Transport facilities and residential choice behavior : a model of multi-person choice processes

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TRANSPORT FACILITIES AND RESIDENTIAL CHOICE BEHAVIOR: A MODEL OF MULTI-PERSON CHOICE PROCESSES

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ABSTRACT The aim of this paper is to gain further insight into the way in which residential location choice behavior is related to the existence of public transport facilities and to distance to the workplace. More specifically, the objectives of this paper are two-fold. The first objective is to gain more insight into the influence of the characteristics of residential locations on residential location choice behavior. The selected characteristics are related to three aspects: (a) the residence itself (dwelling type, costs, type of neighborhood); (b) the transportation facilities in the residential neighborhood (frequency of bus services, availability of railway station, accessibility to main road system); and (c) the travel time from the residential location to the workplace (car, public transportation, and bike). The second objective is to test a model of joint (multi-person) decision making behavior. The results of this research indicate that the preference for a particular residential location is highly dependent on the characteristics of the dwelling and its environment, and to a lesser extent on the travel time to the workplace. The characteristics pertaining to transportation facilities seem to be less important. These results imply that transportation policy is not necessarily an effective instrument to influence residential choice behavior and the associated mobility.

1. INTRODUCTION

Predicting housing demand is still an area of major concern in regional science. Estimates of housing demand are also an important input in the process of developing housing programs, and are used as a basis for assessing

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the likely impact of such programs in terms of consumer satisfaction, equity, etc. Two different modeling approaches dominate this field of study: discrete choice models, based upon *revealed* choice data, and decompositional preference and choice models, derived from data on *stated* preferences and choices. The latter type of model has gained increasing popularity in housing market studies in recent years (see, e.g., Phipps and Clark 1988; Louviere and Timmermans 1990a; Timmermans et al. 1992).

Decompositional preference and choice models are based upon the assumption that individuals arrive at a choice by first cognitively integrating the utilities attached to the magnitudes of attributes that constitute the choice object (e.g., a house), according to a simple algebraic rule. Next, they implement a utility-maximizing rule to convert their preferences into a choice. In order for the researcher to be able to estimate the assumed utility function and to test the underlying choice model, individuals in a sample are typically presented with choice sets that may vary in size and composition, and are asked to select from each choice set the alternative they like best. The choice alternatives may be examples from the real world (e.g., existing housing situations), but more typically they represent profiles of hypothetical housing situations. Choices are aggregated across individuals for each choice set, and analyzed according to a formal choice model, usually a multinomial logit model. Once a specific model is assumed, the aggregated choice frequencies may be decomposed to determine the contribution of each attribute.

Existing decompositional models of housing choice behavior suffer from at least two shortcomings. First, and most importantly, these models are based upon individual data. It is thus implicitly assumed that housing choice behavior is an example of individual choice behavior, and the modeling approach represents an attempt to uncover this process under experimental conditions. However, housing choice behavior is often an example of joint or multi-person choice and decision making, in the sense that at least two adults have to reach a joint decision. Second, the role of transport facilities is often given less attention in studies of housing choice, or at least, their impact is not adequately assessed. Most models of housing choice behavior assume that housing choices involve three dimensions of attributes: (a) housing attributes; (b) attributes of the residential environment; and (c) attributes of relative location. To the extent that transport facilities are considered, they are assumed to be part of the dimension that pertains to relative location. However, researchers often limit the consideration of this aspect to the inclusion of a simple variable that measures distance to place of work.

The present study is an attempt to fill the indicated gaps. A model of joint choice behavior of dual earner households is developed. Of course, joint choices are not only made by dual earner households, but the present study was restricted to this particular type of household because this aspect was of specific interest to the transportation planners who funded it. The general approach is similar to the one used in a previous paper (Timmermans et al. 1992) and follows some tentative suggestions published in the transportation literature (Louviere 1988a). However, the present model differs from the previous one in that much more consideration is given to the impact of transport

facilities on residential choice behavior. This specific interest resulted from the information needs of the transportation planners who funded the study. They felt that variables pertaining to access, which are typically measured in terms of (relative) distance or travel time, cover only a subset of the attributes that might affect the residential location decision, and therefore can be manipulated by transport policies.

