INTRA-URBAN MIGRANT LIFELINES: A SPATIAL VIEW

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Changes in residential locations within the urban area play an important role in altering urban systems and urban spatial structure. On the one hand, households change residences in response to changes in the urban environment and in the patterns of their daily lives. On the other hand, their migration produces changes in neighborhood characteristics and in the spatial distribution and quality of the amenities which serve them. While attention has been directed toward identifying the relevant variables related to migration [Brown and Longbrake, 1970; Lansing and Hendricks; Rossi] to the modeling of the residential site selection process [Brown and Longbrake, 1969; Brown, Horton, and Wittick; Brown and Moore; Kain; Herbert and Stevens; Wolpert, 1965, 1966], and to the modeling of producer decisions [Chapin and Weiss; Kaiser, 1968a, 1968b; Weiss, Smith, Kaiser, and Kenney] relatively little attention has been given to the spatial patterning and geometrical aspects of intra-urban migrations. [1]

Recently, in response to this situation, a number of studies have been initiated. Brown and Holmes report research on spatial aspecta of migrant search behavior. Research on directional biases in intra-urban migration is reported by Adams, while Greer-Wooten and Gilmour together and Gilmour alone have studied both directional and distance biases in intra-urban migration for decaying subareas of Montreal. Cox, Moore, and Moore and Brown consider spatial aspects of urban contact fields, particularly those among acquaintances. In this paper, the main consideration is with directional biases in the sequence of residential movements of a household within a single urban area, termed intra-urban migrant lifelines. [2] Attention is also given to the methodology by which directional biases may be examined.

Adams, in his study of directional bias in intra-urban migration for three time periods (1890-1895, 1920-1925, 1946-1951) in Minneapolis, argues that intra-urban residential movements depend to a large measure on the migrant household's perceptual image or cognitive map of the urban area. This argument is compatible with that of Brown and Moore who suggest that the migrant's search behavior is constrained and buided by (the form of) his awareness space--the set of locations within the urban area about which the migrant possesses some knowledge (and attitude), whether from direct contact or indirect sources. Adams argues further that the individual builds up and retains a relatively narrow perceptual image of his urban area which is sharply in focus for the areas with which he has direct contact as a result of daily and weekly activities, the activity space in Brown and Moore's paradigm. These areas are generally in the immediate vicinity of the home and within a wedge-shaped sector extending from the house to the downtown center and out to the urban periphery. Similar areas in other parts of the city are not as well known since the household has fewer contacts with them.

Given that migrants do possess a wedge or rectangular shaped perceptual image of the city, the spatial pattern of intra-urban migrant lifelines should reveal a directional bias rather than a propensity to move freely in any direction. In particular, given Adams' view of spatial aspects of the housing market (that housing quality grades upward with distance from the city center), migrant households would be expected to restrict residential choices to their own sector of the city and prefer to move to neighborhoods more distant from the center, that offer a more desirable housing environment, than to similar neighborhoods in other sectors. The result would be a pattern of moves in which the majority would be radially outwards, with few cross-city moves. Such a pattern has been postulated and partially validated by several researchers including Adams and Caplow, both of whom examined Minneapolis.

Since Adams' argument and resulting hypotheses generate expected behavior patterns that are compatible with some traditional models of urban structure (particularly concentric circle formulations) and social area organization [Murdie], they have considerable intuitive appeal. For several reasons, however, we believe that further testing is in order.

First, Adams' empirical study focuses upon a large metropolis, Minneapolis, rather than a medium-sized town such as Cedar Rapids, Iowa, our study site. In the larger town, considerably more friction exists with cross-town travel than with radial travel, so that sectorial travel patterns and perceptual maps are to be expected. Intuitively, this is not the case for a small town.

Second, a recent study by Horton and Reynolds on urban awareness spaces in Cedar Rapids shows that while a sector type pattern characterizes the degree to which a suburban resident is familiar with locations within the city, a more clustered multiple nucleii pattern (no directional bias) characterizes the inner city resident. A similar conclusion may be reached by applying the theoretical model of Moore that considers both trip preferences of households and their opportunity sets [Moore and Brown].

Third, we believe that better means for measuring directional bias are available than those used by Adams and others. This point is taken up in the next section.

The Measurement of Directional Biases

Given origin locations and destinations for a particular type of movement, directional biases may be measured by transforming the resulting distribution to one with common origin (or destination), termed translation of axes, and then recording the distribution of destinations around the common origin. Such recording is often accomplished by laying out equal sectors from the origin and counting the number of destinations in each sector. If no directional bias exists, all sectors will have approximately the same number of destinations. An example using migration is to be found in Wolpert (1967).

