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SPATIAL CONSTRAINTS-ORIENTED MODELING AS AN ALTERNATIVE APPROACH TO MOVEMENT, MICRO-ECONOMIC THEORY, AND URBAN POLICY

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1. INTRODUCTION

This paper is concerned with some fundamental issues about the relations of urban geography and the behaviors of urban individuals and population groups. It presents the case for new ways of conceptualizing, modeling, and developing related data designs to analyze, the travel decisions of selected sub-populations in cities. Such sub-populations include, but are not necessarily limited to, groups suffering inequities, such as the elderly, racial minorities, women. The paper, however, has implications which extend beyond the study of travel into the area of new modeling and quantitative data analytic approaches for urban public policy. Because of the limitations on the paper's scope, the broader implications of the approach outlined here can only be indicated.

The first point is that conceptual issues precede modeling and data collection and analysis issues, and policy prescriptions.[1] Although this point may be self-evident to many, it is worth repeating here, given the current clash between the orthodox analytical-deductive approach to modeling movement, which has been used for both aggregate and disaggregate travel demand modeling (Wilson, 1974; Domencich and McFadden, 1975; Stopher and Meyburg, 1976; Williams, 1977), and those recent more empirico-inductive approaches adopted by workers such as Heggie (for rationale see June, 1978, manuscript), Heggie and

Jones (1978) and Brog et al (1976). Central to this clash are unclarified a priori positions about how the causal structures of individual and group travel should be verbally defined, prior to quantitative study, for different policy purposes. Obviously, how the world of the individual and the population group is initially conceived by the researcher, that is, the language in which it is initially thought about, is reflected in what is taken throughout all subsequent work as axiomatic and not axiomatic, and then in what variables are included as relevant, in how they are related to each other, and, even more importantly, in what variables and relationships are omitted and what differing emphases are placed on both present and absent variables and relationships. Raising and resolving conceptual issues therefore should take precedence over modeling and data analysis issues, and different resolutions of conceptual issues will lead to different models and/or data analysis designs, and hence different findings and policy implications for any kind of human behavior.

Given the current state-of-the-art, it is necessary now to clarify whether individual and group behaviors are appropriately conceptualized for the study of the movement of subpopulations in cities. This paper contends that for many purposes they are not, indicates how, suggests and documents an alternative conceptualization for the study of individual and group travel, and notes the broad range of societal issues it might address, including some of specific interest to inequitably-treated groups.

Several recent papers from the aggregate and disaggregate urban travel demand modeling areas will serve as pointed illustrations of the ways in which conceptualization proscribes analysis and policy prescriptions. For example, Hartgen (1978) describes how standard Urban Transportation Survey data bases may be treated to give answers to some women's travel issues. In particular, the author points out how such information may be analyzed to indicate current patterns and trends in behaviors, and in the causal variables controlling them, with future policies designed to meet preferences and needs so revealed. This kind of analysis, however, rests on the common conception which assumes first, that the world is planned largely to accommodate present aggregate patterns and trends in behavior, without radical alterations or modifications in them; and second, that the changing distribution of behaviors over given and known destination or other alternatives reflects what individuals and groups actually prefer to do. This view of the world, while usual, is of course debatable, and planning on the basis of it for any group even claiming severe inequities still more so!

A further illustration may be taken from a paper by Koppelman, Tybout and Syskowski (1978), which reflects current conceptions of individual and group decision-making in disaggregate travel demand modeling. The paper views the world as composed of individuals and groups who distribute choices over given alternatives (choice sets), and concentrates therefore on investigating the differences in the observed decisions of different subpopulations. While this common approach to decision-making yields much valuable information concerning the needs of different groups, assuming fixed or constant choice sets (here, a set of travel alternatives such as modes, which is the same for all individuals), it says little about the degree of variability between individuals and groups in the contents of their choice sets in the first place and how this might affect decision rules and behavior. (See also the classical 'space preference' and related studies of decision-making in behavioral geography, for example, Rushton, 1969, 1971; Horton and Reynolds, 1971.) This approach cannot therefore address questions about the possible effects of unequal travel opportunities on, and the possible need to equalize opportunities for, the mobility of different groups, a subject which surely cannot be ignored as one major focus for studies of human behavior in cities. This is especially so since planning cities on the basis of distributing behavior over constant choice sets, as the Koppelman, Tybout and Syskowski paper suggests, with no precise knowledge as to how these are formed, runs the risk of re-engraving on the urban world immense differences in opportunities between individuals and groups, or at least never precisely addressing the potent issues which could be raised by considering explicitly systematic differences in the spatial supply of, as well as the spatial demand for, the travel opportunities (activities, destinations, modes) for different kinds of people. Variations in the supply of travel opportunities are particularly important, since they comprise variations in the availability to the urban individual of 'life resources' (places for employment, recreation, social activities, medical care and travel itself), many of which are now widely dispersed at different locations outside the individual's home (Peet, 1975, pp. 567-570). A revised conception of individual and group behavior in cities, relating movement of different types of individuals to spatial variations in the contents of their choice sets, is clearly essential for the study of differences in the social and economic welfare of urban populations. However, neither the Hartgen, nor Koppelman, Tybout and Syskowski conceptualizations, stemming from older aggregate and newer disaggregate approaches to movement, respectively, and both closely related to traditional perspectives on human spatial behavior in geography, permit this central question to be addressed.

Clearly, there is a need for an alternative perspective to existing ones for the analysis of travel behavior, still more sensitive to the effects of space on movement, which can at the very least handle some important unaddressed aspects of the welfare of different population groups. The key assumptions of the principal present limiting, and then, to highlight the contrast, of an alternative conceptualization of individual and group behavior for the development of new models of movement, are therefore outlined. Arguments and data analysis are presented to document the increased accuracy and potential usefulness of the latter conceptualization, which focuses especially on several important specific kinds of constraints of space on movement. The manner in which the conceptualization could address other urban issues of societal concern, besides that of individual and group welfare in cities, is also described.

2. AXIOMATIC FOUNDATIONS OF PRESENT AND FUTURE CONCEPTIONS OF MOVEMENT

2.1 Axioms of Current Choice Models. At the moment, disaggregate travel demand models still provide perhaps the best-developed approach for understanding and predicting the travel behavior of different urban individuals and population groups. The random utility multinomial logit model (MNL) in particular is often used to describe the distribution of "trips" (travel choices) by different population groups over sets of destinations, as well as over sets of possible travel times, sets of possible modes and so on (Charles River Associates, 1976; Hall et al, 1978). The MNL, as is well-known, can be derived from micro-economic theory (see Stopher and Meyburg, 1976, pp. 4-12). Recently the axiomatic foundations of this model, which can be traced back to its micro-economic utility theory base, have been criticized because:

(1) The observable unit of behavior, the dependent variable, is considered to be simple, not complex; as, for example, a trip is considered a path by a single person simply between two points in physical space, instead of as a daily path linking r stops ($r \geq 2$) in an n-dimensional space, the two critical dimensions of which are physical space and clock time (Figures 1 and 2);

(2) The choice set of an individual for any decision is assumed to contain at least two and often "many" alternatives, and

usually to be the same as, or more rarely, to vary randomly from (Kostyniuk and Kitamura, 1978), or to differ in some ad-hoc fashion from (Adler and Ben-Akiva, 1977), other individuals' choice sets; despite some initial work by Tardiff (1976) and Recker and Stevens (1977), there is generally no systematic variation assumed to exist between individuals in their choice sets, with such systematic variation explained in terms of causal constraining variables (especially vectors of variables describing the spatial distributions of land uses about the individual's place of residence);

(3) Each and every individual is assumed to behave in the complicated strict utility-maximizing fashion; that is, each person develops an overall unique utility for each alternative in the characteristically-spatially-invariant choice set, normally by summing part-utilities of the alternatives on a number of different criteria: the person is then able to order the so-derived set of unique utilities for each alternative and to make choices so that the ratio of the probabilities of selecting any one alternative in comparison with any other is the same as the ratio of the alternatives' utilities.

(See also Burnett and Hanson, 1979).

These three assumptions are, of course, commonly disputed simply on the grounds that they are "unrealistic," using the traditional argument that it is a goal of all sciences to produce models with increasingly realistic axioms, and, more interestingly, that this might be particularly appropriate now, especially with reference to the choice set axioms (following Jones, 1977; Dix, 1977, 1978; Heggie, 1978 (a), (b); Heggie and Jones, 1978). However, as has been argued elsewhere (Burnett and Hanson, 1979), models in the social sciences have still more stringent requirements for "realistic" assumptions than do models in other sciences, because the possibility should remain open for their use to obtain many currently desired radical alterations in societal or group behaviors (or alternatively to conserve "beneficial" ones). This constitutes an additional reason for the creation of models and the conduct of data analyses based on increasingly accurate assumptions about individual and group behaviors. For example, in the area of transportation policy, it is widely accepted that, to induce mode switch or changes in car-ownership or destination selection for energy conservation, the actual attributes of modes and destinations which govern choice and the actual decision rules need to be known, requiring models with "correct" assumptions about human decision-making (see also Burnett, 1978). Also, in the case of the possibly large number of inequitably treated persons, the notion cannot be ruled out _a priori_ that some major changes in their world might still be required, and some radical alterations in their travel needs or travel habits might consequently need to be allowed for. It thus behooves us now particularly to explore the possibility of developing models and theories of travel with still more realistic behavioral assumptions, the better to identify policies to create desirable changes, and to predict accurately responses to proposed policy alternatives. (This argument can, of course, be extended into any social science policy-related area).

The remainder of the paper therefore concentrates on demonstrating the potential of a more realistic conceptualization of movement: one which assumes that individual and group behaviors are spatially and temporally complex; and that such behaviors might be explained, firstly, by choice sets which are highly variant and whose contents are significantly related to inter-individual and group variations in spatial constraints, and, secondly, by decision processes which are simpler than hereto conceived and which vary with the kind of spatially-constrained situation which the individual and group might confront.

Quite clearly, arguments for, and data analysis to support, such fundamental revisions in assumptions for the case of travel behavior have much broader implications for the theory and modeling of individual and group choice behaviors in general. In all cases where a problem might be construed as having an important spatial dimension and where utility theory from micro-economics or psychology provides the current foundation for policy-related models (e.g., urban housing and employment demand), the need for the same kinds of revisions of the axioms of the underlying theory and the models is indicated.

2.2 Modeling and Data Analysis Implications of Changing the Axioms.

Although each of the three kinds of axioms listed above have been mentioned in recent criticisms of models of travel behavior, the relative importance of each one is different. In particular, the relaxation of the 'constant choice set' axiom seems the most critical to investigate. By focusing on how the choice sets of individuals and groups are formed in cities, and by thus defining access to urban resources, the mathematical modeling of recurrent movement might be related quantitatively and causally to broader aspects of the urban environment (e.g., the spatial structure of land uses), and thus not only to urban design and equity in urban systems, but also to the different 'lifestyles,' and those aspects of the 'quality of life' which are reflected in individual and group daily activity-travel and opportunity patterns. Urban design, equity, differing lifestyles and the quality of life are facets of urban existence which, while admittedly of great societal and ethical importance, have been intractable to analytic inquiry so far at the aggregate or the disaggregate level.

Then, too, the quantitative analysis of the associations between access to opportunities (modes, destinations) by individuals and groups, and their daily activity-travel patterns, is essential for the study of urban energy demand in general and of the relations between urban spatial structures and energy consumption in particular. Such quantitative analysis seems a necessary precursor to policies directed toward energy conservation, for example, by manipulating the travel decision-making mechanisms of homogeneous population groups (market segments) (such as through gas price controls or rationing) or by altering urban land use densities (a la Pushkarev and Zupan, 1975).

Thus, investigating the possibility of assuming systematic effects of spatial distributions of urban land uses on individual and group choice sets and hence on behaviors seems therefore to have many more far-reaching implications than simply investigating the possibility of more realistically defining travel itself, or more closely approximating the decision rules of different groups. However, the important unexplored modeling and data analysis issues of each 'more realistic' assumption are discussed in turn.

Movement as complex, not simple, behavior. The assumption that the individual's behavior is simple, reflected in the definition of a trip as a single point-to-point movement by a person, has, of course, been criticized for many years (e.g., Nystuen, 1959, 1967; Hanson and Marble, 1971). However, redefining the dependent variable for explanation and the basic unit of observation as a complex rather than a simple phenomenon now has some little-considered consequences for the ways in which mobility differences between individuals and groups might be measured, described and evaluated for modeling and associated policy purposes. These consequences can perhaps best be traced out by considering in some detail what is meant by complex as distinct from simple behavior, particularly with reference to the travel of different types of individuals and groups.

Initially conceiving the trip as a link between two points in space (bases or destinations), currently permits trip activity, frequency, mode, time of day and destination etc. to be conceptualized and modeled as travel "choices" made according to rational economic utility-maximizing principles by differing types of individuals (e.g., Domencich and McFadden, 1975). The trip itself becomes theoretically the unit of 'derived demand' and there are many varieties of trips from which to choose (e.g., trips to regional or local shopping centers; or trips for shopping or for work). However, American geographers early remarked that movement in cities was <u>not</u> simple base-to-base travel, but a complex sequencing by the individual of his/her activities over space and through time during a given decision period (usually considered a day). Much emphasis was placed on the statistical analysis of longitudinal data on the linkages of land use types to define the types of multiple-purpose journeys which persons tended to make (Nystuen, 1959 and 1967; Marble, 1967; Hanson and Marble, 1971), though patterns in the linkages of other aspects of trips (such as the linkages of modes on successive trips) were not investigated. The contributions of this conceptualization of behavior and related data analyses were: an early emphasis on the individual's travel as movement through time and over urban space on an extended series of stops; a demonstration that patterns or regularities in the complex behaviors of individuals might be objectively identified, comprising measurable systematic behaviors which could be manageable as dependent variables in models and theory, though not necessarily in the way described above (see also Hanson, 1977); and, above all, an implication that such patterns of behavior might be associated statistically with the sociodemographic characteristics of individuals, such as race, class, age, culture, sex (Marble and Bowlby, 1968; Marble, Hanson and Hanson, 1973; Hanson and Hanson, 1978) and could thus be capable of scientific explanation using normal aggregation approaches within a disaggregate modeling framework (Koppelman, 1974).

