Chapter 4

Studying Human Spatial Decision-making and its Environmental Effects, beginning with an Article by Gerard Rushton

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4.1 Introduction

My research interest in intra-urban residential choice and mobility evolved from Rushton's models of retail consumer spatial behaviors in rural environments. His models theorized residents' choices of dispersed towns for purchases as revealing their preferences for attributes of those places. The theoretical and methodological culmination of his research into consumers' revealed space preferences was, in my opinion, in a relatively early article [1], even though these models have been written about since then [2] [3].

In his article, Rushton [1] begins by proposing a normative decision-rule for residents' choice of the nearest dispersed location for shopping goods and services, and he then deduces the emergent environment in which they would live. He subsequently compares this environment with a more realistic one if residents utilized his computer-simulated decision-rule revealed from observed spatial choices of dispersed locations for goods and services.

His article's four contributions to understanding individuals' and households' spatial decision making are in: (1) Methodology of psychometric methods for decomposing and interpreting real-world decisions. (2) Theory of human spatial choice, by means of comparison of real-world decision processes with normative and/or experimental ones. (3) Methodology with the use of computer simulation, especially (4) in theory predicting environmental effects on or of human spatial decision-making.

This paper will critically discuss each of these four contributions, and illustrate how my subsequent research has refined them in applications to individuals' and households' residential choice and mobility decisions, as opposed to his retail consumers' spatial behaviors. Regardless of research area, however, Rushton [4, p. 395] was prophetic when he wrote, "...though sufficient has been said to show that the theory of choice as developed in economics and psychology is directly applicable to the problem of spatial choice. This being so, many fruitful lines of inquiry, as well as the methodology for pursuing them, await the geographer interested in individual spatial choice behavior".

4.2 Psychometric Methodology for Decomposing and Interpreting Spatial Decisions

Rushton's primary dataset for his research consisted of up to 603 rural Iowa households' choices of towns for major expenditures on groceries and clothing in spring 1960 or 1961 [5]. His secondary datasets contained comparable earlier choices in 1934 of 5,500 rural Iowa households [6], and later choices in 1966-8 of 287 rural Michigan households [7].

Rushton's [8] major research breakthrough in recovering a space preference function from surveyed households' choices occurred after he discovered a box of computer cards for a non-metric multidimensional scaling program (MDS) in his new university office. This early MDS program required an input matrix of dissimilarities between phenomena of interest in order to construct a summary interval scale of distances between them [9].

In preparation for calculating what were later called utilities from survey data [10], Rushton firstly conceptualized a consumer's choice of a particular place for major purchase of a good, such as groceries or clothing, as being the result of that consumer's implicit paired comparison with each other potential destination up to a maximum travelled distance. Subsequent researchers have redefined sets of potential destinations to be independent of consumers' observed choices, and have theorized the behavioral consequences of consumers' being spatially indifferent within them [11] [12].

Rushton secondly classified a chosen destination for a purchase and the rejected ones as members of 30-or-more locational types defined in terms of population size groupings and ranges of distances from a household's home. Definition of a dispersed place's attractiveness and accessibility in terms of these two attributes helped to produce an elegant visualizable solution, even if it oversimplified consumer retail choice. Subsequent redefinitions of Rushton's elementary locational types have been with time-distances in a transportation network, number of employees in retailing in shopping centers or zones, and surveyed reasonable travel time for maximum travelled distance [13].

Rushton's MDS calibrated a unidimensional interval scale of utilities for locational types. One output goodness of fit was a consistency index of 0.975 for the transitivity of the original choice probabilities from which were calculated the input dissimilarities [8, p. 216]. Another was a stress index of 0.23 for the calibrated monotonic relationship between those input dissimilarities and the output scaled utilities [14, p. 47].

