable approach which, in theory at least, avoids most of these methodological problems. This is not to say that behavioural models will be superior in terms of accounting for the variability of observed interaction patterns. Nor can it be said that behavioural models are free from problems. On the contrary, although behavioural models avoid some problems of the traditional models, some new types of problems are introduced. We therefore do not suggest that behavioural models are better than the traditional models in every possible way, but we merely argue that behavioural models represent an alternative approach which deserves further attention. In theory at least, it satisfies some methodological conditions which are considered extremely important when using models in the applied context of physical planning. To illustrate some of the advantages and difficulties of behavioural models, the second part of this paper discusses some theoretical developments and empirical research findings in the application of behavioural models to the study of shopping and residential choice behaviour.

Theoretical considerations

Consider an environment or physical space which may be described by a matrix $[X_{ij}]$, denoting the level or value of location i on attribute j . Each destination is conceived of as a bundle of objective attributes. Some of these attributes are of a quantitative nature, others are truly qualitative. These attributes may include aspects of site, neighbourhood, and relative location. Spatial choice behaviour is concerned with the way in which individuals choose a particular destination from among the set of all possible destinations. How may this decisionmaking process be modelled?

Following a long-standing tradition in behavioural geography (for example, Louviere et al, 1980), it is assumed that spatial choice behaviour is contingent upon the attribute levels of the destinations. We assume that individuals have established an evoked set of alternatives. This set is a subset from the set of all possible destinations.

The evoked set is bounded by locational, income, family size, and other environmental and personal factors. Given this evoked set of alternatives, it is assumed that individuals evaluate these alternatives on the basis of the attributes they consider relevant to their decisionmaking task. This evaluation process is guided by the individual's cognitive representation of the physical space, (x_{ij}), his value system, his motivations, and possibly by other personal characteristics. Individuals are assumed to combine their evaluations of the values or levels of the relevant attributes according to some combination rule into an overall evaluation. The result of this process is a subjective preference scale ($E_i, i = 1, \dots, n$) which gives an ordering of the n alternatives on the basis of their utility. It is assumed that an individual will select that alternative which received the highest overall evaluation or utility.

The theoretical considerations underlying the applications may be formalised as follows in terms of a number of functional relationships:

$$x_{ij} = f(X_{ij}), \quad (1)$$

$$E_i = g(x_{ij}), \quad (2)$$

$$B_i = h(E_i), \quad (3)$$

$$B_i = h\{g[f(X_{ij})]\}, \quad (4)$$

where B_i defines the probability that alternative i will be chosen. This recursive equation system shows that consumer behaviour is considered to be a response to a set of objective attributes of spatial alternatives through a decisionmaking process by which consumers evaluate these alternatives. Validation of these equations requires the identification of the relevant attributes of the alternatives, the establishing of the relationships between the levels of these attributes and the corresponding evaluations of consumers, the inferring of the nature of the combination rule involved in the decisionmaking process, and, finally, the obtaining of the relationship between overall evaluation and choice behaviour. Elements of this approach have been applied successfully by Louviere and his colleagues in a variety of contexts (for example, Louviere, 1976; Louviere and Wilson, 1978). We will now illustrate some operational aspects of the approach by two examples.

Example 1: spatial shopping behaviour

The conceptual model previously outlined was employed in a study of spatial shopping behaviour in part of the region of Southeast Brabant in the South Netherlands. 771 households participated in the survey, and respondents were randomly selected on the basis of their willingness to participate in the survey. They were asked to mention the shopping area they usually patronise to buy clothing, and the total number of visits to each shopping area was taken as a measure of choice behaviour.

To calibrate the model, it is first necessary to identify the relevant attributes of the shopping areas. For the present analysis three attributes were identified: selection, distance, and availability of parking space. All three attributes are policy sensitive. Their choice was dictated by alternative retailing plans, which differed on these dimensions. Respondents were asked to provide a numerical evaluation of each shopping area for each attribute on a 1-9 rating scale, the ends of which were defined as 'worst possible place to shop for clothes' (1) and 'best possible place to shop for clothes' (9). Respondents were asked only to evaluate the shopping areas they felt familiar with. Consequently, sample sizes for shopping areas were unequal. Since the analysis was conducted at the aggregate level individual responses were averaged over respondents to yield mean ratings, and these mean ratings were assumed to correspond to the x_{ij} of equation (1) for the aggregate sample. Respondents provided a numerical evaluation of the distance variable for a series of abstract distance categories.