A shortcoming of the sector approach, of course, is that the angle width of the sectors is purely arbitrary, and different results may be obtained by varying that width. A better measure of orientation is application of the circular normal (von Mises) distribution, the statistics of which reflect the dispersion of directions of move about a mean direction. This has been applied extensively in biology and geology research [Batschelet; Carr; Griffiths; Schmidt-Koenig, 1964, 1965; Stephens, 1962, 1964; Waterman] and recently Greer-Wooten and Gilmour have applied this to migration streams. The drawback of this approach is that the circular normal is a uni-modal distribution, while bi-modal distributions are frequently found in human movement examples [Adams].[3] A second shortcoming is that, even if a uni-modal distribution exists, it does not consider distance biases in the migration stream, since the distribution is fitted by considering the origins and destinations of moves to be located, respectively at the center and circumference of a unit circle.

Vector trend analysis which makes use of techniques for fitting a trend surface using orthogonal polynomials also has been applied to directional data. Examples are to be found in geological research [Fox] and, recently, immigration research [McNulty]. In vector trend analysis, the linear, quadratic, or cubic trend surfaces can be used to represent trends of 'regional' flow pattern and residuals to show local anomolies or deflections from the 'regional' trend McNulty notes that a serious drawback in using this technique is its inability to deal effectively with the distance as well as the direction of movement although he suggests that this problem might be overcome by confining the analysis to movements within specific distance bands.

The approach of Adams differs in that he considers three attributes of intra-urban moves, length of move, distance of the origin from the downtown center, and the angle of the move with respect to the location of the downtown center (Figure I-A). He then considers the mean and standard deviation of each of these three measures for each of the three samples (1890-1895, 1920-1925, 1946-1951). An important aspect of Adams' approach is the definition of directional bias in terms of a node which is functionally significant to the movement being studied. In his case the node is the CBD. Further, he has identified what seem to be three major elements for studying the morphology of movements. His methods of aggregating and analyzing these elements, however, do not provide unambiguous results with regard to distance and directional biases.

Our approach to identifying the spatial properties of movements involves two phases. The first is transforming the movement data into a distribution which retains both its distance and directional biases using the program TRANSMAP [Brown, Moore, and Moultrie]. Phase two is application of techniques associated with standard ellipse analysis of the transformed distribution. These are discussed in detail below.

Transformation of the spatial distribution of the movement data first involves classifying nodal locations as either <u>reference nodes</u> (for interaction initiators or origins) or <u>related nodes</u> (for interaction receivers or destinations). For a given reference node, all of its destination nodes together are termed its <u>related node set</u>. Thus if the first location in a migrant lifeline is taken as the reference node, all successive locations in the urban area for a particular household comprise its related node set. For this study, two approaches were taken. One was to use the initial locations as the reference nodes. The second, which proved more successful and is reported in the following section, was to employ each origin of each successive migration as a reference node, in which case only one node (the destination) comprises the related node set.

In addition to identifying reference and related nodes, it is also necessary to identify an <u>orientation node</u>. This is seen as one that is functionally important to the migration process, and in this case was designated to be the CBD.

The objective of the transformation is to establish a spatial distribution (employing a base of Cartesian coordinates) that reflects the relationship between reference and related node vis-a-vis the orientation node. Under one option, termed <u>rotation of axes only</u>, the resulting distribution will retain the distance bias in terms of the distance of move, the directional bias in terms of the orientation of the move vis-a-vis the CBD, and the location of the reference node in terms of distance from the CBD, the same qualities Adams retained. For analysis purposes, however, it is better to collapse all reference nodes to a common location, thus retaining only the first two qualities. This option, which was used here, is termed <u>translation and rotation of axes</u>. More specifically, this involves the following. (1) The vector linking the reference node to the orientation node is rotated until it is coincident with a common axis emanating from the orientation node. (2) Each node in each reference node's related node set is rotated the same amount and in the same direction as its reference node. (3) Each reference node is moved along the common axis to a common point. (4) Each node in each reference node's related node set is shifted the same distance and the same direction as the reference node. Thus, both the spatial relationships (distance, angle, direction) existing among the nodes in the related node set and the reference node, and the orientation of each reference node and its related node set to the orientation node (CBD) are retained (Figure I-B, I-C).[4] The computer algorithm outputs a plot of the resulting distribution, as well as cards containing the transformed coordinates of the observations.

