ABSTRACT

DAILY ACTIVITY SEQUENCES AND TIME-SPACE CONSTRAINTS

By

John Dickson Stephens

The principal aim of the research is to develop a methodology for investigating how individuals' decisions about their time-space behavior interrelate. What determines where, when, for how long, and in what sequence activities are performed? In attempting to understand more clearly the structuring of everyday behavior, the research adopts a methodology based on the time-space mechanics of constraints.

The major research hypothesis is that the critical determinant of the structure of a person's day is the extent to which one feels constrained relative to certain activities, times, and locations. The term structure is interpreted to mean not only the types and sequences of activities, but also their location and duration.

In order to test the hypothesis it was necessary to isolate a sample population and to develop a survey instrument for obtaining the needed data. The sample was drawn from the faculty, staff, and student populations of Michigan State University, located in East Lansing, Michigan. In order to study the time-space constraints operating on the formation of activity sequences, attention must be focused on the paths, or behavior, of the individual through time-space. The instrument chosen for collecting this type of information, the time-space budget, incorporates the sequence, linkage, timing, duration, and frequency of activities, as well as the spatial and temporal coordinates of one's

behavior. The time-space budget focuses on two related aspects: people's overt behavior and the perceptions of their social and physical environment. This method of activity accounting is unique in that, as far as their activities for the sampled time span are concerned, individuals are treated as totalities; their entire, unbroken sequences of activities in time-space are made available.

A methodology was formulated which was built around the notion that subjective constraints are the critical determinants of one's behavior in time and space. The vehicle used to examine this hypothesis is that of simulation. Thus, an attempt was made to simulate the unknown variables--the timing, sequencing, and location of activities--in terms of the parameters or known variables, the subjective constraints.

As a first step toward the goal of developing a simulation model, an attempt was made to isolate that behavior which demonstrates recurrent patterns in time-space. Hence, an initial hypothesis regarding the principle of consistency in human behavior was tested using the sample of time-space budgets. The claim was made that the concept of pattern could be applied to the set, or a subset, of time-space budgets and that this pattern is partly defined by the sequence in which activities are performed. Behavior patterns are also partly defined by activity durations. The amount of time a person devotes to an activity follows a pattern over groups of individuals just as much as does the position it occupies in that person's sequence. Such simple patterns of activity are necessary conditions for the development of a simulation model.

In order to test this hypothesis, the time-space budget data for all respondents in the university sample had to be compressed in a systematic manner. Therefore, an algorithm was devised which groups individuals on the basis of the amount of time which they spend on different activities and the order in which they are performed. Based upon the sequential behavior patterns of individuals, the algorithm decomposed the sample population into several groups each of which maximized within-group similarities and between-group differentials. As a result of the preliminary analysis of time-space budget data, it was concluded that patterned variations do exist between subgroups of the university population, where the concept of pattern is construed in terms of sequence and duration of daily activities.

Can activities, their timing and location be associated with the pattern of time-space constraints throughout the day? This is the question that the simulation model addresses. In conjunction with this problem, it was hypothesized that time-space constraints and levels of activity commitment are the critical determinants of activity sequences in time-space.

The first step in the computer simulation is to develop six cumulative probability distributions which are approximations of the activity structure for a given pattern group. A Monte Carlo procedure is then invoked to select activities and their spatial and temporal locations. The distributions are treated as discrete cumulative probability vectors, and uniform random numbers bounded by zero and one are drawn to determine the activities, durations and locations. Thus, the time-space path of each individual's day is built up by assigning random numbers in accordance with the calculated probabilities, and by comparing numbers drawn for every time period with these distributions.

The structure of the model is necessarily tied to the conceptual framework of behavior and time-space constraints. Therefore, the simulation first establishes the major constraints in each person's day, and then, how one relates his behavior to these constraints.

The findings of the modelling experiments demonstrate that the subjective constraints acting on the choice, timing, and location of activities are modestly important in understanding the formation of activity sequences and the paths people follow through time-space. The statistical results of the model's output suggest that they are not as significant as they were hypothesized to be. Hence, it was concluded that for the sample population that subjective constraints alone are not the critical determinants which structure time-space paths at a daily scale.

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CHAPTER 1

INTRODUCTION

The industrialization of man's activities involved a most dramatic retiming of his whole way of life. One important change in the advancement of society from a simple to a complex state has been the growing need by man for accurate timepieces. Increasing specialization, more than anything else, demands this. Many years ago, Mumford observed that:

> The clock not the steam engine, is the key machine of the modern industrial age. For every phase of its development the clock is both the outstanding fact and the typical symbol of the machine ... the effect is pervasive and strict. It presides over the day from the hour of rising to the hour of rest ... when one thinks of time not as a sequence of experiences, but as a collection of hours, minutes, and seconds, the habits of adding time and saving time come into existence: it could be divided, it could be filled up, it could be expanded by the invention of labor-saving instruments ... the new medium of existence is abstract time ... organic functions themselves were regulated by it, we ate not upon feeling hungry, but when the clock sanctioned it.[1]

As our societies have grown more complex, so have our cities and as the range of activities expands, the economic base of the city becomes more complicated and time disintegrates into smaller and smaller units.[2] Some primitive societies have no word for time, for

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[1]Lewis Mumford, Technics and Civilization (New York: Harcourt, Brace and Co., 1934), p. 14.

[2]Kevin Lynch, What Time is This Place? (Cambridge, Mass.: The M.I.T. Press, 1973), p. 64.

others the time it takes a pot of rice to boil is the basic unit of social time. The shortest unit of social time in the city, on the other hand, has been described as the period between a traffic light turning green and the sound of the car horn from behind.[3] There can be little doubt that time is symbolic of the urban way of life,[4] and will become increasingly so. Cities are, above all, finely timed life spaces.

TIME AND SOCIETY

The individual in contemporary society is very aware of time. Time, as a pervasively awkward scarcity, is perhaps the main rival to money in our society; in many situations, time is money. Time is not simply a quantity to be spent, saved, or squandered; we also have to "keep time," meet deadlines, and order our activities in particular sequences, simultaneously taking into account the amounts of time required to move from place to place. The property of time which distinguishes it from other commodities is that it comes in a unique, irreversible sequence as well as having an amount or duration.

With the aid of clocks and calendars, the modern citizen organizes his daily life in accordance with deadlines over which he often has little or no control. Today formal time constraints are greater than ever before, and the resulting clock-watching obsession shows little sign of abating, despite continuing advances in time- and labor-saving technology. Indeed, these advances demand more

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[3]W.E. Moore, Man, Time, and Society (New York: John Wiley & Sons, Inc., 1963), p. 37.

[4]Louis Wirth, "Urbanism as a Way of Life," American Sociological Review, 44 (1938), pp. 1-34.

accurate time-keeping. In a production-oriented society, the quest for scale economies, and the increased specialization and interdependencies have led to a greater spatial separation of some of the interdependent elements--in particular those which directly affect the ordinary citizen.[5]

Social Time and Space and the Individual

A belief that has pervaded our thinking from the beginning of the industrial revolution through present post-industrial society is that ideas of "specialization" and "division of labor" ought to be applied without reservation to almost all spheres of human activity. As a result, a continually growing bureaucracy, a vast number of technical specialists, and powerful interest organizations attempt to regulate more and more narrowly defined sets of events, whether they be economic, social, or cultural activities. Consequently, individuals conducting their specialized roles have come to be treated in an increasingly piecemeal fashion. The growing division of labor and specialization, or increasing societal scale, have intensified the segregation of man's activities in time and space. This logic has resulted in bigger and bigger firms, buildings, institutions, and cities to contain them.[6]

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[5] James Anderson, "Living in Urban Space Time," Architectural Design, 41 (January, 1971), p. 41.

[6] Melvin M. Webber, "The Urban Place and the Nonplace Urban Realm," Explorations into Urban Structure, eds. Melvin M. Webber, et al. (Philadelphia: University of Pennsylvania Press, 1964), pp. 85-86.

As large metropolitan areas continue to grow even larger, they are simultaneously becoming the places at which the widest variety of specialists offer the greatest variety of specialized services, thus further increasing their attractiveness to other specialists. This tremendous accumulation of specialized competence is on its way to creating an aggregate outcome which is much less than satisfactory. It is difficult to continue dividing up tasks systematically and still respect the facts that the human being is indivisible and that there are needs and wants of individuals which can never be satisfied with money transactions or professional mediation of one kind or another. It also tends to go unnoticed that things and processes in the real world do not only operate in the ways the experts think to be important. These events also interact in a variety of unexpected and unwanted configurations because of their coexistence in time and space.

The limitations of time and space to accommodate things and events were intuitively clear in a less complicated, preindustrial society. In preindustrial society, inhabitants knew how their settlement functioned in terms of social relationships, working procedures, and land use. This was primarily because work and the conduct of everyday life was organized vertically.[7] However, with the advent of industrialization and concomitant urbanization, society has undergone a radical transformation which has been described as a transition

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[7]Torsten Hägerstrand and Sture Öberg, "Befolknings-fordelningen och dess förandringar," Urbaniseringen i Sverige: En geografisk samhallsanalys. Bilagadel I till Balanserad regional utveckling, Statens offentliga utredningar, 1970: 14, bil. 1 (Stockholm: Esselte tryck, 1970), p. 2.

from a vertically organized way of life to one with horizontal linkages.[8] Industrialization outmoded the practice of self-sufficiency and brought an increased division of labor. With growing urbanization, work was subdivided into an increasing number of units which could only produce goods and services through collaboration. The complex interdependence of activities grew rapidly. The result was a society built on the principle of horizontal linkages which demand the constant movement of material, people, and information among increasingly specialized work functions. The growing interdependencies show few signs of abating and are likely to be accentuated in the future.

As things have been divided into smaller and smaller pieces of knowledge, responsibility, and action, the connections among events have become more and more invisible to today's policy makers and planners. Since so much is now unobservable, we have lost touch with the kind of direct information which is needed for intuitive understanding and rational planning.

Freedom and Constraints

For some time now, the benefits of urbanization have been extended to an ever-growing proportion of the population. From among these benefits, the improvements in transportation and communications media have enabled individuals to be relatively free of spatial constraints in establishing and maintaining their ties of association with others. However, this situation may have led us to believe that

[8]Ibid.; the author's use of the term vertical linkages denotes independence or self-sufficiency while horizonal linkages signify interdependence.

the loosening of local ties have given us an altogether free personal choice of events in which to engage. It is true that the assortment of possible combinations, resulting in part from a shift of "place" communities to diverse communities of "interest,"[9] is greater than it ever was, but certain fundamental limitations still exist. Just as we can achieve only limited rationality in our day-to-day existence, so is only a limited freedom available when it comes to action. A vast number of situations in which the individual becomes involved are of a kind that he cannot escape or counter. Circumstances like availability of employment, housing, education, health care, recreation, and transportation are among environmental resources outside immediate control by the average citizen.

As Harvey[10] has recently pointed out, the manner in which urban areas are structured and the ways in which urban activities are organized have important consequences for the distribution of real income among the urban population. Real income is construed not only as money income in a narrow sense, but also as access to environmental resources and opportunities of all kinds.

Given this point of view, one can conclude that an urban population, given its particular location and configuration, sends it inhabitants into sequences of events which, by their distributions

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[9]Melvin M. Webber, "Order in Diversity: Community Without Propinquity," Cities and Space: The Future Use of Urban Land, ed. Lowdon Wingo, Jr. (Baltimore: The Johns Hopkins University Press, 1963), p. 29.

[10]David W. Harvey, Social Justice and the City (Baltimore: The Johns Hopkins University Press, 1973), pp. 53-54. For a similar view, see: R.E. Pahl, Whose City? And Other Essays on Sociology and Planning (London: Longman Group Ltd., 1970), pp. 215-225.

and characteristics, describe the performance of the system as a whole. An innovative effort to estimate performance in a comprehensive way has been suggested by Parkes.[11] His emphasis is on measures of urban time relevant to planning considerations. Through timing of cities he suggests that we will be able to develop "an urban time-use classification which will serve a more flexible and sensitive purpose than land use classification schemes, if only because the utility derived from spending time has much to do with our satisfaction rating for the quality of urban life."[12] The transactions included in his aggregate time-allocation accounts do not exactly measure what is under discussion here. From a cross-sectional perspective, they cannot show how roles become divided in the process and how events come to affect individuals in a longitudinal perspective.

For the moment no effort seems to be more important than to find a just distribution of benefits and sacrifices between all individuals. If so, we should give greater attention to individual behavior as an unbroken sequence of actions. A step in this direction is taken more clearly in the surveys collecting so-called "social indicators" of the quality of life.[13] The growing interest in

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[11]Donald Parkes, "Timing the City: A Theme for Urban Environmental Planning," Royal Australian Planning Institute Journal, 11 (October, 1973), pp. 130-135.

[12]Ibid., pp. 132-133.

[13]Richard L. Meier, "Human Time Allocation: A Basis for Social Accounts," Journal of the American Institute of Planners, 25 (January, 1959), pp. 27-33.

time-budgets as a research tool is an indication of a further move toward a less aggregated and abstract form of observation.[14]

These trends in research are clear achievements. Empirical approaches of this kind, however, entail those disadvantages which follow measurement without theory. It is true that by observing the behavior of people, one learns something about their living conditions. But this information does not clearly distinguish what are wants and needs from what are various degrees of necessity. In the field of human geography, in particular, the problem with advances in this area is perhaps not so much that we have failed to understand man's needs and wants as that our geography is too incomplete to be able to catch the conditions which circumscribe man's actions. Behavior, in and of itself, does not fully reveal the underlying pattern of constraints which shapes the situations in which action occurs. And this also means that no good clues are provided for how to reshape the living conditions, if that is the goal. Instead, we must look to latent structure and latent processes to find the clues. Purposeful changes in the distribution of risks and opportunities among individuals requires an understanding of how constraints interact and how choice potential is affected by changes to one or more of those which can be influenced at all. If it is

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[14] See, for example: Richard L. Meier, A Communications Theory of Urban Growth (Cambridge, Mass.: The M.I.T. Press, 1962), pp. 45-59; and, William Michelson, "Time Budgets in Environmental Research: Some Introductory Considerations," Environmental Design Research: Volume Two, Symposia and Workshops--Fourth International EDRA Conference, ed. Wolfgang F.E. Preiser (Stroudsburg, Pa.: Dowden, Hutchinson & Ross, Inc., 1973), pp. 262-267.

assumed that people survive in "niches" of possible actions, then the shapes and volumes of these niches are more fundamental objects of research than actual behavior at a particular point in time.[15] Actual behavior at a given moment is only a subset from the universe of permitted events. The pattern of niches as formed by constraints in operation describes something different--a map of potential events. The notion of potentials contains a more general measure of performance.[16] The question of how to go about finding the map remains.

TOWARD A TIME-SPACE FRAME OF REFERENCE

In order to get at this issue, consider first geography's dominant instrument of recording, the map. We require that observations be rendered graphically on maps. This habit is perhaps more risky today than it once was, because we have started to take the map much more seriously. Earlier the map was used primarily as a means of general orientation and as an aid to discussion. Our private field experience has helped us to extract much more synthetic information intuitively than was directly displayed symbol by symbol. Now the symbols are the direct basis for serious and precise measurement. To a considerable extent the recent quantitative analysis in geography represents an in-depth study of the patterns of points,

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[15] Torsten Hägerstrand, "The Impact of Social Organization and Environment upon the Time-use of Individuals and Households," Plan: Tidskrift för planering av landsbygd och tutorter, 26 (1972), p. 27.

[16] Torsten Hägerstrand, "What About People in Regional Science?" Papers of the Regional Science Association, 24 (1970), p. 11.

lines, areas, and surfaces depicted on maps of some sort or defined by co-ordinates in a two- or three-dimensional space.

The real significance of this development has been the strengthing of our feelings regarding the value of the geometrical outlook. The danger lies in its influence on how we come to view the relation between map symbols and real-world phenomena.[17] Quite possibly, the map's limitations have forced us to consider only certain classes of spatial phenomena for investigation while neglecting others. This is to suggest that perhaps, we have been so interested in the distributional arrangements of things that we have tended to overlook the space-consuming properties of phenomena and the consequences for their ordering which these properties imply. The map is a poor instrument for depicting packing problems,[18] except in the simpler cases (e.g., land use). The map has to be supplemented with some more abstract spatial notation before we can develop an understanding of these processes.

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[17]Robert D. Sack, "The Spatial Separatist Theme in Geography," Economic Geography, 50 (January, 1974), p. 1.

[18]The term packing refers not only to the space-consuming properties of objects, but also to the process whereby objects compete for space. In discussing the issue of packing, Hägerstrand states that "as soon as one object has found a location, the space it occupies is not available for a host of other 'weaker' objects and the probability field of their location has changed. Of course, objects are sometimes more or less closed and elastic relative to each other, and this makes the packing process very complex. Whatever the complexities are, however, packing adds a meaning to interaction which is different from what we usually have in mind. Many objects interact just because they have come to be located adjacent to each other and for no other reason. This very kind of interaction can have great significance both for the structure of an area and for the sequence of events occurring there." See: Torsten Hägerstrand, "The Domain of Human Geography," Directions in Geography, ed. R.J. Chorley (London: Methuen & Co., 1973), p. 71.

This observation leads to another feature of the traditional geographical format, namely, a noticeable emphasis is laid upon the thin spatial cross-sectional view of the flow of terrestrial events. Indeed, the widespread dissatisfaction with existing geographic theories may be due to a preoccupation with spatial patterns and a neglect of small-scale generating processes over time.[19] Of course, various efforts have been made to include a time-perspective of some sort, and historical geography in its most ambitious form tries to reconstruct the geography of selected dates in the past. Change, then, is visualized as a strip of film where the sequence of frames provides some idea of long term trends. Those concerned with process approaches to the analysis of spatial behavior often proceed in the same fashion, only the number of time intervals is considerably reduced.[20] That is, researchers commonly map some index of change, calculated between two points in time. Models for making spatial extrapolation into future time have been developed[21] but, on the whole, researchers have not yet succeeded in handling events as located and

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[19]Gunnar Olsson, "Inference Problems in Locational Analysis," Behavioral Problems in Geography: A Symposium, Studies in Geography No. 17, eds. Kevin R. Cox and Reginald G. Golledge (Evanston, Ill.: Department of Geography, Northwestern University, 1969), p. 21.

[20]For a more detailed review of process approaches to the study of spatial behavior, see: Reginald G. Golledge, Process Approaches to the Study of Human Spatial Behavior, Department of Geography, Discussion Paper No. 16 (Columbus, Ohio: The Ohio State University Press, 1970).

[21]Michael Chisholm, Allan E. Frey, and Peter Haggett, eds., Regional Forecasting, Proceedings of the Twenty-second Symposium of the Colston Research Society (London: Butterworth & Co. Ltd., 1971).

and connected within a compact time-space block. Again, to overcome this problem requires a new type of notation.

Interdependence of Time and Space

To obtain a proper perspective on the quality of life in modern cities, it helps to consider time as well as space; better still, consider them simultaneously, thinking of peoples' activities and their environments in terms of locations in time-space. Time and space are among man's most fundamental resources, and they are also among the most difficult to study due to their scarcity characteristics. Not the least of the problems is their unique pattern of interdependence and interaction. Time and space combine to form a four-dimensional "volume" which continuously surrounds us, and these dimensions also provide a co-ordinate reference system which we use to organize our own activities, and which can be used to describe the environments and the activities of others.[22] Time and space are interrelated dimensions of human behavior because individuals cannot consume one without the other.[23] In a sense, movement in either case must be continuous, since one must experience every point in time sequentially, and one must pass through a series of points in space in order of their contiguity. Alternatively, the continuous function of time is more

[22]Hägerstrand, "The Domain of Human Geography," op. cit., p. 77.