The corresponding physical attributes of the shopping alternatives were measured as follows: selection was measured by totalling the number of shops in each shopping area; distance was measured in terms of travel time to the shopping area, and availability of parking facilities was measured as the average percentage of occupied parking places on an average Saturday afternoon. In order to calibrate equation (1) and assess the strength of this relationship Spearman rank order correlations between the physical measures of the shopping alternatives and the average subjective evaluations of these measures were computed. Values obtained were +0.96, +0.99, and +1.00, respectively, indicating almost perfect monotonic relations. Iterative least-squares procedures were used to obtain the functional relationships between the pairs of variables. The best fitting functions were:

$$x_i(\text{selection}) = 2.85 + 0.94X_i^{0.27}N_i^s, \quad (5)$$

$$x_i(\text{parking}) = 7.62 - 0.09X_i^{0.70}P_i, \quad (6)$$

$$x_i(\text{distance}) = 7.94 - 0.58X_i^{0.37}T_i^t, \quad (7)$$

where N_i^s is the number of shops, P_i the percentage of occupied parking places, and T_i^t the travel time for location i . These results show that the relationships are nonlinear. Hence, changes in physical attributes of spatial structure will not result in one-to-one changes in evaluations and consumer behaviour, providing these empirical relationships are also theoretically true.

In order to validate equation (2) a laboratory experiment was conducted. A factorial design was used to infer the algebraic composition rule subjects use to arrive at an overall evaluation. Eighteen subjects participated in the experiment. Twenty-seven hypothetical shopping alternatives, each describing a three-attribute profile were used as stimulus combinations. Each attribute was varied over three levels: number of shops (N^s) varied over 10, 40, and 70; travel time (T^t) varied over 15, 30, and 45 minutes; and time to find a parking place (T^p) varied over 3, 6, and 9 minutes. Subjects evaluated each of the twenty-seven hypothetical stimulus combinations. The subjects also evaluated two additional stimulus combinations which were more extreme than the design combinations; these they were asked to consider 'best' and 'worst', on a 1-100 mm scale. The resulting data were subjected to an analysis of variance. All main effects and the $N^s \times T^t$ effect were statistically significant whereas the $N^s \times T^p$ and $T^t \times T^p$ effects were not statistically different from zero beyond the 0.05 level. Hence, one cannot conclude firmly the presence either of a multiplicative or of an additive composition rule.

Equation (3) suggests that consumer choice behaviour is related to consumer's overall evaluations. Since the laboratory experiment did not yield conclusive findings, both the additive and the multiplicative composition rules were tested, assuming that consumer choice behaviour is linearly related to overall evaluation. The multiplicative rule yielded the best results. The relationship between spatial choice behaviour and overall evaluation based upon a multiplicative rule is reasonably linear [$r = 0.85$; $F(1, 14) = 36.45$; $p < 0.01$]. The additive compositive rule performs less well in terms of its F -value [$r = 0.82$; $F(1, 14) = 28.57$; $p < 0.01$]. These results tentatively suggest that a multiplicative composition rule is superior in describing consumer shopping choice behaviour. In terms of retail planning this result would suggest that a new retailing development will probably only come up to expectations if every important attribute of the new development is above some minimum level!

Example 2: residential choice behaviour

It has been argued that the environmental, individual, and social constraints may change dramatically through time, and, hence, that prediction from observed interaction

patterns may yield inferior results. Instead preferences and utilities should be measured directly at the personal level by use of questionnaires; the results should be used in models to calculate the demand so that consequently the residential choice behaviour patterns can be predicted from the confrontation of demand and supply. This applies especially to residential location as dwellings can normally only be occupied by one household at the time.

In the preceding example it has been shown that utilities of shopping centres can be measured and used successfully for the prediction of shopping behaviour. In the second example we will show that the same type of measurement can be used for establishing housing utilities; however, assessment of the relationship between housing utilities and consequent observed behaviour is not possible as the constraints are very imposing. What may be done is the formulation of a model in which the utilities are, amongst other things, used to predict location and relocation patterns of households and afterward to make a comparison with reality. In this case a possible model is being discussed.

