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Environment and Planning A, 1984, volume 16, pages 1573-1582

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Received 2 May 1983; in revised form 12 March 1984

Abstract. This research note presents the main findings of a comparative analysis conducted to assess the validity of magnitude estimation, conjoint measurement, and functional measurement for specifying and evaluating residential utility functions. The results of the analysis suggest that all three measurement procedures may be used to evaluate an individual's evaluations of attributes of residential environments and to identify overall evaluations. In addition, the results support the view that multiplicative models perform slightly better than additive models in terms of capturing the way in which subjects integrate part-worth utilities into some overall measure of utility or evaluation.

1 Introduction

Recently several attempts have been made to conceptualise the decisionmaking process underlying intraurban migration and residential choice. In general, residential area evaluation, that is, the process by which individuals subjectively judge the overall attractiveness of alternative residential areas, has been considered as a key component of this process (for example, see Louviere, 1981; Brummel, 1979; 1981; Boehm, 1982). Consequently a number of studies have attempted to identify the factors influencing residential choice behaviour and satisfaction (for instance, Galster and Hesser, 1981; Preston, 1982), to measure residential utilities (for example, Whitbread, 1978; Cadwallader, 1979; Hourihan, 1979a; 1979b), and to infer empirically the form of individual utility functions in housing choice (for example, Knight and Menchik, 1976; Louviere and Meyer, 1976; Louviere and Henley, 1977).

A critical assumption underlying these cognitive behavioural models is that individual residential utilities can be measured accurately. Specifically, if measures of residential utility are to be used as independent variables in such models, it should be proven that they remain constant in time and that they are independent of the particular measurement procedure used in a particular study. Unfortunately, however, to the authors' knowledge little empirical evidence exists to substantiate these issues.

The main purpose of this research note therefore is to assess the validity of some alternative measurement procedures for measuring residential utility functions. Specifically, the validity of psychophysical measurement (magnitude estimation), conjoint measurement, and functional measurement will be compared. In addition, this study will address the issue of which functional form of the utility function is most appropriate in describing the way in which individuals combine their part-worth utilities, defined on attribute levels of residential environments, to arrive at an overall evaluation of residential areas.

2 Three measurement procedures

The choice of a house can be conceptualised as the result of a decisionmaking process by which an individual cognitively integrates the part-worth utilities, defined on the levels of the various attributes of alternative houses, into some overall utility, according to some mathematical function. The application of a cognitive-behavioural choice model therefore involves first the choice of an appropriate procedure for measuring these part-worth utilities and second the identification of the functional form of the utility function.

Two general approaches may be used to measure the (part-worth) utilities of respondents. The compositional approach involves an explicit evaluation of each individual attribute of the choice alternatives and a measurement of the importance individuals attach to these attributes in arriving at a choice. A measure of overall utility is obtained by combining these evaluation scores according to some prespecified algebraic function. Several procedures may be used to measure these evaluations. In the present study, magnitude estimation has been used. Basically this procedure involves asking subjects to express their evaluations in terms of absolute numbers which reflect the absolute magnitude of these evaluations (for example, see Hamblin, 1973). The importance weights for attributes are obtained either by measuring them directly or by linear regression procedures. A potential disadvantage of the application of the regression procedure is that it might yield less reliable importance weights in the case of a large number of attributes.

Unlike the compositional approach, the decompositional approach attempts to derive part-worth utilities defined on the levels of the attributes by decomposing some overall utility measure into scale values for the attribute levels, given some type of composition rule. A detailed account of this approach is given in Timmermans (1984). Subjects are typically requested to judge a set of hypothetical choice alternatives, designed according to the principles of experimental design, in terms of overall preference or satisfaction. Subjects might be asked to rank the choice alternatives, as is commonly done in nonmetric conjoint measurement (Luce and Tukey, 1964), or to rate the choice alternatives, as in the functional measurement approach (Anderson, 1974). The obtained measure of overall preference is then decomposed according to some algebraic rule into the separate contributions of the attribute levels. Techniques like multidimensional scaling, regression analysis, analysis of variance, or linear programming might be used for this purpose. The testing of the appropriate functional form of the utility expression also differs between these approaches. In the compositional approach, a researcher must specify a priori a mathematical function to combine the separate evaluations and, consequently, the approach does not allow testing the appropriateness of the a priori specified function unless data on some external criterion, for example overall evaluation or overt behaviour, are available. In contrast, the appropriateness of the form of the utility expression in the decompositional approach may be explicitly tested either by some statistical goodness-of-fit measure or by comparing measures which indicate how well a derived scaling solution approximates the manifest data.