Of course, in the middle of the seventies, work in the disaggregate modeling of destination choice outside geography broached the question of patterns in the spatial linkages of non-work trips by individuals. A recent discussion by Adler and Ben-Akiva (1977), for example, "A Theoretical and Empirical

Model of Trip-Chaining Behavior," independently elaborates on the geographers' earlier conceptualization of movement as complex behavior. The current proliferation of concepts such as "tours", "chains", "journeys", "travel patterns" (Spear, 1976; Horowitz, 1979) in the non-geographic literature reveals a recognition that travel is in fact a linking of stops by individuals in a sequence over space and time, implying not only destination linkages but also linkages of activities, modes, timing, and other aspects of travel as well. Little work in America has so far been carried out on the possible further implications of this reconceptualization of travel: namely, that quantitative research is required with longitudinal trip data for large samples of individuals for American cities to establish firstly, what, if any, kinds of linkage patterns exist in reality; secondly, how these might vary for different kinds of groups; thirdly, whether such patterns do comprise manageable analytic variables for new models of movement; and, lastly, what changes in the utility-based theory of decision making might flow from this redefinition of the trip as the basic unit of observation, of consumption and of derived demand.

The increasingly familiar two-dimensional geometric representation of the individual's movement as a space-time path, as shown in Figure 1, attributable to Lenntorp (1976) and reappearing under various guises in Thrift (1976) and Dix (1977), represents a first attempt to depict in quantitative form what the individual's movement might be in reality, once it is granted that he/she does not make a trip, but a sequence of trips to different places, that is, a sequence of stops over time, where a day is simply one arbitrary division of time.[2] One of the less obvious features of the representation of the individual movement in Figure 1 is that, by portraying it just as a line in two dimensions (time of day. distance), information about what is normally considered as other crucial aspects of tripmaking (such as activities, modes, destination types and locations) has been collapsed into that two-dimensional space. Technically, Figure 1 is a simplified representation of the individual's movement as a path in n dimensions, one being time of day, one being distance from last stop to the next, and the others representing the remaining particularly important aspects of travel which could be considered, such as mode, activity type and location of destination, at least. The individual's path, properly represented in the n-dimensional space where some of the dimensions are spatial and categorical or qualitative variables, and some are not, becomes a line joining a sequence of points, representing stops, each stop possessing a set of coordinates (or values) on a separate axis giving at least time of arrival at stop, distance from last stop, location of present stop on north-south and east-west axes, mode used to get to stop and activity conducted at the stop (it is clear that any other important aspects of travel could be portrayed on further dimensions, e.g., duration of stay at a stop). The more rigorous geometrical representation of the individual's travel as a path in n dimensions in which time of day and distance traveled are but two, is shown in Figure 2. (See also Burnett and Hanson, 1979).

This reconceptualization of travel does not seem particularly important of itself: what is important is what it implies for future data analysis, modeling and policy related to the decision-making of different population groups. First of all, it is evident that the most important differences between the behaviors of different population groups, such as, to take the most simple example, differences between men and women, might not show up when the unit of observation and explanation is conceived as 'simple'. For example, most studies show that the average distance traveled by women, measured for simple interbase trips, is shorter than that of men (reviewed Kostyniuk and Cleveland, 1978). This could be taken to imply that women have a shorter range about the home than men, and even as an indication that they are less mobile. However, if the total typical daily travel patterns of women are compared with those of men, then the number of stops on a day and the distances and directions they lie from each other will determine whether, in reality, women do travel a shorter distance, are less mobile and have a smaller range than men. It is conceivable that women, particularly women employed in the paid labor force part-time or not at all, might make many more stops over a day than do men, that their total distance traveled is greater even though the average interbase trip length is smaller, and that the maximum distance and area they need to range away from home is even greater to or equal to men's. In addition, by simply comparing the distribution of women's and men's interbase trips between different modes, no information is gained as to the complexity of the sequence of modes which men and women use to accomplish their daily activity-travel pattern. For example, homemakers in one-car households, deprived of a car during the day, might need to use two or three non-auto modes while men might simply use a car for all trips (Hanson and Hanson, forthcoming). The total costs of the female transit-oriented group would be clearly greater in this case than the travel costs of the male auto-oriented group, to a degree that is not reflected in simple statistics showing that women use transit on trips and men use cars, or in current MNL models of demand where it is widely accepted that only 'simple trip' travel time by alternatives is a critical decision variable.

Thus, it is particularly important to reconceptualize the dependent variable of travel demand models as complex behavior, that is, in the form of a path over space and time, in order to provide, among other things, for more appropriate measures of differentials in overt behavior between population groups, and for a more appropriate specification of models to capture their causes. One related policy implication that flows from this is a clearer understanding of how demands for flexibility and reliability in travel might arise, particularly for some kinds of population (for example, the population groups in Koppelman, Tybout and Syskowski, 1978). Indeed, it could be remarked that until travel is redefined as in Figures 1 and 2, crucial spatial aspects of different modes such as routing and scheduling which might effect the demands for them are likely to be ignored and/or under-emphasized in modeling, data analysis and policy. For all these reasons, it is exceedingly important to determine what typical kinds of paths exist, how they are associated with different kinds of individuals, and how they are formed by individual and group decision-making under differentials in the supply of travel opportunities.

Systematic variations in choice sets. The suggestion that systematic differences exist in the choice sets of urban individuals of different kinds posits a need for the development of a causal choice set formation model to focus empirical research into the question. Specifically, current popular model structures like the MNL might be rewritten so that the probabilities of an individual or member of a group selecting a particular option (such as a kind of travel behavior) can be re-expressed as a function both of the probability of an option being in the choice set, at present omitted from consideration, and the probability of the option's selection conditional on its inclusion in the set, at present all that is considered. That is, the structure of constraints-oriented models for the study of the behavior of urban population groups should be:

$$P(j) = P(j \varepsilon A) \cdot P(j | j \varepsilon A), \quad j=1,\ldots,n \qquad (1)$$

where A is the set of complex travel options containing j and n is the total number of options. Empirical research to identify the variables and their functional relations to specify $P(j \varepsilon A)$ for a type of individual would lead to a causal choice set formation model of an explanatory-descriptive variety. There is an initial discussion of some of its variables, especially spatial ones, and of the further use of all of (1) to redevelop microeconomic choice theory and thence reformulated analytic deductive demand models in Burnett (1978) and Burnett and Hanson (1979).

The discussion distinguishes between the effects of 'institutionally-related spatial constraints' and 'personal constraints' on choice sets. Spatial constraints comprise the distance properties of the spatial distributions of very diverse urban activities (the locations of residences, work places, different kinds of shops etc. relative to home) and the scheduling of such activities in different locations. Such constraints limit the numbers and kinds of options, respectively, in the individual's "opportunity set" (all options), "cognitive opportunity set" (all known options), and "choice" or "contact set" (all options ever used) (Marble and Bowlby, 1968; Hanson, 1973; also Westelius, 1973; Lenntorp, 1976; Brog et al, 1976; Heggie and Jones, 1978; Dix, 1977; Recker and Stevens, 1977; Wermuth, 1978). Spatial constraints are termed 'institutionally-related' because they result from collective decisions beyond the individual's control which operate through the institutions of an advanced capitalist society, for example, through urban planning and government, and through corporate organizational and locational decisions. Personal constraints on choice sets comprise variables more under the person's control and may be related to his/her sociodemographic characteristics. Such personal constraints might include auto accessibility, and personal time and money budgets (Zahavi, 1974; Lerman and Adler, 1976; Tardiff, 1976; Wermuth, 1978). Preliminary work has shown how personal constraints might be defined by the individual's 'role complex', that is, by societally-expected activities and behaviors through the person's categorization by the classic role descriptors of race, class and gender (Fried et al, 1977; Dix, 1977; Jones, 1977; Heggie, 1978; Koppelman, Tybout and Syskowski, 1978). Some measurable socio-demographic correlates of such categories (income, marital status, stage in life cycle, occupation, for example) might therefore also comprise appropriate explanatory terms in a causal choice set formation model for different kinds of individual and urban population groups (see also Lerman and Adler, 1976 and Tardiff, 1976 for the use of sociodemographics to develop "mode choice set generating models").

How much such personal constraints are under the individual's control and how much under the control of such fundamental societal institutions as the job market and the family remains, of course, a moot point. It is clear, though, that the inclusion of vectors of explanatory variables describing spatial and personal constraints in choice set formation models for different types of individuals and urban population groups will forge a link between behaviors at the micro level and many macro scale variables reflecting both urban spatial and societal structures. Such variables are typically considered exogenous in the explanation or prediction of the behaviors of urban individuals and groups. Although their inclusion as endogenous will lead to messy and complicated modeling in the initial stages, in the long-run it should produce both a better grasp of determinants of human behavior in cities for political purposes, and an ability to study adjustments by urban population groups to ongoing changes, both planned and unplanned, in societal institutions and urban environments.

Both kinds of constraints (spatial, personal) need detailed definition and measurement for the case of travel by urban population groups, and the relative significance of the institutionally-related spatial constraints versus personal constraints needs to be determined. More specifically, for practical purposes, an assessment is required as to how much of the variance in the observations of the complex daily travel patterns of different individuals is explained by variables more-or-less under their control, with such behaviors therefore being perhaps manipulable by marketing strategies, and how much is outside the individual's control, arising from organizational decisions restricting choice sets by the private or corporate sectors, and certainly needing government policy or industrial reorganization to handle. Such an assessment appears to be more important however for new disaggregate modeling and theoretical purposes, since it would permit the segmentation of the metropolitan population aggregate into a number of different groups each requiring a different kind of constraints- or choice-oriented model. Firstly, there would be groups for whom neither spatial nor personal constraints contribute significantly to the explanation of their behavior. For these groups, current choice-oriented models like the MNL would be appropriate and only the $P(j|j \varepsilon A)$ component of (1) needs further investigation. Secondly, there would be groups whose behaviors are explained solely by spatial constraints: for these extreme cases of a new "geographic determinism", only elaboration of the $P(j \varepsilon A)$ component of (1) is required. Thirdly, there would be groups for whom personal constraints are most significant, for whom modifications of models like the MNL to take time and money budgets, for example, into account, might be appropriate. And, finally, there would be groups (one suspects, the largest number) for whom both personal and spatial constraints of different kinds are significant and for whom complete specification of (1) is now required.

All this implies that in order to specify a choice set formation model for appropriate types of individuals, considerable exploratory data analysis needs to be done to identify relevant population groups, to specify and measure the variables which define the individual's choice set, and to develop the mathematical statements about the ways in which these variables determine the probabilities of different alternatives being in or out of the individual's set. This is clearly a very complex question for future empirical research, perhaps best commenced by the use of special analysis of large-scale data sets (see below) followed by special behavioral simulation procedures (following Biel, 1972; Burnett, 1974; Brog, 1977; Heggie, 1978 (a), (b); Jones, 1979).

Variable decision rules and variable decision situations. In instances where individuals _do_ have choices, that is, more than one alternative in their choice set, it is now known that decision strategies may vary both with the type of individual and with the type of 'situation', that is, with the number of and salient attributes of alternatives in their choice sets. Individuals' 'situations' in an urban environment may be spatially constrained to different degrees, so that decision strategies themselves may well be related to the properties of the spatial distributions of urban land uses. Hence we may neatly expect individuals to fall into groups with different types of complex travel behaviors, associated with differences, ranging from considerable to nil, in the effects of spatial constraints on their options and decision rules. This expectation supports the approach of this paper as a viable alternative to current disaggregate models of movement.

In addition, decision strategies may often be much simpler than the strict utility-maximizing assumption postulates: "In general people prefer strategies that are easy to justify and do not involve reliance on relative weights, tradeoff functions or other numerical computations." (Slovic, Fischoff and Lichtenstein, 1977, p. 8). Simple strategies may include elimination-by-aspects, disjunctive, conjunctive, or lexicographic rules (Einhorn, 1970; Tversky, 1972): features of these are firstly, reliance on threshold values of one, or a few, very important dimensions of alternatives to partition choice sets into satisfactory and unsatisfactory options; and secondly, several stages of judgment. Especially, simple decision strategies seem likely for routine problem-solving, and, given frequent observations of the routine nature of intra-urban movement (Hensher, 1976) it is evident that travel decisions should be of "simple" and "easy kinds".

Thus, the expansion of $P(j|j \varepsilon A)$, the choice model component of Equation I, will require the identification of simple choice strategies which different kinds of individuals use in different situations. There has been no investigation so far of differences between human groups in different micro-environments in decision rules for modeling travel behavior: there are, for example, no studies of the differences between the less affluent and educated in inner cities, and the more affluent and educated in suburbs, in the criteria used for judging travel options <u>and</u> in the importance of the criteria <u>and</u> in how the criteria are used to make a decision. For public policy or corporate strategies directed towards changing travel behaviors, given a specified set of options, such as selling new places of employment or new modes or shopping centers, the possibility of such group differentials should be allowed for. For example, threshold choice strategies, in contrast to utility-maximizing ones, seem to imply zero return to anything but "critical" major alterations in only a few very "important" dimensions of alternatives: there will no response to incremental alterations. Because decision strategies seem to exist which imply different responses from strict utility-maximizing ones, the effects of intergroup differentials in all aspects of decision-making should be considered when the actual choice process is being modeled, and when choice data is being analyzed.

It remains to produce some evidence that different decision strategies might be used by different types of urban individuals and population groups in spatially-constrained situations of different kinds. Small-sample data analysis shows that the combination of variable choice sets and variable decision rules can explain interindividual and intergroup differences in complex travel behaviors. This documents not only the potential but also the validity of spatial constraints-oriented modeling as an alternative approach to movement, and, by analogy, also as an alternative approach to other kinds of complex human behaviors and decision-making in cities.

3. DOCUMENTATION FROM A SMALL-SAMPLE EXPERIMENT

3.1 The Data. The sample comprised the 35-day travel records of 40 individuals selected as a stratified proportional random sample from members of each of six life-cycle groups; the latter comprised a larger proportionate random sample of 531 individuals and 296 households by life cycle group in Uppsala, Sweden, 1971 (Table 1). The Uppsala data set was chosen for two reasons: firstly, because it contained demographic information about social roles (especially gender-related roles) which is missing from other data bases, and which is now believed to describe the characteristics of groups most significantly related to movement (see Section 2.2 and Fried et al, 1977; Heggie, 1978 (a), (b); Jones, 1979); and, secondly, because it was the only one containing the detailed longitudinal data for the analysis of an individual's complex travel consistent with Figures 1 and 2. The travel record for each individual in the sub-sample was basically of a standard variety, as can be seen from the example of a person's travel diary in Table 2; each individual recorded, for each stop, time of arrival and departure from the stop, activity at the stop, expenditures at the stop, and so on. However, in addition, on the final data tape, the land use at each stop, by one of 99 classes, was entered, together with north-south and east-west grid coordinates of the location of the stop, and the distance traveled from the stop before, information not available in other data sets on recurrent movement.

