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RESEARCH NOTE

UNCOVERING SPATIAL DECISION-MAKING PROCESSES: A DECISION NET APPROACH APPLIED TO RECREATIONAL CHOICE BEHAVIOUR

by

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Introduction

The focus of much recent research on spatial choice behaviour has been on constructing formal representations of choice processes. Many attempts have been made to represent spatial choice processes in terms of some form of algebraic model. Although such algebraic models have been applied successfully in a variety of spatial contexts, nevertheless these models are based upon some inherently limiting assumptions. Discrete choice models and decompositional multiattribute preference models (see Wrigley (1985) and Timmermans (1984b) respectively for extensive introductory reviews) all have in common the assumption that individuals arrive at some choice or preference by cognitively integrating their part-worth utilities associated with the attribute levels of the choice alternatives into some overall utility or preference measure according to some simple algebraic rule. Especially the linear additive rule has been applied frequently, implying that spatial decision-making is assumed to be the result of a compensatory decision-making process in which low evaluations of some attribute may be compensated, at least partially, by a higher evaluation of one or more of the remaining attributes of the choice alternative. In addition, a common assumption underlying these modelling approaches is that the parameters of the models and the nature of the algebraic rule itself are invariant across different choice sets. Hence, it is implicitly assumed that context effects are negligible. Finally, in most applications of discrete choice models it is implicitly assumed that individuals face the same choice set. Choice set constraints are typically not endogenously incorporated in choice models. The identification of individual choice sets constitutes a separate step in the model-building process and the development of reliable methodologies for this step so far has received relatively little attention.

Empirical evidence accumulated so far in marketing science, management science and psychology however suggests that these assumptions may not always be valid. It has been found that individual decision-making is context-dependent: as the number of choice alternatives and/or the number of attributes increases individuals make greater use of non-compensatory decision strategies (Payne 1976; Olshavsky 1979). Moreover, it has been argued (Burnett 1980, 1981; Burnett & Hanson 1982) that spatial choice behaviour is a form of complex behaviour: individual choice behaviour shows considerable fluctuation depending upon constraints, past behaviour, composition of the choice set, etc.

Since many types of spatial choice behaviour are typically influenced by personal, spatial and institutional constraints and typically involve decision-making among complex choice sets with many attributes, existing modelling approaches may be based upon too rigorous assumptions for uncovering individual spatial decision-making processes.

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An approach which in theory at least may be less based upon such limiting assumptions is that of the decision net approach, which has to the authors' knowledge hardly been used in geographical research.

The purpose of the present article therefore is to discuss the potentials of the decision net approach in the study of spatial decision-making processes. The approach is applied to the study of recreational choice behaviour. The article is organized as follows. First, an introduction to the decision net approach is given. This is followed in section 3 by a presentation of the main findings of an application of the decision net approach to the problem of recreational choice behaviour. In section 4 the potential advantages and disadvantages of the decision net approach are discussed. Finally, some brief general conclusions regarding the usefulness of the approach are drawn.

Decision nets

A decision net is a representation of a decision-making process by which an individual arrives at some choice. It is also a model of how an individual makes choices. The net specifies the attributes of the choice alternatives that are considered important by the individual, the sequence in which these attributes are considered and the combination rule used by the individual to compare the choice alternatives and arrive at some choice.

The attributes of a decision net are typically arrayed in a branching structure. At the top one finds the most important attribute for the individual. In addition, the net contains information about the individual's response if this attribute is not satisfactory. If an attribute is not satisfactory, an individual might reject the corresponding choice alternative or the individual might still consider the alternative, for example if the choice alternative is satisfactory on all remaining attributes. It is also possible that the individual accepts the choice alternative conditionally in the absence of its satisfactory level if other attributes sufficiently compensate for this unsatisfactory level.

An attribute leading to an immediate rejection of any choice alternative failing to reach a satisfactory level is called a *rejection inducing dimension* (Park *et al.* 1981). Likewise, an attribute which requires that all other attributes be satisfactory for any choice alternative to be considered is called a *relative preference dimension.* Attributes that may be compensated by satisfactory levels of other attributes are called *trade-off dimensions.*

A decision net thus portrays at a very detailed level an individual's decision-making process. In constructing such nets an individual is asked first to name the attributes that are sequentially considered when choice alternatives are being evaluated. Once this task is completed, the individual is asked whether a choice alternative would still be considered if an attribute is unsatisfactory. In case of a dichotomous attribute, a choice alternative might either comply with the requirement or not. In case of a continuous attribute, the individual should specify some minimum or maximum threshold or some range. If a choice alternative is still considered, the researcher tries to identify under what circumstances the choice alternative will be accepted. In this way the set of feasible or acceptable choice alternatives may be reconstructed and an individual's preference for each choice alternative within this choice set may be measured.