In the remainder of the paper, the theoretical underpinnings of the modeling approach and its measurement procedures are described first. This is followed by an illustration of the approach, utilizing data on residential choice behavior in The Netherlands. The paper is concluded with a discussion of some potential avenues for future research.

2. A DECOMPOSITIONAL MODEL OF JOINT DECISION BEHAVIOR

Theoretical Background

Before beginning the discussion of our approach to modeling joint choice processes, the theoretical background of decompositional approaches is first summarized. This approach has only recently been introduced in regional science. Decompositional or stated preference and choice models can be derived from several theoretical perspectives, among which random utility theory is often considered to be the most appropriate. This perspective assumes that choice alternatives such as houses or residential environments can be quantified in terms of levels for a bundle of attributes. Individuals are assumed to derive some part-worth utility from the levels of each attribute. In addition, individuals are assumed to choose alternatives by cognitively integrating their part-worth utilities into overall utilities for each alternative. This integration process can be described by a simple algebraic rule or utility function. Moreover, in decompositional choice models, individuals are assumed to maximize their utility. In such a behavioral framework, the probability that a particular choice alternative will be chosen equals the probability that the utility associated with that alternative exceeds the ones associated with the other alternatives in the choice set. If it is assumed, as is commonly done, that the stochastic components of the utility functions are identically and independently distributed, following a double exponential density function, the choice probabilities are given by the well known multinomial logit (MNL) model.

Decompositional or stated preference and choice models assume that utility functions and choice models can be estimated on the basis of data gathered by means of an experimental design. These models typically observe judgments by individuals (ratings or rankings) on hypothetical choice alternatives that are described by different combinations of attribute levels, following the principles of experimental design. In an application of these models, one first defines the attributes and associated levels that are relevant in a particular study. Experimental designs are used to generate hypothetical choice alternatives (profiles describing attribute combinations) by combining the levels of attributes in a controlled manner. Individuals are then requested to rank,

rate or otherwise express their evaluations of or preferences for the designed multiattribute alternatives in a quantitative manner. There has been considerable discussion regarding the most appropriate task to use, but it seems that substantial empirical evidence is available to support the assumption that individuals are able to rate the choice alternatives on a cardinal scale with equal intervals, provided that the experiment is conducted carefully (Anderson 1974, 1981, 1982; Timmermans 1984; Louviere 1988b). Following this, the individuals' (quantitative) evaluations of the hypothetical choice alternatives are analyzed by means of scaling approaches or multiple regression methods, in order to determine the part-worth utilities associated with the levels of each attribute.

If the aim of the study is to predict choice behavior, the predicted utilities or preferences need to be related to actual behavior by identifying constraints and by applying an ad hoc decision rule to the constrained choice set, e.g., "choice equals highest utility." However, this approach has some shortcomings. Because the conventional stated preference methods are concerned with ordering preferences rather than choices, it is difficult to accommodate constraints on choice. Of course, once part-worth utilities have been estimated for an individual, one can postulate choice rules to map the predicted utilities into choices that an individual is likely to make. However, choice rules that are defined on the basis of preference data are either ad hoc, or require that a number of strong assumptions be satisfied. Moreover, one cannot explicitly test the validity of an assumed choice model such as the multinomial logit model.

Louviere and Woodworth (1983) have therefore suggested to use choice rather than preference tasks to model the preference formation and choice processes of individuals simultaneously. Their approach requires one to first identify a set of influential attributes and relevant levels. Then, one constructs multiattribute choice alternatives by means of fractional factorial experimental designs, in which each attribute is treated as a factor with varying levels. Finally, one constructs choice sets that satisfy the statistical conditions required by choice models such as the MNL model. It is in the use of standard fractional factorial design techniques to generate the choice sets that stated choice experiments differ fundamentally from stated preference experiments.

In contrast to tasks that involve rating or ranking, decompositional choice models are based upon discrete choice tasks in which individuals select one and only one alternative in each experimentally designed choice set. Alternatively, individuals might be asked to allocate a fixed set of resources across a set of competing alternatives, although this is probably not a reliable task in the context of housing choice. Since the response data are choice frequencies, i.e., empirical estimates of choice probabilities, the parameters of the MNL model should be estimated by means of weighted multiple linear regression (generalized least squares, or GLS) or by maximum likelihood techniques, rather than by ordinary multiple regression. Woodworth and Louviere (1985) discuss using iteratively re-weighted least squares to produce the maximum likelihood estimates by iteratively updating the weight and parameter vectors. In their approach, the dependent variable consists of the observed

choice frequencies. The elements of the weight vector used in the GLS approach are the observed absolute choice frequencies for each alternative. In their iterative procedure, the weighting elements are the predicted frequencies based on the updated parameter estimates from the previous iteration.