A housing situation is essentially a multiattribute situation (for example, Knight and Menchick, 1976; Louviere, 1976; and others), which contains at least six or seven important attributes. Because of this number of attributes, overall utility cannot be measured directly (for example Slovic and Lichtenstein, 1971; Fischer, 1975; Veldhuisen and Kapoen, 1979). The measurement of the utilities of the separate attributes can be performed either directly (through scaling) or through factorial designs. It has been shown (Green et al, 1972; Veldhuisen and Timmermans, 1981a; 1981b) that results of factorial designs can be approximated by the comparatively easy direct measurement methods. Consequently the utility of a number of attributes were measured directly in a survey of 560 households in the area of Southeast Brabant in the South Netherlands. Valuations were gathered (amongst others) for the following list of physical and spatial attributes:

1 the floorspace of the dwelling;	5 the distance to (designated) playing facilities;
2 the area of private land around the dwelling;	6 the situation of the dwelling with regard to traffic;
3 the area of public space (green);	7 the distances to shops for convenience goods;
4 the distance to playgrounds;	8 the distances to the public transportation system.

The relationships between spatial-physical properties and their valuations [equation (1)] have been worked out for households differing in their stage of the family cycle (the number of household categories being 7). In all of the cases, the form of the relationships was nonlinear and could be described by a function of the form:

$$f(x) = \frac{m}{1 + ax^b},$$

Figure 1. The dwellers' evaluations of 'floorspace' and 'distance to park' as a function of these attributes.

where

m is the maximum value of the evaluation,
 x is the value of the physical attribute, and
 a, b are parameters to be estimated.

Examples of two such functions are shown in figure 1.

As to the best form of the integration model [equation (2)], it was found in experiment 1 that the best model was the multiplicative one. This form also appeared to hold in the case of housing utilities. The overall utility can be computed from the single utilities under the assumption that the utilities are mutually independent.

The model to be used for the prediction of residential choice patterns is based on Brown et al's application of Wolpert's concept of place utility (Brown et al, 1970; Wolpert, 1965; Veldhuisen, 1979a) and has the following form: the objective function is

$$\text{minimise } Z = \sum_{i,j} c_{ij} x_{ij},$$

subject to

$$\sum_i x_{ij} \leq d_i,$$

$$\sum_j x_{ij} = s_j,$$

where

$$c_{ij} = -(u_j - u_i).$$

Households from origin dwellings i are moving to destination dwellings j such as to maximise the total gain in utility ($u_j - u_i$).

The constraints state that not all of the demand from i may be allocated and that all the vacancies (supply in j) are filled.

By manipulating the utilities of the destination dwellings, five attributes are introduced into the allocation model: (1) the home-work distance for the breadwinner(s), (2) the social integration of the household, (3) the renter or ownership of the dwelling, (4) the type of dwelling (single-family unit versus multiple-family unit), and (5) the price. Preliminary results of using this model are promising.

Conclusions

It has been argued that geographic models relying upon areal aggregation and observed interaction patterns suffer from a number of methodological shortcomings which make them less suited for predicting the effects of policy decisions on consumer spatial behaviour. It has also been argued that, in theory at least, behavioural models avoid most of the problems related to such issues as generalisability and policy-sensitive independent variables. However, to apply behavioural models it has to be demonstrated that consumer evaluations bear some systematic relationships both with manipulable attributes of spatial alternatives and with overt choice patterns. This paper has provided some additional evidence that these relationships prevail. In view of the quality of physical planning it is hoped that these findings will stimulate the further development and application of behavioural models in geography and regional science or at least point to the direction in which fruitful research can be pursued.

References

- Anas A, 1973 "A dynamic disequilibrium model of residential location" *Environment and Planning* 5 633-647
 Anas A, 1975 "The empirical calibration and testing of a simulation model of residential location" *Environment and Planning A* 7 899-920