[23]In a sense space and time are independent of each other because while we continually consume both, the allocatable time is fixed for everyone, but the space available varies. Time, therefore, as distinguished from space, comes in a unique, irreversible sequence having an amount or duration. Movement in time can only be in one direction, whereas movement in space may proceed in any of an infinite number of directions.

demanding of the individual than the more discrete function of space. Although an individual is required to experience every point on the time-scale, he need only be at some point in the physical and social environment that provides him with the minimum requisites for survival. Given either interpretation, it is hardly reasonable to assume that locations in space can effectively be separated from the flow of time.

Paths and Traces within the Time-space Frame

A promising way to overcome the problems discussed above has been suggested by Hägerstrand.[24] He recommends translating all necessary concepts, old or new, into a strictly "physical" language. In this procedure, it is essential that the unity of time and space be fully respected. The use of a single spatial-temporal system to identify the particulars of human discourse is fundamental. With regard to this matter, Sack comments:

> The single physical time-space system makes it possible to identify and individuate events that are separate from any single observer and to communicate, discuss, or make public, observations that are not immediately apparent to the senses by everyone. Clearly, these functions cannot be provided by a plurality of physical spaces, for that would lead to confusion of identification and perhaps ultimately to solipsism. Only one system of physical space and time can provide the function of identification and individuation of events.[25]

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[24] Hägerstrand, "The Domain of Human Geography," op. cit., pp. 77-79.

[25] Robert D. Sack, "A Concept of Physical Space in Geography," Geographical Analysis, 5 (January, 1972), pp. 25-26. The use of a system of physical space and time is also treated by Sack in: Sack, "The Spatial Separatist Theme in Geography," op. cit., p. 17.

A physical time-space system is illustrated in Figure 1. For purposes of illustration, three-dimensional space has been collapsed into a two-dimensional map, leaving the third dimension to represent time. This procedure makes it possible to incorporate time and space into one unified geometrical time-space picture with full continuity in the time direction. This also means that form and process would not seem to be so essentially different as they appear today. Process takes shape as four-dimensional form. To man, time and space are not only dimensions for viewing and analyzing the location of events, they are also, in a very real sense, scarce resources. This makes the time-space outlook fundamental. It is in this context that the "packing problem" reaches its full weight and it is here that the importance of not omitting any portion of man's time and surrounding space becomes critical. In reality one must always keep both dimensions in mind, for to a certain extent they are interchangeable. Furthermore, in the conduct of human affairs, time often makes itself felt as a more demanding dimension than do spatial constraints.

The acting individual, therefore, describes an unbroken path in time-space (Figure 1). It is easy to imagine how the total population of interacting individuals within the block form a network of unbroken time-space paths, but with the fundamental property that identity is retained. Similarly, the time-space traces of elements of known human importance in the environment, such as other organisms, tools, buildings, materials, can be depicted. The scenario makes it immediately clear that compatability among individuals, buildings,

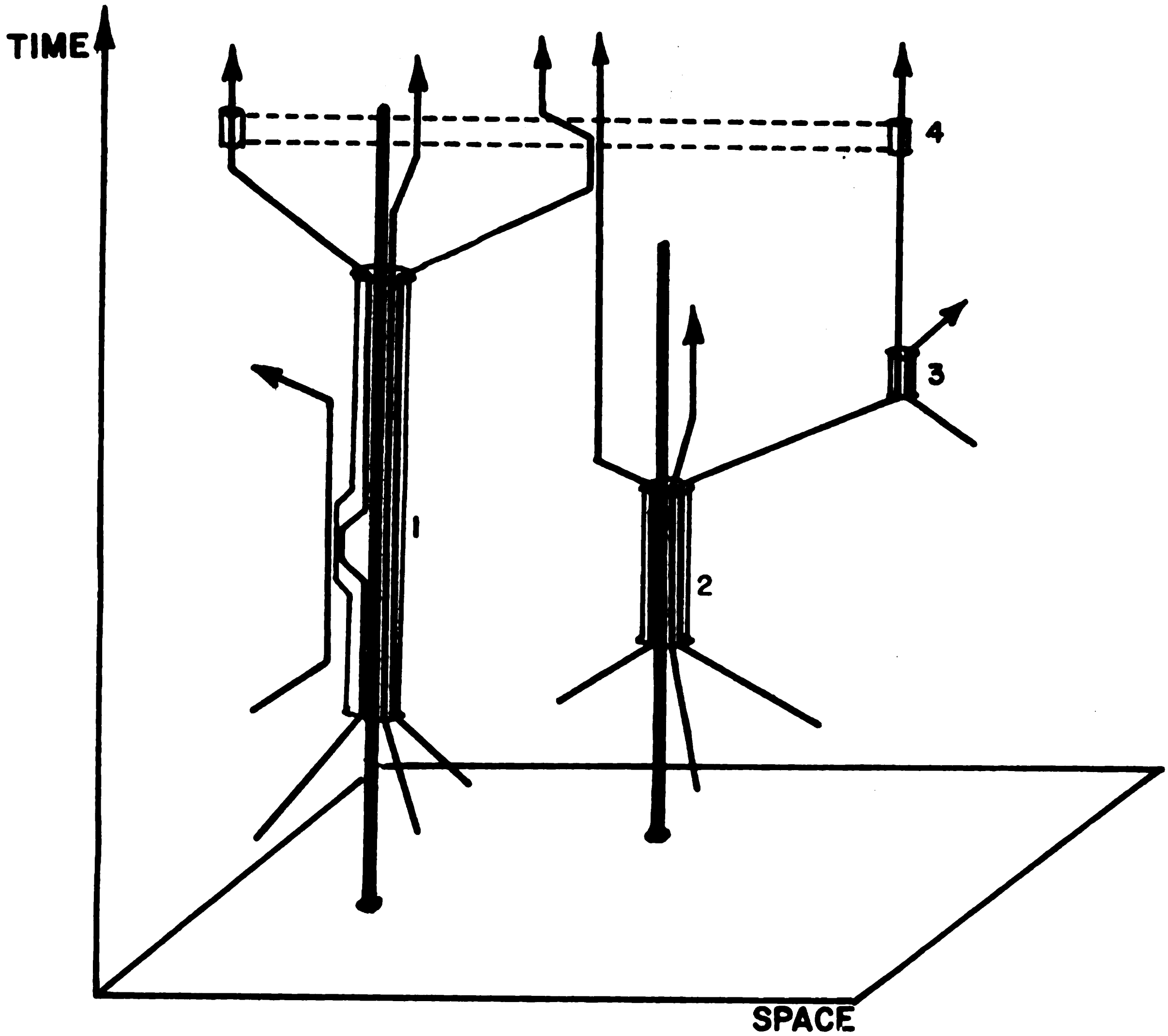

FIGURE 1

THE PATHS OF A GROUP OF INDIVIDUALS IN
A TIME-SPACE SYSTEM*

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*The numbers 1, 2, 3, and 4 indicate different kinds of activity bundles which are locations in time-space where people come together in order to exchange information, transact business, or perform a common activity. 1 is connected with some fixed installation; 2 and 3 are meetings with different durations. All three types of bundles require movements, before and after, in order to be formed. 4 represents a telephone call which does not require movement but, nevertheless, ties two individuals together into one activity. (After Hagerstrand, "A Socio-environmental Web Model," op. cit., p. 24).

tools, materials, and signals requires both (temporal) synchronization and (spatial) synchorization. Seen as a whole, the system exhibits a skeleton of meeting times and meeting places, much of which is frequently built up in advance, in order to fit activities to the timetables of other people, facilities, and institutions.

This is a complex situation even in a space-free timetable sense. Even if members of a population do nothing more than exchange messages by telecommunication media (so that transportation is practically instantaneous), the indivisibility of the human being is a severe constraint on what can occur. As soon as a communicating group has come into being, the duration of its activity inevitably creates waiting-times among those who want to come into contact with one or more members of the group. The conflicts that arise will become a more obvious difficulty as we move toward a society in which the processing of information develops into the main activity.[26]

NATURE OF THE RESEARCH PROBLEM

When trying to disentangle the seeming chaos of paths and traces inside the time-space block, several modes of investigation come to mind.[27] In attempting to understand more clearly the structuring of

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[26] Webber, "Order in Diversity," op. cit., pp. 42-44.

[27] For various approaches, see: James Anderson, "Space-time Budgets and Activity Studies in Urban Geography and Planning," Environment and Planning, 3 (1971), pp. 353-368; Ian G. Cullen, "Space, Time, and the Disruption of Behavior in Cities," Environment and Planning, 4 (1972), pp. 459-470; and, Alan G. Wilson, "Some Recent Developments in Micro-economic Approaches to Modelling Household Behavior, with Special Reference to Spatio-temporal Organization," Papers in Urban and Regional Analysis, Alan G. Wilson (London: Pion Ltd., 1972), pp. 216-236. These and other alternative approaches will be covered in more detail in the following chapter.

everyday behavior, this research adopts a methodology that can be described as the time-space mechanics of constraints.[28]

Conceptually, the behavior, or activities, of an individual can be viewed as a series of discrete episodes occurring in a sequence through some specified period of time. These episodes have meaning at different temporal scales. Most relate to a day's activities, such as work, housekeeping, or eating, but some have meaning in the weekly time scale, such as visiting with relatives, in the yearly time scale, such as taking a holiday, or in a generational time scale, such as migration.[29] The activity sequence is seen to be a continuous stream of events where days flow into weeks, weeks into months, seasons into years, and years into a lifetime. Further, the events in this sequence are seen to possess an essential order in the sense that certain types of events occur in fairly predictable cycles or routines and take place in a space of fairly predictable locus. Activities, therefore, occur in a time-space continuum: there are temporal regularities inherent in spatial regularities, and temporal rhythms obviously vary over space.

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[28]Hägerstrand, "What About People in Regional Science?" op. cit., p. 11; see also: Torsten Hägerstrand. "A Socio-environmental Web Model," Studier i planeringsmetodik, ed. Gösta A. Eriksson, Memorandum från ekonomisk-geografiska institutionen, nr. 9 (Åbo [Turku], Finland: Handelshögskolan vid Åbo akademi [Åbo Swedish University School of Economics], 1969), pp. 19-28.

[29]Torsten Hägerstrand, "On the Definition of Migration," Väestöntutkimuksen vuosikirja (Yearbook of Population Research in Finland, 11 (1969), p. 65.

This research addresses itself to the general question: How do an individual's decisions about his time-space behavior interrelate? In striving to answer such a question, practical as well as theoretical considerations must be taken into account. At a very basic level, the strategy of this research is based upon a simple belief: if one is to improve the lot of the individual living and working in the city, then one essential element is a study of the behavior of that individual, seen as an unbroken sequence of actions. The study of this behavior, through time and space, in its normal metropolitan context cannot be avoided if one's intention is to shed some light upon potentially dysfunctional relationships between the two. No alternative approach will reveal the ways in which the context structures, constrains, or even frustrates the behavior which it is intended to facilitate.

The Approach

Two general approaches to the study of time-space behavior can be identified. One orientation, clearly the more common, focuses on choices of activity that are manifest in behavior. The second approach, and the one adopted here, focuses on the constraints which circumscribe man's actions. Since choices can only be realized within the context of constraints, the latter approach is more general and more likely to lead to a discovery of how the decisions regarding one's time-space behavior interrelate.

Two broad groups of constraints are proposed. Objective constraints constitute the first group and are those which are imposed by the environment. It is this group that tends to shape the "niches" of possible action open to an individual. The pattern of niches formed by objective constraints describes a map of potential events. These potential events can be more narrowly defined by a second group, the subjective constraints, which are more or less self-imposed. Such constraints occur as a result of the individual's physical and social environment. In most contexts, a given environmental situation is subjectively perceived by different people as constraining choice to varying degrees. Although the peculiarities of the environmental context are important, an individual's reaction to that situation is crucial. Any situation tc which an individual reacts has at least three dimensions: a temporal position, a location in space, and a potential activities set. These dimensions interact to produce a feeling of constraint upon the individual.

The basic proposition of this research is that the critical determinant of the structure of a person's day, given environmental forces, is the extent one feels constrained relative to certain activities, times, and locations. These points at which one feels most constrained and around which one's day tends to be organized will be used as the basis for modelling experiments.

The principal aim of the present inquiry is to develop a methodology for investigating just how an individual's decisions about his time-space behavior interrelate. The approach adopted is based on the time-space mechanics of constraints. The adequacy of the methodology will be judged against its ability to replicate observed behavior. For the purposes of this research, it is assumed that one goal of geography, and social science in general, is to construct mechanisms sufficient to produce the observed results. These mechanisms take the form of constraints which determine the structuring of paths of behavior in time-space. As noted earlier, an alternative approach is based on choice-mechanisms which manifest themselves in actual behavior. But, by observing the actual behavior of members of a population in a given period of time, this approach risks becoming lost in a description of how aggregate behavior develops as a sum total of individual behavior, without revealing the really critical determinants of behavior in time-space. What we "see" may be only a very small portion of the phenomena and, thus, behavior does not fully unveil the underlying pattern of constraints which shapes the situations in which action takes place. We must go well beyond a description of overt behavior to answer the question posed above. We must look for latent structure and latent processes in human behavior, or the hidden mechanics of constraints, to find the clues. Therefore, it seems more promising to try to define, using simulation procedures,[30] the time-space mechanics of constraints which determine how paths are built-up, coordinated, or constrained.

The Organization

The primary objective of this inquiry is to report on a research and modelling strategy that attempts to reveal the processes or rules which govern the integration of the individual's time-space behavior. The remainder of this inquiry is devoted to five main topics:

(a) Time-budgets of Human Behavior: A Synthesis and Critique of Selected Approaches.

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[30] Hägerstrand, "What About People in Regional Science?" op. cit.

In this section the development of the time-budget approach to the study of behavior is reviewed. The purpose is, on the one hand, to comment on the applicability of time-budgets other than the one which is developed and used here and, on the other hand, to reformulate the conceptual foundation within which this research tool can be considered.

(b) Time-space Paths of Human Behavior: Conceptualization and Implementation of the Research Strategy.

Building on the synthesis and critique of time-budget use in urban and regional analysis, this section formulates a conceptualization and research propositions designed to investigate the structuring of daily behavior through the time-space mechanics of constraints. In order to substantiate or illuminate the research propositions, a research strategy is established and involves the design and implementation of a survey.

(c) Empirical Analysis for Model Development.

The third section involves the application of several analytical techniques to the survey data. Many modes of analysis appropriate for time-space budget data exist and are briefly reviewed. However, only those methods which are intimately related to the ultimate goal of developing a simulation model will be treated here. Employing data on the daily activities of members of Michigan State University, East Lansing, Michigan, these analytical procedures will be employed in the evaluation of specific hypotheses about time-space behavior.

(d) Simulation Model of Time-Space Paths and the Mechanics of Socio-environmental Constraints.

Given the results of the preceding section, a simulation model is formulated for determining the time-space paths of individuals in an urban environment. Through the use of simulation procedures, it is recognized that the full complexity of individual paths in time-space cannot be reproduced. Rather, it is intended as a deductive device for partial verification and as a mechanism for controlled observation of constraints interacting in the context of daily behavior. The findings of the simulation modelling experiments will then be evaluated in relation to the major research propositions.

(e) Summary and Conclusions: Retrospect and Prospect.

This section is divided into two parts: (1) a summary of the methodology and the main conclusions about the validity of the modelling strategy that attempts to reveal the processes which govern the integration of the individual's time-space behavior and (2) a discussion of possible lines of further inquiry.

In this introductory chapter, the intention has been to explicate the motivation and purpose of the following study. Detailed arguments for the rationale of the viewpoint have been omitted. To have included these would have involved some reasonably abstruse arguments from the philosophy of science--for instance, the relationship of description, explanation, and prediction,[31] the implications of

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[31]May Brodbeck, "Explanation, Prediction, and Imperfect Knowledge," Readings in the Philosophy of the Social Sciences, ed. May Brodbeck (Toronto: The Macmillan Co., 1968), pp. 363-397; Abraham Kaplan, The Conduct of Inquiry (Scranton, Pa.: Chandler Publishing Co., 1964), pp. 327-369.

determinism and probability,[32] and the individual in scientific inquiry and the reductionist viewpoint.[33] As this study is not the proper place for these comments, the reader is referred to the more detailed treatments in the bibliography. The purpose of the present inquiry is simply to develop a conceptual framework for the study of the integration of an individual's time-space behavior; the philosophic issues serve only as a background against which to view these efforts.

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[32]Gustav Bergmann, "Imperfect Knowledge," Readings in the Philosophy of the Social Sciences, ed. May Brodbeck (Toronto: The Macmillan Co., 1968), pp. 413-436.

[33]M.B. Turner, Philosophy and the Science of Behavior (New York: Appleton-Century-Crofts, 1967), pp. 301-374; May Brodbeck, "Methodological Individualisms: Definition and Reduction," Readings in the Philosophy of the Social Sciences, ed. May Brodbeck (Toronto: The Macmillan Co., 1968), pp. 280-303.

CHAPTER 2

TIME-BUDGETS OF HUMAN BEHAVIOR: SYNTHESIS AND CRITIQUE OF SELECTED APPROACHES

Many interesting patterns of social life are associated with the temporal distribution of human activities, with regularities in their timing, duration, frequency, and sequential order. Certain techniques of data collection based on direct observation, interviewing, and the examination of records permit the establishment of itemized and measured accounts of how people spend their time within the bounds of a working day, week-end, a seven-day week, or any other time period. Investigations of this particular aspect of social life based on the quantitative analysis of such accounts, have produced a lineage of research commonly referred to as "time-budget studies."

The purpose of this chapter is to briefly review the development of the time-budget approach to the study of human behavior. The objective is, on the one hand, to comment on the applicability of time-budgets other than the one which is developed and used in this inquiry and on the other hand, to review selected uses of this research tool in urban and regional analysis.

THE TIME-BUDGET PERSPECTIVE

The term "time-budget" signifies an accounting scheme describing the allocation of time to activities during a given period--how many hours and minutes people spend daily on chores and past-times such as doing work, shopping, eating meals, socializing, leisure-time pursuits, and sleeping. The time-budget investigation is somewhat similar to the procedure by which the allocation of funds for different purposes in financial budgets is analyzed. As far as personal or household budgets are concerned, the similarity will even extend to many specific types of expenditure, because a great number of everyday activities involve not only the expenditure of time but also money.[1] At this point, however, the resemblance comes to an end. Time can only be spent, not "earned" therefore, time-budgets have no income side. Due to the fixed limits of time, everybody disposes equally of the 24 hours of the day. The fund of time which is being allocated to various activities (24 hours in daily time-budgets) serves simply as a frame of reference for setting out the temporal proportions of people's engagement in the whole gamut of their daily activities. Thus, it is not time itself, either as a physical or as a subjectively perceived entity, but rather the use people make of their time which is the real subject of time-budget studies.