An important practical limitation in the application of decompositional preference models is that the size of the experimental task grows exponentially with the number of attributes and the number of attribute levels. As a result, the reliability of the measurements may be questionable. As a possible solution to this problem, Louviere (1984) suggested a new method called *hierarchical information integration*. This method can be considered to be an extension of Anderson's information integration theory (Anderson 1974, 1981, 1982). It is based on the assumption that in complex decision making problems, subjects divide the set of attributes that influence their choice behavior into subsets. They evaluate these subsets separately and then aggregate their evaluations of each of them in order to arrive at an overall judgement or choice. The experimental tasks closely follow these assumptions.

In an experimental context with hierarchically structured conjoint tasks, one has to carry out the following steps (for a more elaborate discussion, see Louviere and Timmermans 1990b):

- (a) Cluster the attributes into a fixed number of sets, based on logic, empirical evidence, or theory;
- (b) Construct separate experimental designs for each of the sets identified in the first step, in order to produce multiattribute alternatives that define different levels, positions, or degrees associated with the decision construct;
- (c) Ask individuals to evaluate each combination of attribute levels or positions in a particular construct set by means of a category rating scale;
- (d) Analyze the response data for each construct separately, in order to develop statistical models that describe how the different attributes associated with each construct combine to define the construct;
- (e) Treat each of the higher order decision constructs as factors whose levels are categories from the rating scales used in the third step to carry out an overall design rating task;
- (f) Ask individuals to respond to the combinations of construct ratings on a different category rating scale, or to choose among two or more descriptions of higher-order construct ratings, as if they had given the ratings implied by each construct combination;
- (g) Analyse the response data obtained in the previous step by means of multiple linear regression techniques, or by estimating a multinomial logit model;
- (h) Concatenate the statistical models that define each higher order construct with the overall model produced in the previous step.

In order to carry out this last step, one must assume that each separate decision process has an error distribution with a mean of zero and which is uncorrelated with any of the errors for the other decision processes.

Originally, hierarchical information integration was restricted to preference tasks, but Timmermans (1989) and Louviere and Timmermans (1990a) have demonstrated that these principles can be generalized to choice problems by using discrete choice rather than preference experiments in estimating the model that represents the overall integration process.

A Model Of Multi-person Decision Making

The model of multi-person decision making applied in the present study is based on developments in information integration theory in general (Anderson 1974, 1981, 1982) and in hierarchical information integration in particular (Louviere 1984; Louviere and Timmermans 1990a,b). It is assumed that individuals arrive at an overall utility for choice alternatives by cognitively integrating the part-worth utilities they associate with various attribute levels into an overall measure of utility or preference. This integration process can be approximated or represented by simple algebraic rules. It is assumed that the response by an individual to an attribute profile as observed on a numerical psychological scale is linearly related to the individual's underlying overall utility (which remains unknown and unobservable) for that choice alternative. In addition, it is assumed that the responses observed on the psychological scale used in the experiment approximate an equal interval measurement scale. Finally, it is assumed that algebraic models are valid to approximate the way in which individuals combine their part-worth utilities to arrive at an overall preference or choice.

In common with hierarchical information integration, it is assumed that the residential choice process is complex, in the sense that many attributes are influential. Individuals are assumed to group the large set of attributes into higher order constructs (e.g., dwelling, residential environment, relative location). They first evaluate the attributes associated with a higher order construct to arrive at a preference for the choice alternatives, but only taking into consideration that single higher order construct. In a subsequent step, individuals are assumed to trade off their evaluations of the higher order constructs to arrive at an overall preference or choice.

The model of multi-person decision behavior rests on the additional assumption that there are two partners who have to choose jointly the alternative they like best, given their individual evaluations of the higher order constructs. This model thus requires slightly different measurement procedures and design strategies compared to the ones typically used in hierarchical information integration models.