Such spatial distribution may be analyzed by standard point analysis techniques such as quadrant analysis, nearest neighbor, surface fitting, standard distance, or standard ellipse analysis. Our procedure (Phase II) is first to establish classes of reference nodes for which aggregate spatial distributions are derived, using the translation and rotation option. These are (1) the total sample, (2) reference nodes classified according to their location in either the inner or outer ring of Cedar Rapids, (3) reference nodes classified according to socio-economic characteristics of their areas of origin, (4) reference nodes classified according to whether the occupation of the household head was white collar or blue collar, (5) reference nodes classified according to whether the tenure status of the household was renter or owner.[5] The spatial properties of each distribution are identified using standard ellipse techniques [Lee, Neft, Bachi] to provide measures of dispersion (standard radius from both mean center and reference node), orientation (angle of rotation, coefficient of circularity), and shape (coefficient of circularity).[6] In addition, by measuring the distance and angle of displacement of the mean center of the distribution from the location of the reference node, further specification of directional bias properties is possible. These measures are illustrated in Figure II.

Empirical Analysis

Using the city directory for Cedar Rapids, Iowa, for 1950, two hundred thirty-eight households were selected by randomized sampling of all households. The subsequent residential history for each household was traced over the period 1950 to 1965, also using city directories. Recorded for each household residence were its location, occupational status (as either blue collar or white collar), tenure type (as either owner or renter), and marital status. Some households, of course, experienced no moves since 1950. Consequently, the data set was divided into movers and non-movers. It is the mover sample that received primary attention in the analysis reported here. This sample comprises 119 households that together experienced a total of 203 moves from 1950 through 1965.

In a strict interpretation of the migrant lifeline concept, the 1950 residence site should constitute the reference node and all subsequent locations should constitute the related node set. Preliminary analyses of this sort, however, proved unsatisfactory, and, as a consequence, it was decided to use each origin site as reference node and each destination as related node. Thus, for intermediary moves from 1950 through 1965, a given location serves both as a related node (to the prior location of the household) and as a reference node)for the subsequent location of the household). The rationalization for this procedure stems from the conceptual framework offered previously. Since a selection of a migration destination is dependent upon the household's perceptual image of the city at the time of the migration, and since this image is primarily a function of its activity system which is in turn modified according to residential location, the origin site, not the 1950 site, should be a more relevant reference point for directional and distance biases in intra-urban migration.

The initial empirical analysis of the mover sample sought to identify whether dimensions of movement morphology could be identified from variables descriptive of the spatial aspects of the move, and whether, on the basis of movement morphology, there existed significantly different groupings of moves. To accomplish this, principal components analysis was applied to the sample using as variables the distance from the CBD to the reference (origin) node, the distance of the move (reference node to related node), the distance from the CBD to the related (destination) node, the angle between the move axis (connecting reference node to related node) and the reference axis (connecting orientation node to reference node), and the angle between the reference axis and a base line drawn through the orientation node that was the same for all observations (Figure I-A). Our analysis indicated that these variables were essentially independent of one another, thus comprising in themselves necessary descriptors of movement morphology. Also, on the basis of these variables, no groupings emerged that were significantly different from those already designated for TRANSMAP and standard ellipse analysis, as described in the previous section. With regard to those groupings, it should be noted that locational characteristics of the migrant household, as well as social-economic characteristics, are considered. It is deemed, therefore, that in collaboration with the TRANSMAP transformation, all the elements of movement morphology noted above and treated by Adams are considered.

Statistics derived from the standard ellipse analysis of the lifeline data subjected to TRANSMAP to preserve directional and distance characteristics are presented in Table I. The graphical expressions of these are presented for the total sample (Figure III), for subsamples specified on the basis of of social-economic characteristics of aggregate areas of origin (Figure V), for subsamples specified on the basis of occupational characteristics of households (Figure VI), and for subsamples specified on the basis of tenure characteristics of households (Figure VII).

One conclusion to be immediately drawn from comparison of subsamples with each other and the total sample is that characteristics based on location, area, occupation, and tenure of the household generally have negligible effect on movement morphology for intra-urban lifelines. [7]

With regard to dispersion, the statistics standard radius from mean center of the distribution and standard radius from the reference node must be considered. (For a bivariate normal distribution, approximately 66 percent of the related nodes would fall within the standard radius.) The former indicated an average radius of about 1.8 miles. For reference nodes located in more peripheral areas, the comparable figure is about 2.0 miles, whereas for reference nodes located in inner city areas it is about 1.5 miles. The standard radius from the reference node shows similar variation. Thus variations in dispersion according to location are not significant.