It must be noted that the analysis of these data for 40 individuals is not intended to provide any definitive statements as to how different urban population groups behave, but rather to examine the idea that a new, more realistic conceptualization of travel behavior for individuals and groups can yield an adequate description (in some statistical sense) of common information in individual trip records. The intent is to demonstrate that hypotheses consistent with assumptions about the complexity of the daily movement of individuals of different types, and also consistent with assumed intergroup variations in choice sets and in simple decision rules, match forms of travel data which are also currently fitted by logit models derived from different premises. Since the new hypotheses are more realistic and lead to the study of many interesting theoretical, modeling, data analysis and policy issues for urban population groups which are not addressed by other approaches to movement, further support is provided for future work based on the new notions of decision-making and behavior.

3.2 Plots of Complex Travel in n-Dimensional Space. The results of reconceptualizing the individual's travel as complex human behavior and plotting it mathematically as a path in n-dimensional space are indicated in Figure 3. For each of the 40 randomly sampled individuals, the day of his/her most complex behavior, as indicated by the day with the maximum number of stops, was selected. Two-dimensional computer plots, following Figure 2, were prepared for each individual, showing the sequence of stops plotted against each pair of stop descriptors-activity at stop, time of arrival at stop, distance from last stop, NS and EW location coordinates of stop, land use at stop, and mode to stop.

Simple inspection of the diagrams of Figure 3 is sufficient to show that, even in the most complex cases, any individual's daily travel has a less, rather than more, complicated structure. The illustrative selection of diagrams show how, for example, the ranges of each individual through a day are apparently limited to some maximum distance and area, and how there is a limited number of different modes taken on successive stops, and some limit on the total distance traveled. More importantly, the diagrams in Figure 3 are sufficient to indicate how the structure of paths in n-dimensional space might be differentiable by type of individual or population group; younger groups with more children seem to exhibit more complex daily travel patterns in terms of the numbers and locations of stops and the variety of modes taken, and men appear to have significantly different modal combinations and total daily distance traveled from women. Thus, systematic differences between the paths for different persons could exist which might be identified by classifying or measuring them and associating them with role-related socio-demographic characteristics of persons. This implies that reconceiving human behavior as complex, in the case of travel at least, should not lead immediately to too complex a dependent variable for handling in new kinds of mathematical models and data analyses for the study of individual and group behavior. Another paper (Burnett, 1979, forthcoming) describes multivariate statistical procedures whereby paths in n-dimensional space are classified and the associations of complex travel classes with appropriately defined combinations of sociodemographics, giving different kinds of individual and population groups, are more thoroughly investigated. (See also Table 4).

3.3 Inter-Group Variations in Choice Sets. The revised axiomatic base for new kinds of models and data analysis postulates that choice sets of individuals are both more spatially constrained and more systematically variant between persons and groups than has been considered the case. One way of examining this statement is to see whether it appears true of travel choice sets for the Uppsala subsample. The hypothesis is tested by showing how, if it is true, specific patterns should appear in the data for the complex travel behaviors of urban population groups in general and the Uppsala subsample in particular.

From the redefinition of travel in Figures 1 and 2, it is apparent that what have been conceived to date as separate "choices" (activity, mode, destination-location, destination-type, time of day, etc.) may in fact be simply descriptors or aspects of stops to the individual. From this, one tenable hypothesis, consistent both with the foregoing reconceptualization of the individual's movement, and with the notion of constrained and systematically varying choice sets, is that different types of individuals choose from a limited number of different and distinctive activity/mode/ destination type/destination-location/distance/time of day aspect combinations defining stops. For example, if the person is a full-time employed individual, then "shopping for groceries" may always and only be associated with "five minutes from home on the way from work to home", "travel by auto mode", and "5:30 p.m.", while "shopping for clothing" might be associated always and only with "nearest regional shopping center", "ten miles from home", "auto mode", and "6 to 9 p.m. Thursdays and Saturday mornings". Only stops which can be labeled in this way will belong in this type of individual's choice set, and the labels reflect the distinctive effects of spatial, and also personal, constraints on options for the group. Other kinds of individuals will have possible stops described by different combinations of attributes.

What this implies is that, in any individual's daily n x 7 travel matrix, comprising observations for all 7 aspects of n stops (mode, activity, time of arrival, distance from last stop, EW and NS locational coordinates, land use), the column of n numbers defining the set of observations of an aspect for each stop should be associated with each of the columns of n numbers describing each other aspect of the stops. Thus, if 1 (or any other) number represents "shopping activities", it should always, or almost always, recur with, one single other number, say 7, representing land use, and the appropriate single numbers for activity, mode, time of day and distance from home. This implies that some measure of the pattern of association between the aspects of stops could be used to determine how restricted the individual's choice set is, and then permit interindividual and intergroup comparisons in the degree of restriction of choice sets. The Pearsonian simple correlation coefficient, r, can be used to measure the patterns of association between each pair of aspects for each individual.[3] The magnitude of $|r|$ is an index of the degree of constraint of the individual's choice set; low $|r|$ values ($\rightarrow 0.0000$) represent little association, that is, the pairing of one value for one stop aspect (e.g., representing one mode) with highly variable values of another aspect (e.g., representing many different kinds of land use or destination types), and thus little or no effects of spatial or personal constraints on choice sets. High values of $|r|$ indicate a consistent association of one value of one stop aspect (e.g., one mode) with one value of another stop aspect (e.g., a single land use), reflecting a highly constrained situation. High degrees of interindividual variability in r values indicate the possibility of 'groups' of r (types of choice set) being statistically defined by normal procedures to minimize within-group and maximize between-group variance of them. Such groups of r may then be associated with the role-related sociodemographics for complex travel, by multiway analysis of variance, for example. Both the magnitudes and variability of individual r values for each pair of stop aspects could therefore provide a preliminary indication of whether systematically constrained and variant choice sets exist for different population groups.

Consequently, the inter-correlations of all pairs of aspects of stops were computed for each individual in the Uppsala subsample and a summary table prepared (Table 3). From this Table, it can be seen that, while the majority of individuals tend to have r values between .25 and -.25 for all aspect pairs, and while this is also the case for each aspect pair separately, there is significant inter-individual variation in both the magnitude and the nature of the association. This is reflected in the high coefficient of variation, and the symmetrical distribution of r's over the entire range of its possible values for the sample of individuals, both in the case of each aspect pair separately and all aspect pairs taken together. Certain kinds of individuals might hence be found with differences in their choice sets, or, more specifically, systematic differences in the choice sets of urban population groups might exist which could be modeled. Of course, how variables (spatial, personal) constrain choice sets is left open for exploration in future work, but at least there is evidence that significant choice set variations could exist, somehow spatially and/or personally constrained, between different population groups.

Since it has been suggested that role-related sociodemographics are those most closely related to complex travel behaviors (Sections 3.1), and that they operate through both a varying influence on choice sets and on decision rules (Section 2.2), some preliminary work was done to investigate the association between the r measures of the degree of constraints on the individual's choice sets and available sociodemographic information for the Uppsala subsample. Three analyses of variance of the differences in correlation coefficients for aspect pairs by life cycle, gender, and life cycle/gender groups recorded for the 40 Uppsala individuals showed, however, no statistically significant main or interaction effects. The conclusion with this small sample should not be that it is highly doubtful that there <u>are</u> role-related differences in choice sets; rather, more attention should be paid to the development of additional role descriptors (socioeconomic status, race) which might interact with or complement the effects of gender and lifecycle on choice sets, decision rules and behavior. The experimental design outlined in Table 4 for much larger samples of individuals will permit a better exploration of possibly complex role effects on movement. It will also permit, more especially, an investigation of the relative effects of role-related constraints and spatial constraints on the travel of different groups, for the specification of the choice set formation model component of Equation (1).

3.4 Simple and Variable Decision Strategies. Finally, the trip records for the sample of 40 can be used to investigate the hypothesis that decision strategies are simple rather than complex and that they vary between different individuals and hence population groups in different situations. If decision strategies are simple, and variable in these ways, one hypothesis which is tenable under the present reconceptualization of movement is that the measures of observed aspects of chosen stops which compose the individual's complex travel and which reflect the variable choice sets, should also reflect the use of simple decision rules which differ between individuals and groups. Thus, we may ask, if persons of different types are evaluating stops, which are defined by values on different aspects, how could individuals have evaluated the stop aspects 'simply' and 'differently' to select those they chose? First, what criteria could have been used to judge 'simply' the different aspects of stops? Two or maybe three dimensions which could have been used 'simply' to assess the costs and benefits of all aspects of stops for travel are the familiar subjective travel time, travel cost, and, perhaps, service. The salience of these dimensions could also plausibly vary significantly between different urban population groups, reflecting not only simple but variable decision rules, and could be manifested in the kinds of stop selections made.

If this is true then:

(1) The $|r|$ values describing the association between pairs of

aspects of stops for the individual measure similarities between stimuli to the individual for judgment purposes:

(2) If so regarded, the 40 intercorrelation matrices for each of the 40 Uppsala individuals, of the values for each possible pair of aspects describing the chosen stops, represent similarities matrices for input into a psychometric scaling algorithm such as INSCAL;

(3) Recovered configurations from the algorithm should show a high degree of resolution in two or three dimensions, with a dispersion of the stimuli (aspects of stops) along each dimension in individual and group spaces;

(4) There should be a high level of variation in the subject weights for each dimension, perhaps exhibiting statistically significant differences for individuals grouped by role-complex-related sociodemographic group.

(See Burnett and Hanson, 1979 for fuller details of this use of INSCAL).

Thus, the subjection to INSCAL analysis of certain types of individual intercorrelation matrices, formed from data on observed behaviors, should produce results to test the assumption of the simplicity of the decision rules of individuals, and their variation between different population groups in different spatially constrained situations.[4]

Results of such an INSCAL analysis for the 40 individuals in the Uppsala sample, are shown in Figure 4. The notion that there are two or three underlying dimensions which are used for the 'simple' judgment of different stops appears to be upheld. However, MANOVA analysis of the weights on each dimension, to test for the effects of available role-related sociodemographics (gender, life cycle, gender/life cycle groups) on configurations or decision rules, produced no significant main or interaction effects for either two or three dimensions. These latter results indicate that role complex descriptors associated with movement have probably not been appropriately defined, and again support the need for further large-sample data analysis with more information about both sociodemographics and travel (Table 4).

In sum, some evidence has been presented to indicate that, by conceiving the individual's travel as complex, choice sets as constrained and systematically varying between types of individual or population group, and decision rules as simple and also varying between individuals and groups in different situations, statistical hypotheses can be generated which are consistent with observations of travel behavior. Thus, hypotheses and data analyses which are derived from radically different kinds of assumptions about movement might provide just as good a fit to normal kinds of observations of travel behavior as current formal choice models like the MNL, which are based on different and less realistic hypotheses, and, in particular, omit consideration of the possible systematic effects of spatial constraints on choice sets and hence on the complexity of situations in which decisions are taken. In the long run, both for scientific and policy purposes, there appears to be a case for developing the new kinds of spatial constraints-oriented model for individual and group behavior to which the present reconceptualization can lead (Equation 1), and for exploratory data analysis first with large samples of individuals to investigate the relations of the travel behaviors and opportunities for different kinds of population groups (Figure 4).

4. CONCLUSION

This paper has produced arguments and some evidence to support the development of an alternative approach to movement through a reconsideration of the effects of space on travel, on choice sets and on decision rules. It advocates the use of a synthesis of insights from past work in three areas of urban geography to revise the underlying axioms of choice models currently drawn on as a basis for explaining, predicting and modifying the behaviors of human population groups in cities; the axioms are reflected in travel decision-making models as one applied example. The explicit recognition that movement occurs as a process over space and through time, that is, as path linking stops with time and space coordinates, originating in Hagerstrand's "time-space" geography (1970 on; reviewed Pred, 1977), emphasizes the fact that most human behaviors of interest in cities have space and time dimensions which are as important as any other (such as the modal dimension in the travel case); moreover, the exploratory work conducted here shows that admitting the complexity of the behavior of human population groups in cities through recognition of this fact will not necessarily lead at once to intractable data analytic or model specification problems. Secondly, well-known macro-scale work on the distance properties of land use distributions (spatial structures) in cities dating from the sixties, together with 'institutional analysis' explanations of them found in the seminal work of Harvey (1972, 1974), clearly underlies the discussion of the need to develop spatially-constrained choice set models for different urban population groups. This is perhaps the most fundamental and necessary precursor for the revision of policy-related theories for the study of human population groups in cities. Finally, an admission that much human behavior is complex because it occurs in space and time dimensions and in differently spatially-constrained situations leads to a recognition that models of the choice process may themselves need revision to handle the variable decision strategies and rules that different groups might adopt under different circumstances. This will permit some modifications (admittedly minor) of the description of the choice process per se in human spatial behavior as it has been typically modeled in behavioral geography.

The elaboration of Equation (1) to accommodate all these changes in the axiomatic base of the current theories and models of the behavior of different urban population groups will no doubt be difficult. However, sufficient evidence appears to have been presented here to demonstrate that such revisions are necessary, timely and not beyond the bounds of possibility. It seems appropriate that geographers now attempt to move beyond asking what insights other policy-related disciplines have to say about their 'spatial' problems, which can manifest itself in a focus of energy on a fruitless search for identity, a perceived lack of relevance, and also an apparent lack of intellectual content. We may need to be asking what our now quite profound scientific insights into human behavior in cities as a spatial process; into the social and economic geography of cities; into urban space as a mirror of institutional organization; and into human decision-making in real world environments, <u>all</u> have to say about urgent revisions of the microeconomic/psychology choice theories currently drawn on by many local scientists for models, empirical research and related policies for human beings in cities. Models of movement, the analysis of travel data and related urban transportation policies have served but as an illustrative focus for the discussion of this type of advance.