- Brown L A, Horton F E, Wittick R I, 1970 "On place utility and the normative allocation of intra-urban migrants" *Demography* 7 175-183
- Choukron J H, 1975 "A general framework for the development of gravity-type trip distribution models" *Regional Science and Urban Economics* 5 177-202
- Clark W A V, Huff J O, 1977 "Some empirical tests of duration-of-stay effects in intraurban migration" *Environment and Planning A* 9 1357-1374
- Clark W A V, Huff J O, Burt J E, 1979 "Calibrating a model of the decision to move" *Environment and Planning A* 11 689-705
- Cliff A D, Martin R, Ord J K, 1974 "Evaluating the friction of distance parameter in gravity models" *Regional Studies* 8 281-286
- Cliff A D, Martin R, Ord J K, 1975 "Map pattern and friction of distance parameters: reply to comments by R J Johnston, and by L Curry, D A Griffith, and E S Sheppard" *Regional Studies* 9 285-288
- Cliff A D, Martin R, Ord J K, 1976 "A reply to the final comment" *Regional Studies* 10 341-342
- Curry L, 1972 "A spatial analysis of gravity flows" *Regional Studies* 6 131-147
- Curry L, Griffith D A, Sheppard E S, 1975 "Those gravity parameters again" *Regional Studies* 9 289-296
- Fischer G W, 1975 "Experimental applications of multi-attribute utility models" in *Utility, Probability and Human Decision Making* Eds D Wendt, C Vlek (Reidel, Dordrecht) pp 7-46
- Fotheringham A S, Webber M J, 1980 "Spatial structure and the parameters of spatial interaction models" *Geographical Analysis* 12 33-47
- Ginsberg R B, 1971 "Semi-Markov processes and mobility" *Journal of Mathematical Sociology* 1 233-262
- Ginsberg R B, 1972a "Critique of probabilistic models: application of the semi-Markov model to migration" *Journal of Mathematical Sociology* 2 63-82
- Ginsberg R B, 1972b "Incorporating causal structure and exogenous information with probabilistic models: with special reference to choice, gravity, migration and Markov chains" *Journal of Mathematical Sociology* 2 83-103
- Ginsberg R B, 1973 "Stochastic models of residential and geographic mobility for heterogeneous populations" *Environment and Planning* 5 113-124
- Ginsberg R B, 1978 "The relationship between timing of moves and choice of destination in stochastic models of migration" *Environment and Planning A* 10 667-681
- Ginsberg R B, 1979 "Tests of stochastic models of timing in mobility histories: comparison of information derived from different observation plans" *Environment and Planning A* 11 1387-1404
- Girt J L, 1976 "Some extensions of Rushton's spatial preference scaling model" *Geographical Analysis* 8 137-157
- Golob T F, Beckmann M T, 1971 "A utility model for travel forecasting" *Transportation Science* 5 79-90
- Golob T F, Gustafson R L, Beckmann M T, 1973 "An economic theory approach to spatial interaction" *Papers and Proceedings of the Regional Science Association* 30 159-182
- Green P E, Carmone F J, Wind Y, 1972 "Subjective evaluation models and conjoint measurement" *Behavioral Science* 17 288-299
- Griffith D A, Jones K G, 1980 "Explorations into the relationship between spatial structure and spatial interaction" *Environment and Planning A* 12 187-203
- Härsman B, Snickars F, 1975 "Disaggregated housing demand models: some theoretical approaches" *Papers and Proceedings of the Regional Science Association* 34 121-145
- Hay A M, Johnston R J, 1979 "Search and the choice of shopping centre: two models of variability in destination selection" *Environment and Planning A* 11 791-804
- Hubbard R, 1979 "Parameter stability in cross-sectional models of ethnic shopping behaviour" *Environment and Planning A* 11 977-993
- Hudson R, 1976 "Linking studies of the individual with models of aggregate behaviour: an empirical example" *Transactions of the Institute of British Geographers new series* 1 159-174
- Huff J O, 1979 "Residential mobility patterns and population redistribution within the city" *Geographical Analysis* 11 133-148
- Huff J O, Clark W A V, 1978 "Cumulative stress and cumulative inertia: a behavioral model of the decision to move" *Environment and Planning A* 10 1101-1119
- Hyman G M, 1977 *A Local Value Theory of Spatial Choice* Occasional Paper 1 (Centre for Environmental Studies, London)
- Johnston R J, 1973 "On frictions of distance and regression coefficients" *Area* 5 187-191