Both goodness-of-fit indices are more useful for comparisons between different MDS solutions than for absolute determination of goodness of fit [15]. Neither has a formal statistical distribution and, besides, each has an unintuitive scale. An ideal consistency index above 0.9990 for a transitive matrix will only be decimals-different from a unity upper limit [16]. Correspondingly, an ideal stress#1 value below 0.025 (or double that for stress#2) for a metric preference- or perception-scale's description of ordinal relationships in a proximity matrix will only differ in decimals from a zero lower limit [9] [17]. Moreover, ideal indices do not guarantee interpretable MDS solutions, such as in another study's similarly-positioned shopping centers from consumer ideal points in metric preference space [18].

Rushton confirmed the interpretability of his MDS-calculated interval-scaled utilities for locational types by graphically interpolating isolines of equal overall utility in the form of a three-dimensional 'indifference' surface, with one axis for their population sizes, and another for their distances from households [8, Figure 4.2]. Patronized nearer functionally-complex places were most preferred. Un-patronized farther-away and simpler places were least preferred. And mentally-in-between were places with traded-off combinations of the two attributes.

Each isoline should therefore be monotonically increasing with farther distance to towns and larger town population for residents' deriving constant utility from trading-off farther distances to larger towns. Trade-offs, however, will not be revealed where an isoline of equal overall utility is vertical for a range of town sizes, or horizontal for a range of distances – and definitely not where it has a non-monotonic reversal, such as that of the (-1.5) isoline for towns of approximately 4,000 to 6,000 populations located approximately 3.2 km (two miles) away [8, Figure 4.2].

Graphed isolines between overall utilities without the possibility of statistical errors from MDS thus become a liability when those isolines are uninterpretable [19, p. 182]. Either the overall utilities are statistically imprecise; or additional information is needed to account for why consumers could have equal utility for a larger town located nearer than a smaller town, or why they could have equal utility for a near or a far same-sized town.

Rushton's [6] further examples of non-monotonic vertical and reversed segments of isolines of equal overall utility on an indifference surface will be discussed below. Additional examples of both vertical and horizontal isolines of equal overall utility are displayed on Lentek, Lieber and Sheskin's indifference surface for food shopping in rural Mexico in 1968 [20, Figure 2]. These authors interpret the vertical segments of utility isolines as representing 637 survey respondents' walking to the nearest center if this was within three kilometers of their homes. Horizontal segments of utility isolines express the spatial indifference of 69 respondents located farther than three kilometers from the nearest food store, who rode the bus to regional centers regardless of distance [20].

On the one hand, these findings for rural Mexicans may confirm that food shoppers do not necessarily trade-off farther distance against larger town population in spatial choices. On the other hand, however, the authors' interpretations are questionable not only as a single indifference surface was calculated for two subsamples with different modes of travel and, thus, dissimilar social and economic costs of travel. They are also questionable if scaled overall utilities were a degenerate MDS solution. The authors' interpolated isolines of equal overall utility only differ in the second decimal, and so, their scaled utilities are quite truncated relative to those in other studies using the same methodology. Neither aforementioned index of MDS goodness of fit is presented by these authors.

Applications of MDS for recovering space preference scales and cognitive distances were popular during the 1970s [14] [21]. I subsequently applied a new individual differences scaling methodology, called the weighted additive model of alternating least squares (WADDALS) for recovering households' utility functions for housing attributes [22] [23].

Just as Rushton had to adapt his MDS program to run on a mainframe computer, I adapted WADDALS to run on a portable personal computer. Mine was also an interactive PC application for graphically displaying WADDALS output in real time, thereby permitting subjects' manual adjustments of computed utilities for levels of attributes [24].

My application of MDS was for measuring individuals' utilities for residential attributes of especially older-urban homes. Another difference was my measurement of stated preferences as opposed to revealed preferences in order not only to circumvent specifying a choice rule [25], but also to have enough data for populating an input data matrix. The data analyzed by WADDALS have a factorial design organization in which hypothetical homes are described with realistic combinations of levels of attributes of the dwelling unit, neighborhood, neighborhood residents, and accessibility.