Development of Time-Budget Research

The time-budget approach was first developed in social surveys reporting on the living conditions of the working class. The long working hours characteristic of early industrial development and the struggle which organized labor led from its very beginning for the shortening of the working day, make it fully understandable that the

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[1]Historically, the time-budget concept is apparently derived from the practice of maintaining a set of household income and expenditure accounts which dates to the nineteenth century. It was a simple step to move from money accounting to time accounting with the movement to the hourly wage as the predominant kind of income workers received.

proportions of work and leisure in the daily life of laborers became a matter of considerable public concern in all countries where industrialization was in progress.[2] The famous "3 x 8" password of labor movements around the turn of the century, claiming eight hours of sleep, eight hours of work, and eight hours of recreation as a rightful daily schedule of all laborers, expressed a social demand in the form of a concise time-budget. Just about then, chronometric time-and-motion analyses were introduced into industrial practice by the pioneers of "scientific management".[3] This also meant time-budgeting of a sort, by setting up precise accounts of the amounts of paid time spend by workers on all kinds of "necessary" or "wasteful" activities during their work in the factory.

The bulk of time-budget studies published before World War II originated in Great Britain, the Soviet Union, and the United States (see Figure 2).[4] In general, these earlier studies focused on the following topics:

1. the share that such broad categories of activity like paid work, housework, personal care, family tasks, sleep and recreation have in the daily, weekly, or yearly time-budget of the population;

2. characteristic time expenditures of certain social groups or strata (e.g., industrial workers, farm homemakers, college students, unemployed men) on more or less specified types of everyday activities;

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[2] Alexander Szalai, "Trends in Comparative Time-Budget Research," The American Behavioral Scientist, 9 (May, 1966), p. 3.

[3] Ibid., pp. 3-4.

[4] Ibid., pp. 5-7.

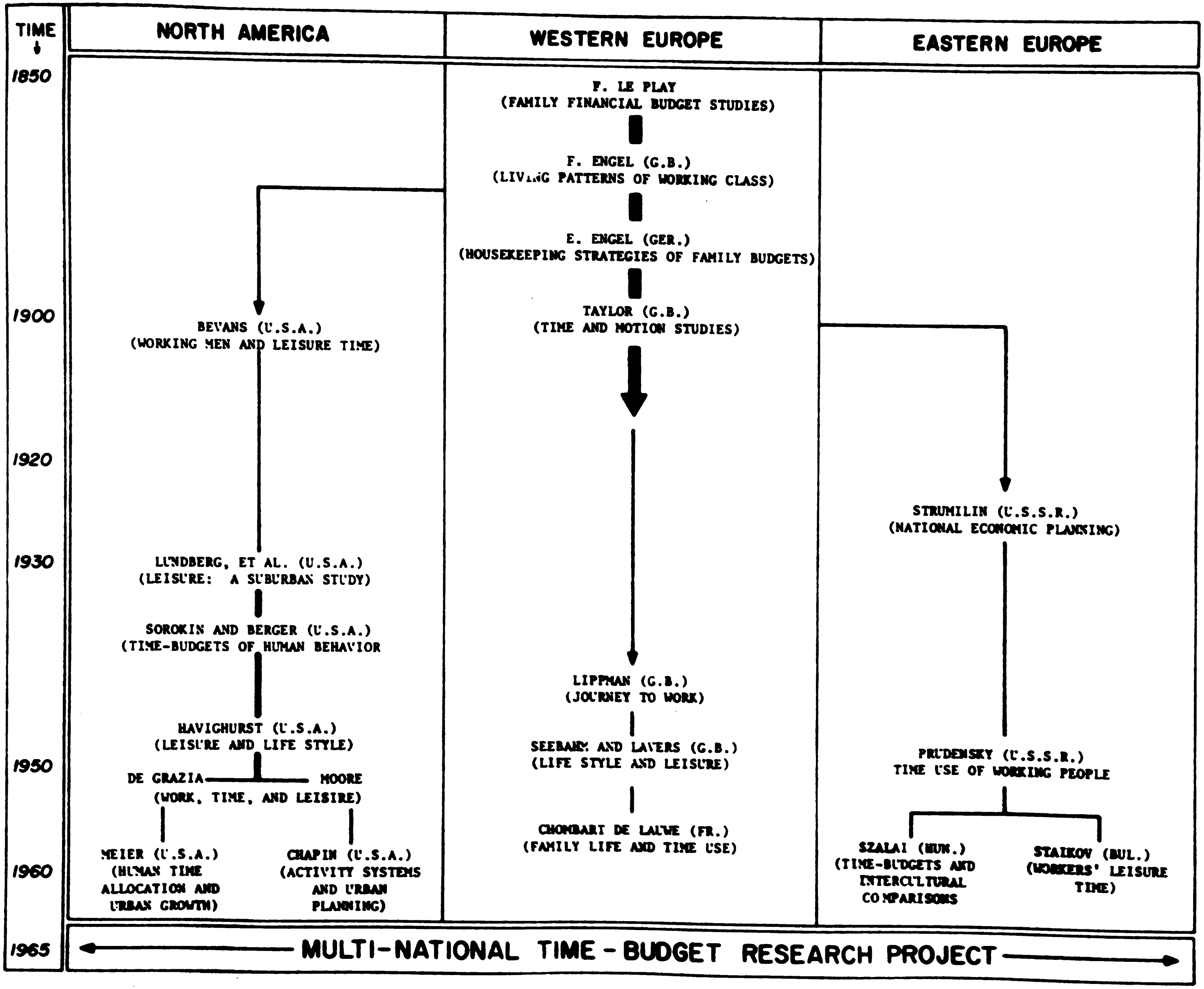

FIGURE 2.

TIME-BUDGET RESEARCH THROUGH THE MID-1960'S

3. the use made of "free time", especially leisure.

Data were collected mostly by means of simple forms on which the respondents were requested to report the time and the general character of their various activities during the day. Quite often only the remembered (or guessed) average duration or frequency of specified activities in the daily life of respondents was asked. Some moderate use was also made of "yesterday interviews" intended to reconstruct the course of events in the life of respondents on the preceding day. Finally, for some global accounting purposes, certain estimates were secured by analysis of available data on traffic densities, cinema attendance, newspaper circulation, and participation in social organizations or gatherings.

As experience accumulated it was a logical step to extend time-budget studies to entire cities, recording the allocation of time to different activities in the form of time accounts for the whole population. But, as will become clear from the organization and conduct of the present study, this would not have been feasible if modern-day sampling techniques had not been perfected, nor would it have been achieved without the development of computer technology.

Systematic empirical work in the analysis of individual and family use of time first appeared in the 1920's, and it was a researcher in the Soviet Union who produced the first time-budget study which was concerned with the quantitative measurement of an entire day's activities. The Soviet economist, S.G. Strumilin, conducted this investigation in Moscow in 1924 in which quite advanced social statistical concepts were introduced in time-budget surveys.[5] These surveys were designed to identify areas of activity that are used inefficiently, and thus might be subject to policy and planned state manipulation. With the massive effort in the Soviet Union to increase production and worker productivity since then, there followed a widespread application of this work to other Soviet cities. For example, Strumilin's study was repeated some 35 years later with a similar sample of the working population by his former pupil, Prudensky.[6] This represents the first longitudinal time-budget analysis for the purposes of historical comparison. This comparison made by Prudensky clearly demonstrates the changes that industrialization has brought to the time and activity patterns in the Soviet Union. A number of Soviet investigations followed these initial undertakings and concentrated on particular groups, such as radio listeners, television viewers, or farm workers, and on particular activities, such as leisure and work.[7]

As a result of the earlier use of time-budgets in the Soviet Union, a substantial tradition developed in Eastern European social research. For example, in 1963, time-budgets formed part of an official census in Hungary.[8] The purpose of the time-budget analysis

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[5]Ibid., p. 4.

[6]Ibid., p. 4.

[7]Ibid., pp. 5-7.

[8]In Hungary, where periodic micro-censuses (nationwide sample surveys of demographic changes in the population) have been introduced to bridge the long gaps between the regular census years, a subsample of the micro-census of 1963 served also for obtaining time budgets of the population throughout the country. The results have been published and may be found in: Hungarian Central Statistical Office, <u>The Twenty-four Hours of the Day: Analysis of 12,000 Time-Budgets</u>, English Version

was to supply information on a special aspect of the manner of living of different social groups, i.e., how their time is spent. This was the first time that overall information was given on the time schedule, the rhythm of life, the diversity or monotony of the way of life of different groups of the population (whether earners or dependents, men or women, intellectuals or manual laborers), and the smaller or greater burdens to be borne by different social strata.

The Soviet Union, however, has produced the most extensive set of time-budget accounts.[9] The Soviet work has been used primarily within an economic planning context and there have been numerous efforts to improve policy and planning for the labor force, industry, and transportation systems through the use of time-budget research.[10] Between 1959 and 1965 alone, time-budget surveys involving well over 100,000 man-days of recorded human activities were carried out by the Institute of Economics of the Soviet Academy of Sciences in Novosibirsk and related research organizations--partly for general scholarly purposes, and partly for supplying much needed data to authorities concerned with the planning of manpower resources, educational facilities, communal services, etc.

(Budapest: Hungarian Central Statistical Office, 1965). This is probably the first instance where time-budget data were collected in connection with a micro-census.

[9]Alexander Szalai, ed., The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries (The Hague: Mouton & Co., 1972), pp. 861-864.

[10]Gerald A. Gutenschwager, "The Time-Budget--Activity Systems Perspective in Urban Research and Planning," Journal of the American Institute of Planners, 39 (November, 1973), p. 382.

The use of time-budgets in Western Europe and the United States has been directed almost exclusively to a study of discretionary or leisure time activities. Moreover, from the earliest studies carried out in the 1930's the interest has been primarily academic rather than administrative.[11] The first serious studies in the United States appeared in the 1930's in the works of Lundberg-Komarovsky-McInerny, McCormick, and Sorokin-Berger.[12]

The study of leisure by Lundberg and others,[13] is meticulous and monumental in its data collection. Lundberg and his co-workers collected nearly 5,000 diary records of individual days as part of their study of leisure in Westchester County, New York. But the investigation is particularly important in its attempt to describe different time/activity patterns for groups in the suburban area. Also, the research develops useful questionnaire investigations of activities related to place, companionship and activity satisfaction, as well as techniques that allow respondents to express preference for activities within constraints of money, time, and accessibility.

Sorokin and Berger's study of Time-Budgets of Human Behavior[14] has probably done most to popularize the time-budget method of research.

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[11] Ibid., p. 382.

[12] George A. Lundberg, Mirra Komarovsky, and Mary A. McInerny, Leisure: A Suburban Study (New York: Columbia University Press, 1934); Thomas C. McCormick, "Quantitative Analysis and Comparison of Living Cultures," American Sociological Review, 4 (August, 1939); Pitirim A. Sorokin and Clarence Q. Berger, Time-Budgets of Human Behavior (Cambridge, Mass.: Harvard University Press, 1939).

[13] Lundberg, et al., op. cit.

[14] Sorokin and Berger, op. cit.

Sorokin and Berger undertook a rather interesting time-budget study during the 1930's in and around the city of Boston. This research is best recognized for its sophisticated conceptual approaches for the analysis of detailed personal diaries covering relatively extended periods of individual daily activity. In their book, the authors demonstrate some surprising insights into the conceptual problems of time-budget analysis such as activity classification, social interaction, psychological motivations for activities, and the potential for activity prediction of one's own behavior. Despite the acknowledged deficiencies in their survey research methodology; their insights regarding conceptual problems of time-budget analysis remain valuable. About the same time, McCormick proposed the use of time-budgets for behavioral comparisons across cultures—a suggestion that would not be acted upon for nearly thirty years.[15]

The leisure time focus of these early studies did ultimately evolve into, and was often related to, mass media studies where the interest became more practical, namely, how to measure audience potential. In fact, the largest surveys have been geared to market research for the mass media (e.g., in radio and television programming).[16] The focus of these surveys have most frequently been on general leisure, an emphasis continued in the recent UNESCO sponsored cross-cultural time-budget research project involving twelve nations.[17]

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[15]McCormick, op. cit.

[16]Gutenschwager, loc. cit.

[17]The International Time-Budget Research Project directed by Szalai represents the most extensive series of studies of this kind ever undertaken. See Alexander Szalai, "The Multi-national Comparative Time-Budget Research Project," The American Behavioral Scientist, 10 (December, 1966), pp. 1-4.

Other efforts followed in other countries. The more recent studies in the analysis of the use of time take a variety of forms--national studies of time allocation,[18] studies of family adaptation to urban conditions,[19] the analysis of commuting behavior,[20] investigations on the use of leisure time,[21] and the broad synoptic type of study focusing on the comparative aspects of urban living patterns.[22]

The Multinational Time-Budget Project

A huge amount and very great variety of time-budget data have been accumulated over the years by many researchers in several countries. To some extent time-budget work has become so preoccupied with "picture-taking" as a technique, i.e., obtaining one cross-sectional survey in time, that it has not moved out from this kind of

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[18]Ibid.

[19]Szalai, "Trends in Comparative Time-Budget Research," op. cit., pp. 6-7, cited Jean Stoetzel, "Une étude de budget-temps de la femme dans les aggolomerations urbaines," Population, 1 (1948); Paul Chombart de Lauwe, La vie quotidienne ouvierès: Recherches sur les comportements sociaux de consommation (Paris: Centre National de Recherche Scientifique, 1956); and, Paul Chombart de Lauwe, "La vie familiale et les budgets," Traité de Sociologie du Travail, Vol. 2, eds. G. Friedman et al. (Paris: A. Colin, 1962).

[20]The classic study of this kind is: Kate Liepmann, The Journey to Work (London: The Oxford University Press, 1944). Since World War II, the American studies of trip behavior using the Bureau of Public Roads standard design for "origin and destination studies" have become widespread.

[21]Examples include Eric Larrabee and Rolf Meyersohn, Mass Leisure (New York: The Free Press, 1958); and Sebastian de Grazia, Of Time, Work, and Leisure (New York: The Twentieth Century Fund, 1962).

[22]Szalai, The Use of Time, op. cit.; Szalai, "The Multinational Comparative Time-Budget Research Project," op. cit.

emphasis into a more fundamental concern with examining human activity at the micro-level, its organization into systems, and the functioning of these systems within the larger societal framework. Furthermore, little effort has been made to develop some more generally applicable methodological standards of time-budget research so as to enhance the possibilities for a comparative evaluation of such data. This topic came up for discussion at the International Conference of the Use of Quantitative Political, Social and Cultural Data in Cross-National Comparison, held in 1963 at Yale University.[23] Some new approaches to the differential evaluation of time-budgets for comparative purposes were proposed. However, the widely divergent methods of data collection, registration, coding, and classification used by researchers belonging to different countries of different schools of thought posed serious restrictions for comparative research. In view of these difficulties, practically not comparative method could be made workable until at least some agreement and cooperation were achieved among a number of researchers in various parts of the world who have an active interest in this field. The idea was promoted that by carrying out a series of well-standardized time-budget surveys in different countries, such agreement and cooperation could well be promoted. Furthermore, a stock of standard multinational time-budget data would be created which might provide the basis for the further refinement of time-budget research methods for comparative purposes.

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[23]Alexander Szalai, "Differential Evaluation of Time-Budgets for Comparative Purposes," Comparing Nations: The Use of Quantitative Data in Cross-National Research, eds. R.L. Merritt and S. Rokkan (New Haven, Conn.: Yale University Press, 1966), pp. 101-102.

This was one of the major considerations which led to the most comprehensive efforts at time-use study. During the mid-1960's, the Multinational Comparative Time-Budget Research Project was begun by the Vienna Coordination Centre for Research and Documentation in the Social Sciences, with Alexander Szalai heading a team composed of representatives from nearly a dozen countries. Representatives from the various countries met to agree on the uniform selections of survey sites, sampling procedures (two-stage random), survey forms and data-collecting techniques ("yesterday interviews" plus one-day diaries), classification and coding procedures (using a 99-code activity classification scheme--Appendix C), and methods for card punching and data analysis. There were three basic kinds of study areas which could be used by participating nations: (1) a town of 30,000 to 280,000 population, (2) a series of towns satisfying the above population requirement with a specified minimum number of respondents from each of the towns, and (3) a national survey. A grand total of 24,932 individuals successfully completed the interviews and survey forms in the ten countries. The survey universe was comprised of members of households between 18 and 65 years of age, where at least one member was employed in a non-agricultural occupation. The respondents were asked to record their activities for the next day on schedules provided for the 24 hour period beginning at 12:01 a.m. Two days later when the respondents were revisited, the schedule was picked up, and any additions the interviewer thought necessary were made to fill out the schedule.

The data coded from the time-budgets in the multi-national study included the beginning time, primary activity undertaken, a secondary activity code if listed, other persons present, and the location of the activity episode. Such a set of characteristics used to describe a particular activity is termed an "activity module." Within the multi-national project a three-digit primary and secondary activity code was allowed within each activity module. Actually, a two-digit coding system was adopted for common use by all countries, with the development of the third digit of code left to individual countries. A standard set of demographic information was required from all participants, and an optional set was left open for individual interests, as in the activity codes.

Preliminary results from this large-scale national and comparative study were reported at the Congresses of the International Sociological Association at Envian, France, in 1966, and Varna, Bulgaria, in 1970, as well as in the American Behavioral Scientist.[24] The main volume was published in 1972.[25] While unquestionably the work from the multinational study will yield important benchmarks for research on time allocation, this effort seems to be but a prelude to a much more extended interest in time studies.

[24] International Sociological Association, Transactions, Sixth World Congress of Socilogy, Evian, Vol. 5 (Milan: International Sociological Association, 1966); International Sociological Association, Transactions, Seventh World Congress of Sociology, Varna, Vol. 5 (Milan: International Sociological Association, 1970); Szalai, "The Multinational Comparative Time-Budget Research Project," op. cit.

[25] Szalai, The Use of Time, op. cit.

The Analysis of Time-Budget Data

The late 1950's and 1960's saw the mushrooming of time-budget research and data collection. Yet the analyses of these data, especially prior to the multinational project, have been subject to many of the pitfalls that accompany measurement without theory. Nevertheless, a variety of approaches have been developed for the analysis of the voluminous data collected in time-budget surveys.

Beginning with the classification of activities, Foote and Meyersohn first proposed that respondent's activity descriptions could be analyzed grammatically.[26] This idea has been developed by Kranz, who devised computer techniques for analyzing and classifying activity responses.[27] His approach is a computerized form of content analysis in which activities are defined from the semantic context of respondent time-budget diaries. This method attempts to circumvent the necessity for assigning recorded events on the basis of some arbitrary scheme established a priori.[28]

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[26] In trying to code the activities recorded in the diaries, they hit upon an interesting scheme of considering each entry as a sentence. Activities were seen to have a grammatical structure, with an implied subject, a verb, and an object. See: Nelson N. Foote and Rolf Meyersohn, "Allocations of Time Among Family Activities" (paper read at the Fourth World Congress of Sociology, 1959, Stresa, Italy); Nelson N. Foote, "Methods for Studying Meaning in Use of Time," Aging and Leisure, ed. R.W. Kleemeier (New York: Oxford University Press, 1961), pp. 84-97.

[27] Peter Kranz, "What Do People Do All Day?" Behavioral Science, 15 (May, 1970), pp. 286-291.