It is evident that the decision net approach constitutes a relatively general way of representing decision-making and choice processes. Traditional compensatory decision rules may be easily included by a series of trade-off dimensions. However, noncompensatory decision heuristics such as lexicographic rules, conjunctive or disjunctive rules (see Timmermans (1984a) for an extensive review and axiomatization and Timmermans (1983) for an application in the context of spatial shopping behaviour) can also easily be dealt with by a combination of relative preference and rejection-inducing dimensions.

An illustrative application

Method – As part of a wider study which seeks to develop a model of variety-seeking behaviour of recreation choice (see Timmermans 1985) first the attributes influential to this type of choice behaviour were identified. Attributes were identified using a variety of methods, one of which was the decision net approach. A random convenience sample of 14 respondents was selected. All interviews took place at the respondents' homes. On average, an interview took approximately 60 minutes to complete.

A procedure very similar to Park's procedure for constructing decision plans was used to construct the decision nets. First, each respondent was asked to name the attributes in order of importance which he/she would consider when choosing a recreation area or object. These attributes were entered on a sheet and then respondents were invited to specify the conditions associated with these attributes under which they would consider the corresponding choice alternatives satisfactory. For each less important attribute respondents were told to assume that the previous attributes were at satisfactory levels. This process continued until respondents indicated that all main attributes influencing their choice process had been mentioned.

In the second step respondents were asked what they would do when a choice alternative would not be satisfactory on a specific attribute. Respondents could either reject the choice alternative or still consider it. The first option denotes of course a rejection-inducing dimension. If respondents said they would still consider the choice alternative, they were asked under what circumstances they still would consider it. Three cases are important in this respect:

- respondents may indicate that they still would consider the choice alternative if all remaining attributes are satisfactory.
- respondents may indicate that they still would consider the choice alternative if some of the remaining attributes are satisfactory, in which case respondents were asked for those attributes of which satisfactory presence is not viewed necessary for consideration.
- respondents may indicate that they still would consider the choice alternative if still other features, in addition to the remaining ones, would be satisfactory.

This procedure was repeated for each attribute in turn until all attributes were considered. The result is a graphical portrayal of a decision net.

Analysis and results – The first step in the analysis involved constructing a decision net for each subject individually. Two such nets are portrayed in Figs. 1 and 2. These figures illustrate that noncompensatory elements are included in the decision-making strategies of these subjects. For example, the subject portrayed in Fig. 1 states that he will not consider any recreation object that doesn't allow to become involved in different kinds of recreational behaviour. Thus, the attribute 'things to do' is a rejection-inducing dimension for this subject. Likewise, attributes like distance and facilities are rejection-inducing dimensions for the second subject. Figs. 1 and 2, however, also evidence the existence of relative preference dimensions. To illustrate, the second subject views a total costs level of *f* 25,– as a satisfactory level for this attribute. Even if the total