The conceptual considerations discussed above require an experimental design which structures the overall evaluation process of each partner into a number of separate tasks for the higher-order constructs and into an overall integration task associated with multi-person decision making. The model of joint decision making thus involves the following steps:

- (a) Identify attributes that are assumed to influence the choice process;
- (b) Cluster causal variables into N sets, where N equals the number of selected higher order constructs;
- (c) Construct an experimental design to produce multiattribute descriptions of each higher order construct separately;
- (d) Interview each spouse to determine his or her evaluation of attribute levels for each higher order construct separately and individually;
- (e) Analyze the response data for each set and each spouse separately in order to develop statistical models that describe how the part-worth utilities associated with the attributes for a higher order construct are integrated to arrive at the overall preference for these constructs;
- (f) Develop statistical models to describe the contribution of the selected attributes to the evaluation of the overall profile (optional);
- (g) Convert the preference scores of the two spouses for the higher order constructs into factors whose levels are numerical categories from the rating scales that the spouses used to evaluate the N higher-order constructs;
- (h) Create choice sets;
- (i) Ask the spouses to imagine that they gave the ratings for the selected higher order constructs and choose jointly among the descriptions included in the choice set;
- (j) Analyze the choice data statistically based on an assumed choice model such as a multinomial logit model.

3. ILLUSTRATION

The model of multi-person decision behavior will be illustrated in the context of housing choice behavior. More specifically, interest focused on the influence of transport facilities as determinants of the residential choice process. The data for this study were collected at the beginning of 1991 in The Netherlands.

A total of 95 respondents participated in the study. They constitute a convenience sample of dual earner households, in the sense that no attempt was made to obtain a random sample. Consequently, the results of the present study cannot be generalized with any confidence. However, since our interest primarily focused on issues related to measurement procedures, design strategies and task complexity, the results obtained from this sampling frame remain useful. The particular type of household was chosen because their residential choice is probably more complex. Addresses of the households were supplied by colleagues, students and acquaintances of the authors.

Respondents were not paid for participating. They received questionnaires by post, were told about the aim of the project, encouraged to carefully read the instructions, and were requested to return the completed questionnaires by means of a stamped return envelope that was included in the package. About 200 questionnaires were posted, of which 95 usable ones were returned, yielding a response rate of almost 50%.

Attributes

The first step in the process of building the model involves the selection

TABLE 1. Selected Attributes

Higher-order Construct	Attribute	Level
I. Residence	1. dwelling type	a. detached
		b. semi-detached
		c. townhouse
		d. apartment building
	2. costs	a. fl 700, - per month
		b. fl 900, - per month
		c. fl 1100, - per month
II. Accessibility	3. type of neighborhood	a. city centre
		b. new neighborhood (>1970)
		c. older neighborhood (<1970)
	1. frequency of public transport	a. 4 times per hour
		b. twice per hour
		c. once per hour
	2. railway station	a. available within 1 km
		b. not available
	3. highway	a. 2 minutes by car
		b. 4 minutes by car
		c. 6 minutes by car
III. Relative Location	1. home to work by car	a. 10 minutes
		b. 20 minutes
		c. 30 minutes
	2. home to work by public transport	a. 15 minutes
		b. 25 minutes
		c. 35 minutes
	3. home to work by bike	a. 20 minutes
		b. 30 minutes
		c. 40 minutes

of the attributes that are considered to be influential in the process of housing choice. Based on an examination of the relevant literature and on a desire to include more attributes pertaining to transport facilities than is usually the case, a total of 9 attributes was selected. They are listed in Table 1.

The residential choice process was conceptualized in terms of three higher order constructs: residence, accessibility and relative location. Each of these were defined in terms of three attributes. Residence was operationalized in terms of dwelling type, type of neighborhood, and costs. Accessibility was measured in terms of frequency of public transport, availability of a railway station, and travel time to a major highway. Relative location was defined in terms of travel time to work, respectively by car, public transport and bike.

Design

All attributes were varied in terms of three attribute levels, except dwelling type (four levels) and availability of a railway station (two levels). Accordingly, a full factorial design would involve $2 \times 3^7 \times 4 = 17,496$ profiles. In the present study, a fractional factorial design involving 32 profiles was created. This design did not allow for the estimation of interaction effects, but it was orthogonal both within and between the higher order constructs.