[28] Perhaps the most widely recognized scheme of this kind is the 99-code system developed by the Multinational Time-Budget Project. See: Szalai, "The Multinational Comparative Time-Budget Research Project," op. cit. [Appendix]

A common proposal has been the longitudinal analysis of data on time use as a means of gauging social change.[29] Szalai compares the time-budgets of workers in Moscow in 1924 and 1959.[30] Robinson attempts to ascertain changes in the use of time in the United States, using the Lundberg data on Westchester County and the Sorokin-Berger data on Boston, both collected in the 1930's, a Ward-Mutual Broadcasting Company national survey from 1954, and the Jackson, Michigan and national sample data obtained in 1965-66 as part of the Multinational Project. All of the conclusions are only suggestive, however, as there are serious problems with the populations surveyed, the sampling procedures, and the non-comparability of the various activity-classification schemes.[31]

Szalai has developed a measure of the relative "compressibility" of different activities when the amount of available time is reduced. The concept is analogous to elasticity in economics. For example, workers with less free time because of a longer journey-to-work will devote considerably less time to some leisure pursuit, but virtually the same amount of time sleeping as other workers. Thus, the

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[29]Richard L. Meier, "Human Time Allocation: A Basis for Social Accounts," Journal of the American Institute of Planners, 25 (January, 1959), p. 27.

[30]Szalai, "Trends in Comparative Time-Budget Research," op. cit., p. 4.

[31]John P. Robinson, "Social Change as Measured by Time-Budgets," Journal of Leisure Research, 1 (Winter, 1969), pp. 75-77.

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leisure-time activity is more compressible than sleeping.[32] The Hungarian microcensus includes this type of analysis.[33]

Converse employs a slightly more sophisticated approach in comparing the use of time among nations. A Euclidean measure of "distance" between time-budget profiles, developed by Szalai, gives measures of intergroup differences. Guttman-Lingo smallest-space analysis is then used to determine the primary dimensions of difference among nations. The results are fascinating, since, in the two dimensions, the nations cluster geographically. Unfortunately, Converse does not suggest the value of this approach.[34]

Soviet researchers are focusing attention not on individual time-budgets but on the aggregate time balance of a region. For economic planning, they argue the primary consideration is the total amount of time spent by everyone on a given activity. Plans can then be devised for the most efficient use of time.[35] The Bulgarians take this approach for the forecasting of time use in the future.[36]

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[32]Alexander Szalai, "Differential Work and Leisure Time-Budgets as a Basis for Inter-Cultural Comparisons," New Hungarian Quarterly, 5 (Winter, 1964), pp. 105-119.

[33]Hungarian Central Statistical Office, op. cit.

[34]Phillip E. Converse, "Country Differences in Time Use," The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries, ed. Alexander Szalai (The Hague: Mouton & Co., 1972), pp. 145-177.

[35]V.D. Patrushev, "Aggregate Time-balances and Their Meaning for Socio-economic Planning," The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries, ed. Alexander Szalai (The Hague: Mouton & Co., 1972), pp. 429-440.

[36]Zahari Staikov, "Time Budgets and Technological Progress," The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries, ed. Alexander Szalai (The Hague: Mouton & Co., 1972), pp. 461-482.

Virtually all of the analyses of time-budget data consider either the <u>frequency</u> in which people engage in different activities, or the <u>duration</u> of those activities. No one has successfully solved the very difficult methodological problems involved in looking at other aspects of time use such as the sequencing of activities. Another problem which underlies much of the analytical work is the seeming lack of direction in much of the research. Time seems important, so time-budget surveys are conducted and attempts are made to analyze the data. Since so many of the researchers have little notion of exactly what they want to find out, the analyses often appear diffuse and purposeless.

CURRENT THRUSTS IN URBAN AND REGIONAL ANALYSIS

The preceding review of the time-budget concept serves as an introduction. Out of these roots there has arisen an interest on the part of urban and regional researchers in the use of time-budget analysis in both theoretical and planning applications.[37]

<u>Time and Space</u>

The primary difference between the time-budget studies discussed to this point and the work to be discussed in geographic and planning research centers on the fact that a spatial dimension is explicitly

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[37] For reviews of time-budget analysis in both theoretical and planning applications, see: Gutenschwager, op. cit., pp. 381-386; Trevor MacMurray, "Aspects of Time and the Study of Activity Patterns," <u>Town Planning Review</u>, 45 (April, 1971), pp. 195-209; and, F. Stuart Chapin, Jr., "The Use of Time-Budgets in the Study of Urban Living Patterns," <u>Research Previews</u> (The University of North Carolina), 13 (November, 1966), pp. 1-7.

included in planning and spatial analyses while, heretofore, the spatial concerns have been submerged. Hence, the planning researcher sees the activity choice occurring within the dimensions of time and space, and carries his time-budget survey beyond a concern for the when, what, and with whom to also include the "where" of activity choice.

During the period immediately following the Multinational Survey, there occurred a noticeable increase in the use of time-budgets and their logical extension, the "time-space budget."[38] The period can be characterized by an ever-increasing sophistication in conceptual approaches to time-budget analysis. A preoccupation with accounts of human time allocation as ends in themselves has passed, to be replaced by a search for theory of human behavior in time and space.

Human behavior, though highly variable, does display some marked temporal regularities because of physiological, physical, and social constraints. Activities occur in a time-space continuum: there are temporal regularities inherent in spatial regularities, and temporal rhythms obviously vary over space. Although this premise has been advanced by a number of researchers over the past decade, their conceptual apparatus used to investigate human time-space behavior differs considerably. The ensuing discussion attempts to highlight the various conceptual approaches evolving over the past decade in North America and Western Europe (Figure 3).

[38] James Anderson, "Space-Time Budgets and Activity Studies in Urban Geography and Planning," Environment and Planning, 3 (1971), pp. 353-354.

TIME NORTH AMERICA WESTERN EUROPE EASTERN EUROPE

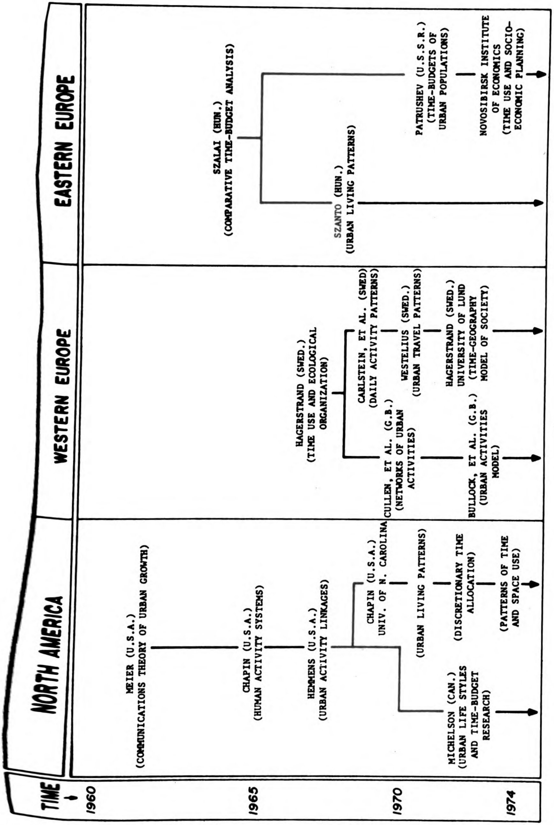
TIME
1960
1965
1970
1974
NORTH AMERICA
WESTERN EUROPE
EASTERN EUROPE
MEIER (U.S.A.) (COMMUNICATIONS THEORY OF URBAN GROWTH)
CHAPIN (U.S.A.) (HUMAN ACTIVITY SYSTEMS)
HEMMENS (U.S.A.) (URBAN ACTIVITY LINKAGES)
CHAPIN (U.S.A.) UNIV. OF N. CAROLINA
(URBAN LIVING PATTERNS)
(DISCRETIONARY TIME ALLOCATION)
(PATTERNS OF TIME AND SPACE USE)
MICHELSON (CAN.) (URBAN LIFE STYLES AND TIME-BUDGET RESEARCH)
HAGERSTRAND (SWED.) (TIME USE AND ECOLOGICAL ORGANIZATION)
CULLEN, ET AL. (G.B.) (NETWORKS OF URBAN ACTIVITIES)
BULLOCK, ET AL. (G.B.) (URBAN ACTIVITIES MODEL)
CARLSTEIN, ET AL. (SWED) (DAILY ACTIVITY PATTERNS)
WESTELIUS (SWED.) (URBAN TRAVEL PATTERNS)
HAGERSTRAND (SWED.) UNIVERSITY OF LUND (TIME-GEOGRAPHY MODEL OF SOCIETY)
SZALAI (HUN.) (COMPARATIVE TIME-BUDGET ANALYSIS)
SZANTO (HUN.) (URBAN LIVING PATTERNS)
PATRUSHEV (U.S.S.R.) (TIME-BUDGETS OF URBAN POPULATIONS)
NOVOSIBIRSK INSTITUTE OF ECONOMICS (TIME USE AND SOCIO-ECONOMIC PLANNING)

FIGURE 3.

Activity Conceptual System

Apart from some of the Russian examples,[39] the longest tradition in the use of the time-budget approach in urban planning is found in the work of Chapin, his students and research associates at the University of North Carolina.[40] Drawing primarily on ideas from within planning, Chapin first proposed that the city be viewed in terms of systems of activities. For more than a decade, Chapin has been intimately concerned with the planning and policy implications of the relationships between urban space, time, and activity. Until then, planners and geographers alike had not sought to record the activity dynamic of how the environment is used, and the activity component "of human time allocation ... is missing from the available urban accounting system."[41] "Planners have jumped directly into land use studies, essentially studying the effects of activity systems rather than seeking to define and understand activities themselves as producers of land-use patterns."[42] The behavioral antecedents of land use are not adequately represented by the usual constants and proxies of mapping techniques.

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[39] Szalai, The Use of Time, op. cit., pp. 838, 861-867.

[40] For some of the earliest statements by Chapin, see: F. Stuart Chapin, Jr., ed., Urban Land Use Planning, 2d ed. (Urbana, Ill.: University of Illinois, 1965), pp. 221-253; and, F. Stuart Chapin, Jr. and Henry C. Hightower, "Household Activity Patterns and Land Use," Journal of the American Institute of Planners, 31 (August, 1965), pp. 222-231.

[41] Richard L. Meier, A Communications Theory of Urban Growth (Cambridge, Mass." The M.I.T. Press, 1962), p. 303.

[42] Chapin, op. cit., p. 221.

Origins of the Approach. Mitchell and Rapkin were among the first researchers to suggest the relationship between activities and the spatial structure of the city.[43] Their work undoubtedly has had considerable impact upon urban transportation planning. Although their concept of activities is narrowly restricted to travel behavior, their statement of the role of activities in the city anticipates the formulation offered by Chapin nearly ten years later.[44]

Another crucial influence in the development of the activity approach was Meier's proposal to use time allocation as a measure of well-being of urban residents. The amount and variety of free-time activities available to people in the city could provide a form of social accounting.[45] Meier was also among the first to suggest the notion of a time-space budget, realizing that the allocation of time is closely linked to the use of space.[46]

Urban Activity Systems. Chapin synthesizes these two approaches into a theoretical framework of urban activity systems. An urban modifier is used to indicate the metropolitan community as a convenient study locale. In a systems framework, the metropolitan community is

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[43] Robert B. Mitchell and Chester Rapkin, Urban Traffic: A Function of Land Use (New York: Columbia University Press, 1954).

[44] Chapin, op. cit., pp. 221-253.

[45] Meier, "Human Time Allocation," op. cit., pp. 27-30; Meier's impact on the purpose and directions of Chapin's research can be found in: F. Stuart Chapin, Jr., "Activity Analysis or the Human Use of Urban Space," Town and Country Planning, 38 (July/August, 1970), pp. 345-348.

[46] Meier, A Communications Theory of Urban Growth, op. cit., pp. 48-59.

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conceived as a series of interrelated activity systems fashioned around the pursuits of various entities—persons, firms, voluntary organizations, churches, governments, and other institutions. These entity categories are seen, in turn, to consist of subcategories within which individuals act in certain similar, purposive ways and, at the same time, respond to certain more or less common constraints. Thus, the person category is seen to consist of some set of subcategories (e.g., various socioeconomic classes, stages in the life-cycle, etc.), each consisting of persons which as a class are seen to follow similar lifeways.[47]

In the activity system rationale, time allocation is seen as a means of studying how human activity affects and is affected by the environment and how they jointly influence the structure and functioning of the metropolitan community. It conceives of time as a resource allocated by individuals in the pursuit of their everyday affairs. Through measures of time allocation and the use of a systems framework, possibilities are foreseen of analyzing interrelationships between activities and population and those of metropolitan area assemblages of firms, governments, various organizations, and other institutional agencies. In contemporary society, daily life is organized around time. And the time schedules of various institutions (e.g., work places, shops, service establishments, and public agencies) affect the time schedules

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[47] F. Stuart Chapin, Jr., "Activity Systems and Urban Structure: A Working Schema," Journal of the American Institute of Planners, 34 (January, 1968), p. 12.

of individuals and of one another. Moreover, the environment man has developed for himself, especially the facilities developed to accommodate his personal and his institutions' daily needs, also affect time schedules. For example, time spent in commuting or traveling to activity centers is a familiar measure for establishing how land use as an environmental variable affects activity patterns. Because of the complexity of dealing with time allocations of all entities in all of these pursuits, a general systems approach is thought to be useful in the study of interrelations involved and the dynamics of these systems.

Since "general systems theory seeks to classify systems by the way their components are organized (interrelated) and to derive 'laws' of typical patterns of behavior for the different classes of systems singled out by the taxonomy,"[48] it offers a useful framework in which to conceive of the organization within activity systems and the dynamic relationships between activity systems. Under this rationale, the behavior of a person, firm, or other entity is broken down into discrete "episodes" which have meaning to individuals as they go about their particular affairs. When episodes are found to serve similar purposes, they can be grouped at a more generic level into particular classes of activities as defined by some pre-established activity classification system. Thus, in the case of person entities, a variety of episodes can be grouped into classes such as work-related activities, socializing activities, homemaking activities, or activities involving

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[48] Anatol Rapaport's Forward to Modern Systems Research for the Behavioral Scientist, ed. Walter Buckley (Chicago: Aldine Publishing Co., 1968), xvii.

recreation and relaxation. It follows, then, that an activity system consists of a sequence of activities of some classified content and some specified order. More particularly, when an individual within an entity category--a person, a firm, a voluntary organization or some other entity--exhibits regularities in the content and ordering of its activities in time and space, this sequence is referred to as an activity system, a firm's activity system, and so on.[49]

The preceding, then, is a brief overview of the conceptual framework. Chapin's conceptualization differs from previous theoretical orientations in that it sees the city as composed of activities occurring not only over space, but also through time. This time-space frame of reference eventually led urban researchers to ask questions never before posed.

Urban activity systems encompass a wide range of possibilities. The work at the University of North Carolina focuses on "activities" as measurable components of living patterns in the urban scene, while time allocation serves as one of several dimensions, that include the type, number, and variety of activity choices, their sequence, and their spatial locus. Special attention is given to activity routines of urban residents functioning as individuals. But, since many person-activities are merged with institutional activities, the total system is of concern as well. Increasingly more detailed research has been

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[49]Phillip G. Hammer, Jr., and F. Stuart Chapin, Jr., Human Time Allocation: A Case Study of Washington, D.C. (Chapel Hill, N.C.: Center for Urban and Regional Studies, University of North Carolina, 1972), pp. 13-14.

conducted in an attempt to understand specific aspects of the whole problem. The ultimate goal, however, is to reverse the process and combine these results into a single theory of urban activity systems. The lineage of activity systems research is represented in Figure 4.

The first step taken to narrow the research from a global activity systems formulation was to restrict attention to one segment of the urban population--namely, heads of households and spouses of heads. This was done because of their important decision-making role in the household. The first small-scale surveys undertaken in Durham, North Carolina, had respondents complete a time-budget listing all activities performed on the preceding day, including the timing, location and duration of activities. The temporal (duration and frequency) and spatial dimensions of respondent's activities were analyzed. Respondents were also asked to "play" a trading-stamp game which was designed to elicit leisure time activity preferences.[50] Drawing on the trading-stamp ritual of modern-day retailing, the game is a device to simulate the way in which an individual might budget the use of his time for leisure. The results of the game were then compared with actual activity choices.[51] Patterns of activities at various temporal scales were discussed theoretically, with special consideration given to the effects of changes in daily and weekly activities on the important

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[50] F. Stuart Chapin, Jr. and Henry C. Hightower, "Household Activity Patterns and Land Use," Journal of the American Institute of Planners, 31 (August, 1965), p. 225.

[51] Ibid.; and, F. Stuart Chapin, Jr. and Henry C. Hightower, Household Activity Systems: A Pilot Investigation (Chapel Hill, N.C.: Center for Urban and Regional Studies, University of North Carolina, 1966).

life-cycle activity of moving behavior.[52] The important step, however, was the use of choice theory to explain the patterns of activities of urban residents.

Following his early surveys, Chapin outlined a working schema for the development of a conceptual framework for urban spatial structure using activity analysis and activity systems. Essentially, Chapin sees activity decisions as arising out of an evolutionary process involving motivation-choice-activity.[53] He suggests that motivation is derived from two sets of needs, fundamental and supplemental. Fundamental needs are involved with shelter, clothing, food, and so on, i.e., choices to minimize feelings of discomfort or deprivation. Supplemental needs for reason of achievement and status are requisite to a "full sense of well being" and require choices to maximize satisfaction. He suggests that each of these needs is satisfied by, or is sought for, in different roles and arenas, sometimes simultaneously and sometimes separately.

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[52]Chapin, "Activity Systems and Urban Structure," op. cit., pp. 16-17. Relating to the topic of life-cycle mobility, a current project by Michelson applies and tests many of the ideas and techniques of activity study, in analyzing the activity constraints that prompt residential relocation and the time-budget changes that occur, over time, as a result. See: William Michelson, "Discretionary and Non-discretionary Aspects of Activity and Social Contact in Residential Selection," The Form of Cities in Central Canada: Selected Papers, eds. L.S. Bourne, R.D. MacKinnon, and J.W. Simmons (Toronto: University of Toronto Press, 1973), pp. 180-198; and, Brian P. Holly, "Urban Life Styles and Environment: The Effects of Location and Residence on Behavior in a Time-Space Framework" (unpublished doctor's dissertation, Michigan State University, 1974).

[53]Chapin, "Activity Systems and Urban Structure," op. cit., p. 12.

In a discussion of the choice component, Chapin specifies the activity as output, with motivation and the values it represents forming the inputs to a final decision. "The context is the social system consisting of the environment and all other human activity relevant to the situation in hand."[54] He suggests that in making choices of activities and in budgeting his time, the individual attempts to find an optimal combination based on his needs for "security, achievement, status, and other needs essential to his sense of well-being."[55] The final output is, of course, his set of activities in various time scales: daily, weekly, annually, and throughout his entire life cycle.[56]

In examining the activity patterns that result for the motivation-choice-activity sequence, it is apparent that all three elements of the sequence must be influenced by the alternatives available, which quite obviously are numerous. One clear distinction may be drawn between those activities that occur in and out of the home. Chapin, through the use of time-budgets, conducted an

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[54] Ibid., p. 15.

[55] Ibid., p. 15.