4.3 Comparison of Real-World Decision Processes with Normative and/or Experimental Ones

Description of behavior in a particular space or during a particular time period was not Rushton's primary theoretical objective. Rather, the theoretical objective was to describe the rules by which alternative locations were evaluated and choices consequently made, and which could produce different observed spatial behaviors in different environments at different times [4].

Independent rules of decision making in diverse spatial systems would thus be theoretical underpinnings for more accurate descriptions of consumer spatial behaviors than those starting with a normative rule of patronizing the nearest place offering a good or service. The evidence for having found these descriptive decision rules would be in consistently-similar indifference surfaces in space and time.

As already mentioned, Rushton analyzed indifference surfaces underlying rural Iowans' shopping choices in the 1930s and 1960s [6] [8], and Michiganders also in the 1960s [7]. As also already mentioned, Lentek, Lieber and Sheskin [20] analyzed food shopping choices of rural Mexicans in 1968. And Timmermans has done likewise for consumer shopping of rural and urban Dutch households during 1977 [3] [13].

For example, Rushton [7, Figure 1] visualized (1) the different spatial behavior patterns of 1960s Iowans and Michiganders in terms of typical distances travelled – but (2) the remarkably similar preference structures for each commodity in two different states – even though (3) small Michigan towns at all distances were more attractive to rural consumers than in Iowa.

He however visualized a significant contrast between 1934 and 1960 Iowans' preference structures. Isolines of equal overall utility on the 1934 indifference surface were almost vertical for choices within eight miles of homes, whereas by 1960 households were substituting a larger town at farther distance for a smaller town at shorter distance [6, Figure 1]. Even so, he did not mention the non-monotonic reversals of the 0 and 0.5 isolines for towns with just-below or just-above 1,000 population located 12 to 14 miles from homes in 1934. He did not mention these even though the revealed utilities were from the choices of 5,500 residents who comprised his largest-ever analyzed sample [6, Figure 1].

Visual comparison was thus the original method for assessing (dis-)similarities between indifference surfaces. Rushton [10] later tested two methods for quantifying the relative importance of the town size and distance attributes in 1960 rural Iowans' scaled utilities for dispersed shopping destinations. One method was statistically fitting a polynomial trend surface to an indifference surface, and another author subsequently applied this to one of his indifference surfaces [13]. A second method was calculating linear and curvilinear coefficients for decomposing attributes' independent and possible joint weights in (non-)additive utility functions [15] [19, p. 187].

Rushton and colleagues, nonetheless, did not rigorously compare their recovered three-dimensional indifference surfaces. They reported seeing both dissimilarities and similarities between those indifference surfaces in space and time. They did this even though dissimilarities might not support Rushton's initial hypothesis about consumers' use of the same independent decision rules for different observed behaviors in space.

Rushton [8, p. 219] from the start acknowledged individuals would be revising their space preferences through time and across space if they were constantly learning about themselves and their environments [26] [27]. In further confirmation of use of different forms of utility functions during a search process [28], I inferred individuals' switching between one form of utility function during an early phase of their search for a new home, and another form in a later phase when making a choice [29]. I also computed similar overall residential stress of their chosen new home at the end of the simulated search process, in comparison with that of their new home in reality – although neither stress was the predicted lowest for them [30].

4.4 Computer Simulation

An aforementioned example of computer simulation by Rushton [1] was in his prediction of the types and spacing of towns if rural residents utilized a decision-rule inferred by him as describing observed choices of dispersed locations for goods and services. He however used a simulated indifference surface for those rural residents' choices, probably owing to his aforementioned inability to statistically summarize the observed one [1, Figure 5]. He subsequently used simulated indifference surfaces to generate consumer choices to test his scaling methodology's ability to calibrate that indifference surface [4] [31].

On the one hand, the axes of his simulated indifference surface have the same scales as those of the observed rural Iowans' 1961 indifference surface [8, Figure 4.2]. On the other hand, however, his simulated surface's utility isolines explicitly converge at zero origin for each axis, whereas those in his observed surface would implicitly converge at zero if respondents could not patronize towns located nearer than 2.5 miles with less than an approximate 400 population. Conspicuously-absent from his simulated indifference surface is a utility isoline resembling the aforementioned non-monotonic (-1.5) isoline on his observed surface.