Measurement

Respondents were first requested to provide preference ratings on a 10 point rating scale: (a) for each of the three higher-order constructs; and (b) for the total profile involving all three higher-order constructs. It was assumed that the rating scale is an interval scale. This allows the use of multiple regression analysis to estimate the contribution of the attribute levels to the preference ratings. Spouses were specifically asked to respond to these profiles individually. The profiles were randomly split among the spouses. Each spouse was thus presented only 16 profiles. However, in addition all participants were given two trial profiles so that they could familiarize themselves with the range in attribute levels.

The second step in the measurement procedure involved measuring the joint choices. Preference ratings on each of the three higher-order constructs for both spouses were used as attributes in the choice design. The design thus involved 6 (i.e., 2×3) attributes. The levels of the design were defined as a rating of 4, 6 and 8. A fractional factorial design consisting of 18 treatments was created to vary the profiles (potential preference ratings of the spouses on each of the three higher order constructs). Choice sets were created by randomly pairing each of the 18 profiles without replacement. The sets were checked for dominance and replications. In case of dominance or an identical pair, another choice set was created. In addition, a base choice alternative was added to each pair, described as "none of the above." Spouses were asked to imagine that they had provided the preference ratings that appeared in the profile description and were requested to indicate the profile that they would choose jointly, given their preference ratings.

Results

The following analyses were conducted:

- (a) Estimation of the contribution of the attribute levels to the preference ratings;
- (b) Estimation of the functional relationship between preference for the total profile and the preference ratings for the three higher order constructs;
- (c) Estimation of a model of joint choice behavior.

The attribute levels needed to be coded in order to estimate their contribution to preference ratings. In principle, various coding schemes may be used for this purpose. Although the interpretation of the regression coef-

TABLE 2. Parameter Estimates of the Preference Functions

Attribute	Dwelling		Accessibility		Travel Time		Total	
	avg	m/f ^a	avg	m/f	avg	m/f	avg	m/f
<i>Dwelling Type</i>								
Detached	-0.503		-0.080		-0.058		-0.274	
Semi-detached	-0.257						-0.130	
Townhouse	0.033							
<i>Costs per month</i>								
fl 700,-	-0.464						-0.195	
fl 900,-	-0.118						-0.058	
<i>Neighborhood</i>								
City centre	-0.109		-0.054	0.052			-0.088	-0.053
New	0.057						0.041	0.029
<i>Public transport</i>								
4 times			-0.775	-0.090	-0.177	-0.089	-0.264	
2 times				0.041		0.023		
<i>Railway station</i>								
available		0.035	-0.720	0.067	-0.150		-0.286	0.047
<i>Highway</i>								
2 minutes			-0.218	0.042			-0.053	
4 minutes		0.042	-0.020	0.029				
<i>Travel time by car</i>								
10 minutes					-0.397	0.053	-0.123	
20 minutes			-0.028					
<i>Travel time by public transport</i>								
15 minutes					-0.353		-0.107	
25 minutes				-0.029	0.041			
<i>Travel time by bike</i>								
20 minutes					-0.505		-0.193	
30 minutes					0.044			
Constant	6.147	0.074	6.205	-0.041	6.263		6.042	
R ²		0.991		0.992		0.970		0.982
R ² Adj		0.977		0.980		0.927		0.957

a. m/f indicates the correction for men (minus) and women (plus).

ficients will depend on the particular coding scheme used, the overall goodness-of-fit of the model is not affected by this choice. In the present study, an orthogonal coding scheme was used, which preserves orthogonality in the design matrix. Preference ratings were averaged across respondents for each

higher order construct and for the total profile. Multiple regression was used to decompose these average preference ratings into the part-worth utilities of the attribute levels.

The results of the analysis are given in Table 2, but only for the parameter estimates that were found to be significant at the 10 percent level. Table 2 illustrates that some significant differences exist between men and women. Such sex or gender related effects can be estimated by including additional columns in the design matrix, as outlined in more detail in Oppewal and Timmermans (1991). Usually, only the attributes that are supposed to relate to the higher order construct in the analysis are incorporated in the multiple regression approach. However, in the present study the attributes that are assumed to relate to other higher order constructs were used in the analysis as well, in order to test for the validity of the measurements. One could argue that the effects of these additional attributes should not be statistically significant, since otherwise would indicate that respondents apparently associated other attributes with a higher order construct.