With regard to directional biases, relevant statistics are the angle of rotation of the ellipse and the displacement of the mean center from the reference node, particularly along the horizontal axis in Figures III-VII. Sectoriality in directional bias is indicated by the coefficient of circularity which varies from 0 for complete sectoriality to 1 for complete non-sectoriality (Figure VII).

The directionality measures do indicate an orientation with regard to

TABLE I - STATISTICS ON INTRA-URBAN MIGRANT LIFELINES: CEDAR RAPIDS SAMPLE

	Sample Size	Standard Radius Mean Center	Coefficient of Circularity	Mean Center		Displacement		Rotation	
				Vertical Axis	Horizontal Axis	Vertical Axis	Horizontal Axis	Given	Off Horizontal Axis
Total	203	1.80	0.68	9.40	8.30	0.00	-0.55	89.07	.93
Inner	138	1.63	0.70	9.36	8.54	-0.04	-0.31	76.78	13.22
Outer	65	2.03	0.63	9.49	7.79	0.09	-1.06	100.02	10.02
S.E. I	31	2.14	0.73	9.49	7.63	0.09	-1.22	99.60	9.60
II	57	2.12	0.60	9.36	7.95	-0.04	-0.90	77.27	12.73
III	39	1.45	0.73	9.70	8.59	0.30	-0.26	96.57	6.57
IV	67	1.37	0.70	9.23	8.67	-0.17	-0.18	108.64	18.64
V	9	1.20	0.40	9.34	8.84	-0.06	-0.01	69.46	20.54
White Collar	97	1.53	0.53	9.30	8.43	-0.10	-0.42	103.19	13.19
Blue Collar	106	2.01	0.70	9.49	8.18	0.09	-0.67	75.87	14.13
Owners	42	1.40	0.69	9.25	8.70	-0.15	-0.15	55.80	34.20
Renters	161	1.88	0.65	9.43	8.20	0.03	-0.65	91.60	1.60

the CBD: the standard ellipses are generally rotated no more than a few degrees off the directional horizontal axis, displacement of the mean center from the reference node on the horizontal axis is markedly towards the CBD, and only a slight displacement of the mean center from the reference node occurs along the vertical (and nondirectional) axis. Interestingly, however, the directional bias is towards rather than away from the CBD. In part this is due to moves across the CBD to outlying areas on the opposite side of town (about 15 percent of all moves), but the renewal of inner city areas and conversion there towards rental units must also be held responsible. Comparison of the statistics for the renter versus owner subsample provides partial support for this statement. Possibly related to the renewal and conversion towards renter aspects of inner city areas is the fact that migrant households originating in the outer areas of the city exhibit more directional bias than those originating in inner areas. However, different activity system characteristics must also be considered as relevant [Horton and Reynolds, Chapin and Hightower]. Sectoriality in directional bias appears slight, generally providing a coefficient of circularity of about .70.

Conclusions

The analysis reported here does not appear to support the conceptualization presented at the beginning of this paper, in terms of the sectorial and directional nature of moves. In part this must be deemed to result from Adams' characterization of the housing market; in the case of Cedar Rapids, housing is not strongly differentiated in quality with distance from the CBD. This difference is related to the smaller size of Cedar Rapids in comparison to Minneapolis for which the conceptualization was initially drawn, but in addition, that cobceptualization takes into account neither the upgrading of inner city areas that has occurred in recent years nor the movement restrictions on inner city residents.

The characterization of the individual's perceptual image of the city as it related to migration behavior--as being essentially elongated and sectorial in nature--is also not supported by the work here. Again, this may be due to the size of Cedar Rapids in comparison to, say, Minneapolis.

The disparity between the expectations generated by the conceptual framework presented previously, the findings of Adams, and the findings here may be resolved if the model of Adams is seen as a given case of a more general model of Moore. The latter views activity patterns, one of which is migration, as a function of the household's preference structure for spatial interaction and the opportunity set for a given interaction. Moore's model posits a bivariate normal preference structure centered on the household and a bivariate normal opportunity set centered on the CBD, resulting in an activity surface that peaks somewhere between the CBD and household and which is spatially ellipsoid in form. However, it must be recognized that both opportunity set and interaction preference will vary according to urban characteristics, a particularly important one of which is size. Thus, a sectorial interaction preference surface and an opportunity set (preferred housing) that increases in density with distance from the CBD, as posited by Adams may characterize the large city, whereas a more bivariate preference surface and an opportunity set that tends towards bivariate normality centered on the CBD may characterize the medium-sized city. This view appears to be supported by considering the present study in conjunction with prior work such as that by Adams.