FOOTNOTES

1. This paper simply accepts the now familiar arguments concerning the unavoidable reflection of personal political philosophies and 'values' in any study of human behavior (see, for example, Fay, 1976; Olsson, 1976; King, 1976). Accordingly, a wide interpretation should be given to the word 'policy' here, to cover any kind of implied or stated political activity, from 'revolutionary', through liberal incrementalism to 'counter revolutionary'. It follows that there is an overt linking of theory, data analysis and related 'policies' throughout the paper, and that the development of 'appropriate' kinds of policy is seen as tied to the development of 'appropriate' kinds of theory. The ramifications of resolving the meaning of 'appropriate' is left to the philosophers among us.

2. However, a review of current literature on recurrent travel appears to show that it is accepted that a day is the appropriate time unit with which to deal, probably because this represents the manageable increase in the complexity of the dependent variable (i.e., travel behavior) for modeling and data analysis (see Lenntorp, 1976; Thrift, 1976; Dix, 1977, 1978; Ellegard, Hagerstrand and Lenntorp, 1977; Heggie, 1978 (a), (b); Heggie and Jones, 1978).

3. The choice of r here as a pattern measure was made after an extensive literature search of alternative possibilities for both a measure of patterns of association between mixed variables (cardinal, ordinal, ratio) to examine choice set variation, and, as shall be seen later, a measure of judged similarities between stop aspects (stimuli) to investigate the decision rules which should be manifest in the same data. r would, of course, be entirely inappropriate if the data on modes to stops, land uses etc. were for 'pure categorical variables'. In fact, however, the compilation of lists of categories for such variables, and their sequential numbering, reflect the ordering of the categories by 'importance' so that numbers for categories have scalar properties similar to at least ordinal variables. There was also no apparent alternative measure of both patterns of association between 'mixed variables' and judged similarities of stop aspects.

4. The use of INSCAL here does <u>not</u> imply that the normal utility-maximizing preference model is assumed. The INSCAL model is used here solely as a judgment model, and the data analysis is sufficient to show <u>only</u> that simple criteria are being used for judgment, and that how they are being used varies between individuals. How the 'distances' between stimuli, judged on basic dimensions, then relate to preference and choice is left open: all the sampled individuals <u>could</u> be utility-maximizers, but the evidence is sufficient to show that they clearly also might not be. That is, there is sufficient evidence to suggest the exploration of alternative possibilities as proposed in this paper. (see also Carroll, 1972, where the INSCAL model is presented as a judgment model which can be related to a utility-maximizing preference and choice model, but does not have to be).

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Table 1

The Distribution of Sample Households and Individuals in Uppsala, Sweden, 1971 by Life-Cycle Group

Group No.	Characteristics	Number of Sampled Households	Number of Sampled Individuals
1	Head of household 67 or older	19	25
2	Head of household between 50 and 66 no children living at home	21	32
3	Head of household between 18 and 49 single persons only	23	26
4	Head of household between 18 and 49 two person household with no children	5	11
5	Head of household between 18 and 49; at least one adult and at least one child over seven years; no preschool children	11	24
6	Head of household between 18 and 49 at least one adult and at least one child less than five years of age	13	26
TOTALS		92	144

TABLE TITLES

Table 1	The Distribution of Sample Households and Individuals in Uppsala, Sweden, 1971 by Life-Cycle Group.
Table 2	Sample Individual Travel Diary, Uppsala, Sweden.
Table 3	Frequency Distributions of r Values for 40 Individuals in Uppsala Sample.
Table 4	Large-Scale Experimental Design: Effects of Spatial Constraints and Role-Related Sociodemographics on Travel for Uppsala, West Berlin, Baltimore Data Sets.

Table 2

Page from Individual's Travel Diary, Uppsala, Sweden

CONFIDENTIAL

Household Travel Survey
Uppsala, Sweden - 1971

Name ______________________________

Date __________ 1971

When did you leave home? ________ hours

Is this a continuation from another sheet? Yes No

Stop number ______ Did you plan to make this stop when you left home? Yes No

Means of Travel 1 foot 2 bicycle 3 bus 4 car (driver) 5 car (passenger) 6 taxi 7 moped 8 other __________

Were you accompanied by someone from your household? Yes No If yes, by how many? __________

Where did you make this stop? (please give address) New? ______

When did you arrive at this place? ________ hours When did you leave this place? ________ hours

What did you do at this place? Expenditure
1) ______________________________ __________
2) ______________________________ __________
3) ______________________________ __________
4) ______________________________ __________

Stop number ______ Did you plan to make this stop when you left home? Yes No

Means of Travel 1 foot 2 bicycle 3 bus 4 car (driver) 5 car (passenger) 6 taxi 7 moped 8 other __________

Were you accompanied by someone from your household? Yes No If yes, by how many? __________

Where did you make this stop? (please give address) New? ______

When did you arrive at this place? ________ hours When did you leave this place? ________ hours

What did you do at this place? Expenditure
1) ______________________________ __________
2) ______________________________ __________
3) ______________________________ __________
4) ______________________________ __________

Is this trip continued on the next sheet? Yes No
If, No, fill in the section below.

When did you return to home? ________ hours

Means of Travel 1 car 2 bicycle 3 bus 4 car (driver) 5 car (passenger) 6 taxi 7 moped 8 other __________

Were you accompanied by

Table 3 (cont.)

4. Mode/EW Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	11	.32	-.07	-7.83
-.50 to -.01	7	.21		
.00 to .49	9	.26		
.49 to 1.00	7	.21		

5. Mode/NS Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	8	.24	-.06	-8.88
-.50 to -.01	11	.32		
.00 to .49	9	.26		
.49 to 1.00	6	.18		

6. Mode/Distance

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	0	0	.60	.38
-.50 to -.01	0	0		
.00 to .49	10	.29		
.49 to 1.00	24	.71		

7. Time/Land Use

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	2	.05	-.03	-11.22
-.50 to -.01	16	.47		
.00 to .49	15	.44		
.49 to 1.00	1	.02		

8. Time/Activity

r Value	Number	Relative Frequency (F)	F^b	V_F^b
-1.00 to -.51	15	.44	-.38	-1.08
-.50 to -.01	15	.44		
.00 to .49	2	.06		
.49 to 1.00	2	.06		

Table 3

Frequency Distributions of r Values
for 40 Individuals in Uppsala Subsample

A. All Aspect Pairs, All Individuals

r Value	Number	Relative Frequency (F)	$\bar{F}^a$	V_F^a
0 to .24	260			
.25 to .49	192	.27	.27	.45
.50 to .74	179	.25	.25	.51
.25 to .99	83	.12	.12	.83

B. Separate Aspect Pairs, All Individuals

1. Mode/Time of Arrival

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.01	6	.18	.06	7.83
-.50 to -.01	5	.15		
.00 to .49	19	.55		
.49 to 1.00	4	.12		

2. Mode/Land Use

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	0	0	.43	.86
-.50 to -.01	5	.15		
.00 to .49	12	.35		
.49 to 1.00	17	.50		

3. Mode/Activity

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	7	.21	-.12	-3.52
-.50 to -.01	12	.35		
.00 to .49	14	.41		
.49 to 1.00	1	.02		

Table 3 (cont.)

9. Time/EW Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	12	.35	-.19	-2.71
-.50 to -.01	10	.29		
.00 to .49	8	.24		
.49 to 1.00	4	.18		

10. Time/NS Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	2	.06	-.04	-8.87
-.50 to -.01	13	.38		
.00 to .49	9	.26		
.49 to 1.00	10	.29		

11. Time/Distance

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	2	.05	-.04	-8.87
-.50 to -.01	14	.41		
.00 to .49	18	.52		
.49 to 1.00	0	.00		

12. Land Use/Activity

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	2	.05	-.01	-20.90
-.50 to -.01	14	.41		
.00 to .49	18	.53		
.49 to 1.00	0	.00		

13. Land Use/EW Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	8	.24	-.15	-2.87
-50 to -.01	12	.35		
.00 to .49	13	.38		
.50 to 1.00	1	.02		

Table 3 (cont.)

14. Land Use/NS Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	.15	.15	-.04	-10.11
-.50 to -.01	.41	.41		
.00 to .49	.32	.32		
.50 to 1.00	.11	.11		

15. Land Use/Distance

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	1	.03	.32	.94
-.50 to -.01	1	.03		
.00 to .49	24	.71		
.50 to 1.00	8	.24		

16. Activity/EW Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	8	.24	.04	12.82
-.50 to -.01	7	.21		
.00 to .49	10	.29		
.50 to 1.00	9	.26		

17. Activity/NS Location Coordinate

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	10	.29	-.04	-7.44
-.50 to -.01	7	.21		
.00 to .49	9	.26		
.50 to 1.00	8	.23		

18. Activity/Destination

r Value	Number	Relative Frequency (F)	$\bar{F}^b$	V_F^b
-1.00 to -.51	2	.05	.25	2.41
-.51 to -.01	17	.50		
.00 to .49	14	.41		
.50 to 1.00	1	.03		

Table 3 (cont.)

---

19. NS Location Coordinate/Distance

r Value	Number	Relative Frequency (R)	$\bar{F}^b$	V_F^b
-1.00 to -.51	7	.21	-.13	-3.49
-.51 to -.01	16	.47		
.00 to .49	7	.21		
.50 to 1.00	4	.12		

20. EW Location Coordinate/Distance

r Value	Number	Relative Frequency (R)	$\bar{F}^b$	V_F^b
-1.00 to -.51	7	.21	-.01	-36.71
-.51 to -.01	12	.35		
.00 to .49	7	.21		
.50 to 1.00	8	.24		

---

[a] $\bar{\bar{F}}$ is the mean relative frequency of $|r|$ values in each class, and V_F the coefficient of variation of the relative frequency of r values in each class, over all individuals.

[b] $\bar{F}$ is the mean of the r value for the aspect pair, and V_F its coefficient of variation, for the individuals.