To facilitate the interpretation of the results, the estimated coefficients and the orthogonal coding scheme were used to calculate the utilities associated with the attribute levels. The results in Table 3 show that preferences pertaining to the higher order construct *residence* are highest for detached dwellings, followed by semi-detached dwellings, town houses and apartment buildings. This finding is consistent with the existing literature. The results of the analysis also indicate that preference ratings decrease with higher costs, and this occurs at an increasing rate. This is consistent with previous findings as well. As far as type of neighborhood is concerned, the sample respondents apparently favor city centers, followed by older and more recently developed neighborhoods. Thus, these results are satisfactory. However, two additional variables are significantly associated with preference for residential profiles: the availability of a railway station and travel time to a major highway. It is not readily evident why these effects occur. They might be due to the small sample size, but this needs to be looked into in more detail in future research.

Most of the results are in the anticipated direction for the higher order construct *accessibility*. Preferences decrease with decreasing frequency of public transport; preferences are higher when a railway station is available; and preferences decrease with increasing travel time to a major highway. For this higher order construct, there are significant differences in estimated part-worth utilities between men and women. The results suggest that women place more importance on the frequency of public transport, whereas men weigh the availability of a railway station and travel time to a major highway heavier. This might indicate that women depend more on public bus services compared to men who may rely more on the car or the train. Table 3 also demonstrates that some other attributes are significantly related to preference ratings for the construct *accessibility*. In particular, the dwelling type, type of neighborhood, travel time to work by car, and travel time to work by public transport are significant. The effects of the latter two variables are small and their signs are confusing, but this is not true for the dwelling type and neighborhood type attribute.

TABLE 3. Estimated Part-Worth Utilities by Gender

	Dwelling			Accessibility			Travel time			Total		
	male	fem	both	male	fem	both	male	fem	both	male	fem	both
<i>Dwelling type</i>												
Detached			1.22			0.24			0.17			0.68
Semi-detached			0.86			0.08			0.06			0.45
Townhouse			-0.34			-0.08			-0.06			-0.19
Apartment			-1.73			-0.24			-0.17			-0.94
<i>Cost per month</i>												
fl 700,-			0.35									0.14
fl 900,-			0.24									0.12
fl 1100,-			-0.58									-0.25
<i>Neighborhood</i>												
City centre			0.17	0.00	0.11					0.05	0.21	
New			-0.11	0.00	0.00					-0.02	-0.14	
Old			-0.05	-0.00	-0.11					-0.02	-0.07	
<i>Public transport</i>												
4 times				0.64	0.91		0.07	0.29				0.26
2 times				0.08	-0.08		0.05	-0.05				0.00
1 time				-0.73	-0.82		-0.11	-0.24				-0.26
<i>Railway station</i>												
Available	0.04	-0.04		0.79	0.65				0.15	0.33	0.24	
Not available	-0.04	0.04		-0.79	-0.65				-0.15	-0.33	-0.24	
<i>Highway</i>												
2 minutes	-0.04	0.04		0.21	0.18							0.05
4 minutes	0.08	-0.08		0.10	-0.02							0.00
6 minutes	-0.04	0.04		-0.31	-0.17							-0.05
<i>Travel time by car</i>												
10 minutes						-0.03	0.45	0.34				0.12
20 minutes						0.06	0.00	0.00				0.00
30 minutes						-0.03	-0.45	-0.34				-0.12
<i>Travel time by public transport</i>												
15 minutes				0.03	-0.03				0.39			0.11
25 minutes				0.06	0.06				-0.08			0.00
35 minutes				0.03	-0.03				-0.31			-0.11
<i>Travel time by bike</i>												
20 minutes									0.55			0.19
30 minutes									-0.09			0.00
40 minutes									-0.46			-0.19
Constant	6.07	6.22		6.25	6.16				6.26			6.04

Similar findings were obtained for the third higher order construct, *relative location*. All coefficients are in the anticipated direction: preference decreases with increasing travel time; the importance weight for travel time to work by car for men exceeds that for women; and there is no statistically significant difference between men and women for the other two travel time attributes.

Again, some of the other attributes are significantly related to this higher order construct as well. In particular, this is true for frequency of public transport, availability of a railway station and dwelling type.