Thus it seems that each of these procedures can, in theory at least, be applied for specifying and measuring residential utility functions, although each with its own restrictions. Magnitude estimation seems to be a straightforward measurement procedure. Its main restrictions concern the validity of the applied measurement scales and the lack of an inherent mechanism to test the form of the utility function. In contrast, conjoint measurement and functional measurement are relatively sophisticated procedures. Both allow testing the functional form of the utility expression. Perhaps conjoint measurement is less demanding in terms of a subject's ability to express his/her preferences because it only requires ordinal responses. On the other hand, functional measurement has an associated error theory to test the form of the model statistically, whereas the identification of the best model in the context of conjoint measurement rests on comparing stress measures. A comparative test of these three measurement procedures is described in the next sections.

3 Research design

The data for this study were obtained in the autumn of 1979 from a convenience sample of nineteen subjects who were paid for participating. The experiments generally took 4.5–5 hours, Some tasks were performed at the university whereas the replicative tasks were performed at home.

The stimuli consisted of hypothetical residential environments described in terms of ten attributes: size of the house, balcony–garden, monthly payments, distance to work, public greenery, adjacency, distance to the neighbourhood shopping centre, distance to the city centre, situation of the house, and age of the house. Each attribute was categorised into three to seven levels, to yield in total fifty-one attribute levels (table 1). A combination of verbal descriptions and pictorial sketches was used to represent the choice alternatives. Each subject was asked to perform the following tasks for the psychophysical measurements. First, each subject was requested to express his/her evaluation of each of the fifty-one attribute levels on a 0–100 mm graphical rating scale ranging from extremely bad to excellent. Second, each subject was asked to provide numerical evaluation scores for the same fifty-one attribute levels by assigning points reflecting his/her degree of preference. The most frequently occurring level was assigned a value of 100. Each subject was asked to assign a numerical value for the various levels of the attributes. Third, each

Table 1. The attributes of the residential environments.

1 Size of the dwelling
- 1 1 room[a]
- 2 3 rooms
- 3 4 rooms
- 4 5 rooms
- 5 9 rooms

2 Balcony/garden
- 1 no balcony or garden[a]
- 2 ordinary balcony
- 3 terrace balcony
- 4 terrace garden
- 5 ordinary garden
- 6 large garden
- 7 very large garden[a]

3 Monthly payments (gulden)
- 1 800.00[a]
- 2 550.00
- 3 400.00
- 4 250.00
- 5 100.00[a]

4 Distance to work (mins)
- 1 90[a]
- 2 50–60
- 3 25–35
- 4 5–10
- 5 1[a]

5 Public greenery
- 1 no greenery in street[a]
- 2 green belts
- 3 park
- 4 park with playgrounds
- 5 common open space

6 Adjacency
- 1 adjacent to 4 dwellings
- 2 adjacent to 3 dwellings (on top floor)
- 3 adjacent to 3 dwellings (on ground floor)
- 4 adjacent to 2 dwellings (on ground floor)
- 5 semidetached
- 6 detached

7 Distance to neighbourhood shopping centre
- 1 more than 45 minutes[a] walking
- 2 approximately 25 minutes walking
- 3 approximately 15 minutes walking
- 4 approximately 5 minutes walking
- 5 approximately 1 minute[a] walking

8 Distance to city centre
- 1 more than 1 hour by car[a]
- 2 25–30 minutes by car
- 3 15–20 minutes by car
- 4 5–10 minutes by car
- 5 approximately 1 minute by car[a]

9 Situation of the dwellings towards traffic
- 1 on a traffic street
- 2 on a street with destination traffic only
- 3 on a footpath