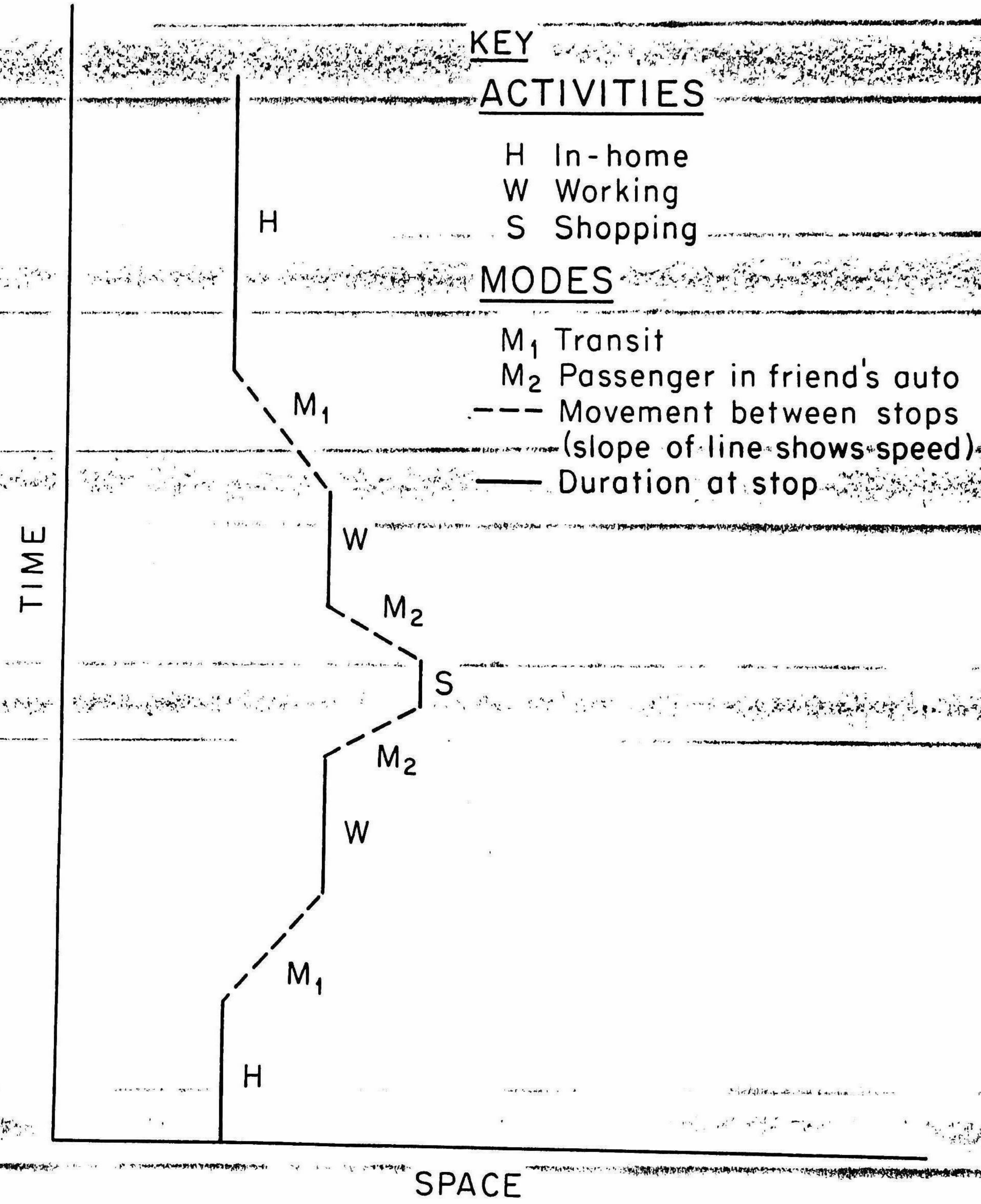
FIGURE TITLES

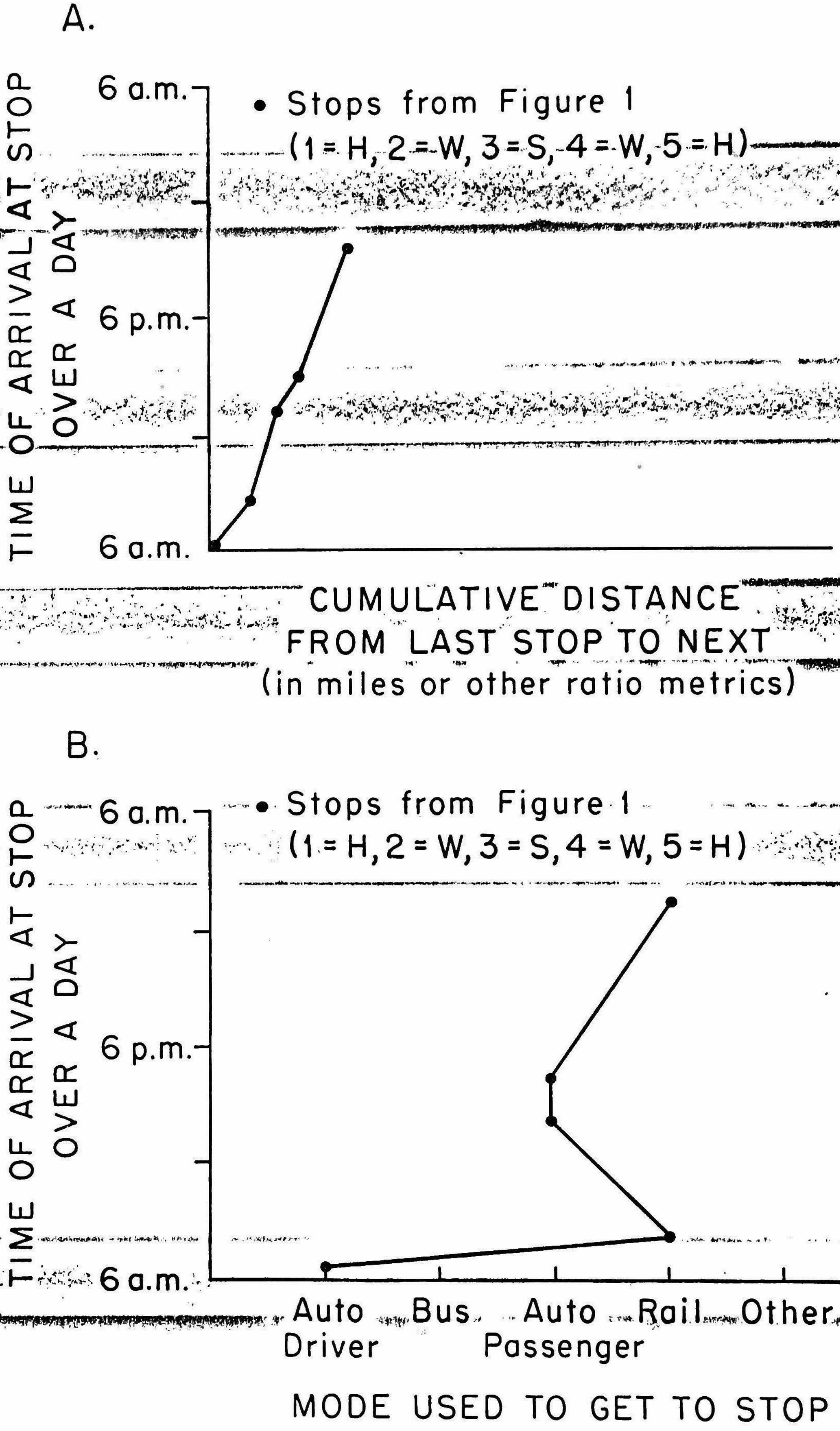
Figure 1 The Individual's Path in Time and Space Dimensions (after Thrift, 1976, p. 18; Dix, 1977, p. 20).

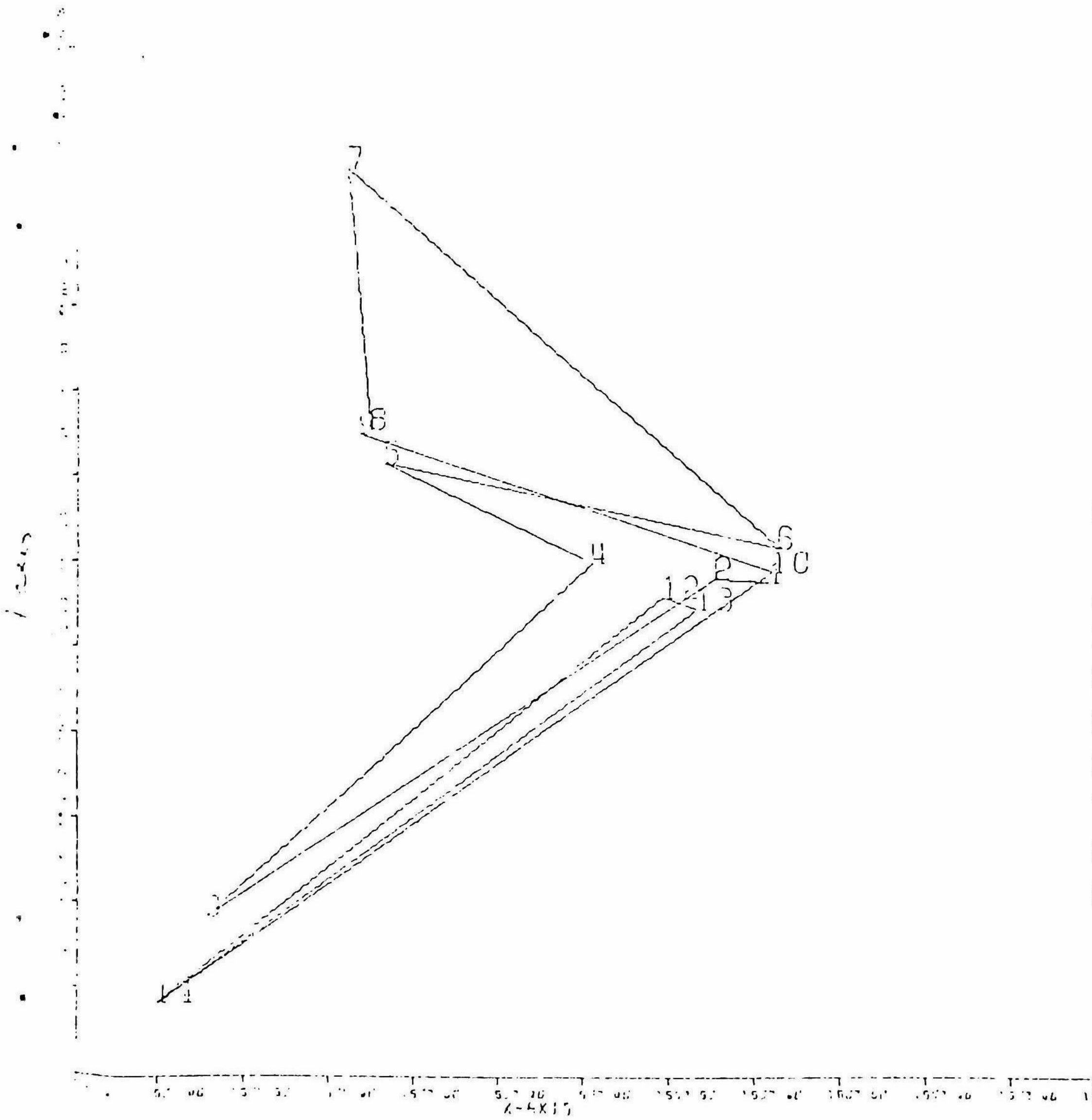
Figure 2 Sample Diagrams for Representing the Individual's Path in n Dimensions Through a Series of 2-Dimensional Cross-Sections.

Figure 3 Plots of Representations of n-Dimensional Paths for Selected Individuals in the Uppsala Subsample (the circled number represents the life-cycle group; M and F are male and female respectively).

Figure 4 Two-Dimensional INSCAL Solution, Group Stimuli Space and Weights; "explained variance" is 61% for two dimensions.

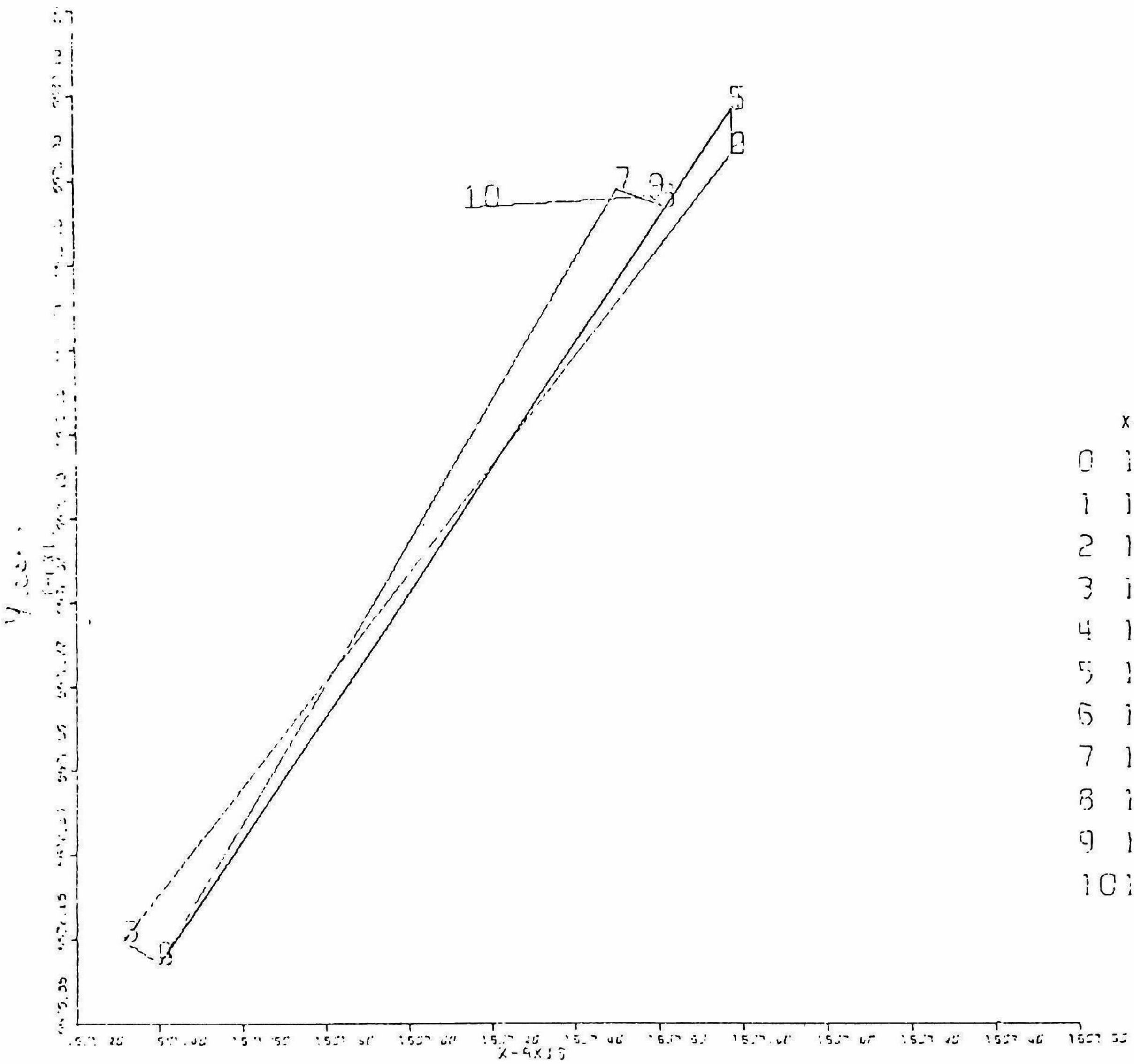

KEY
ACTIVITIES
H In-home
W Working
S Shopping
MODES
M_1 Transit
M_2 Passenger in friend's auto
--- Movement between stops (slope of line shows speed)
—— Duration at stop
TIME
SPACE
H
M_1
W
M_2
S
M_2
W
M_1
H


A.
TIME OF ARRIVAL AT STOP OVER A DAY
6 a.m.
6 p.m.
6 a.m.
• Stops from Figure 1
(1 = H, 2 = W, 3 = S, 4 = W, 5 = H)
CUMULATIVE DISTANCE FROM LAST STOP TO NEXT
(in miles or other ratio metrics)
B.
TIME OF ARRIVAL AT STOP OVER A DAY
6 a.m.
6 p.m.
6 a.m.
• Stops from Figure 1
(1 = H, 2 = W, 3 = S, 4 = W, 5 = H)
Auto Driver
Bus
Auto Passenger
Rail
Other
MODE USED TO GET TO STOP



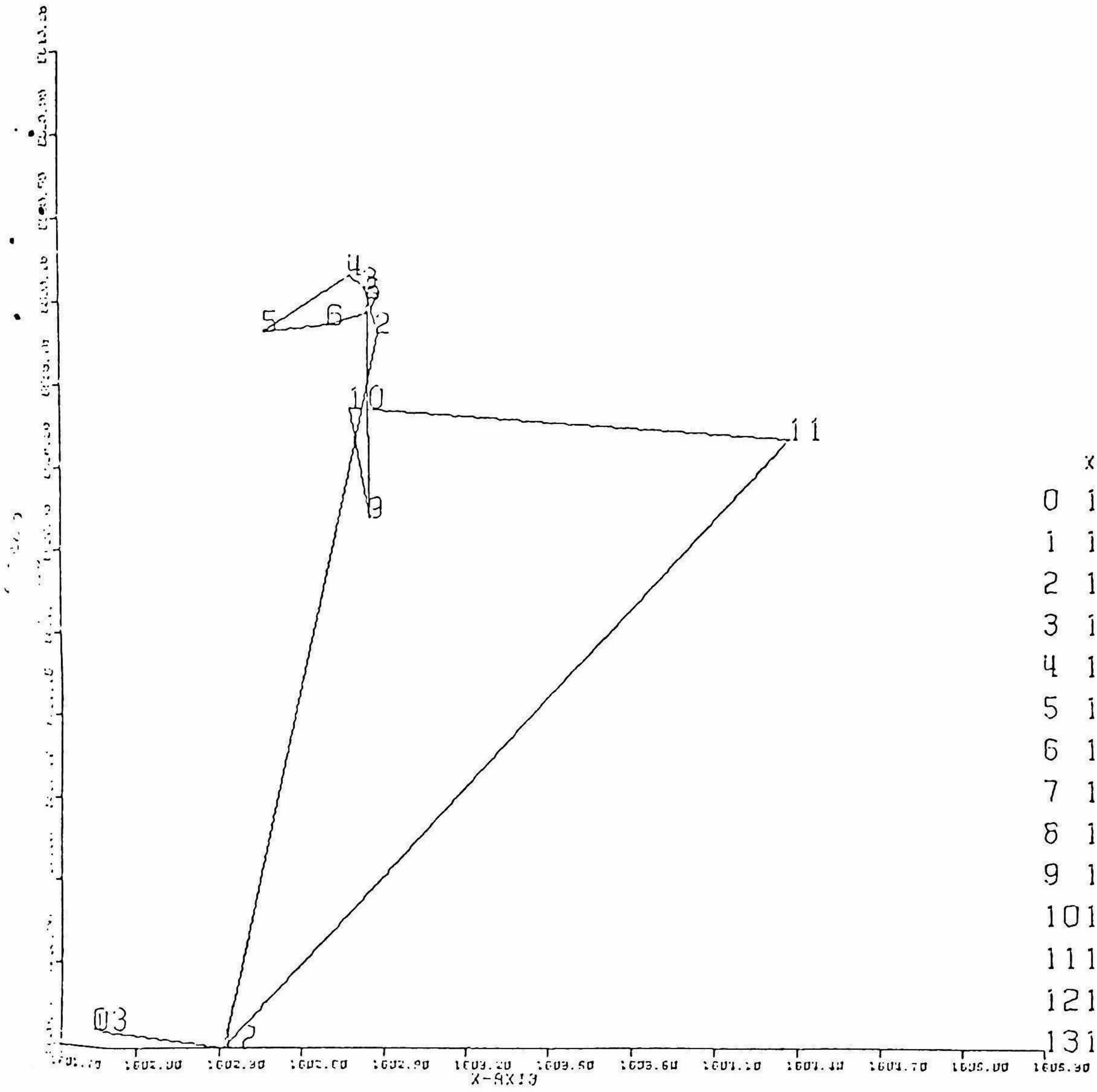
	X-COOR	Y-COOR
0	1602 71	6639.
1	1602.83	6639
2	1602.71	6639
3	1601.51	6637.
4	1602 42	6639
5	1601.93	6639
6	1602 85	6639.
7	1601.84	6641.
8	1601.89	6639.
9	1601.87	6639.
10	1602 84	6639
11	1601 40	6637.
12	1602 58	6639.
13	1602 56	6638.
14	1601.40	6637.