[56] Activities are clearly cyclical. Some are daily--the trip to work, eating, some sort of recreation. Others may be weekly--grocery shopping, trips to the bank. Still others may be monthly, annual, or at even longer periods (e.g., the decision to move). A general discussion of cyclical activity is given by Chapin, Urban Land Use Planning, op. cit., pp. 221-253.

investigation on this division of the various activities which compose each subset.[57] In brief, the patterns observed resulting from the motivation-choice-activity sequence of urban residents are fundamental factors in many decisions that affect the physical structure of the urban area. At the same time, the components of the physical structure--the spaces adapted to various activities--exert an influence on the choices made. The situation is strongly analogous to the economic concepts of supply and demand and their interaction with price and production.

Next came the national surveys of activities in 1966 and 1969. In using these survey data, their interest focused on household time allocation, but largely ignored the spatial dimension. Thus, the research was quite similar to the time-budget studies reviewed earlier in this chapter. Efforts during this research phase were directed toward identifying factors significantly associated with the occurrence of various classes of activity in a weekday's itinerary. An additional result of this research was the construction of a typology of life styles based upon the activity patterns of groups distinguished by various social and economic variables.[58]

Further research was conducted in Washington, D.C., including an activities survey of the entire metropolitan area, as well as a

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[57] Chapin and Hightower, Household Activity Systems, op. cit.

[58] F. Stuart Chapin and Richard K. Brail, "Human Activity Systems in the Metropolitan United States," Environment and Behavior, 1 (December, 1969), pp. 107-130; and, F. Stuart Chapin, Jr. and Thomas H. Logan, "Patterns of Time and Space Use," The Quality of the Urban Environment, ed. Harvey S. Perloff (Baltimore: The Johns Hopkins University Press, 1969), pp. 305-332.

somewhat more intense survey in a low-income black neighborhood.[59] During this stage of the research, the focus narrowed to activities of a discretionary nature. Time-allocation to discretionary, or "free-time" activities was considered a most important indicator of differences between groups.[60] Attempts were made to account for discretionary activity choice in terms of both opportunity and propensity to engage in the activity. The latter included both preconditioning factors (i.e., background social variables that constrain choice such as sex, income, and occupational status) and predisposing variables (i.e., variables that stimulate choice, such as felt needs for security, social status, etc.). This represents the first detailed application of choice theory to activity selection.[61]

Further research is underway on the spatial patterning of activities which involves a combination of temporal and spatial allocation of activities into a more comprehensive theory of human activity systems. This phase is seen to be particularly important, for until now, it is unlikely that the technique can be adapted for practical use by urban planners and policy makers. The conception

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[59] Hammer and Chapin, op. cit.; and, F. Stuart Chapin, Jr., Edgar W. Butler, and Fred C. Patten, Blackways in the Inner City (Urbana, Ill.: The University of Illinois Press, 1973).

[60] F. Stuart Chapin, Jr., "Free Time Activities and the Quality of Urban Life," Journal of the American Institute of Planners, 37 (November, 1971), p. 411.

[61] See: Ibid., pp. 411-417; Hammer and Chapin, op. cit.; Chapin, et al., Blackways in the Inner City; and, Richard K. Brail and F. Stuart Chapin, Jr., "Activity Patterns of Urban Residents," Environment and Behavior, 5 (June, 1973), pp. 163-190.

of the city as a system of activities is still quite new. The utility of the approach for understanding urban phenomena, despite its popularity, remains to be proven. Still, an orientation encompassing both the temporal and spatial dimensions of human behavior is appealing and is well worth pursuing.

In summary, the activity systems research of Chapin and others is composed of two phases. The first, descriptive phase has been briefly sketched out above and summarized in Figure 4. In the descriptive phase, the concern has been with activity analysis which involves identifying the kinds of activity a population of individuals in the metropolitan community engages in over some defined period of time, classifying them, and then ordering the persons into groups on the basis of similarities in the occurrence or sequences of activities. The aim of this ordering process is to minimize within-group variation and to show variation between groups at significance levels sufficient to enable the investigator to draw inferences concerning the activity patterns of these groups in the population. The activities found to cluster under these arch types are treated as person systems and generalized to the appropriate subtotals in the population.[62]

The second and more recent phase has focused on the explanation and simulation of human activity systems. Just as Chapin has provided the impetus in the descriptive phase of urban activity

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[62]F. Stuart Chapin, Jr., "Activity Systems as a Source of Inputs for Land Use Models," Urban Development Models, Special Report No. 97, ed. George C. Hemmens (Washington, D.C.: Highway Research Board, 1968, pp. 81-83.

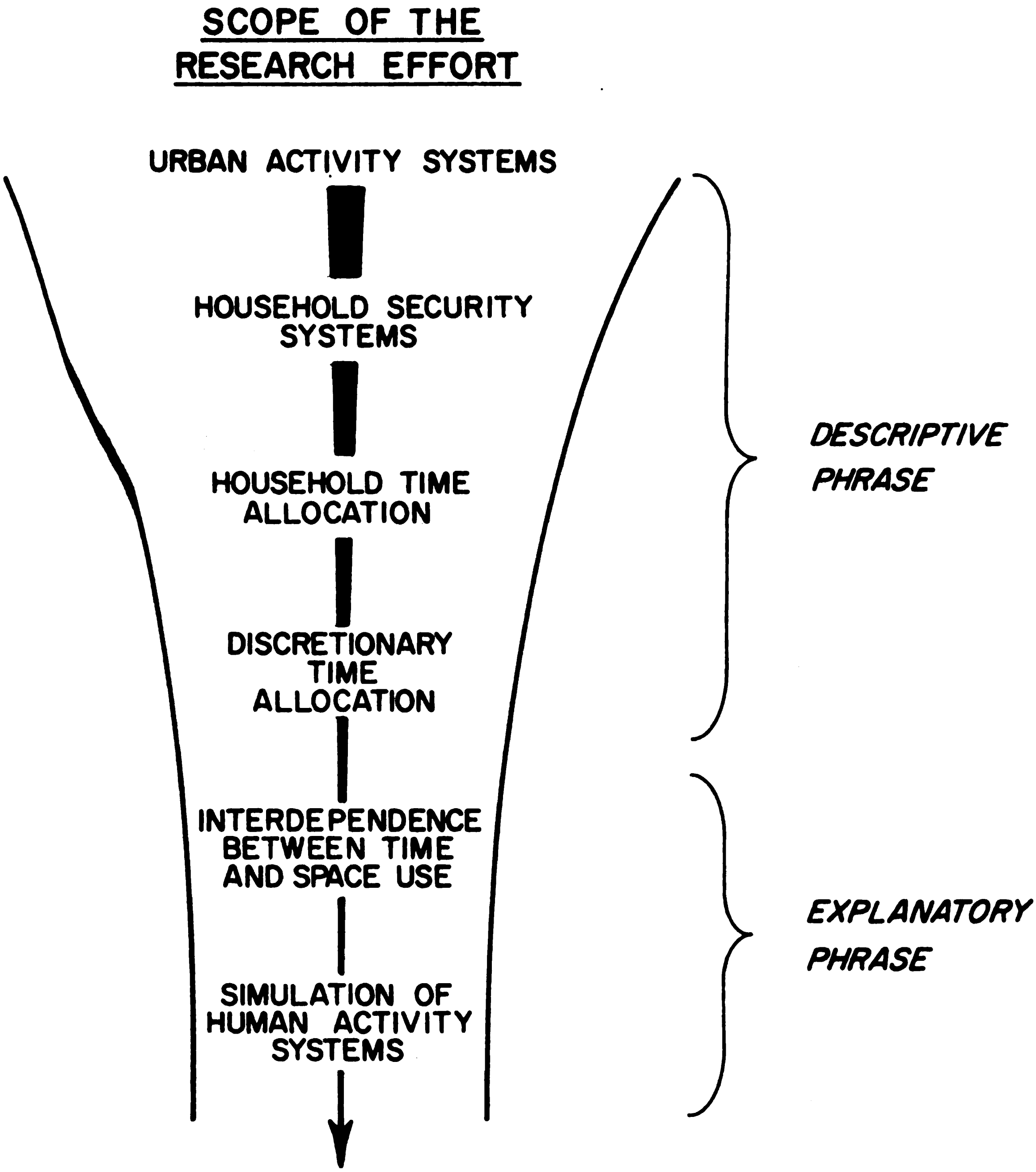

FIGURE 4.

DEVELOPMENTS IN ACTIVITY SYSTEMS RESEARCH analysis, so too has the work by Hemmens been the seminal force with regard to the modeling of human activity systems.[63] In the development of a capability for simulating the behavior of one or more urban activity systems, the concern shifts to acquiring an understanding of not only what patterns this arch type person's activities take, but why these patterns evolve. The concern is with the interdependencies of the temporal and spatial aspects of the flow of events—why activity patterns develop, what structures them, and how sequences in one system relate to those in another system. In short, in the simulation phase, the aim is to reproduce the regularities in the ordering of activities observed in the descriptive phase in such a way as to approach the sequencing, timing, and spatial distribution that occurs in reality.[64]

In conclusion, the studies by the North Carolina group have made considerable progress in quantifying the amounts of time which different groups spend on various sorts of activity and many interesting ideas have been generated—notably the trading stamp concept of activity choice. But despite the group's use of time-budget diary techniques to collect information, there has been very little in the way of developing either ideas or data relating explicitly to the

[63] George C. Hemmens, The Structure of Urban Activity Linkages (Chapel Hill, N.C.: Center for Urban and Regional Studies, University of North Carolina, 1966); and, George C. Hemmens, "Analysis and Simulation of Urban Activity Patterns," Socio-Economic Planning Sciences, 4 (1970), pp. 53-66.

[64] Brail provides a comprehensive discussion of modeling approaches to the simulation of activity systems; see: Richard K. Brail, "Activity Systems Investigations: Strategy for Model Design" (unpublished doctor's dissertation, University of North Carolina, 1969).

question of interdependence between activity choice decisions over time. The task of pattern recognition has not yet taken the form of identifying sequences of activities which can be viewed as activity modules or of trying to understand the processes which govern the integration of the individual's time-space behavior.

Time Use and Ecological Organization

Theoretical work on time use is surprisingly limited, given its considerable history. An interesting set of theoretical considerations relating to time-use and ecological organization have been presented by a group of Swedish geographers at the Royal University of Lund. The following is but a brief account of some of their studies that have a close connection with the work presented here.

Origins of the Approach. In a number of research projects recently emanating from Swedish geographers, the organizational aspects of society and of its substructures (e.g., manufacturing and industrial firms, political administrations, etc.) are the focus of interest.[65] When forming concepts and models, researchers have

[65] Some recent examples of this research thrust (in English) include: Gunnar Törnqvist, Contact Systems and Regional Development, Lund Studies in Geography, Series B, Human Geography, No. 35 (Lund: C.W.K. Gleerup, 1970); Allan R. Pred and Gunnar Törnqvist, Systems of Cities and Information Flows, Lund Studies in Geography, Series B, Human Geography, No. 38 (Lund: C.W.K. Gleerup, 1973), Olof Wärneryd, Interdependence in Urban Systems, Meddelanden från Göteborgs universitets geografiska institutioner, Ser. B, Nr. 1 (Göteborg: Kulturgeografiska institutionen, Göteborgs universitet, 1968); and a review of other studies, Claes-Frederik Claeson, "Systemic Approaches in Present Swedish Social Geography," Svensk Geografisk Årsbok, 44 (1968), pp. 140-150.

found inspiration and guidance in organization theory, system theory, and like modes of thinking. Not long ago, for example, location of industry was viewed mainly in terms of the transportation costs of goods. Today's researchers seem to find it more profitable to look into the links of communication, both internal and external, between functional units of firms and organizations. These links require nearness or allow spatial independence in quite clearcut ways which seem to give a more profound understanding of locational behavior than earlier approaches, as well as better clues as to how influence and control might be exerted.[66]

Hägerstrand suggests that not only firms and organizations may be studied in terms of linkages and systems, but also the very local aspects of the modes of daily life may be analyzed in a related manner. He writes further that:

> One of the questions asked when the discussion of future regional and urban policy and planning started was how exactly did the physical and social environment--for example as reflected in city size--affect the life of individuals and families? In order to find out, we need a picture of how the daily activities of people are canalized through time-space.[67]

<u>Hägerstrand's "Time-Geography" Model of Society</u>. Throughout Hägerstrand's writings on migration, there is a common underlying theme linking social communication networks and "the changes in time

[66]Wärneryd, op. cit., pp. 19-22.

[67]Torsten Hägerstrand, "Methods and New Techniques in Current Urban Research and Planning," Plan: Tidskrift för planering av landsbygd och tutorter, 22 (1968), p. 10.

and space jointly experienced by the individual and society as a whole."[68] In recent years Hagerstrand has experienced a growing preoccupation with the fate of the individual in an increasingly complicated environment. This combination of circumstances has led him and his research associates to undertake an ambitious project to devise a "time-geography model of society" (en tidsgeografisk samhällsmodell) for the purposes of guiding urban and regional planning and locational policies in general.[69]

The basic problem of the future as seen by Hägerstand, is how society should be organized and how settlement patterns ought to be

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[68]See, for example, some of Hägerstrand's more recent statements on the topic of migration: Torsten Hägerstrand, "Geographical Measurements of Migration: Swedish Data," Les déplacements humains, ed. J. Sutter (Monaco: Entretiens de Monaco en Sciences Humains, 1962), pp. 61-83; and, Torsten Hägerstrand, "On the Definition of Migration," Väestöntutkimuksen vuosikirja [Yearbook of Population Research in Finland], 11 (1969), pp. 64-72.

[69]Some published reports of the project include: Torsten Hägerstrand, "A Socio-environmental Web Model," Studier i planeringsmetodik, ed. G.A. Eriksson, Memorandum från ekonomisk-geografiska institutionen, Nr. 9 (Abo [Turku], Finland: Handelshögskolan vid Åbo akademi [Åbo Swedish University School of Economics], 1969), pp. 19-28; Torsten Hägerstrand, "What About People in Regional Science?" Papers, The Regional Science Association, 24 (1970), pp. 7-21; Torsten Hägerstrand, "Tidsanvändning och omgivningsstruktur," Urbaniseringen i Sverige: En geografisk samhällsanalys. Bilagadel I till Balanserad regional utveckling, Statens offentliga utredningar, 1970: 14, bil. 4 (Stockholm: Esselte tryck, 1970); Torsten Hägerstrand, "Frihet och tvång i Stockholm och Ruskele. Några observationer av individ och familj i skilda svenska omgivningar," Forskning och samhällsutveckling (Stockholm: AB Allmänna Forlaget, 1970), pp. 66-77; and, Torsten Hägerstrand, "Tätortsgrupper som region-samhällen: Tillgången till förvärvsarbete och tjänster utanför de större städerna," Regioner att leva i, Expertgruppen för Regional Utredningsverksamhet (Stockholm: AB Allmänna Forlaget, 1972), pp. 141-173.

structured so as to ensure a "livable" day-to-day existence for the individual. Or, given the time restrictions on human movement and the fact that every economic and noneconomic activity is space-consuming, how ought the system of human activities to be organized spatially so as to provide substance to that portion of each individual's environment which lies outside the realm of income acquisition.[70]

In order to assault the details of his broadly defined problem, a Swedish research project on "time-budgets and ecological organization" was initiated during the mid-1960's by Hägerstrand and other Swedish geographers.[71] The purpose of the project was to discover in what way urban environments affect and constrain the daily activities of individuals, to see how activity schedules can be accommodated in a "fixed" spatial-temporal system. The project is characterized by a fresh approach to location problems, using notions derived from organization and systems thinking, and new modes of classification.[72] In Hägerstrand's time-budget study of household

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[70] Torsten Hägerstrand, "The Impact of Social Organization and Environment upon the Time-use of Individuals and Households," Plan: Tidskrift för planering av landsbygd och tutorter, 26 (1972), pp. 24-25.

[71] Torsten Hägerstrand, Arbetsplan rörande projektet--Tidsanvändning och miljö (Lund: Institutionen for kulturgeografi och ekonomisk geografi vid Lunds universitet, 1967).

[72] Swedish geographic research is not necessarily technique-oriented, but in their pragmatism, the Swedes have in fact developed new techniques and ideas with both theoretical and utilitarian value. For more comprehensive reviews of concepts and methods coming from Swedish human geography, see: Allan R. Pred, "Urbanization, Domestic Planning Problems, and Swedish Geographic Research," Progress in Geography: International Reviews of Current Research, Vol. 5, eds. Christopher Board et al. (New York: St. Martin's Press, 1973), pp. 1-76; James Anderson and John Goddard, Some Current Approaches to

activity patterns, individuals are classified not in conventional socio-economic terms but in terms directly related to how these activities are constrained, and to the constraints they impose on other members of their household.

Relevant components of the "fixed" spatial-temporal system include given locations (houses, workplaces, shops) communications networks (roads, telephone, public transport routes), and a variety of institutional timetables (work hours, opening and closing times of service establishments, transport timetables). These interrelated components of the urban system are influenced by activity patterns, but at the same time, they also restrict the activities of individuals and of households. They result in spatial and temporal regularities in human behavior. In addition, human behavior displays inherent "pattern" due to other factors of which the physiological (e.g., food and sleep requirements) are perhaps the most important. Physiological needs, that provide basic motivation for many activities, are themselves time-consuming and have a direct influence on people's time-use and movements. But, while such factors are taken into account, as they were in the research of Chapin, the Swedish project focuses on relationships between daily behavior and the spatial and temporal variations in the environment.[73]

Human Geography in Sweden, Graduate Discussion Paper No. 33 (London: London School of Economics and Political Science, 1969); and, Claeson, op. cit.

[73]Two of the earliest pieces of documentation on the project include: (1) a comprehensive annotated bibliography of relevant time—budget studies--T. Carlstein and Solveig Mårtensson, Bibliografi röramde tidsanvändning och ecologisk organization, Urbaniseringsprocessen, rapport nr. 3 (Lund: Institutionen för kulturgeografi och ekonomick geografi vid Lunds universitet, 1967); and (2) a description,

<u>Time-geographic Conceptualization</u>. In his time-geography model, Hägerstrand views every individual as being surrounded by an "environmental structure" (omgivingsstruktur), or a pattern of activity or resource opportunities (conceived very generally to include, for example, employment, services, social and informational contacts, leisure-time pursuits, and a variety of resource goods) that are necessary to satisfy needs and wants and which are distributed unevenly in time and space. The environmental structure is relative to the individual; its composition depends on one's information and economic resources and psychological make-up. The time-space movements of any individual can be depicted graphically by compressing geographical space into a two-dimensional surface and representing the scale and direction of time along a vertical axis (Figure 5). Seen from this perspective, movement is transformed into geometrical form, which permits us to view an individual as a unique object, whose time-geography (defined by time and space coordinates) proceeds along a path. While earning a living and satisfying one's informational, social, and recreational needs and wants, an individual in time-space describes such a path, starting at a point of birth and terminating at a point of death. Depending on the perspective desired, the individual path may be strictly defined either as a "daily-path" or a "life-path" through the use of time and space coordinates.[74]

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based on survey work of the daily time-use and movements of household members in a number of selected households--T. Carlstein, Bo Lenntorp, and Solveig Mårtensson, <u>Individers dygsbanor i några hushållstyper</u>, Urbaniseringsprocessen, rapport nr. 17 (Lund: Institutionen för kulturgeografi och ekonomisk geografi vid Lunds universitet, 1968).

[74] Hägerstrand, "Tidsanvändning och omgivingsstruktur," op. cit., pp. 14-15.