10 Age of the dwelling (period of construction)
- 1 pre-1900[a]
- 2 1900–1920
- 3 1930–1950
- 4 1970–1975
- 5 1979[a]

[a] Fillers (extreme attributes).

subject was asked to express his/her subjective importance weights for the ten selected attributes on a 0–100 mm graphical rating scale ranging from totally unimportant to extremely important. In this phase of the experiment, the subject was asked first to examine the ten attributes. Then he/she was asked to select the one attribute that seemed most important to him/her and to assign a value of 100 to it. Each subject was then asked to rate the other nine attributes such that these ratings indicated the relative importance of these attributes to the most important attribute. These measurements constitute the set of measurements for the psychophysical model. The first measurement was repeated after one week to test the reliability of the measurements.

As far as conjoint measurement and functional measurement models are concerned, each subject performed the following tasks. First, each subject was asked to rank separately the combinations of attribute levels within fifteen trade-off matrices. Each combination of attribute levels was printed on an index card. Prior to presentation to each subject, all cards were randomised. Each subject was then asked first to sort the cards into three ordered categories of overall evaluation and then to rank the cards within each category from most preferred to least preferred. In addition, each subject was asked to ascertain that the resulting rank ordering of the hypothetical residential environments was correct. Otherwise shifting cards across categories was allowed. The result of this sequential procedure was a strict rank order of the combinations of the ten attributes for each subject. Each subject only ranked fifteen trade-off matrices because the ranking of all possible trade-off matrices (forty-five) was considered to be too time-consuming and would probably lead to less reliable measurements. Each subject provided scores for ten trade-off matrices which involved those five attributes that proved most important in previous analyses. The remaining twenty-five trade-off matrices, consisting of pairwise combinations of these five attributes and the remaining five attributes, were randomly allocated to the subjects. Four subjects provided evaluation scores for each of the twenty-five trade-off matrices. Second, each subject was also requested to express his/her degree of preference for every attribute combination in his/her fifteen trade-off matrices on a 0–100 mm graphical rating scale ranging from extremely bad to excellent. The measurements related to the first ten combinations were performed during the experiment at the university, the remaining tasks were performed at home.

4 Analysis and results

Three types of analysis were conducted: a test on the internal consistency of the measurement for each subject, an identification of the most appropriate form of the function which describes the way in which subjects combined part-worth utilities to arrive at an overall measure of evaluation or utility, and, finally, an analysis of the relationships between the three measurement procedures.

4.1 *The internal consistency for each subject*

The internal consistency of each subject's evaluation scores was tested, first, by determining the strength of the relationship between the repeated measurements and the measurements obtained during the experiment; second, by examining the stress values for the ranking tasks; and, third, by assessing the degree of correspondence between the rank orderings and the scores on the graphical rating scale, both for the tasks performed at the university and the tasks performed at home. The results are given in table 2.

The table provides the value of the Pearson product-moment correlation coefficient (r) between the subject's evaluations of the fifty-one attribute levels expressed on a graphical scale during the experiment and the subject's evaluations of these levels expressed on a graphical scale during the repeated measurement at home; the average stress value for the first ten rank orderings of the residential environments (stress 1); the average stress value for the first ten trade-off matrices in which the evaluation scores on the graphical rating scale are converted into rank orders (stress 2), and the average Spearman rank correlation coefficient (R_s) between the rank orders directly provided by a subject for the first ten trade-off matrices and the corresponding rank orders obtained by converting the rating scale values into rank orders.

Table 2 clearly illustrates that in general the internal consistency of the measurements is satisfactory. With the exception of subject 9, the product-moment correlation coefficient is good, ranging from 0.492 to 0.943 with an average value of 0.76. In addition, all stress values are acceptably low and the Spearman rank correlation coefficient is very high, ranging from 0.850 to 0.995 with an average value of 0.932.

Table 2. Some measures of internal consistency.