The same analysis was also conducted for the total profile that includes all three higher order constructs. The results are satisfactory: all coefficients are consistent with our theoretical expectations; preferences are highest for detached dwellings and decrease with increasing travel times; and most coefficients are not significantly different between men and women at the 10 percent probability level.

Measures of explained variance are satisfactory for all three higher order constructs, as well as for the total profile. The traditional R^2 measure of goodness-of-fit ranges from 0.970 to 0.992. Of course, this might not be surprising since the degrees of freedom are low. Therefore, adjusted R^2 values were calculated as well, which were still very good, ranging from 0.927 for the *relative location* construct to 0.980 for the *accessibility* construct, as indicated in Table 2. The adjusted R^2 for the total profile is 0.957.

The second step in the analysis involved estimating the functional relationship between preferences for the total profile and the preference ratings for each of the three higher order constructs. Multiple regression analysis was used to estimate this functional relationship. The results are reported in Table 4, which shows that the preference for the residence contributes most to overall preference, followed by travel time to work and accessibility. All parameters are significant. The explained variance is high: the R^2 is 0.985, and the adjusted R^2 is only slightly less (0.984).

The third step in the analysis involved the estimation of the model of multi-person choice behavior, represented by a multinomial logit specification. A maximum likelihood approach was used to estimate the parameters of the MNL model and orthogonal coding was implemented to incorporate the higher order constructs into the choice model. The results, displayed in Table 5, demonstrate that all linear effects are significant. The model performed well: the log likelihood for the estimated model was -1005.1, compared to a log likelihood for the null model of -1816.0, which indicates that the estimated model significantly improves upon the null model. The results are easier to interpret when estimated utilities are calculated. These are given in Table 6 and indicate that most utility functions increase at a decreasing rate with higher preference ratings. The higher order construct *residence* influences choice the most, followed by *relative location* and *accessibility*. Overall differences between men and women appear to be minor. The only unexpected result is obtained for the construct *accessibility*. For both men and women, the utility for a preference rating of 8 is much less than the utility for the ratings of 4 and 6. There is no ready explanation for this result.

4. DISCUSSION AND CONCLUSION

Decompositional preference and choice models have found increasing application in regional science lately. The main thrust of the present paper was to extend the existing decompositional choice modeling approach to the problem of multi-person decision behavior. The model was applied to res-

TABLE 4. Functional Relationship between Preference for Total Profile and Preference Ratings for Higher-Order Constructs

Higher-order construct	parameter	t-value
dwelling	0.457	40.54
accessibility	0.278	18.02
relative location	0.353	14.26
constant	-0.722	-4.80

TABLE 5. Estimated Parameters of the Joint Choice Model

Higher-order construct	parameter	t-value
Propensity to move	-1.401	-16.77
Men		
dwelling (linear)	1.782	18.17
dwelling (quadratic)	-0.232	-5.00
accessibility (linear)	-0.144	-1.74
accessibility (quadratic)	-0.081	-1.84
relative location (linear)	0.670	8.78
relative location (quadratic)	-0.058	-1.34
Women		
dwelling (linear)	1.871	18.40
dwelling (quadratic)	-0.260	-5.58
accessibility (linear)	-0.159	-1.91
accessibility (quadratic)	-0.016	-0.36
relative location (linear)	0.763	10.02
relative location (quadratic)	-0.118	-2.76

TABLE 6. Estimated Utilities for Constructs

Construct	Male			Female		
	4	6	8	4	6	8
dwelling	-2.014	0.464	1.550	-2.131	0.520	1.611
accessibility	0.063	0.163	-0.225	0.143	0.032	-0.175
relative location	-0.728	0.116	0.612	-0.881	0.236	0.645

idential choice behavior and included the role of transport facilities as an explanatory factor.

In substantive terms, the present study, although based on data pertaining to only 95 dual earner households, has indicated that transport facilities do influence residential choice behavior. However, they are less important as an explanatory factor than attributes pertaining to the dwelling and the residential environment. This finding is consistent with most of the literature on residential choice processes. It implies that transport policy is not nec-

essarily a strong tool to influence residential choice behavior and the associated mobility. It seems that planning objectives in this area should be satisfied primarily by appropriate housing policy and urban planning programs.