- Johnston R J, 1975 "Map patterns and friction of distance parameters: a comment" *Regional Studies* 9 281-283
- Johnston R J, 1976 "On regression coefficients in comparative studies of the frictions of distance" *Tijdschrift voor Economische en Sociale Geografie* 67 15-28
- Knight R L, Menchick M D, 1976 "Conjoint preference estimation for residential land use policy evaluation" in *Spatial Choice and Spatial Behavior* Eds R G Golledge, G Rushton (Ohio State University Press, Columbus, Ohio) pp 135-157
- Lieber S R, 1978 "Place utility and migration" *Geografiska Annaler B* 60 16-27
- Lieber S R, 1979 "An experimental approach for the migration decision process" *Tijdschrift voor Economische en Sociale Geografie* 70 75-85
- Louviere J J, 1976 "Information-processing theory and functional form in spatial behavior" in *Spatial Choice and Spatial Behavior* Eds R G Golledge, G Rushton (Ohio State University Press, Columbus, Ohio) pp 211-249
- Louviere J J, 1979 "On the interregional and intercultural transferability of disaggregate choice models: some selected comments" technical report 111, Institute of Urban and Regional Research, University of Iowa, Iowa City, Iowa
- Louviere J J, Wilson E H, 1978 "Predicting consumer response in travel analysis" *Transportation Planning and Technology* 4 251-259
- Louviere J J, Wilson E H, Piccolo M, 1980 "Applications of psychological measurement and modelling to behavioural travel-demand analysis" in *Behavioural Travel Modelling* Eds D A Henscher, P R Stopher (Croom Helm, London) pp 713-738
- MacLennan D, Williams N J, 1979 "Revealed space preference theory: a cautionary note" *Tijdschrift voor Economische en Sociale Geografie* 70 307-309
- Menchick M, 1972 "Residential environmental preferences and choice: empirically validating preference measures" *Environment and Planning* 4 445-458
- Niedercorn J H, Bechdolt B V, 1969 "An economic derivation of the 'gravity law' of spatial interaction" *Journal of Regional Science* 9 273-282
- Nijkamp P, 1975 "Reflections on gravity and entropy models" *Regional Science and Urban Economics* 5 203-225
- Olsson G, 1975 *Birds in Egg* Michigan Geographical Publication 15, Department of Geography, University of Michigan, Ann Arbor, Mich.
- Pankhurst I C, Roe P E, 1978 "An empirical study of two shopping models" *Regional Studies* 12 727-748
- Pipkin J S, 1977 "Some probabilistic revealed preference models of the choice process in recurrent urban travel" *Geografiska Annaler B* 59 82-94
- Pirie G H, 1976 "Thoughts on revealed preference and spatial behaviour" *Environment and Planning A* 8 947-955
- Potter R B, 1979 "Factors influencing consumer decision making" *Psychological Reports* 44 674
- Putman S H, 1977a "Calibrating a disaggregated residential allocation model-DRAM" in *London Papers in Regional Science 7: Alternative Frameworks for Analysis* Eds D B Massey, P W J Batey (Pion, London) pp 108-124
- Putman S H, 1977b "Calibrating a residential location model for nineteenth century Philadelphia" *Environment and Planning A* 9 449-460
- Putman S H, 1978 *Studies in Applied Regional Science* 13. *Urban Residential Location Models* (Martinus Nijhoff, Leiden)
- Putman S H, Ducca F W, 1978a "Calibrating urban residential models 1: Procedures and strategies" *Environment and Planning A* 10 633-650
- Putman S H, Ducca F W, 1978b "Calibrating urban residential models 2: Empirical results" *Environment and Planning A* 10 1001-1014
- Recker W, Kostyniuk L, 1978 "Factors influencing destination choice for the urban grocery shopping trip" *Transportation* 7 19-33
- Rushton G, 1969 "The scaling of locational preferences" in *Behavioral Problems in Geography, A Symposium* Eds K R Cox, R G Golledge (Northwestern University Press, Evanston, Ill.) pp 197-227
- Sayer R A, 1976 "A critique of urban modelling: from regional science to urban and regional political economy" *Progress in Planning* 6 187-254
- Sayer R A, 1979a "Understanding urban models versus understanding cities" *Environment and Planning A* 11 853-862
- Sayer R A, 1979b "Philosophical bases of the critique of urban modelling: a reply to Wilson" *Environment and Planning A* 11 1055-1067