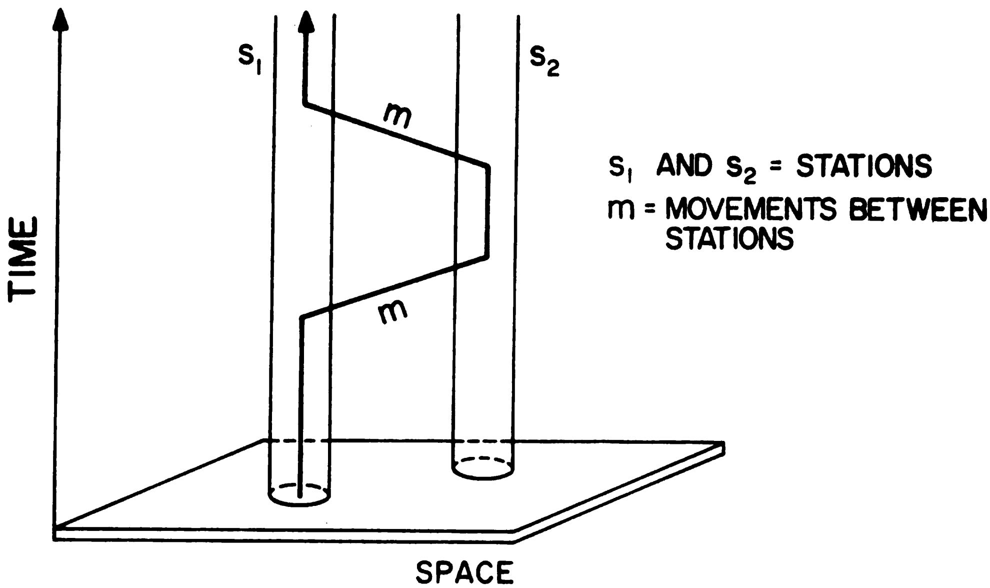

FIGURE 5.

AN INDIVIDUAL'S PATH IN TIME-SPACE

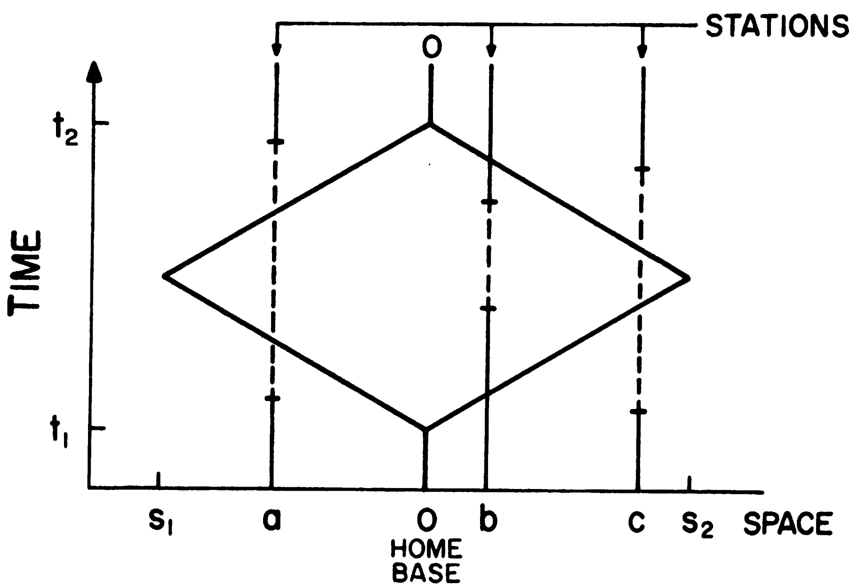

FIGURE 6.

TIME-SPACE IN TWO DIMENSIONS: THE TIME-SPACE PRISM. The prism, or "budget-space," represents the time-space frame within which a person can move.

While engaging in production, consumption, and social activities, the individual stops at physically permanent "stations" (e.g., homes, workplaces, and recreation locations), or locations where movement is not observed over time. Individuals "spend time" at particular stations, send messages, and move between stations to satisfy various needs and perform specific functions. Hägerstrand's station concept is quite flexible in terms of both its time and space scales. For instance, a city of residence, viewed as a station from the "life-path perspective," can be dissolved into a complex of stations when viewed from a "daily-path perspective."[75]

The environment with which the individual path comes in contact can be viewed at two scales. First, the "daily-living environment" is the geographical space that a person can reach within a single day and still return to his home base. Theoretically, it has a fixed definable outer boundary (as seen in Figures 6 and 7), owing to the capability of available means of transport to carry the individual back and forth within a fixed time-interval. Naturally, the space within the boundary of the daily-living environment (or daily-prism) is never fully exploited in every direction, but there remains the potential for choice of stations, such as workplace, shopping, recreation, and social contacts.

The second scale exposes those places in which the individual might choose to reside during longer periods of his lifetime. The restrictions imposed on an individual's life-path are not quite as

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[75] Ibid., p. 15.

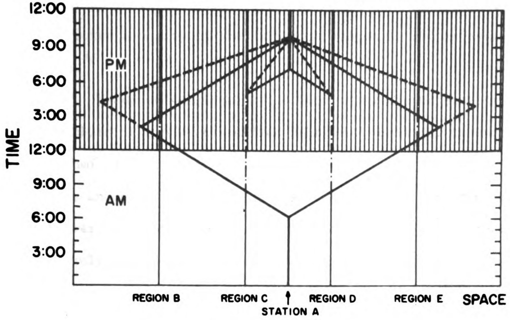

FIGURE 7.

TRANSPORT MODES AND THE DAILY PRISM

DAILY PRISM ILLUSTRATING THE RANGE FROM REGION A GIVEN CERTAIN SPEEDS OF MOVEMENT IN COMBINATION WITH TIME RESTRICTIONS. WITHIN REGIONS C AND D, THE MAXIMUM POSSIBLE TIME-STAY IS 8 HOURS. WITHIN REGIONS B AND E, THE MAXIMUM TIME-STAY IS 3 HOURS. OUTSIDE REGIONS B AND E TIME-STAY IS NOT SUFFICIENT FOR A CONTACT. IF TRAVEL TIMES ARE ASYMMETRIC (E.G., ONE MODE OF TRANSPORT IN ONE DIRECTION AND A DIFFERENT MODE IN THE OTHER) THIS MAY MAKE IT POSSIBLE TO EXTEND TIME-STAYS OR TO REACH OTHER REGIONS.

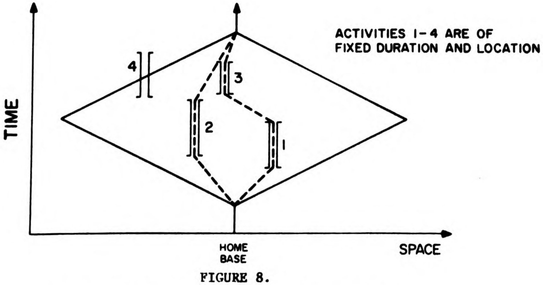

FIGURE 8.

FEASIBLE PATHS WITHIN THE TIME-SPACE PRISM

FROM HOME BASE THE CHOICES LIE BETWEEN 1 AND 3 ON THE ONE HAND, OR 2 ON THE OTHER HAND. ALTHOUGH 3 BEGINS AFTER 2 ENDS, THE INTERVENING TIME IS TOO SHORT TO PERMIT MOVEMENT BETWEEN BOTH STATIONS. 4 CANNOT BE CHOSEN SINCE ITS END POINT LIES BEYOND THE TIME-SPACE PRISM.

clear as those imposed on the daily-path environment and, consequently, the outer boundary of the life-path region is not as easily determinable.[76]

Needs and desires of the individual can be considered as variables that make themselves felt, more or less, in a regular rhythmical way as time passes.[77] The satisfaction of an individual's needs and wants usually requires movement from one station to another. However, the individual's set of potentially possible actions is severely restricted by the presence of other people, the complexity of private and public decisions, and social and behavioral norms. The individual's freedom to move from station to station is also limited by a number of more obvious physical and physiological restrictions. Thus, time-space paths become captivated in a network of constraints of which they can never free themselves. Constraints can become

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[76]Ibid., pp. 16–17. Although Hägerstrand suggests that the life-perspective environment has no "ineluctable outer boundary," Jacobsson has documented that such a region for the majority of the present day Swedish population does not usually extend for more than some ten kilometers in any direction. Within such a range occurs most of the movement. See: A. Jacobsson, Omflyttningen i Sverige 1950–1960: Komparativa studier av migrationsfalt, flyttningsavstånd och mobilitet, Meddelanden från Lunds universitets geografiska institution, Avhandlingar 59 (Lund: Lund universitets geografiska institution, 1969), pp. 78–83.

[77]Westelius has attempted to model the cyclical nature of needs and desires and their satisfaction in the context of urban travel behavior; see: Orvar Westelius, "The Individual Pattern of Travel within an Urban Area--An Interaction Between the Need of Contact with Different Activities and the Structure of the Location Pattern," Plan: Tidskrift för planering av landsbygd och tutorter, 22 (1968), pp. 92–100; and, Orvar Westelius, The Individual's Pattern of Travel in an Urban Area, Document D-2 (Stockholm: Statens institut för byggnadsforskning, 1972).

imposed by society and interact against the will of the individual.[78] Normally, the individual has limited means for influencing these varied restrictions, most of which fall into one of three general categories:

1. Capability constraints, being those physiological needs which regulate behavior, on the one hand, and distance restraints or areas within reach in the time available, on the other;
2. Coupling constraints, being those paths within the capability constraints, the timing and synchronization of activities, and the bundles of converging paths facilitated by telecommunications; and,
3. Authority constraints, being time-space entities under the control of particular individuals for groups (e.g., patterns of ownership and jurisdiction); the hierarchy of domains and the resulting limits on accessibility imposed by those in control.[79]

The individual is thus seen by Hägerstrand to operate within this complex of constraints which together constitute a "highly institutionalized power- and activity-system."[80]

In summary, Hägerstrand envisages the individual's day to be undertaken in a two-dimensional time-space framework, in which

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[78] Hägerstrand, "What About People in Regional Science?" op. cit., p. 12.

[79] Ibid., pp. 12-14.

[80] Ibid., p. 12.

a person's path through the day is structured by the fact that at certain times he has to be at particular places and that in order to meet these commitments his area of potential movement in the intervening periods is limited to varying extents depending on the type of transport available to him. His choice of activities in these periods, between those activities which were time and space fixed, was limited to those which could be undertaken within the time-space prism defining the feasible region of activity.

The main features implicit in this model of daily behavior are, therefore, the notion that certain activities are fixed in both time and space, the division of the day into two types of period--fixed and unfixed, and the delimitation of feasible prisms within which the entire day is confined, but more specifically, within which unfixed activities may be performed. Thus, the very essence of the model is the explicit demonstration of the vital interdependence of time-space decisions. The decision of where to shop at 3:00 p.m. is no longer taken in the context of a purely theoretical and cross-sectional "action space" surrounding the individual's home-base, but is taken in terms of a highly specific time-space prism anchored between the individual's location at that time and his next forecast commitment (Figure 8).

Applications of the Model. In the past, time-use studies have been mainly concerned with average or "typical" time allocations to various activity categories for various population classes (e.g., the Multinational Comparative Time-Budget Research Project). Where the time dimension has been considered in spatial analysis, it has been given only partial treatment, being used as a measure of distance or disutility, usually without explicit reference to overall time-budgeting.[81] In contrast, the Lund project attempts an integrated analysis of time use, with time spent overcoming physical distance as just one general category in the time-budget, but a category which constrains other time-uses. And, unlike many of the sociological time-use studies, the project does not attempt to typify populations or areas by time-use. It is mainly concerned with the sequence, timing, and location of activities (i.e., organizational aspects of time-use) in particular environments. These co-ordination aspects exist in greatest degree in large cities.[82]

In the first stage of the "time-use and ecological organization" research project, surveys on time-budgeting were completed in Lund and Stockholm, following an exploratory study in a small village in Skåne.[83] The daily-paths of individuals from different household types were recorded on time-budgets. These diaries showed the organization in time-space of their activities, both individually and as households. The samples were small and no attempt was made to

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[81] James Anderson. Time-Budgets and Human Geography: Notes and References, Graduate Discussion Paper No. 36 (London: London School of Economics and Political Science, January, 1970), p. 11.

[82] Meier, A Communications Theory of Urban Growth, op. cit., pp. 48-54.

[83] Carlstein et al., op. cit.

obtain samples which were statistically representative, of either areas or households.[84]

Obtained in the Lund and Stockholm questionnaire interview were data on household composition, facilities, modes of transportation, and the frequency of various activities which do not follow a daily cycle. For individual members there were questions regarding the frequency and location of recreation activities, school activities, and work-related activities. On the following day, members were required to record on time-budget diaries their activities, the respective locations visited, mode of transportation, and also telephone contacts.

The published results of these surveys used, for tabular and graphic presentation, a five-category classification of household members: (1) full-time worker, (2) part-time worker, (3) students, (4) children under seven requiring care, and (5) home-centered individuals (e.g., housewives and elderly, but not those whose workplace is in the home). This classification is related to the duration and frequency of activities outside the home. Combinations of these individual "types" gave a range of household compositions.[85]

The time-budgets of the members of thirteen selected households were represented diagrammatically. A sample two-dimensional diagram is presented in Figure 9, where the vertical axis defines the 24-hour

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[84]Ibid., p. 27. Given the quality of official Swedish census data, these surveys did provide realistic sets of activity schedules which could be assigned to households in areas not surveyed.

[85]Ibid.

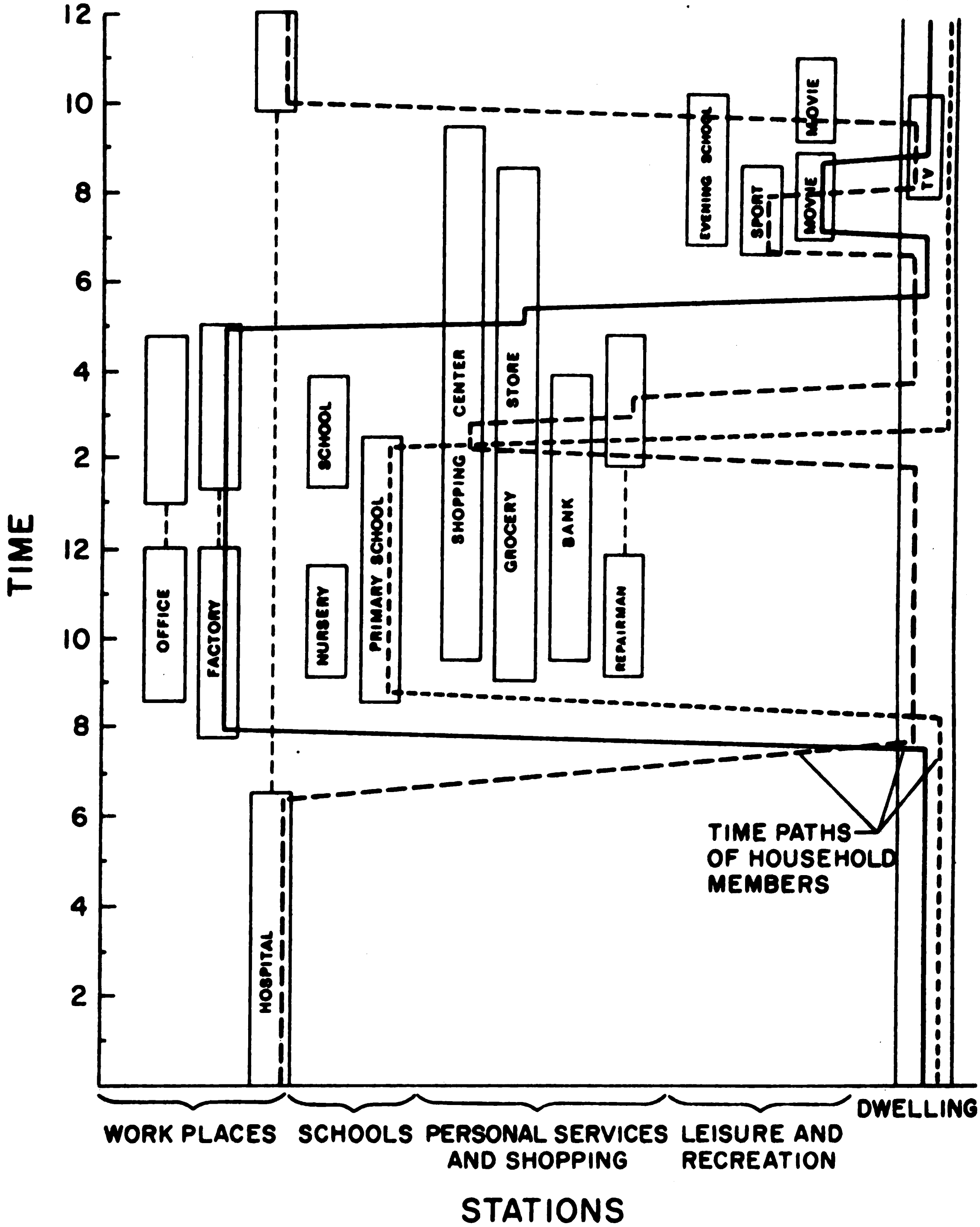

FIGURE 9.

TIME-PATHS AND INTER-STATION MOVEMENTS

period, and the horizontal axis is divided into seven station categories. Activities are defined in terms of stations visited; each station has three divisions that indicate different stations in that category. In Figure 9 an individual's time-use (or time-path) is shown by a continuous line, vertical segments represent time-periods spent at particular stations; sloping segments represent travelling-time between stations.

Since it is difficult to adequately represent the spatial dimension in this type of diagram, space is only treated implicitly. Thus, the distance between stations is a component of travel-time and not a measure of spatial separation. The authors provide interpretations to such diagrams according to background information on household members, their available means of transport, telephone calls, mealtimes, and home location (in relation to workplaces, shops, and service locations). Using examples from these selected time-budgets, various types of activities (e.g., physiological, contractual, recreation, etc.) and some facets of household and family organization are discussed. By portraying graphically the different activities of family members with specific reference to spatial settings and time, it is possible to observe the functioning of the family as a system.[86]

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[86] This type of graphical analysis is quite versatile, and Michelson, for example, suggests that one can learn from it at what age and under what environmental conditions children become independent of their parents for specific purposes. "Since the accomodation of children is an extremely sensitive aspect of current housing programs, this would appear to be a promising analytical tool to provide information for fruitful design." See: William Michelson, Selected Aspects of Environmental Research in Scandinavia, Research Paper No. 26 (Toronto: Centre for Urban and Community Studies, University of Toronto, March, 1970), pp. 8-9.

In more recent reports that relate to Hägerstrand's time-geography model, there has been more explicit treatment of spatial aspects of time-use—station locations, means of transport, travel-times at different times of day, institutional timetables, and variability in service standard between stations in the same category.[87] Lenntorp has developed a computer model to determine the alternative station-to-station movements and daily paths of individuals in a given environment.[88] In conjunction with this, information on the locational pattern and opening hours of eight types of stations in nine differently characterized urban environments has been gathered and restrictions on contact possibilities have been charted.[89] Using a time-geographic perspective, Sweden's regional variations in the accessibility to dental care, eye clinics, apothecaries, libraries, and other services have been studied and interpreted.[90] Hägerstrand himself has embellished his model in order

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[87]Hägerstrand, "Tidsanvändning och omgivingsstruktur," op. cit.; Solveig Mårtensson, Tidsgeografisk beskrivning av stationsstruktur, Urbaniseringsprocessen, rapport nr. 39 (Lund: Institutionen för kulturgeografi och ekonomisk geografi vid Lunds universitet, 1970); Bo Lenntorp, Tidsgeografiska synpunkter på uppläggning av transport-analyser—Sammanfattning av några föredrag, Forskagruppen i kultur-geografisk process- och systemanalys (Lund: Institutionen för kul-turgeografi och ekonomisk geografi vid Lunds universitet, 1973).