FOOTNOTES

[1]Wolpert (1967) observes that while there is a need for further understanding of the forces which generate the movements within a population, a parallel effort is required in examining the geometrical elements of migration streams. Rossi also argues that the most seriously neglected aspect of mobility is its spatial patterning.

[2]This term is borrowed from Hagerstrand with slight alteration. His term is "migrant lifeline," which refers to the sequence of successive moves made by an individual through his lifetime.

[3]A bi-modal distribution would result if, for example, there occurred heavy migration in opposite directions with very little in right angle directions.

[4]One problem we have encountered in working with the translation-rotation option of the TRANSMAP program is ascertaining whether a distribution bias towards the orientation node arises because related nodes are between the orientation node and their reference node or because they are on the far side of the orientation node. This is particularly critical when the orientation node is the CBD, as here. In solving this problem the rotation only option is quite useful since the original spacing of orientation node, reference nodes, and related node sets is retained.

[5]The classifications by location and socio-economic characteristics are based upon classifications of subareal units within Cedar Rapids that have been used in other studies. See Brown, Horton, and Wittich, and Brown and Longbrake (1970).

[6]The standard ellipse program used in this analysis is CENTRO, programmed initially by John Hultquist of the Department of Geography, University of Iowa, with modifications by John Holmes of the Department of Geography, Ohio State University.

[7]The relevance of location, socio-economic characteristics of origin area, occupation, tenure, and marital status characteristics for distinguishing movers from non-movers was also tested using x^2. Only the socio-economic characteristics of origin area and tenure status showed significant variation between movers and non-movers. The tendency is for movers to be renters (or from neighborhoods with a high porportion of rental housing) and non-movers to be owners.

REFERENCES

Adams, John S., "Directional Bias in Intra-Urban Migration," Economic Geography, XLV, 1969, pp. 302-323.

Bachi, Roberto, "Standard Distance Measures and Related Methods for Spatial Analysis," Papers of the Regional Science Association, X, 1962, pp. 83-132.

Batschelet, E., Statistical Methods for the Analysis of Problems in Animal Orientation and Certain Biological Rhythms (American Institute of Biological Sciences, 1965).

Brown, Lawrence A. and John Holmes, "Search Behavior in an Intra-Urban Migration Context: A Spatial Perspective," (Ohio State University Department of Geography, 1970).

Brown, Lawrence A., Frank E. Horton, and Robert I. Wittich, "Place Utility and the Normative Allocation of Intra-Urban Migrants," Demography, VII, 1970.

Brown, Lawrence A. and David B. Longbrake, "On the Implementation of Place Utility and Related Concepts: The Intra-Urban Migration Case," in Kevin R. Cox and Reginald G. Golledge, eds., Behaviorial Problems in Geography: A Symposium (Northwestern University Studies in Geography Number 17, 1969).

Brown, Lawrence A. and David B. Longbrake, "Migration Flows in Intra-Urban Space: Place Utility Considerations," Annals of the Association of American Geographers, LX, 1970, pp. 368-384.

Brown, Lawrence A. and Eric G. Moore, "The Intra-Urban Migration Process: A Perspective," Geografiska Annaler, Series B, LII, 1970.

Brown, Lawrence A., Eric C. Moore, and William Moultrie, "TRANSMAP: A Program for Planar Transformation of Point Distributions," (Ohio State University Department of Geography, Discussion Paper Number 3, 1969).

Caplow, T., "Incidence and Direction of Residential Mobility in a Minneapolis Sample," Social Forces, XXVII, 1949, pp. 413-417.

Carr, A., "Orientation Problems of the High Seas Travel and Terrestrial Movements of Marine Turtles," American Scientist, L, 1962, pp. 359-374.

Chapin, F. Stuart, Jr. and Henry C. Hightower, Household Activity Systems: A Pilot Investigation (Institute for Research in Social Science, University of North Carolina, 1966).

Chapin, F. Stuart, Jr. and Shirley F. Weiss, Factors Influencing Land Development (Institute for Research in Social Science, University of North Carolina, 1962).