The results of the empirical application were rather mixed. We found support for the new modeling approach in the sense that overall goodness-of-fit measures were satisfactory, that utility values were in line with theoretical expectations, and that no substantial implementation problems were encountered. If similar results can be obtained in future studies, the new decompositional modeling approach may constitute an important step forward in modeling multi-person choice behavior.

However, we also obtained some unexpected results. The most troublesome of these was the fact that attributes not selected to represent a particular higher order construct were still significantly related to the preference for that higher order construct. Most of these effects were relatively small, except for the attribute dwelling type, where it was significant. Such a significant effect undermines the validity of the constructs used in this study and/or the reliability of measurement. It may be that these effects follow from the fact that respondents were shown descriptions of the higher order constructs simultaneously. Consequently, their preference ratings for higher order constructs might be influenced by some attributes belonging to another higher order construct, particularly by the most important ones. If this is indeed the case, it would be better to present descriptions of higher order constructs each in turn.

Related to this issue is the problem of aggregate versus individual preference models. In this study, only aggregate analyses were performed. While this seems difficult to avoid for the integrative joint task, in principle at least, individual models could be estimated for the preference task as well, as long as the number of treatments required to estimate such models is small.

Another issue that deserves further attention concerns the reliability of the overall joint task. It was assumed that respondents can choose between alternatives represented in terms of preference ratings for higher order constructs. Recently, Oppewal, Timmermans and Louviere (1991) have developed an alternative method for hierarchical information integration that depends on multiple choice experiments. In this approach, respondents are presented profiles that vary in terms of the attributes for a particular higher order construct and in terms of ratings for the remaining constructs, in a single treatment. This avoids the problem described above. Future research should indicate which of these alternative methods produces the best results.

In the present illustrative application, the attributes of the residence are rather few, especially compared to the hedonic price literature. Because the interest focused on methodological issues, the number of influential attributes was deliberately restricted. However, any substantive future study should deal with the problem of including large numbers of attributes in experimental designs. This will not affect the measurement procedures and model specifications used in this study, but it might require a different design strategy. As long as the number of attributes is limited, the conventional, well documented fractional factorial designs may be used (Timmermans 1984; Louviere

1988b). However, if the number of attributes becomes too large, one probably has to cluster the attributes into higher order constructs and then either develop an experimental design for each construct according to the method of hierarchical information integration (Louviere and Timmermans 1990a), or use multiple choice experiments (Oppewal, Timmermans and Louviere 1991).

Finally, it should be noted that the suggested model of multi-person decision behavior is based on developments in decompositional preference and choice modeling, and consequently that it may share some possible limitations. For example, the model assumed that the underlying utility function is measured on a cardinal scale. The advantage of this assumption is that powerful statistical techniques can be used to test the assumed specification of the utility function. Of course, the assumption of a cardinal utility function may be invalid. If one is willing to accept that the underlying utility function is at least ordinal, this problem may be solved by using multidimensional scaling algorithms or linear programming techniques to estimate the utility function. In fact, this has been done in the past in many applications (for a review, see Timmermans 1984), but at the cost that one no longer can perform rigorous tests on the correctness of the form assumed for the utility function (for a more elaborate discussion, see Timmermans 1984; or Louviere 1988b).

The present model of multi-person decision behavior does not explicitly take into account the extent to which constraints modify actual behavior, as is also the case in traditional decompositional preference and choice models. To deal with such constraints, one has to assume (a) that their effects are reflected in the estimated utilities, or (b) that the distribution of unobserved effects is invariant across time, implying that the choice model can be used to predict actual market behavior. Alternatively, one could identify explicitly constraints of interest and then simulate actual market behavior, for example, by assuming that individuals will choose the alternative with the highest utility in their constrained choice set (see, e.g., Timmermans and van der Heijden 1984). In ongoing work, Anderson et al. (1992) have suggested an approach to explicitly incorporate choice set constraints in decompositional choice models. This approach allows one to estimate the extent to which choice set constraints modify actual preferences and choice behavior. As an interesting problem for further research, the present model of multi-person decision making could be extended along similar lines.

Notwithstanding the indicated problems, the results seem sufficiently promising to use the outlined approach for modeling multi-person decision behavior. It is hoped that the present paper will stimulate others to test the approach and to develop improved models of multi-person decision behavior.

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