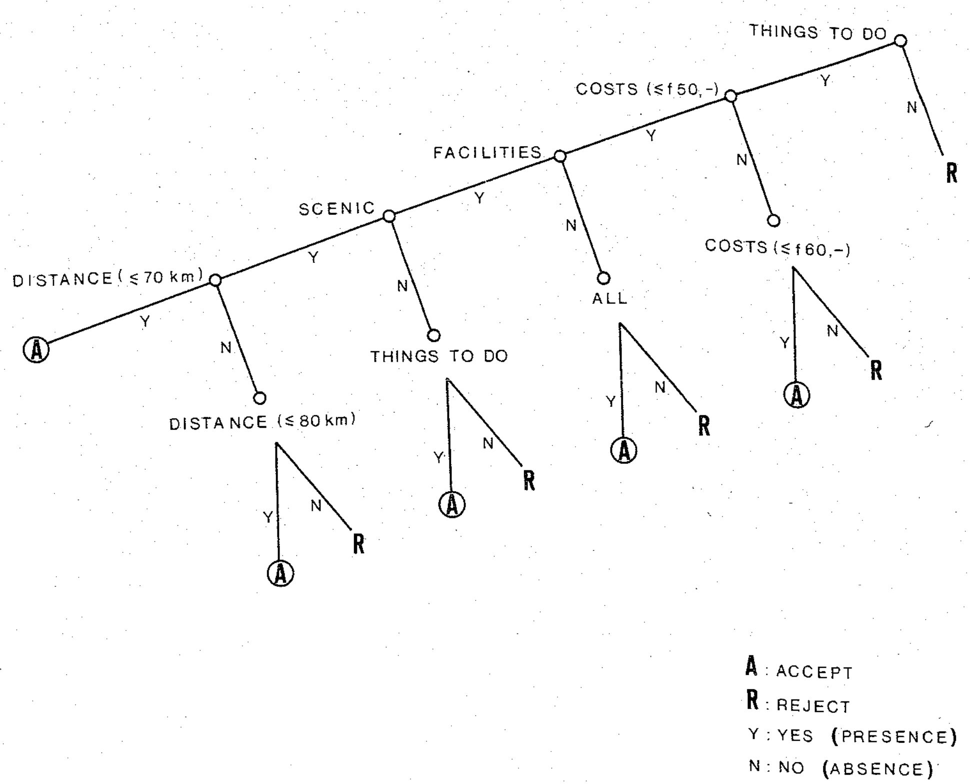

Fig. 1. *Decision net of subject 1.*

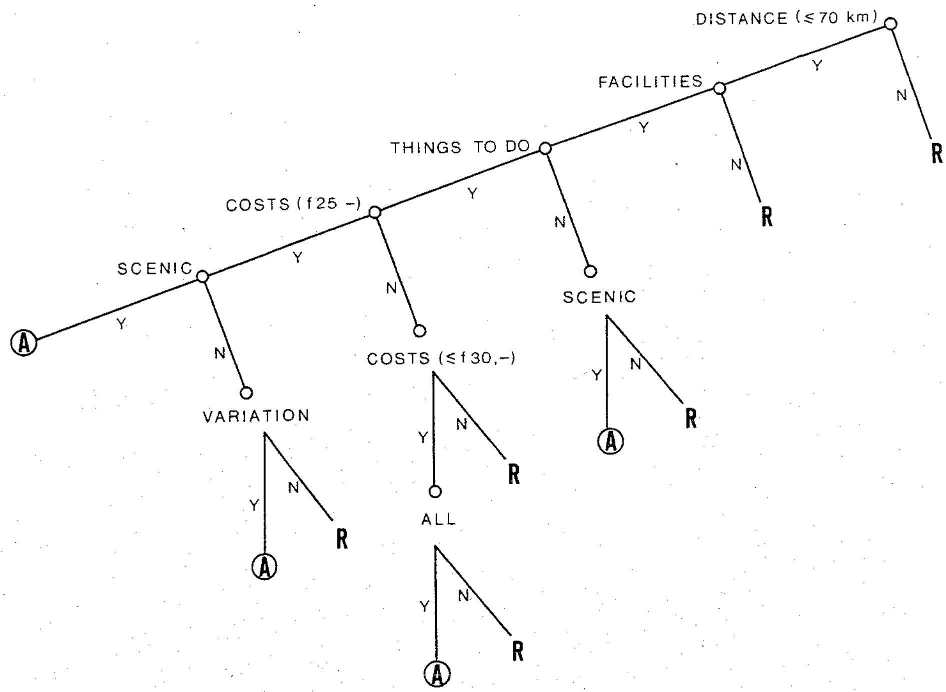

Fig. 2. *Decision net of subject 2.*

costs for visiting a choice alternative is *f* 30, – , though, he will still consider it acceptable if the choice alternative is satisfactory on all remaining attributes. Finally, an example of a trade-off dimension is given in Fig. 2. This subject reveals that he would accept a recreation object which he finds unsatisfactory in terms of scenic quality if this is compensated by a satisfactory presence of 'variation'. Thus in this case the acceptance or rejection of a choice alternative depends on the offsetting improvement of some other attribute.

The next step involved analysing the decision nets for all subjects in terms of counting the frequency with which different attributes were said to influence the subjects' decision-making when choosing recreation objects. In addition, the nets were analysed in terms of the role that is played by the various attributes. That is to say, the nets were examined to see whether the attributes serve as rejection-inducing, relative preference or trade-off dimensions. The results are given in Table 1, which shows that 'distance' and 'variation' are the most frequently mentioned attributes, closely followed by 'total costs', 'facilities', and 'things to do'. An intermediate group of attributes consists of such attributes as 'scenic quality', 'crowding' and 'social contacts', while the attributes 'weather-independence' and 'atmosphere' are only mentioned once in the present sample. These results appear to

Table 1. *Analysis of decision nets: aggregate results.*

Attribute	Frequency	Rejection-inducing dimension	Relative preference dimension	Trade-off dimension
Distance	8	0	2	6
Variation	8	4	2	2
Things to do	7	4	1	2
Costs	7	0	2	5
Facilities	7	2	3	2
Scenic quality	4	1	0	3
Crowding	4	3	0	1
Parking facilities	4	1	1	2
Social contacts	3	3	0	0
Atmosphere	1	1	0	0
Weather-independence	1	1	0	0

suggest that, overall, economic and spatial attributes tend to outweigh social attributes in the decision-making process.