40052 31 F



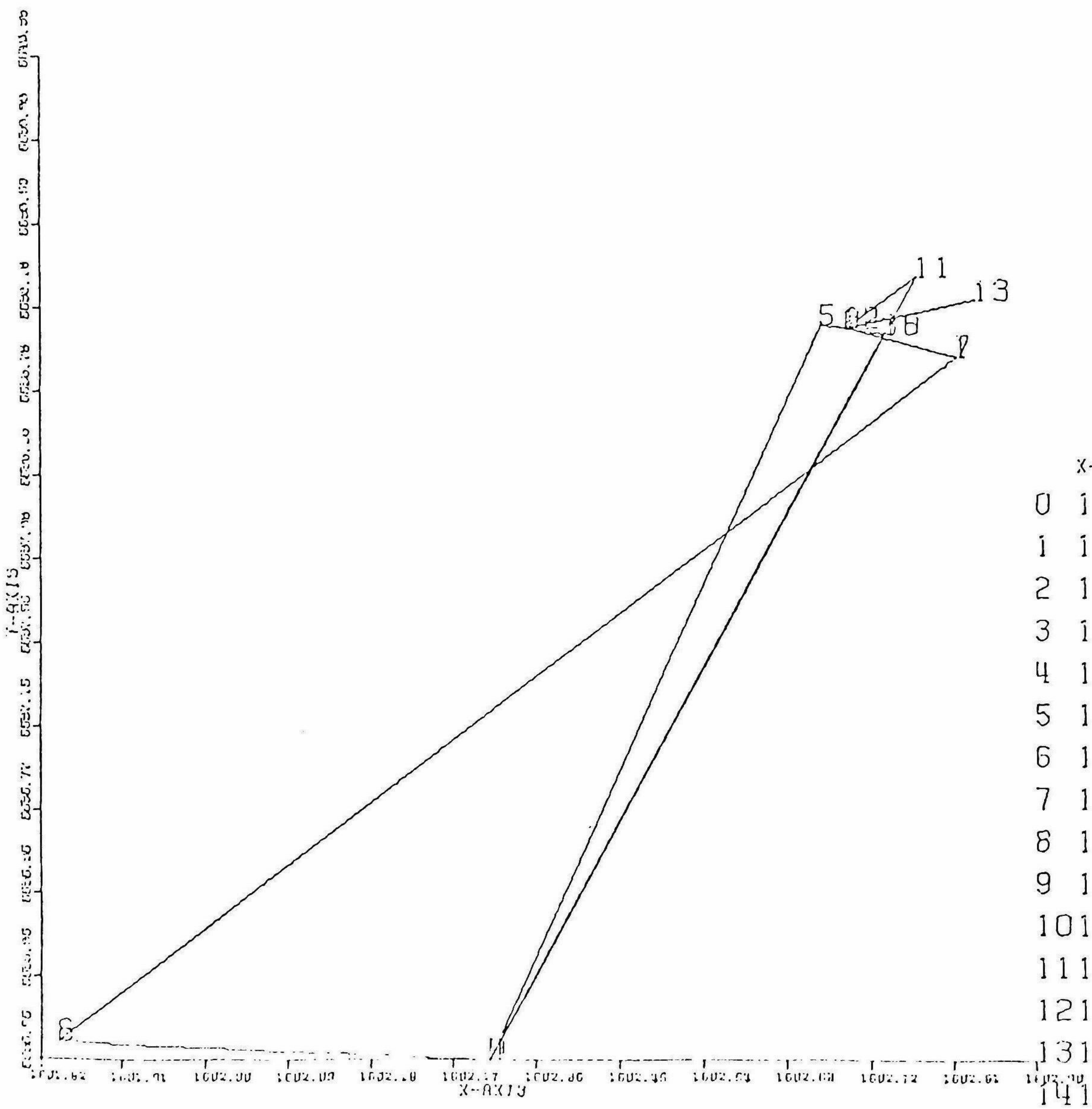
	X-COOR	Y-COOR
0	1602 76	6638
1	1602.78	6639
2	1602 78	6639
3	1601.31	6637
4	1601.40	6637
5	1602.78	6638
6	1601.40	6637
7	1602.50	6636.
8	1602 61	6636
9	1602.58	6636
10	1602.14	6636

4②051 18 M



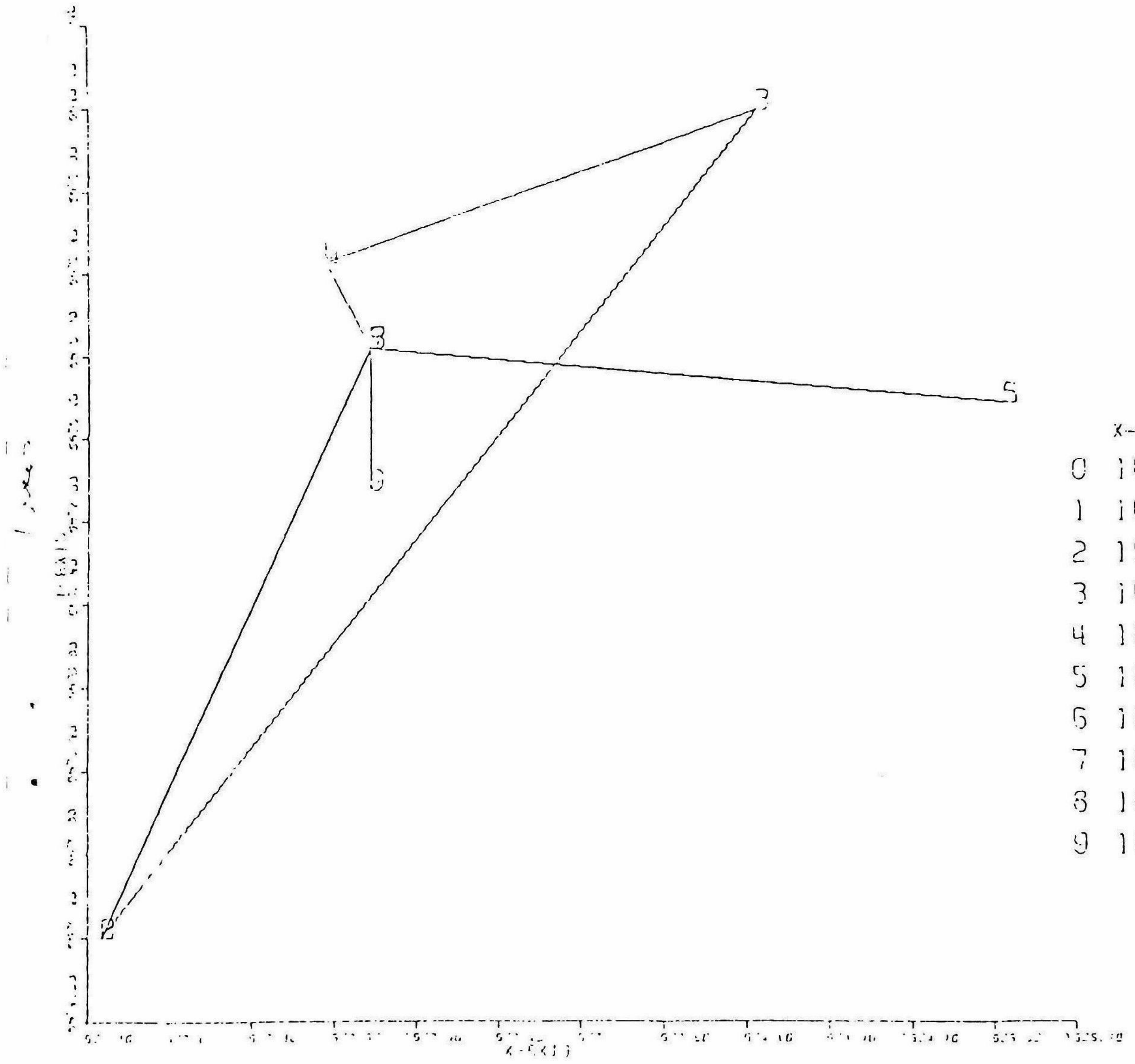
	X-COOR	Y-COOR
0	1601.84	6635.
1	1602.31	6635.
2	1602.87	6639.
3	1602.82	6639.
4	1602.77	6639.
5	1602.46	6639.
6	1602.69	6639.
7	1602.82	6639.
8	1602.83	6639.
9	1602.84	6638.
10	1602.77	6638.
11	1604.37	6638.
12	1602.31	6635.
13	1601.84	6635.

1⑤142 24 F



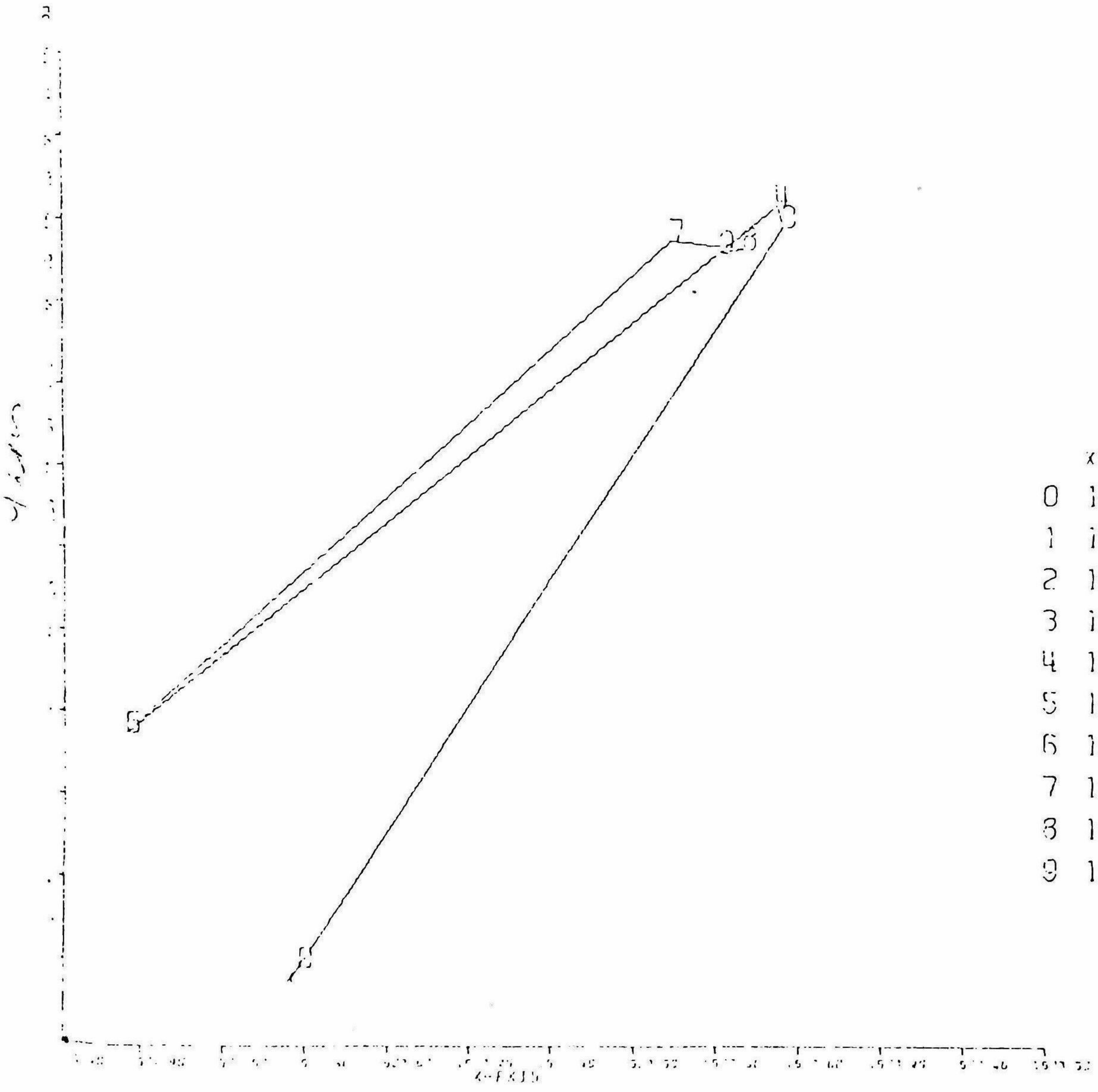
	X-COOR	Y-COOR
0	1602.69	6639.
1	1602.81	6638.
2	1602.69	6639
3	1602.73	6639
4	1602.31	6635
5	1602.66	6639.
6	1602.69	6639
7	1602.81	6638.
8	1601.84	6635
9	1602.31	6635.
10	1602.73	6639.
11	1602.77	6639.
12	1602.69	6639.
13	1602.83	6637.
14	1602.69	6639
15	1602.73	6639