Subject	r^{a}	Stress 1[b]	Stress 2[c]	R_S^{d}
1	0.842	0.0001	0.0000	0.984
2	0.684	0.0000	0.0000	0.995
3	0.928	0.0001	0.0003	0.935
4	0.507	0.0003*	0.0017*	0.850
5	0.665	0.0013*	0.0012*	0.906
6	0.770	0.0001	0.0856	0.873
7	0.797	0.0000	0.0023	0.964
8	0.899	0.0000	0.0344	0.984
9	−0.110	0.0002	0.0003	0.939
10	0.492	0.0002	0.0595	0.851
11	0.874	0.0001	0.0128	0.977
12	0.943	0.0003	0.0456	0.924
13	0.791	0.0000	0.0005	0.978
14	0.573	0.0001	0.0280	0.921
15	0.918	0.0001	0.0221	0.914
16	0.819	0.0000	0.0319	0.914
17	0.651	0.0001	0.0002	0.977
18	0.741	0.0017*	0.0218*	0.939
19	0.798	0.0008	0.0791	0.905

* Multiplicative model.
[a] Pearson product-moment correlation coefficient between evaluations made at the university and at home.
[b] Average stress for first ten rank orderings of residential environment.
[c] Average stress for first ten trade-off matrices.
[d] Spearman rank correlation coefficient between rank orders from trade-off matrices and rating scale values.
Note: See text for further explanation.

4.2 *The integration model*

In the present study, only the additive and the multiplicative models were tested in terms of their ability to account for the overall evaluation measures. First, Roskam's UNICON algorithm (Roskam, 1974) was applied individually to each subject's rankings of each of the first ten trade-off matrices. The results are given in table 3. It is evident that table 3 does not clearly indicate which of the two models should be preferred. In seventy-eight cases the additive model yielded the lower stress value, in thirty-one cases the multiplicative model outperformed the additive model, whereas in eighty-one cases both models yielded a stress value of zero. However, this analysis is only concerned with one trade-off matrix. Therefore, in a second analysis, the fifteen trade-off matrices for each subject were submitted simultaneously to a scaling algorithm which was developed on the basis of Johnson's method (Johnson, 1973). The results of this analysis are given in table 4.

Table 3. Composition rules for each subject and the first ten combinations.

Subject	Combination									
	1	2	3	4	5	6	7	8	9	10
1	O	O	A	A	O	O	O	A	O	A
2	A	O	O	O	A	A	O	O	A	O
3	M	A	O	O	A	O	O	O	A	A
4	A	M	M	M	M	M	M	M	O	A
5	A	M	O	A	A	A	M	M	A	M
6	A	O	O	O	A	A	O	A	O	M
7	A	O	A	O	M	O	A	A	A	A
8	O	A	O	O	A	O	A	M	M	O
9	O	A	O	O	A	M	M	A	A	O
10	A	O	A	O	A	O	A	A	A	A
11	M	O	A	O	A	O	O	O	M	M
12	M	M	A	A	A	O	O	O	O	A
13	O	O	A	O	O	O	O	A	M	O
14	O	O	A	O	O	O	O	A	A	A
15	O	O	O	A	A	A	O	A	A	A
16	O	O	M	O	A	O	A	O	O	A
17	O	M	O	A	A	A	A	O	A	A
18	O	O	A	O	A	M	O	A	M	M
19	A	O	A	A	O	A	A	A	M	O

Note: A, additive; M, multiplicative; O, stress = 0 for both models.

Table 4. Comparison between additive and multiplicative model.

Subject	Rank ordering (stress)			Graphical rating scale		
	additive model	multiplicative model	preferred model	additive model	multiplicative model	preferred model
1	0.0048	0.0019	M	0.097	0.093	M
2	0.0754	0.0237	M	0.106	0.093	M
3	0.0713	0.0231	M	0.138	0.107	M
4	0.0429	0.0232	M	0.151	0.109	M
5	0.0099	0.0216	A	0.113	0.098	M
6	0.0021	0.0019	M	0.082	0.086	A
7	0.0038	0.0008	M	0.078	0.074	M
8	0.0011	0.0010	M	0.086	0.079	M
9	0.0033	0.0015	M	0.116	0.106	M
10	0.0040	0.0024	M	0.103	0.090	M
11	0.0053	0.0029	M	0.100	0.099	M
12	0.0041	0.0026	M	0.086	0.090	A
13	0.0018	0.0007	M	0.081	0.063	M
14	0.0008	0.0006	M	0.134	0.124	M
15	0.0064	0.0021	M	0.086	0.079	M
16	0.0025	0.0024	M	0.086	0.078	M
17	0.0039	0.0030	M	0.104	0.098	M
18	0.0056	0.0034	M	0.130	0.122	M
19	0.0064	0.0003	M	0.152	0.104	M