Perhaps an even more interesting result is obtained by examining the classification of the attributes. Table 1 clearly demonstrates that the various attributes play a different role in the decision-making process. Some attributes tend to serve as noncompensatory or rejection-inducing dimensions for the majority of subjects who mentioned that particular attribute. This is especially true for the less frequently mentioned attributes 'weather-independence', 'social contacts', 'atmosphere', and 'crowding'. It seems that the subjects using those attributes have a very articulated image of an ideal recreation object. Any object failing to meet a minimum set of requirements, which consists of a subset of the above-mentioned attributes, is no longer considered. In contrast, attributes such as 'total costs', 'distance' and to a lesser extent also 'parking facilities', 'facilities', and 'scenic quality' almost invariably are used as either relative preference dimensions or as trade-off dimensions, implying that these attributes are used in some compensatory fashion in the decision-making process.

Potential advantages and disadvantages of decision nets

The decision net approach may prove to be a good alternative to the more conventional discrete choice and decompositional multiattribute preference models, especially when the decision-making process under investigation is characterised by the existence of noncompensatory elements or when a high degree of interpersonal variation in number and types of attributes, influencing the decision-making and choice process, is present. This is not to say that noncompensatory attributes and interpersonal variation cannot be incorporated in discrete choice and decompositional multiattribute preference models, only that these are difficult to deal with in the context of these modelling approaches. Krishnan (1977), Lioukas (1984) and Young (1983, 1984) have developed discrete choice models that incorporate thresholds of acceptance, while Borgers, Timmermans & Veldhuisen (1986) have developed a model which is able to describe mixed or hybrid compensatory/noncompensatory decision-making processes. All these models, however, require large amounts of computing time and are difficult to calibrate. Likewise, in principle it is possible to construct individual-specific decompositional preference models, but in practice such models would probably be too demanding in terms of the time and effort it would take to construct all the different experimental designs and perform the subsequent analyses. It should be noted, however, that the construction of a decision net takes considerable time, perhaps even more than the time required to get the responses to the experimental designs associated with the decompositional models.

An issue of primary importance in this respect concerns the question whether decision nets are really necessary to account for noncompensatory effects. The present analysis seems to indicate that some factors serve as rejection-inducing dimensions, but interestingly, the spatial and economic factors are primarily viewed as relative preference or trade-off dimensions, although evidently some thresholds are associated with these factors as well. The basic research question here is whether these noncompensatory effects can also be accounted for by an appropriate identification of individual choice sets when using discrete choice or decompositional multiattribute preference models.

Another important issue in this respect concerns the validity of the decision nets. Nakanishi (1974) has criticised the validity of the decision nets in that he doubted that individuals operate in such a rigid, inflexible mode as is implied by the decision net approach. A basic question in this respect is whether subjects are able to report accurately on their decision-making processes. It might be argued that they may sometimes be unaware of the existence of an attribute that influenced the decision-making or choice process and hence not be able to specify all influential attributes (compare Lundberg (1984) for a similar discussion related to protocol analysis). Perhaps still more important though is that subjects may mention too many attributes, merely because they are aware of being observed. Previous studies have often identified more than 50 attributes in a decision net. Of course, it is difficult to believe that subjects are capable of memorising the exact sequence and heuristic decision rules incorporated in such decision nets, especially because many studies on information processing have shown that individual decision-making tends to be based on a limited number of attrributes. The problem here is that of reactivity: the subjects know that they are being observed and hence they might become engaged in a much more organised and elaborate decision-making or choice process than would have occurred if they would not have been asked to describe their decision-making or choice process. On the other hand, in the case of discrete choice models, the attributes are specified by the researcher, which of course implies that the selected attributes might not be important at all for the majority of the subjects. To circumvent this problem, the first phase of a decompositional preference model typically involves eliciting the influential attributes in a separate study using techniques like factor listing or the repertory grid methodology (Timmermans, van der Heijden & Westerveld 1982), but essentially one may experience similar problems of reactivity when using these methods.