15141 9 M



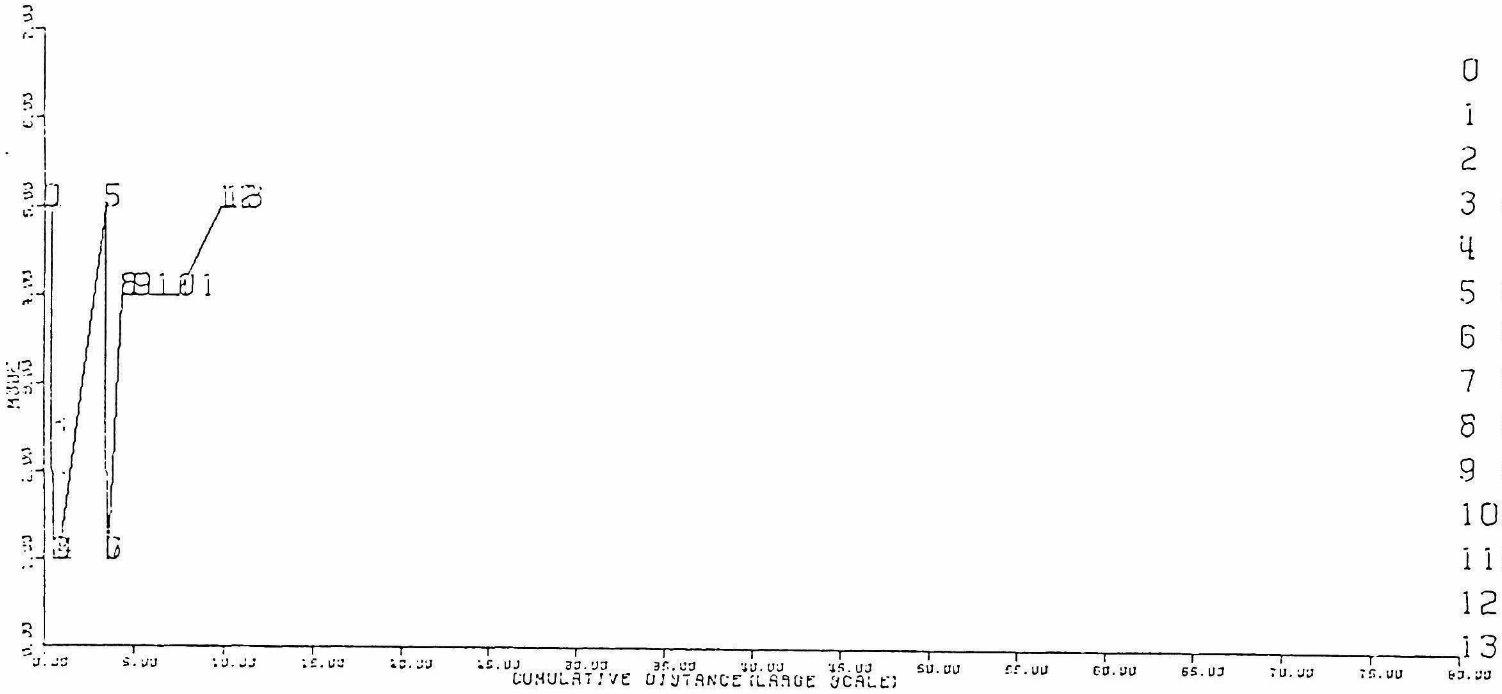
	X-COOR	Y-COOR
0	1601 75	663[illegible].
1	1602.73	6639
2	1501.75	6635.
3	1604.15	6640.
4	1602 57	6639
5	1602.73	6639
6	1605.04	6639
7	1602.73	6639
8	1602.73	6639
9	1602 73	6635.

40[illegible]71   37 M



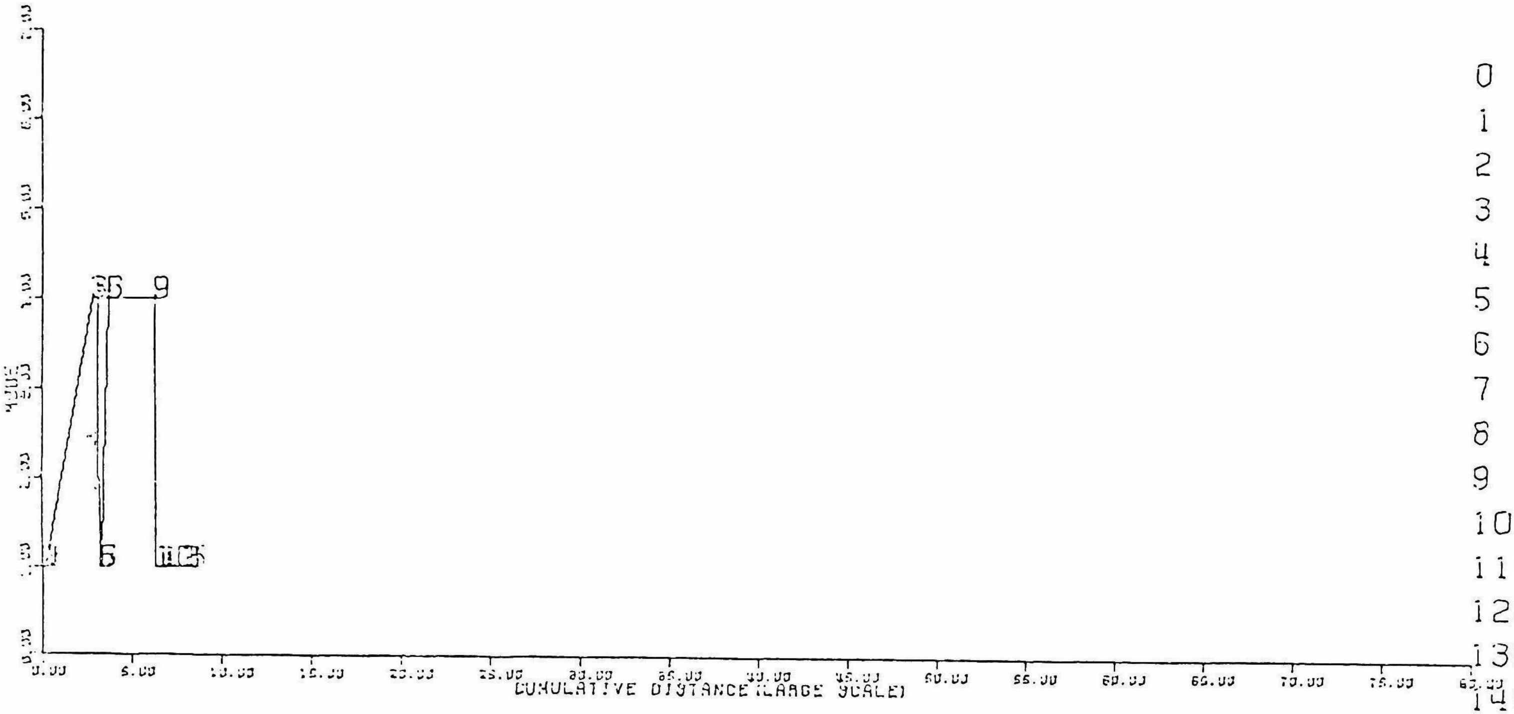
	X-COOR	Y-COOR
0	1601.79	6635.
1	1601.75	6635.
2	1601.79	6635
3	1602 36	6639 1
4	1602.95	6639 2
5	1601.37	6636.5
6	1601.37	6636.5
7	1602 69	6639.(
8	1602.87	6639.(
9	1602.81	6639.(

49072 11 F



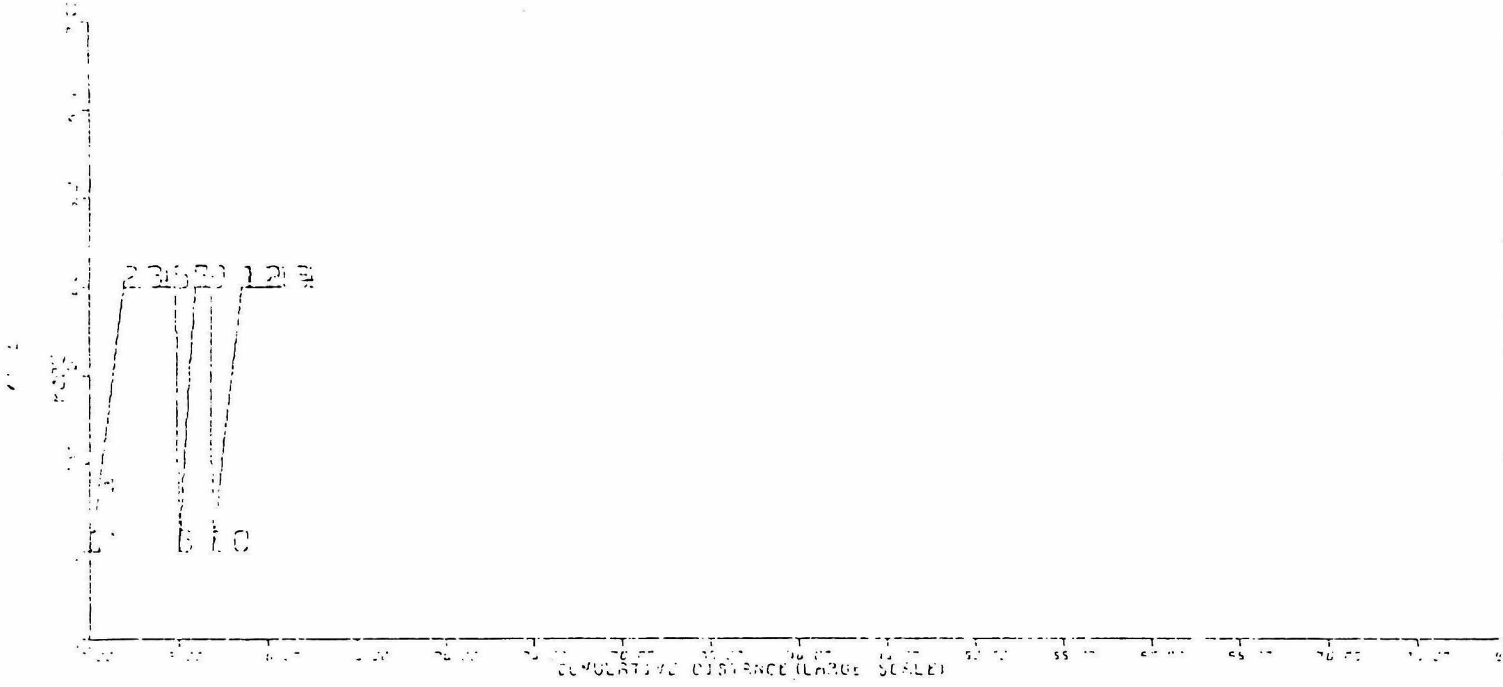
	DISTANCE	MODE
0	0.00	5.00
1	0.48	5.00
2	0.70	1.00
3	0.78	1.00
4	1.04	1.00
5	4.49	5.00
6	4.63	1.00
7	4.70	1.00
8	5.76	4.00
9	6.73	4.00
10	8.34	4.00
11	9.93	4.00
12	13.05	5.00
13	13.52	5.00

1⑤142 24 F



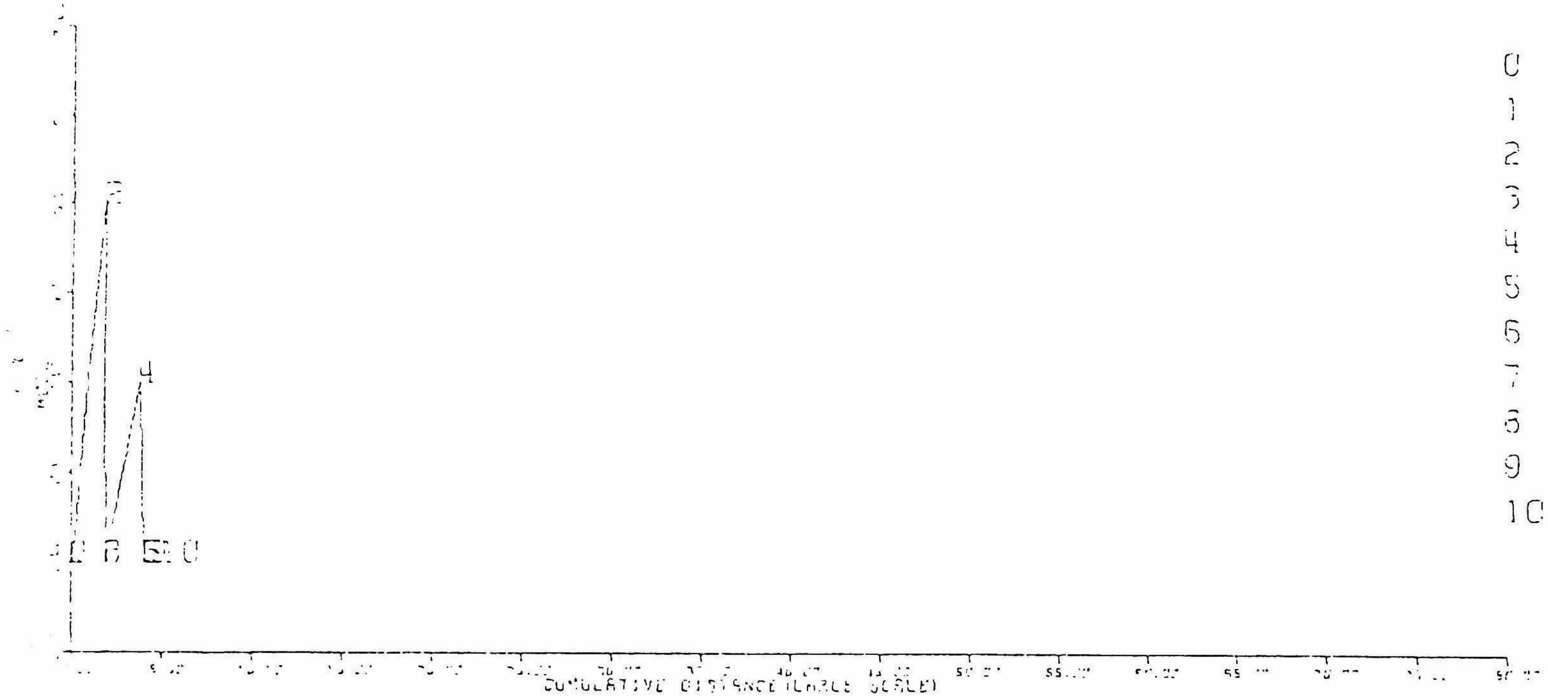
```
    DISTANCE     MODE
0  0.00         1.00
1  0.16         1.00
2  0.23         1.00
3  3.71         4.00
4  4.19         4.00
5  4.22         1.00
6  4.40         1.00
7  4.40         1.00
8  4.88         4.00
9  8.35         4.00
108.41          1.00
118.65          1.00
128.84          1.00
139.03          1.00
149.08          1.00
159.36          1.00
```