Table 4 suggests that the multiplicative model performs better than the additive model. This result applies for the analyses performed on the directly measured rank orders as well as for analyses performed on the rating scores converted into rank orders. Hence it appears that a subject's overall evaluation is low if his or her part-worth utility of one of the attribute levels approximates to zero. On the other hand, table 4 also clearly illustrates that the stress values of the additive models are also relatively low, which indicates the robustness of the additive model.

4.3 *Relationships between the measurement procedures*

An important question in the measurement of residential utilities is whether directly measured evaluations of separate attributes of residential choice alternatives may be combined to derive overall utility measures. The advantage of such direct measurements is that they can easily be included in questionnaires in large surveys. On the other hand, the decompositional methods are more attractive from a theoretical and conceptual point of view. Hence it seems worthwhile to test for the invariance of utility scores under different measurement procedures. In particular, the derived part-worth utilities for the attribute levels of the residential choice alternatives may be compared with the directly measured evaluations of these attribute levels. In addition, the overall utilities for the attribute combinations, as well as their rank ordering, may be computed from the directly measured evaluations of the attribute levels of the residential choice alternatives and from the subjective importance weights of the attributes and may subsequently be compared with the directly measured overall utilities.

In the present study both these analyses were performed. The scores on the graphical rating scales obtained in the repeated measurement were correlated with the part-worth utilities derived from the rank orderings of the fifteen trade-off matrices. In addition, the self-explicated importance weights were correlated with the derived importance weights. The results are given in table 5. This table shows that subjects 9 and 14 have low Pearson product-moment correlations, indicating the problems

Table 5. Product-moment correlation coefficients between derived and directly measured evaluations and weights.

Subject	Attribute						Weights
	1	2	3	4	5	6	
1	0.976	0.958	0.988	0.975	0.638	0.974	0.804
2	0.934	0.977	0.928	0.836	0.907	0.971	0.465
3	0.968	0.993	0.919	0.623	0.806	0.651	0.170
4	0.963	0.999	−0.224	0.933	0.366	0.886	−0.197
5	0.841	0.911	0.202	0.776	0.912	0.945	−0.578
6	0.976	0.920	0.679	0.949	0.414	0.732	−0.250
7	0.986	0.943	0.863	0.953	0.994	0.840	−0.036
8	0.895	0.937	0.819	0.983	0.777	0.930	0.189
9	−0.486	−0.023	0.611	−0.385	−0.323	−0.531	0.672
10	0.932	0.969	0.988	0.961	0.960	0.672	−0.647
11	0.911	0.886	0.976	0.915	0.911	−0.079	0.759
12	0.923	0.998	0.962	0.988	0.930	0.991	0.814
13	0.834	0.975	0.865	0.866	0.957	0.980	0.569
14	−0.735	−0.398	0.458	−0.137	0.199	−0.859	−0.129
15	0.818	0.958	0.964	0.839	0.801	0.991	−0.338
16	0.926	0.957	0.982	0.822	0.917	0.860	0.682
17	0.758	0.811	0.683	0.941	0.789	0.669	0.534
18	0.980	0.877	−0.020	0.484	0.816	0.277	0.445
19	0.657	0.968	0.727	0.977	0.996	0.987	−0.091

these subjects apparently envisaged with providing reliable evaluations. On the other hand, since the correlations with the measurements performed during the experiment for these two subjects were relatively good, this result might suggest that these particular subjects did not take the tasks during the repeated measurements very seriously. In general, however, table 5 demonstrates that the product-moment correlations between the derived and directly measured evaluations are sufficiently high, whereas the correlations between the derived and the self-explicated importance weights are relatively low or even negative. The latter finding suggests that the three procedures measure different quantities. A possible explanation might be that self-explicated weights indicate the importance of the attributes independently of the magnitude of the attributes. Whereas, in contrast, the weights derived from overall evaluations are contingent upon the magnitude of the attributes as perceived by a subject. Hence these different procedures generally yield different importance scales.