Cox, Kevin R., "The Genesis of Acquaintance Field Spatial Structures: A Conceptual Model and Empirical Tests," in Kevin R. Cox and Reginald G. Golledge, eds., Behaviorial Problems in Geography: A Symposium

(Northwestern University Studies in Geography, Number 17, 1969).

Fox, W. T., "FORTRAN IV Program for Vector Trend Analysis of Directional Data," Computer Contribution Number 11, State Geological Survey, University of Kansas, 1967.

Gilmour, Gillian, "Some Aspects of Residential Mobility in Urban Social Space," M.A. Thesis, Department of Geography, McGill University, 1969.

Greer-Wooten, Bryn and Gillian Gilmour, "Distance and Directional Bias in Migration Patterns in Depreciating Metropolitan Areas," Proceedings of the Association of American Geographers, II, 1970.

Griffiths, J. C., Scientific Method in the Analysis of Sediments (McGraw-Hill, 1967).

Hagerstrand, Torsten, "Geographical Measurements of Migration," in Jean Sutter, ed., Les Deplacements Humains (Union Europeenne d'Editions, 1962).

Herbert, John D. and Benjamin W. Stevens, "A Model of the Distribution of Residential Activity in Urban Areas," Journal of Regional Science, II, 1960, pp. 21-36.

Horton, Frank E. and David R. Reynolds, "Behaviorial Implications of Changes in Urban Spatial Structure," in Lawrence A. Brown and Eric G. Moore, eds., Papers Towards the Understanding of Change in Urban Spatial Structure (Economic Geography Hearbook Series, 1970).

Kain, John F., "Journey to Work and Residential Location," Papers of the Regional Science Association, IX, 1962, pp. 137-160.

Kaiser, Edward J., A Producer Model for Residential Growth (Institute for Research in Social Science, University of North Carolina, 1968).

Kaiser, Edward J., "Location Decision Factors in a Producer Model of Residential Development," Land Economics, XLIV, 1968, pp. 351-362.

Lansing, John B. and Gary Hendricks, Automobile Ownership and Residential Idensity (Institute for Social Research, University of Michigan, 1967).

Lee, Douglas B., Analysis and Description of Residential Segregation (Center for Housing and Environmental Studies, Cornell University, 1966).

McNulty, Michael, "Analysis of the Directional Components of Migration Streams," Discussion Paper Number 15, Department of Geography, University of Iowa, 1970).

Moore, Eric G., "Some Spatial Properties of Urban Contact Fields," Geographical Analysis, II, 1970.

Moore, Eric G. and Lawrence A. Brown, "Spatial Properties of Urban Contact Fields: En Empirical Analysis," Discussion Paper Number 52, Department of Geography, Northwestern University, 1970.

Murdie, Robert A., Factorial Ecology of Metropolitan Toronto, 1951-1961: An Essay on the Social Geography of the City (Department of Geography of the City (Department of Geography Research Paper Number 116, University of Chicago).

Neft, David S., Statistical Analysis for Areal Distributions (Regional Science Research Institute, Monograph Series Number 2, 1966).

Rossi, Peter H., Why Families Move: A Study in the Social Psychology of Urban Residential Mobility (Free Press, 1955).

Schmidt-Koenig, K., "Initial Orientation and Distance of Displacement in Pigeon Homing," Nature, CCI, 1964, p. 638.

Schmidt-Koenig, K., "Current Aspects in Bird Orientations," Advances in the Study of Behavior, I, 1965, pp. 217-272.

Stephens, M. A., "Exact and Approximate Tests for Directiona, I and II," Biometrika, XLIX, 1962, pp. 463-477, pp. 547-552.

Stephane, M. A., "The Testing of Unit Vectors for Randomness," Journal of the American Statistical Association, LIX, 1964, pp. 160-167.

Waterman, T. H., "The Analysis of Spatial Orientation," Ergebnisse Biologie, XXVI, 1963, pp. 98-117.

Weiss, Shirley F., John E. Smith, Edward J. Kaiser, and Kenneth B. Kenney, Residential Developer Decisions (Institute for Research in Social Science, University of North Carolina, 1966).

Wolpert, Julian, "Behaviorial Aspects of the Decision to Migrate," Papers of the Regional Science Association, XV, 1965, pp. 159-169.

Wolpert, Julian, "Migration As an Adjustment to Environmental Stress," Journal of Social Issues, XXII, 1966, pp. 92-102.

Wolpert, Julian, "Distance and Directional Bias in Intra-Urban Migratory Streams," Annals of the Association of American Geographers, LVII, 1967, pp. 605-616.