1⑤141 9 M



	DISTANCE	MODE
0	0.00	1.00
1	0.13	1.00
2	2.50	4.00
3	4.39	4.00
4	5.07	4.00
5	5.45	4.00
6	6.61	1.00
7	7.03	4.00
8	7.67	4.00
9	9.03	4.00
10	9.15	1.00
11	11.39	4.00
12	11.46	4.00
13	13.71	4.00
14	14.12	4.00

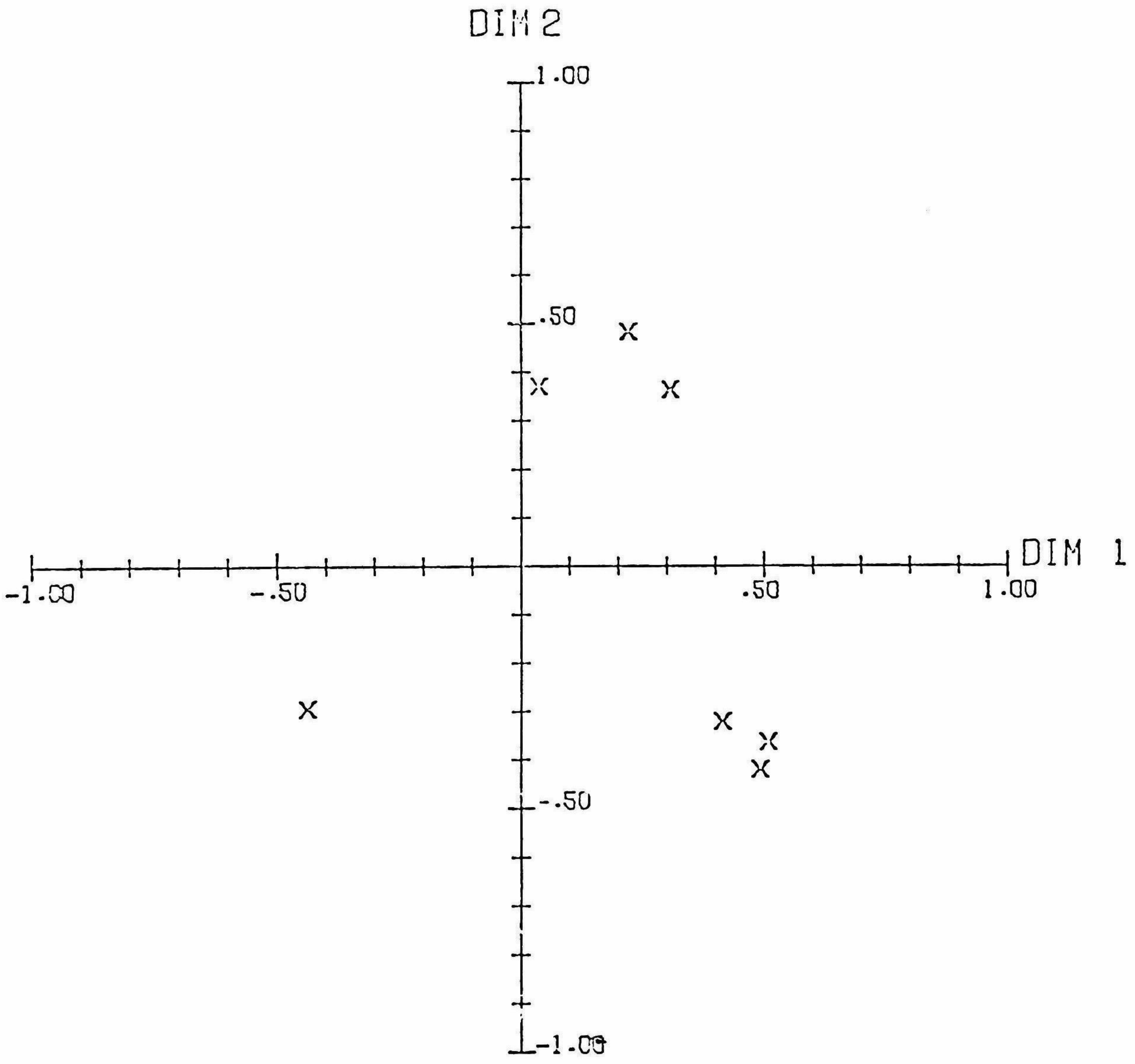
4⑦1:2 31 F

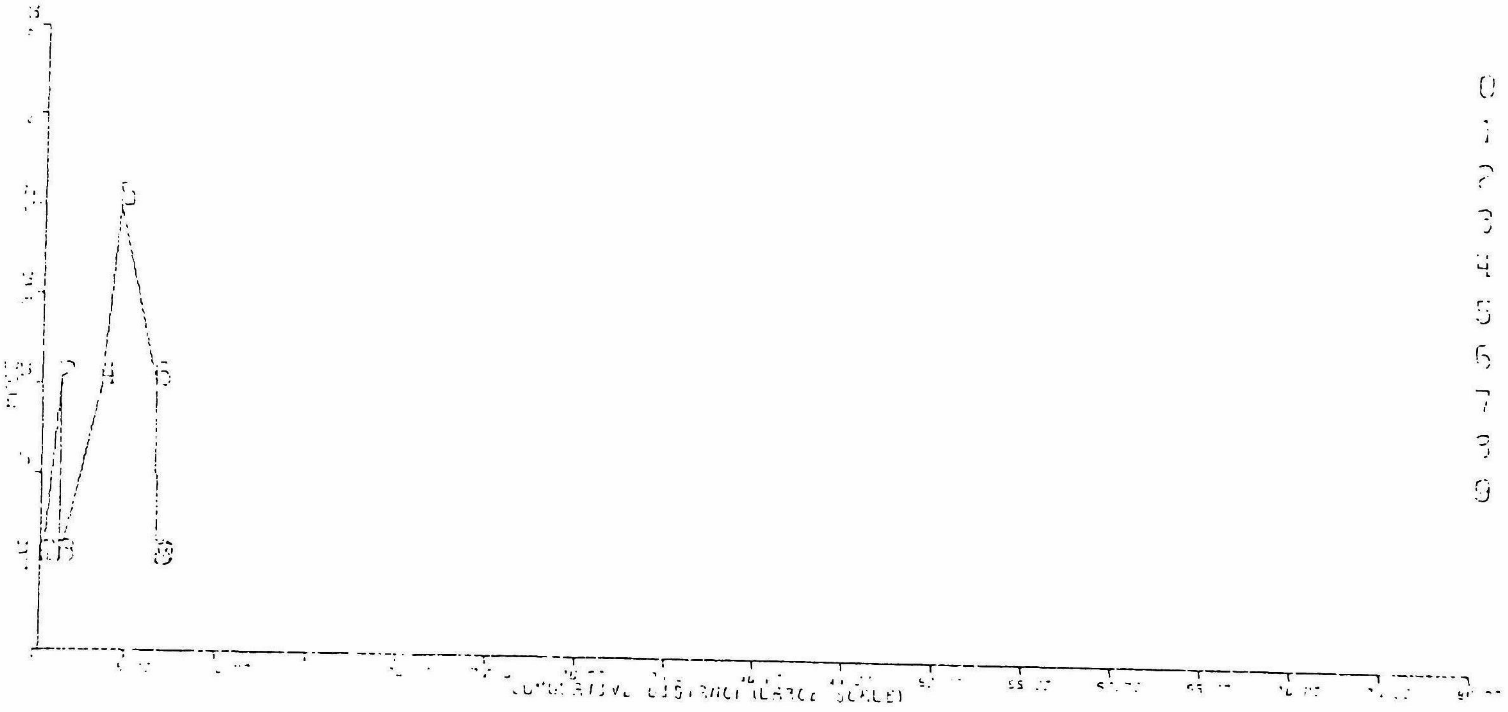


	DISTANCE	[illegible]
0	0.00	1.00
1	0.11	1.00
2	2.46	5.00
3	2.57	1.00
4	5.01	34.00
5	5.34	1.00
6	5.44	1.00
7	5.55	1.00
8	5.59	1.00
9	6.03	1.00
10	6.71	1.00

4②051 18 M

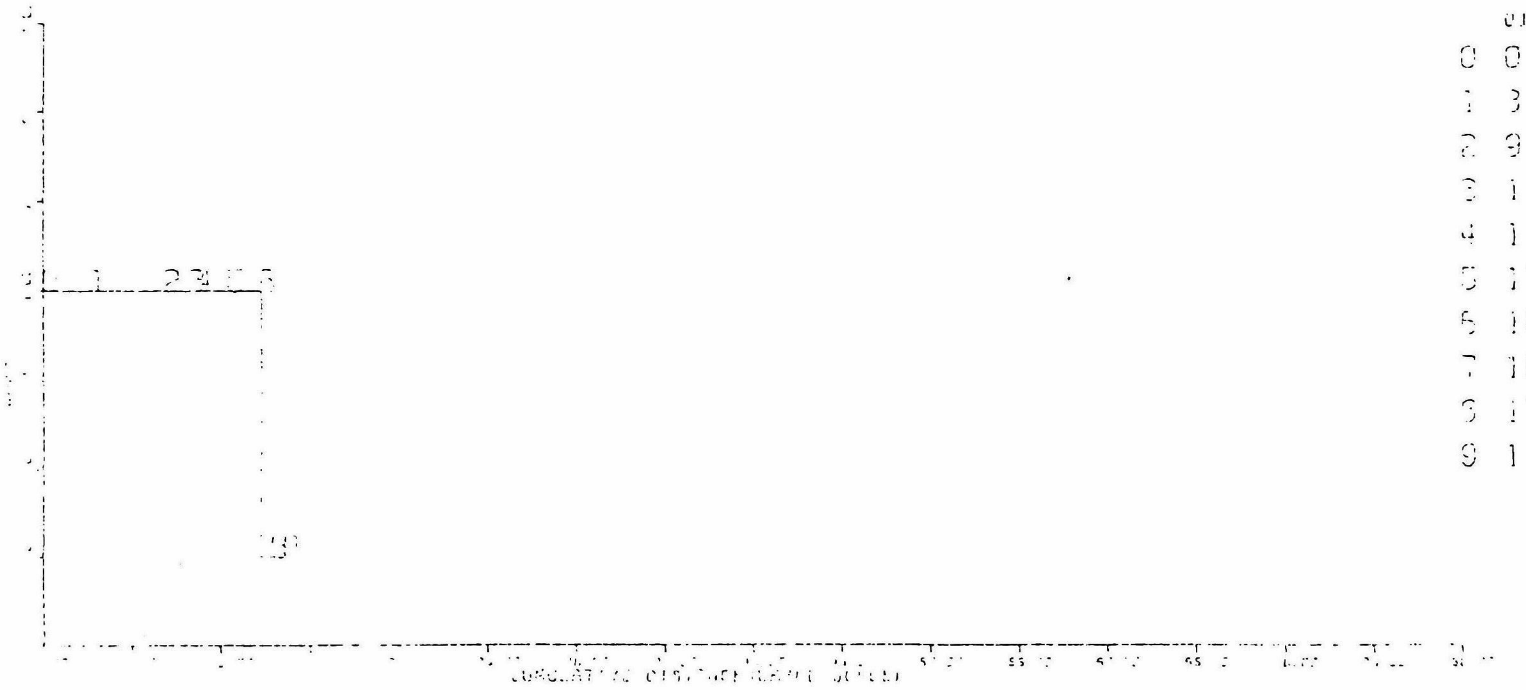
2-D COMMON SPASE :TOTAL SAMPLE





	DISTANCE	[illegible]
0	0.00	[illegible]
1	0.08	[illegible]
2	1.29	3
3	1.39	1
4	4.35	3
5	5.65	5.
6	9.37	3
7	9.55	1
8	9.61	1
9	9.70	1

4⑥072 11 F



	DISTANCE	[illegible]
0	0.00	4.00
1	3.56	4.00
2	9.22	4.00
3	11.04	4.00
4	11.59	4.00
5	13.02	4.00
6	15.26	4.00
7	16.26	1.00
8	17.12	1.00
9	17.93	1.00

[illegible] 1 37 M

Individual	Dimension 1[a]	Dimension 2[b]	Individual	Dimension 1[a]	Dimension 2[b]
1	126.91	142.35	21	102.55	131.60
2	75.09	76.20	22	56.03	65.87
3	113.99	107.46	23	58.74	101.31
4	112.12	131.28	24	66.04	110.62
5	73.52	99.78	25	77.06	105.54
6	29.82	86.15	26	48.05	62.73
7	49.07	51.40	27	112.51	149.58
8	99.98	135.09	28	20.21	78.80
9	62.61	85.81	29	38.06	31.88
10	70.73	125.66	30	122.07	101.07
11	20.61	47.17	31	38.14	49.10
12	36.40	47.95	32	115.23	108.05
13	48.42	69.13	33	59.12	56.31
14	95.78	124.13	34	75.15	72.14
15	67.64	69.07	35	112.42	101.32
16	49.44	59.22	36	116.85	86.59
17	67.63	115.13	37	79.23	67.21
18	106.92	129.67	38	86.31	88.14
19	87.39	88.68	39	54.53	60.49
20	109.44	108.22	40	61.52	70.25

THE TRANSPORTATION CENTER • NORTHWESTERN UNIVERSITY
LEVERONE HALL • 2001 SHERIDAN ROAD • EVANSTON, ILLINOIS 60201

March 14, 1979

Professor R. G. Golledge
Department of Geography
University of California at
Santa Barbara, California 93106

Dear Reg,

Please find enclosed the promised paper for the first edition of Urban Geography. The typing of it has somewhat delayed the completion of my paper for the Cox and Golledge book; but I will get it to you as soon as possible.

Sincere regards,

Pat

Pat Burnett
Associate Professor

P.S. Drawings of Figures, rather than copies of computer output, can be supplied when necessary.

cc: Jim Wheeler