[88]Bo Lenntorp, PESASP--en modell för beräkning av alternativa banor, Urbaniseringsprocessen, rapport nr. 38 (Lund: Institutionen för kulturgeografi och ekonomisk geografi vid Lunds universitet, 1970).

[89]Mårtensson, op. cit.

[90]Hägerstrand, "Tidsanvändning och omgivingsstruktur," op. cit.

to explore, empirically and theoretically, the frequent local incompatability of existing activities in urban environments, and to evaluate the individual's possibilities for making use of his environment.[91] He chose to summarize the ways in which the daily time-uses of a population constitute a system in which activity bundles are dependent upon one another. This necessitates very complex models, which Hägerstrand argues, must be operationalized through computer simulation.[92] It is not possible to go into detail showing how the simulation proceeds analytically. However, the basic scheme is as follows:

Step 1. Assume a "population system" and a related "activity system" in timetable terms. The population system is comprised of all individuals in an area and their biological and social relations to one another. The daily time-income is the 24 hours x the total number of inhabitants. Since needs, wants, and obligations vary according to age, one can imagine the individuals in question, who are tied together in households, as being depicted by daily lines arranged from the youngest to the oldest (Figure 10a). The activity system, on the other hand, consists of all those activities performed at a given location, regardless of their necessity or value. These

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[91] Hägerstrand, "Tätortsgrupper som regionsamhällen," op. cit. See also: Torsten Hägerstrand, "En rättvis stadsstruktur," Plan: Tidskrift för planering av landsbygd och tutorter, 24 (1970), pp. 112-119.

[92] Hägerstrand, "Methods and New Techniques in Current Urban Research and Planning," op. cit., p. 11; and, Hägerstrand, "The Impact of Social Organization and Environment," op. cit., p. 29.

time-consuming activities are seen as a whole, detached from the local population (Figure 10b).

Step 2. Sieve the population and activity systems through an environment. Unlike the situation represented in Figure 10b, all individuals do not have identical time and activity budgets. Rather, the activity system is divided into separate "time packages." Each of these "seeks a bearer in the population." Or, oppositely, each individual picks his way through a series of activity bundles in the offered system. The matching procedure of individuals and activities must occur within the framework of two unavoidable physical restrictions. First, once an individual is matched to and participates in a specified activity bundle at a given time and place, he cannot be somewhere else doing something else at the same time. Secondly, once a "delegatable" activity bundle is fully staffed, it becomes closed to others.[93] Hence, two budget problems exist: how to divide the individual's allocatable time among activities; and how to delegate activities among the total population? Actual matching is only crudely suggested in Figure 10c. Due to the indivisibility of the individual, and the fact that movement from one activity bundle to another is time-consuming, the individual cannot participate in temporally successive bundles that are separated by excessive

[93]Figure 8b represents the "activity system" as being comprised of two major types: (1) Non-delegatable activities--those for which every individual is responsible and cannot be delegated to someone else (e.g., sleep, personal care, and eating); and (2) Delegatable activities--those which can be delegated either from one household member to another or between individuals of other large groups.

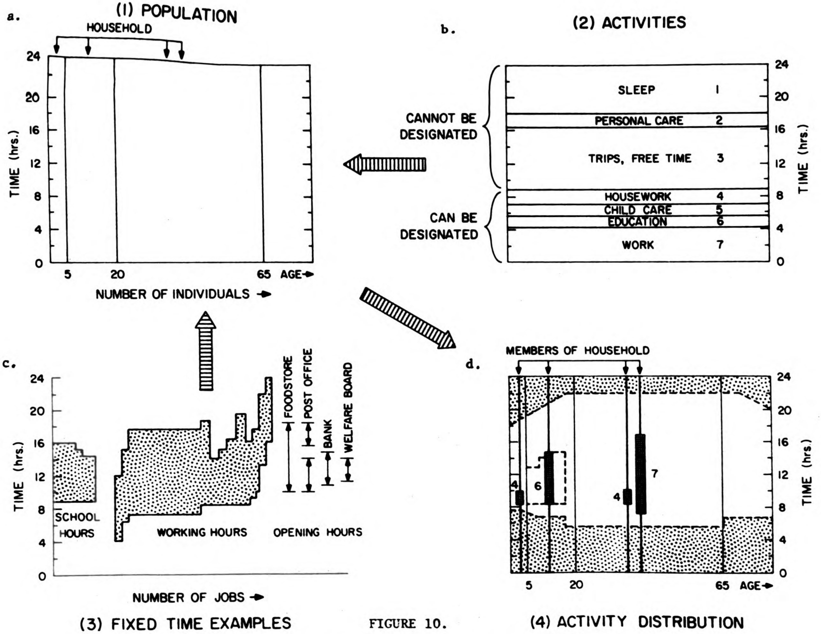

FIGURE 10.

MUTUAL ADJUSTMENTS OF THE POPULATION AND ACTIVITY SYSTEMS AS SEEN FROM A DAILY PERSPECTIVE (after Hagerstrand, 1972).

time-distances. From a daily perspective, it is the relationship of transport-time to the general time-budget situation which, at a given location, delimits the population and activities that can be matched.[94]

Step 3. Register the outcome as it is distributed among individuals in the population. The assigned activity schedules of individuals can then be matched to a "fixed" spatial-temporal environment. A simple graphic example of this is portrayed in Figure 10d. Hägerstrand's time-accessibility evidence for three urban areas demonstrates that problems of matching home, work-place, and service consumption are especially acute in those instances where the individual resides in a small town and opportunities are concentrated to a nearby larger central place and those cases where the individual does not have access to a car.[95]

Only through repeated runs will the model be able to show the ways in which activity schedules are accommodated within the system, and the constraints which the system imposes on behavior. In addition, alternatives in the system may be specified (e.g., change the locations or operating-hours of shops or workplaces) and their effects on activity patterns simulated. This has obvious relevance to planning--the probable effects of various proposed changes could be simulated and choices made between alternative proposals.

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[94]Hägerstrand, "Tätortsgrupper som regionsamhällen," op. cit., pp. 94-109; and, for a more detailed review of step 2 in English, see: Pred, op. cit., pp. 49-50.

[95]Hägerstrand, "Tätortsgrupper som regionsamhällen," op. cit.

A considerable part of the work is basic research dealing with modelling as such. A second component covers empirical testing of the patterns of constraints and opportunities inherent in typical present-day urban environments.

Two time scales have been chosen. One part of the work deals with daily and weekly activities. The other part takes a long-term perspective. Questions are asked about how life chances and environments are related. In neither case are broad statistical surveys of actual behavior essential. Emphasis is laid upon the working of constraints. And, these are in various ways sensed with the aid of ideal-typical sequences of actions which are confronted with actual or model environments. Questions are also asked about how these various environments perform as providers of employment, training, services, recreation, social communication, and free-time.

Hägerstrand's time-geographical analysis should have considerable appeal to scholars in other countries confronted with acute problems that arise from rapid urbanization. This should be the case because it provides a means of considering the plight of the individual while simultaneously attacking large-scale local or regional planning problems within a systems framework.

Other Approaches to Time-budget and Urban Activity Research

Following the lead of Meier, Chapin, and Hägerstrand, there has been an increased use of time-budgets in urban spatial research, particularly by planners, architects, and geographers in Great Britain (Figure 3). Much of the work in Britain is of a practical as opposed to a theoretical bent.[96] The two areas of interest include activity schedules of individuals and households, and institutional and work-place linkages. One focus is on overall time and space patterns of individuals or groups, plus particular activities, such as leisure, personal contacts and communication,[97] and travel.[98] The other focus is on personal activities, especially face-to-face information exchanges that often involve travel, with further attention on working hours and on spatial links and communications underlying functional organization of particular establishments.[99] Although the type of data obtained, the population and time-period, the classification of activities and locations, and the precision of location in time and space varies considerably with study purpose, the same time-budget has proven adequate for the different types of time-space behavior study.

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[96]James Anderson, Time-Budgets and Human Geography: Notes and References, Graduate Discussion Paper No. 36 (London: London School of Economics and Political Science, January, 1970), p. 7.

[97]See: Ian G. Cullen and Vida Godson, Networks of Urban Activities Volume II: The Structure of Activity Patterns, Final Report (London: Joint Unit for Planning Research, University College, London, 1971).

[98]The London Traffic Survey in 1964 and 1966 used a 24-hour diary to analyze aggregate volumes over time and space; London Traffic Surveys: 1964 and 1966, 2 vols. (London: Greater London Council, 1964, 1966).

[99]See, for example, Vida Nichols, An Institution in Metropolis, Seminar Paper NS 12 (London: Joint Unit for Planning Research, University College, London, 1969); and, Ian G. Cullen and Vida Godson, Networks of Urban Activities Volume I: Internal and External Linkages in an Urban University, Interim Report (London: Joint Unit for Planning Research, University College, London, 1971).

A group of architects affiliated with the Centre for Land Use and Built Form Studies of Cambridge University have also contributed to the growing body of literature on activity patterns and the spatial organization of urban areas. The influence of the built environment on the way in which individuals use those structures has long been at the heart of architectural studies.[100] Similarly, the relationship between the spatial organization of an urban area and the expected activity patterns of groups of individuals has been implicit in much of urban design. However, explicit relationships between the layout of a development area or even an entire new town and the patterns of interaction within them have seldom been demonstrated, principally because urban design, like its parent subject, architecture, has traditionally been an art rather than an "exact science." A number of leaps of faith have therefore been required in postulating a relationship between, for instance, urban density and levels of interaction.

The work at the Centre, some of which is described in the essays of Urban Space and Structures,[101] suggests that such leaps of faith may no longer be necessary. The work demonstrates how mathematical models applied to large bodies of data can be used to describe

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[100] Terence Lee, "The Effect of the Built Environment on Human Behavior," International Journal of Environmental Studies, 1 (1971), pp. 307-314.

[101] Leslie Martin and Lionel March, eds., Urban Space and Structures (Cambridge: Cambridge University Press, 1972). In particular, see the essays contained in "Part 2: Activities, Space, and Location," pp. 109-157.

both the relationship between building structures, space and time available, and potential use at the micro-scale. With the aid of such models, these researchers believe that the consequences of alternative building designs and urban spatial structures may be more readily evaluated in the planning stages.

On the basis of empirical evidence derived from individual "time-space budgets" gathered in a number of British universities, these researchers have demonstrated a clear connection between these budgets and student numbers, timetabling, the arrangement of buildings, and their location in the urban area.[102] Data from the diaries are used as a starting point for the modelling of activities in time and space. A model has been developed whose purpose is to predict the distribution of individuals in different activities and locations during the course of a typical day, depending on the effective restrictions imposed by the spatial distribution of buildings and sites, and by administrative and social constraints on the timing of activities.[103]

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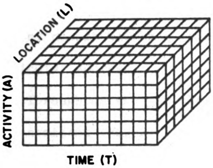
[102] Janet Tomlinson et al., "A Model of Students' Daily Activity Patterns," Environment and Planning, 5 (1973), pp. 231-266.

[103] In the first of their series of working papers, Bullock discusses the theoretical basis for an approach to the simulation of activities; see: Nicholas Bullock, An Approach to the Simulation of Activities: A University Example, Land Use and Built Form Studies, Working Paper No. 21 (Cambridge: School of Architecture, Cambridge University, August, 1970). A more recent report on the development of a model of daily activity patterns may be found in: Nicholas Bullock et al., Development of an Activities Model, Land Use and Built Form Studies, Working Paper No. 41 (Cambridge: School of Architecture, Cambridge University, April, 1971), pp. 53-76.

The assumptions made about the behavior of people in aggregate for the purposes of the model are simple. First, it is assumed that for a given group of people, over some repeated period (a day or a week), the proportion of time spent in various activities will remain the same, although the sequence of activities and their locations would, of course, differ. This overall division of time between activities, the time-budget, is expected to vary for different groups of people. As an input to the model, the time-budget and the hypothesis of its stability for similar populations under dissimilar physical conditions, is of considerable importance. Second, it is assumed that the behavior of people is subject to a number of limiting restrictions which determine either the times or the locations of activities, or both.[104]

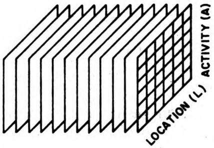
With his simplified view of behavior the problem of modelling day-to-day activities may be seen as distributing the population to activities in time and space in such a way that, first, the proportion of time spent in different activities by the population as a whole is similar to the time-budgets, and second, that the restrictions for different activities on the availability of times or locations (or both) are observed. More formally, the problem may be seen as distributing numbers of people in a three-dimensional space whose dimensions are activities A, times of day T, and locations L (Figure 11a). Not all combinations of A, T, and L are available (Figure 11d).

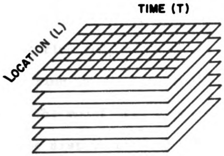
[104] Tomlinson, et al., "A Model of Daily Activity Patterns," op. cit., pp. 24-29.



a. A three-dimensional array of cells representing activity, time, and location.

b. The total population in cells in each activity/location plane must obey the population constraint.





c. The total population in cells in each location/time plane must obey the time-budget constraint for that activity.

d. Some activity/location combinations are not available, nor are some time/activity combinations.

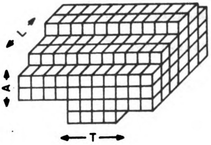


FIGURE 11.

THREE-DIMENSIONAL ARRAY OF TIME, ACTIVITY, AND LOCATION

Both time and location are treated as discrete entities, and thus, a value in a particular cell could represent, for example, the number of people watching television between 6:00 and 7:00 p.m. at a particular address.[105]

Throughout the day the number of people in the AL plane must remain constant (Figure 11b). Equally, the amount of time spent in particular activity at all times in all locations (i.e., the sum of the values on the LT plane) must be equal to the number of hours per day for the whole population (Figure 11c) determined from the time-budget.

Apart from the limiting restrictions of the timing of activities and the constraint of the time-budget, two modelling assumptions are made. People are allocated to activities and locations, first, subject to the availability of locations for that activity at that time and, second, to the constraint that the total amount of travel time in the time-budget for the whole population is maintained.

The model uses an entropy-maximizing method to derive the most probable distribution of the population in time and space, subject to the population and time-budget constraints and the restrictions on the availability of time and space for activities.[106] The resulting

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[105] Ibid., pp. 32-35.

[106] For a review of the entropy-maximizing technique as applied to urban and regional analysis, see: A.G. Wilson, Entropy in Urban and Regional Modelling (London: Pion Limited, 1970). Wilson has also proposed a similar model employing the entropy technique to the spatial-temporal organization of household behavior; see: A.G. Wilson, "Some Recent Developments in Micro-economic Approaches to Modelling Household Behavior, with Special Reference to Spatio-temporal Organization" (Paper 11), Papers in Urban and Regional Analysis (London: Pion Limited, 1972), pp. 216-236.

distribution gives the number of people engaged in each activity, during each time period, and at each location over the day. Thus, no attempt is made to identify or follow the sequence of activity and locational choices made by individuals; only the overall distribution of people in any cell or the flow of people between cells from one time period to another is modelled.[107]

Much of the work at the Centre over the past ten years has been with the application of these ideas first at the scale of an individual institution (e.g., a university) set in its urban context, and second to the entire urban area. However, their approach is not without its disadvantages. One drawback is that once individual time-budgets are input to the model, they lose their individual identity.[108] Furthermore, when working from a totally disaggregated data base to the more aggregated form required by the entropy-maximizing technique, both time (i.e., in terms of activity sequencing) and location come to be treated as discrete entities. Another disadvantage is that their approach deliberately neglects perceptual processes as a vital mechanism relating individual behavior to the built environment. In spite of these caveats, their work reflects numerous

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[107]Because this resulting distribution is statistically the most probable, it is precisely that distribution which assumes least knowledge about activities of individual decision-makers.

[108]The reader will note some similarity between this modelling approach and that proposed by Hägerstrand (above). Unlike Hägerstrand's approach, however, the modelling effort described here makes no attempt to preserve an individual's identity, seen as a continuous sequence of actions in time-space.

insights into the operation of the urban system. In this respect, the philosophy behind much of their work lies in the mainstream of thought that has linked architecture with urban planning by stressing the relationships between activities and the structures that exist at all scales.

A team of British planners, led by Cullen, is taking on an activities approach to individual behavior. Their framework emphasizes the role of activities as linkages between institutions and the patterning of sets of activities. Research is being conducted in the institutional setting of a university where time-budgets are obtained from the students and faculty.[109] The hope is that such a micro-view will enable the researchers to decipher the linkages and constraints which serve to determine the sequences of activities.[110] To accomplish this goal, they employ some of the more advanced analyses of time-budget data.[111]

Cullen's approach draws on Hägerstrand's conceptualization, in which he views the greater part of individual behavior as structured

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[109] Cullen and Godson, Networks of Urban Activities Volume I, op. cit.; Cullen and Godson, Networks of Urban Activities Volume II, op. cit.

[110] Ian G. Cullen and Vida Nichols, "A Micro-Analytical Approach to the Understanding of Metropolitan Growth" (paper read at the Seventh World Congress of Sociology, Varna, Bulgaria, 1970).

[111] See: Ian G. Cullen Vida Godson, and Sandra Major, "The Structure of Activity Patterns," Patterns and Processes in Urban and Regional Systems, ed. A.G. Wilson, London Papers in Regional Science No. 3 (London: Pion Ltd., 1972), pp. 281-296.

about a whole range of environmental constraints. However, Cullen considers Hägerstrand's approach "over-deterministic" in that it allows for "no variation in the perception of constraints, but rather treats each as an unambiguously objective fact."[112] Thus, the work to date of the group at the Joint Unit for Planning Research of the University College, London has been based upon a theoretical framework which emphasizes those elements in a person's day which, from his point of view, lend it coherence, or give it the shape that he feels it possesses. In place of Hägerstrand's "fixed-unfixed dichotomy,"[113] they have characterized the individual's day as an integrated function of a much more elaborate range of flexibility, defined by one's degree of commitment to each activity and by the time and space constraints to which one is subject.[114] These additional items, which reflect their extensions of Hägerstrand's time-geography model, permitted the group to test the hypothesis that an individual's day is structured around certain key events, and that this structure derives from the way in which individuals perceive constraints in their environment. To date, the information which these researchers have collected is purely descriptive of the constraints people experience, and thus, cannot directly inform planning decisions, which is their ultimate objective. Indirectly, however, they were able to contribute to the

[112]Ian G. Cullen, "Space, Time, and the Disruption of Behavior in Cities," Environment and Planning, 4 (1972), p. 465.

[113]Hägerstrand, "Tidsanvändning och omgivingsstruktur," op. cit.

[114]Cullen et al., op. cit., p. 284.

problem of locating large institutions by virtue of the fact that they treated a relatively homogeneous group--the members of one institution.[115]

This review of current research thrusts in urban and regional analysis relating to time-budget approaches is by no means comprehensive of the literature in this field. Rather, these selected projects exemplify some possible uses of a time-budget approach. The studies chosen for review are particularly important for human geography in that they stress the spatial dimension and treat it and the temporal dimension in an integrated manner. Hence, they are seen as precedents in the literature that relate to the general question confronted by this research: How do individuals' decisions about their time-space behavior interrelate?