- Schuler H, 1979 "A disaggregate store-choice model of spatial decision-making" *Professional Geographer* 31 146-156
- Senior M L, Wilson A G, 1973 "Disaggregated residential location models: some tests and further theoretical developments" in *London Papers in Regional Science 4: Space-Time Concepts in Urban and Regional Models* Ed. E L Cripps (Pion, London) pp 141-172
- Senior M L, Wilson A G, 1974 "Explorations and syntheses of linear programming and spatial interaction models of residential location" *Geographical Analysis* 6 209-238
- Sheppard E S, 1978 "Theoretical underpinnings of the gravity hypothesis" *Geographical Analysis* 10 386-402
- Sheppard E S, 1979 "Gravity parameter estimation" *Geographical Analysis* 11 120-133
- Sheppard E S, Griffith D A, Curry L, 1976 "A final comment on mis-specification and autocorrelation in those gravity parameters" *Regional Studies* 10 337-339
- Slovic P, Lichtenstein S, 1971 "A comparison of Bayesian and regression approaches to the study of information processing in judgment" *Organizational Behavior and Human Performance* 6 649-744
- Smith A P, Whitebread P J, Mackett R L, 1977 "The utilization of services" in *Models of Cities and Regions* Eds A G Wilson, P H Rees, C M Leigh (John Wiley, Chichester, Sussex) pp 323-403
- Smith T E, 1975 "A choice theory of spatial interaction" *Regional Science and Urban Economics* 5 137-176
- Smith T E, 1976 "Spatial discounting and the gravity hypothesis" *Regional Science and Urban Economics* 6 331-356
- Smith T R, Clark W A V, Huff J O, Shapiro P, 1979 "A decision-making and search model for intraurban migration" *Geographical Analysis* 11 1-23
- Smith T R, Mertz F, 1980 "An analysis of the effect of information revision on the outcome of housing-market search, with special reference to the influence of realty agents" *Environment and Planning A* 12 155-174
- Timmermans H J P, 1979 "A spatial preference model of shopping behaviour" *Tijdschrift voor Economische en Sociale Geografie* 70 45-48
- Timmermans H J P, 1980 "Consumer spatial choice strategies: a comparative study of some alternative behavioural shopping models" *Geoforum* 11 123-131
- Timmermans H J P, 1981a "Multiattribute shopping models and ridge regression analyses" *Environment and Planning A* 13 43-56
- Timmermans H J P, 1981b "Spatial choice behaviour in different environmental settings: an application of the revealed preference approach" *Geografiska Annaler* 63 57-67
- Timmermans H J P, Rushton G, 1979 "Revealed space preference theory: a rejoinder" *Tijdschrift voor Economische en Sociale Geografie* 70 309-312
- Veldhuisen K J, 1979a "A utility model for the allocation of households" paper presented at the Regional Science Conference, 1979, London, available from the author
- Veldhuisen K J, 1979b "De meting en verklaring van woonwaardering" (The measurement and explanation of residential evaluations) *Mens en Maatschappij* 54 144-169
- Veldhuisen K J, Kapoen L L, 1979 "A regional location model" in *New Developments in Modelling Travel Demand and Urban Systems: Some Results of Recent Dutch Research* Eds G R M Jansen, P H L Bovy, J P J M van Est, F le Clerq (Teakfield, Farnborough, Hants)
- Veldhuisen K J, Timmermans H J P, 1979 *Spatial Structure. Spatial Behaviour and Spatial Interaction Models: Some Critical Comments on the Use of Gravity and Entropy-Maximizing Models for Forecasting Purposes* WP-2, Department of Architecture, Building and Planning, University of Technology, Eindhoven, The Netherlands
- Veldhuisen K J, Timmermans H J P, 1981a "Voorkeuren en waarderingen: Een drietal meet-systemen" (Preferences and evaluations: three measurement approaches) *Mens en Maatschappij* 56 154-172
- Veldhuisen K J, Timmermans H J P, 1981b "Voorkeuren en waarderingen: Toetsing van een drietal meet-systemen" (Preferences and evaluations: tests of three measurement approaches) *Mens en Maatschappij* 56 275-293
- Wheaton W, 1974 "Linear programming and locational equilibrium: the Herbert-Stevens model revisited" *Journal of Urban Economics* 1 278-287
- White R W, 1976 "A generalisation of the utility theory approach to the problem of spatial interaction" *Geographical Analysis* 8 39-46
- Williams H C W L, 1977 "On the formation of travel demand models and economic evaluation measures of user benefit" *Environment and Planning A* 9 285-344

-
- Williams H C W L, Senior M L, 1978 "Accessibility, spatial interaction and the spatial benefit analysis of land use transportation plans" in *Spatial Interaction Theory and Planning Models* Eds A Karlqvist, L Lundqvist, F Snickars, J W Weibull (North-Holland, Amsterdam) pp 253-287
- Wolpert J, 1965 "Behavioral aspects of the decision to migrate" *Papers and Proceedings of the Regional Science Association* **15** 159-169