These problems become even more serious if it is realised that decision nets are inherently deterministic: they do not have an error theory to allow for measurement error or omitted variables. In contrast, both discrete choice and decompositional preference models are probabilistic. Measurement error, omitted variables and the effect of heterogeneity are represented by error terms in the utility function and parametric assumptions are made to account for the distribution of the error terms.

None of the approaches is thus necessarily error-free. The ultimate choice seems to depend, therefore, on their ability to describe or predict real-world choice behaviour. Decision nets are typically highly idiosyncratic and hence require choice simulator systems. The use of choice simulator systems as such is not new; they have been used in connection with decompositional multiattribute preference models as well (Timmermans & van der Heijden 1986). It should be noted, however, that the choice simulator system associated with the decision net approach will probably be much more complex, resulting in many complex analytical problems, and that decompositional multiattribute models may also be based on closed form expressions (see e.g., Timmermans, van der Heijden & Westerveld 1984; Timmermans & van der Heijden 1984). In principle, decision nets can be represented in terms of if-then rules. This opens exciting new avenues for further research because many new computing languages such as LISP and PROLOG and the shells of expert systems as well as many artificial intelligence techniques can be brought to bear on this problem area. Although the decision net approach differs considerably from these approaches, similar lines of research have been followed in the study of information processing models as exemplified by the work of Smith, Golledge and others (e.g., Smith 1983; Smith *et al.* 1982, 1984; Golledge *et al.* 1983) and that of relational models (see e.g., van der Smagt 1985; Hendriks 1986a, 1986b; Reitsma 1986). Nevertheless, some initial trials with such languages seem to suggest that they are still very laborious. Borgers & Timmermans (1987) are therefore currently working on an interactive, menu-based computer program, written in Assembler and Fortran, which defines a set of parameters to represent a decision net, based on a researcher's response to a series of questions. The output of the program can then be used to simulate choice behaviour in a single computer run. Future research should indicate which of these two approaches is the most economical, the fastest and the most easy to use.

Choice simulator systems operate on subject-specific decision nets that are typically stored in a computer file. Alternatively, it might be possible to perform some kind of aggregate analysis. This would imply that the individual decision nets should be aggregated, either empirically or normatively. In the first case, the individual nets should be aggregated by using some type of clustering algorithm. Especially network-based algorithms or pattern matching techniques might prove useful for this analysis. In the second case, it is assumed that the decision heuristics are systematically related to the structural position of the subject. This approach would be very similar to the one that van der Smagt and his associates (van der Smagt 1985; Hendriks 1986a, 1986b; Reitsma 1986) seem to advocate. Again, future research should provide the insight into the reliability and validity of these different options. If the interpersonal variation in the decision nets is large, it is to be expected that an individual choice simulator system will yield the best results *ceteris paribus;* the appropriateness of the empirical vs. normative approach will largely depend upon the strength of the relationship between the features of the decision nets and the structural position of the subjects. If this relationship proves to be weak, the variation within structural groups being larger than or almost as large as the variation between the structural groups, the validity of a normative approach would be seriously questioned; if, on the other hand, the relationship is strong, the normative approach would represent an easy-to-use and reliable way of obtaining predictions of real-world choice behaviour using simple *a priori* decision heuristics.

Conclusions

The primary objective of the present article has been to outline a decision net approach to the study of spatial decision-making processes. This approach may prove to be a good alternative to the more conventional discrete choice and decompositional multiattribute preference models, especially when the decision-making process under investigation is characterised by the existence of noncompensatory elements or when a high degree of interpersonal variation in number and types of attributes, influencing the decision-making and choice process, is present.

The present study seems to indicate that noncompensatory elements and a considerable degree of interpersonal differences in terms of the number and types of attributes influencing the recreation choice process indeed are present. An examination of the decision nets in detail revealed that they are quite different and that various decision heuristics are used. These results would favour the use of the decision net approach for uncovering individual spatial choice and decision-making processes. It should be emphasized, however, that these conclusions are based on a very small convenience sample, implying that they should remain tentative.

In conclusion, the decision net approach deserves more attention in the study of spatial decision-making and choice processes. It may have some potential advantages over more conventional discrete choice and decompositional multiattribute preference models when considerable interpersonal variation in the type and number of attributes, influencing the choice process, and the composition of choice sets are prevalent. On the other hand, some caution is required in that some potentially important methodological problems may counterbalance the advantages of the decision net approach. Future studies should compare the reliability and especially the predictive ability of different modelling approaches by comparing predicted and real-world choice behaviour. A more definitive statement about the potentials of the decision net approach should await such testing.

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