The second analysis was concerned with constructing overall utility measures for combinations of attributes expressed both on an ordinal and an interval scale. The measures were constructed on the basis of the scores on the graphical rating scales as well as on the basis of the numerical scales. In addition, the additive and the multiplicative composition rules were both employed to construct the overall utility scores for the hypothetical residential choice alternatives. Thus, in total six scores denoting the overall utility of residential choice alternatives were computed. These six scores for each of the nineteen subjects were subsequently correlated with the directly measured overall utilities. Product-moment correlation coefficients were then computed for the interval scales and Spearman's rank correlation coefficients were used for the ordinal scales. The results of this analysis are given in table 6. Again, the results are relatively bad for subjects 9 and 14. The results for the remaining subjects, however, are satisfactory (possibly with the exception of subject 4). The correlation coefficients are generally higher than 0.70, with an

Table 6. Average correlations between constructed and observed evaluation scores and rank orders.

Subject	Evaluation scores				Rank orders	
	additive		multiplicative		additive scale	multiplicative scale
	numerical scale	graphical scale	numerical scale	graphical scale		
1	0.84	0.90	0.85	0.90	0.87	0.88
2	0.91	0.89	0.91	0.87	0.94	0.94
3	0.70	0.83	0.59	0.88	0.82	0.82
4	0.25	0.54	0.33	0.55	0.49	0.45
5	0.67	0.74	0.70	0.76	0.72	0.71
6	0.82	0.80	0.84	0.77	0.80	0.79
7	0.85	0.86	0.87	0.86	0.82	0.84
8	0.81	0.85	0.84	0.84	0.81	0.81
9	0.57	0.06	0.53	−0.04	−0.02	0.01
10	0.59	0.81	0.71	0.85	0.89	0.91
11	0.88	0.79	0.90	0.81	0.78	0.78
12	0.77	0.88	0.77	0.87	0.79	0.89
13	0.82	0.89	0.93	0.89	0.86	0.86
14	0.80	−0.07	0.83	−0.24	−0.11	−0.26
15	−0.03	0.85	−0.36	0.88	0.77	0.82
16	0.73	0.86	0.67	0.86	0.85	0.86
17	0.85	0.78	0.86	0.76	0.64	0.72
18	0.77	0.73	0.78	0.73	0.71	0.72
19	0.80	0.80	0.83	0.87	0.88	0.91

average product-moment correlation coefficient of 0.78 both for the additive and the multiplicative model, and an average rank order correlation coefficient of 0.81 for the additive model and 0.83 for the multiplicative model. Table 6 illustrates that on average the multiplicative model performs slightly better than the additive model and that on average the graphical rating scales produce better results than the numerical scales.

5 Conclusions

The present study has sought to demonstrate that psychological measurement can be used validly to measure and specify residential utility functions. In particular, the aim of the study has been to perform some tests on the validity of magnitude estimation, conjoint measurement, and functional measurement. The results of the analyses suggest that these three measurement procedures can be used validly to measure part-worth utilities as well as overall utilities in the context of residential choice behaviour and evaluation.

More specifically, four main conclusions may be drawn. First, there are only minor differences in results obtained by applying graphical rating scales and results obtained by ranking procedures. Second, the results obtained by applying decompositional methods can be reproduced to a rather high degree from the results obtained by direct measurements. This finding suggests that simple direct measurement of residential evaluations may be included validly in survey questionnaires and that overall evaluations of residential areas can be computed by combining these measurements according to some prespecified algebraic rule. Third, again it has been shown that the multiplicative model yields slightly better results than the additive model, although both models perform satisfactorily. Last, subjective importance weights derived from overall judgments are generally not linearly related to the importance weights obtained directly by asking subjects to indicate the importance they attach to various attributes of a residential choice alternative.

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