Computer simulations were not easily executed as batch jobs on mainframe computers, and so, a simulated indifference surface probably simplified a time-consuming procedure, even if the input of a statistical summary of an observed indifference surface was feasible. Interactive CRT computer terminals were available by the time I wrote a computer program in BASIC to computer-simulate an individual's search for a rental apartment [32]. I interestingly remember being challenged with a question that Rushton might have been asked about whether a computer simulation of human decision-making processes was an unrealistic abstraction of real-world behavior. My most recent computer simulation has consisted of computer-animated online maps and graphs of occurrences of crime and disorder, fires, and house sales in older-urban neighborhoods during periods of time, about which residents answered online survey questions [33].

4.5 Environmental Effects on or of Human Decisions

Finally, Rushton's [1] aforementioned computer-simulation predicted the environmental effects of 1960s rural Iowans' consumer choices as being the growth of larger places at the expense of smaller ones. Rural Iowans' space preferences had reciprocally evolved since 1934 in response to better transportation modes and highway network, and price differentials between small and large stores [5]. Their space preferences were thus the causes and effects of the population dynamics of Iowa villages during the 1960s, which were described in an earlier collaboration [34].

Certainly people need food and clothes to live, and so, they should make voluntary decisions about where to shop for them, even if marketing professionals are always trying to manipulate retail choices. In contrast, some decisions about moving home may be involuntary, or may not have been thought through by individuals or households [35]. Residential choice and mobility decisions may furthermore have serious social, economic and environmental consequences for people and neighborhoods, even though the decision to move into or out of a home is infrequent for most residents. I for example have used utility curves to predict residents' intentions to move out in response to environmental changes in their neighborhoods, such as more distant travel to a school as if resulting from a school closure, and inmovement of new neighborhood people and housing if different from those already around them [36].

4.6 Conclusion

Even though 1981 is the date of the last publication I have found about his spatial indifference surfaces, Rushton should look back with pride at the continuing relevance of his four research contributions in the study of human spatial decision-making and its environmental effects. The first contribution was his application of psychometric scaling methodology for measuring space preferences, although in reconsidering this I have questioned the undisclosed statistical errors in his unidimensional utility function. I have similarly reconsidered his second contribution of comparing theoretical decision processes with observed or experimental ones. In this, I have questioned whether more rigorous analysis might have contradicted the visualized similarities between indifference surfaces from which were inferred spatially- and temporally-independent rules of decision making. His third contribution was in the use of computer simulation, but I have questioned the particular efficacy of a simulation omitting the contradictory elements of his observed indifference surface. His final contribution was about the environmental effects of or on consumers' spatial decisions, but his research agenda evolved before fully exploring these.

In conclusion, Rushton began his academic career with an innovative theory at the forefront of the quantitative and behavioral revolutions in geography about how individuals made spatial decisions. He wrote clearly and concisely to explain to readers his sophisticated methodology for scaling residents' preferences for consumer shopping locations, and for representing those preferences by means of three-dimensional indifference surfaces of utilities. He anticipated subsequent criticisms of spatial indifference surfaces in the ways he tested them. His multidimensional scaling methodology attracted the interest of colleagues who applied it for recovering consumers' spatial indifference curves in other countries. My forty-years-late questions in this paper are intended to illustrate at least one former student's continuing interest in the sustainability of his theory of spatial behavior and his methodology for scaling spatial preferences.

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III. Economic Geography

In the first of two chapters on research in Economic Geography, Mike Goodchild compliments Rushton for contributing to his evolution from a graduate student studying karst geomorphology to a protagonist of geographic information science in the face of humanist critiques. Tom Eagle then demonstrates the application of Rushton's decision support system with spatial statistical analysis and GIS for predicting retail sales at existing and new stores of a client in the private sector.