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[115] Cullen, op. cit., pp. 460-461.

CHAPTER 3

TIME-SPACE PATHS OF HUMAN BEHAVIOR: CONCEPTUALIZATION IMPLEMENTATION OF THE RESEARCH STRATEGY

Building upon the preceding synthesis of time-budget research, the objectives of this chapter are twofold. The first intent is to assess the potential of a time-space budget perspective for theory development in human geography. Two possible approaches toward this end are identified and critically evaluated. The second objective is to develop a conceptualization and to formulate research propositions designed to investigate the structuring of daily behavior through the time-space mechanics of constraints. In order to substantiate or illuminate the research propositions, a research strategy is established and involves the design and implementation of a survey.

THE TIME-SPACE BUDGET PERSPECTIVE AND HUMAN GEOGRAPHY

The term time-budget signifies an accounting scheme to describe the allocation of time to activities during a given period. A time-budget's logical extension, the time-space budget, is ostensibly a behavioral approach to geographic and planning research: it incorporates the sequence, linkage, timing, duration, and frequency of activities, as well as the spatial and temporal coordinates of one's behavior. Time-space budgets focus on two related aspects: people's overt behavior, and their perceptions of their physical and social environment.[1] The time-space budget, therefore, can record spatial behavior (moving and stationary),[2] and it can be indirectly related to environmental perceptions (via questionnaire data) as these interact with overt activities.[3] Although the device has potential for a variety of research applications, the previous chapter demonstrates that its use in urban analysis predominates. It is particularly well-suited to metropolitan areas where distance is often considered temporally and where many activities are precisely scheduled by the clock.

Perhaps the primary attribute of time-space budgets is that they record behavior patterns which are not directly observable due to their spatial and temporal extent. Furthermore, this method of

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[1]James Anderson, "Space-time Budgets and Activity Studies in Urban Geography and Planning," Environment and Planning, 3 (1971), pp. 353-368.

[2]The use of a related device, the "travel diary", by Marble and Nystuen has also contributed to the growing interest in relationships between time and space uses. The purpose of a travel diary, however, is to record movements from place to place throughout some specified period of time. It does not attempt to record the totality of behavior in time-space for the selected period (including stationary periods at particular locations or stations), and thus, the sequential properties of activity modules cannot be accomodated. Activities at "fixed locations or stations are not described though some of them may be inferred from trip destination and purpose. For examples of travel diaries and their use, see: Duare F. Marble, "A Theoretical Exploration of Individual Travel Behavior," Quantitative Geography, Part I: Economic and Cultural Topics, Studies in Geography, No. 13 (Evanston, Ill.: Department of Geography, Northwestern University, 1967), pp. 33-53; and, John D. Nystuen, "A Theory and Simulation of Intra-urban Travel," Quantitative Geography, Part I: Economic and Cultural Topics, Studies in Geography, No. 13 (Evanston, Ill.: Department of Geography, Northwestern University, 1967), pp. 54-83.

[3]Ian G. Cullen, Vida Godson, and Sandra Major, "The Structure of Activity Patterns," Patterns and Processes in Urban and Regional Systems, ed. A.G. Wilson, London Papers in Regional Science No. 3 (London: Pion Limited, 1972), pp. 287-291

activity accounting is unique in that, as far as their activities for the sampled time span are concerned individuals are treated as totalities, their behavioral integrity is preserved, and the entire sequence or pattern of activities can be analyzed. Although isolated parts, particular activities such as commuting to work, shopping, and leisure pursuits, may be extracted for analysis, they can be considered in the context of the respondents' overall time and space uses throughout the recorded period of time. Hence, they provide an overall behavior-context within which particular activities may be viewed realistically. This does not mean that the activity sequences or patterns are fully explained as intended and understood by the persons who create them, but at least the totality is there for examination.

Nystuen identifies distance, direction, and connection as three fundamental spatial concepts.[4] Through the use of time-space budgets, distance can be expressed temporally, which is frequently the way urban residents perceive distance, and connection can be given more comprehensive treatment than is customary in geographic research. With regard to the concept of connection, Anderson points out that in the recent trend toward studying cities as contact structures, the emphasis has shifted from distance to contacts and from Euclidean geometry to graph theory and topology. At the same time, the discontinuous and anistropic properties of urban space (e.g., as measured in terms of time, costs, or perceptions) have received increased

[4] John D. Nystuen, "Identification of Some Fundamental Spatial Concepts," Papers of the Michigan Academy of Science, Arts, and Letters, 48 (1963), pp. 373-384.

attention, accompanied by a corresponding dissatisfaction with the assumptions of classical location theory.[5] Whether the use of time-space budgets can directly contribute to improving location theory or underline its shortcomings remains to be seen.

Spatial Behavior, Spatial Structure and Location Theory

In revealing the inadequacies of location theory, behavioral research in geography has demonstrated that it is difficult to improve its postulates, or to match its formal elegance. This has been particularly evident in research that treats the interaction between spatial behavior and spatial structure.[6] Although the spatial structure of activities in an urban area will reflect both current and past patterns of behavior, explanations of spatial structure based on such patterns of behavior often seem to be tautological since it would appear to be just as reasonable to explain behavior as a function of structure as to explain structure as a function of behavior. The relationship is clearly one of mutual dependence; that is, changes in spatial structure elicit changes in spatial behavior and vice versa.

In this regard, the use of time-space budgets entails certain disadvantages that should not be overlooked. They sometimes tempt reasoning and explanation into a "circle of causality" formed by

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[5] Anderson, op. cit., p. 355.

[6] Gerard Rushton, "Behavioral Correlates of Urban Spatial Structure," Economic Geography, 47 (January, 1971), pp. 49-58.

spatial behavior←——→spatial structure.[7] A behavior pattern which contributes to spatial structure is the way individuals make choices between alternatives distributed over an area. Central place theory is only one of many areas of human geography where assumptions about individuals' behavior patterns are incorporated in explanations of spatial structure. Indeed, Curry's work has focused on the problem of developing theory from postulates which do not inherently contain the deduced facts which interest us.[8] Curry argues that since it is possible to deduce the distribution of central places from an accurate description of spatial behavior patterns of people in an area, no insight is gained from studies which explain spatial structure in terms of behavior patterns that occur within it. He points out that the description of spatial behavior is no more a process type explanation of a central place pattern than is the description of the pattern itself.[9] Thus, he concludes that: "A term such as Christaller's 'range of a good' suffers from this conditionality of definition."[10]

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[7]Reginald G. Golledge, Process Approaches to the Study of Human Behavior, Department of Geography, Discussion Paper No. 16 (Columbus, Ohio: The Ohio State University, 1970), p. 2

[8]Leslie Curry, "Central Places in the Random Spatial Economy," Journal of Regional Science (Supplement, 1967), p. 218.

[9]Curry attempts to replace behavioral assumptions with mathematical (Poisson) process descriptions of spatial activity. This strategy is attractive if one's purpose is to construct aggregate models incorporating human behavior. However, the lack of explicit behavioral assumptions reduces its reliability for inferring disaggregate results.

[10]Curry, loc. cit.

Observed behavior is partly determined by the structure of the environment in which it occurs, and Rushton argues that parameters of behavior in a particular environment (e.g., empirically derived distance decay functions) are therefore "not admissable as a behavioral postulate in any theory."[11] What, then, are the critical characteristics which a spatial behavior postulate must have to be admissable in a viable theory? Curry states, in reference to central place theory, that:

> A postulate on spatial behavior should not directly describe the behavior occurring within a central place system, since it is obvious that the system can then be directly derived without providing any insight. The behavior postulate must allow a central place system to be erected on it in a sufficiently indirect manner that a measure of initial surprise is occasioned by the results, and this postulate must still describe behavior after the system has been derived.[12]

Thus, a behavioral postulate should incorporate the rules of spatial choice which underlie behavior patterns, irrespective of the particular environment in which the behavior has been observed. Christaller's postulate that consumers patronize the nearest place offering a required item is, according to Curry's criterion, a logically admissable rule, although consumers frequently disobey it.[13] If more realistic rules of spatial choice are to be discovered through behavior studies,

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[11] Gerard Rushton, "Analysis of Spatial Behavior by Revealed Space Preference," Annals of the Association of American Geographers, 59 (June, 1969), p. 392.

[12] Curry, op. cit., p. 219.

[13] W.A.V. Clark, "Consumer Travel Patterns and the Concept of Range," Annals of the Association of American Geographers, 58 (June, 1968), p. 396.

and studies employing time-space budgets specifically, we must avoid the circle of causality.

An attempt to overcome this problem is reflected in the work by Rushton concerning the locational preferences underlying a population's spatial behavior.[14] In his approach, Rushton assumes that an individual's spatial behavior is affected by his "preference function." Thus, by aggregating the preference functions of individuals, a pattern of behavior can be generated for any distribution of spatial opportunities. In proposing the concept of "revealed space preference," he notes that in economic consumption theory the spatial distribution of shops is not considered a significant variable. However, it is significant when the choice is between different commodities. Although his "spatial preference structures" may have more generality than spatial systems, he concludes that they are not independent of the particular system in which they are derived. Furthermore, his method is descriptive in the sense that no attempt is made to explain why one opportunity is favored over another in the recovered preference function. This approach might eventually provide useful postulates, but thus far it only indicates how elusive general and independent "rules" really are.

As yet there is little evidence to suggest that the use of time-space budgets would be any more successful in finding these rules.

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[14] Rushton, op. cit.; and, Gerard Rushton, "Temporal Changes in Space Preference Structures," Proceedings of the Association of American Geographers, 1 (1960), pp. 129-132.

The notion of trade-offs between time allocations, and between time and space preferences, is conceptually appealing, and the analysis of behavior patterns in a wide variety of environments might produce interesting results. Wolpert insists that an understanding of spatial behavior involves sorting out the regularities or constants in time-space patterns and distinguishing these from the variables.[15] Since there is still so little spatially-oriented comparative time-use research, it is hardly realistic to believe that the constants could be useful as a basis for a deductive location theory; but the variables might prove to be more enlightening.

Accessibility, both in a temporal and spatial sense, is a key variable in determining both the extent to which behavior is shaped by the spatial environment, and the way in which individuals evaluate activities and locations.[16] However, such an abstract variable is itself a very complex set of variables. Their "objective" values (e.g., time and money) vary widely with different populations, transport modes, and their implications also differ considerably depending on a wide range of factors (e.g., age, income, occupation). The relevant set of important accessibility-opportunities varies both with life-cycle stage and with life-style. And although a probable

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[15] Julian Wolpert, "Behavioral Aspects of the Decision to Migrate," Papers of the Regional Science Association, 15 (1965), pp. 159-169.

[16] M.A. Stegman, "Accessibility Models and Residential Location," Journal of the American Institute of Planners, 35 (January, 1969).

set of opportunities may be inferred from time-budget data,[17] it may be misleading since some opportunities which are felt to be relevant by the respondent may not be revealed in his activity pattern because they are too inaccessible.

Chapin and others have discussed a general framework for studying urban living patterns in which time-use is seen through motivation--->choice--->activity set of relationships.[18] They contend that spatial behavior can be conceptualized as the outcome of choices which reflect people's motivations and values. But such choices are realized within the constraints set by personal circumstances (i.e., socioeconomic requisites), accessibilities, and the environment. Therefore, the limits of free choice differ greatly on a wide range of factors (e.g., age, income, mobility, life-cycle stage, etc.)

These trends in research are clear achievements. By observing the behavior of members of a population, one learns something about their living conditions. But this information does not clearly differentiate what are wants and needs from what are various degrees of necessity. For the purposes here, behavior (seen as a manifestation of choices) does not fully reveal the underlying pattern of constraints

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[17] F. Stuart Chapin, Jr., "Activity Systems and Urban Structure: A Working Schema," Journal of the American Institute of Planners, 34 (January, 1968), p. 16.

[18] Chapin, ibid.; F. Stuart Chapin, Jr. and Thomas H. Logan, "Patterns of Time and Space Use," The Quality of the Urban Environment, ed. Harvey S. Perloff (Baltimore: The Johns Hopkins University Press, 1969), pp. 305-332; and, F. Stuart Chapin, Jr., "Activity Systems as a Source of Inputs for Land Use Models," Urban Development Models, Special Report No. 97, ed. George C. Hemmens (Washington, D.C.: Highway Research Board, 1968), pp. 77-96.

which shapes action and the situations in which it occurs. This also means that clues are not provided for how to reshape the living conditions, if that is the goal. In order to find the clues, we must look to latent structure and latent processes. Purposeful changes in the distribution of opportunities and risks among individuals necessitates an understanding of how constraints interact and how choice potentials are affected by changes to one or more of those constraints.

Choice- and Constraint-oriented Approaches to Spatial Behavior

Constraints are implicit in choice, but, depending on the relative emphasis given to "positive" and "negative determinants" of behavior,[19] a distinction may be made between "choice-" and "constraint-oriented" approaches to spatial behavior. If psychological motivations of spatial behavior (i.e., the rules of spatial choice) are sought, then observed behavior must be seen in terms of choices between alternative courses of action.[20] However, the danger exists that important constraints may either be underestimated or go unnoticed. Observed behavior can be conceptualized as reflecting the constraints of the environment (i.e., "objective" constraints) and personal circumstances (i.e., the "subjective" ones). If highly constrained situations are not recognized as such, observed behavior

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[19]Torsten Hägerstrand, "What About People in Regional Science?" Papers of the Regional Science Association, 24 (1970), p. 11.

[20]Rushton, "Analysis of Spatial Behavior by Revealed Space Preference," op. cit., p. 392.

may be misinterpreted as what people "choose" to do, rather than what they are "forced" to do. With the prevailing emphasis on choice and positive determinants in general, situations where actors do not have effective choice may be neglected.[21] That is to say, in the absence of effective choice, individuals may be asked to decide between hypothetical alternatives which in reality they have little chance of achieving.[22]

A less common tack focuses on the outer limits within which behavior can take shape, emphasizing negative determinants of behavior. Such an approach is exemplified in the constraint-orientation adopted by Pahl.[23] Pahl advocates studying "the pattern of spatial and social constraints which operates differentially in given localities" and which fundamentally "affects people's life chances." He argues that there are fundamental spatial and social constraints on access to urban resources and facilities. Spatial constraints are generally expressed in time/cost distance while social constraints reflect the distribution of power in society. The latter are illustrated by

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[21] This is exemplified in the activity systems and time-budget research where activities are simplified into obligatory as opposed to discretionary activities. See: Richard K. Rail and F. Stuart Chapin, Jr., "Activity Patterns of Urban Residents," Environment and Behavior, 5 (June, 1973), pp. 163-190.

[22] One example is the use of the trading-stamp game of choice theory to elicit leisure-time activity preferences; see: F. Stuart Chapin, Jr. and Henry C. Hightower, "Household Activity Patterns and Land Use," Journal of the American Institute of Planners, 31 (August, 1965), pp.

[23] R.E. Pahl, "Urban Social Theory and Research" (Chapter 13), Whose City? And Other Essays on Sociology and Planning (London: Longman Group Ltd., 1970), pp. 209-225.

bureaucratic rules and procedures, and the actions of what Pahl calls "social gatekeepers" (e.g., local government officials and policy-makers, landlords, employers). The gatekeepers are those who distribute and control urban resources and, thus, regulate the quality and accessibility of opportunities such as educational facilities, the housing market, and the job market. Conflicts of interest in this socio-spatial system are inevitable, and the greater the scarcity of valued opportunities, the greater the conflict. Pahl sees populations limited in their access to scarce urban resources and facilities as dependent variables, while those controlling access, the gatekeepers or managers of the system, are the independent variables. He notes that the current emphasis on diversity of choice in physical planning implies that the access to facilities is an independent variable, in contrast to being dependent on the allocation by gatekeepers. This suggests that there are ideological as well as methodological differences underlying the variation between choice and constraint orientations (e.g., differing attitudes to "free market" mechanism).[24]

The interrelationships between time and space uses have perhaps been most clearly worked out by Hägerstrand and his

[24] Ibid., pp. 215-216. A similar attitude has been echoed by Harvey in his conceptualization of the city; see: David W. Harvey, Social Justice and the City (Baltimore: The Johns Hopkins University Press, 1973, pp. 91-95.

colleagues.[25] In the physicalist tradition,[26] their approach similarly focuses on the outer limits within which behavior can occur and emphasizes negative determinants of behavior rather than positive factors such as the attitudes, motives, preferences, and choices which contribute to structuring activities in a time-space framework. The emphasis on positive factors is more common in social science, and the more common response to time-space data sets has been to abstract certain characteristics from them (e.g., time-spending characteristics, in aggregate, of population groups and areas).[27] In many cases, geographers and other social scientists treat a population as a mass of objects, almost freely interchangeable and divisible; i.e., we often impute upon any given individual of the population the modal characteristics of that population. Also, it is common practice to segment the mass into such aggregates as shoppers, migrants, and age and occupational

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[25]See, for example: Torsten Hägerstrand, "Tidsanvändning och omgivingsstruktur," Urbaniseringen i Sverige: En geografisk samhällsanalys. Bilagadel I till Balanserad regional utveckling, Statens offentliga utredningar, 1970: 14, bil. 4 (Stockholm: Esselte tryck, 1970); Torsten Hägerstrand, "A Socio-environmental Web Model," Studier i planeringsmetodik, ed. Gösta A. Eriksson, Memorandum från ekonomisk-geografiska institutionen, Nr. 9 (Åbo [Turku], Finland: Handelshögskolan vid Åbo akademi [Åbo Swedish University School of Economics], 1969), pp. 19-28; and, T. Carlstein, Bo Lenntorp, and Solveig Mårtensson, Individers dygsbanor i några hushållstyper, Urbaniseringsprocessen, rapport nr. 17 (Lund: Institutionen för kulturgeografi och ekonomisk geografi vid Lunds universitet, 1968).

[26]Hägerstrand, "What About People in Regional Science?" op. cit., p. 11.

[27]Anderson reviews examples of these research trends and discusses their limitations; see: Anderson, op. cit., p. 356.

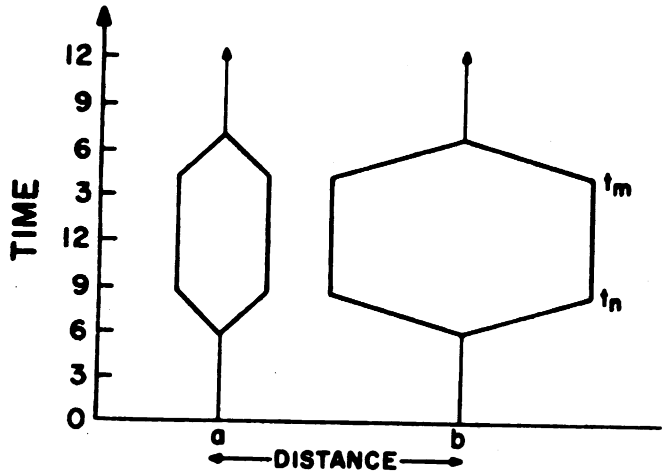

FIGURE 12.

ILLUSTRATION OF CAPABILITY CONSTRAINTS

THE DAILY PRISM'S MAXIMUM DIMENSIONS FOR AN INDIVIDUAL WHO HAS TO SPEND TIME T_n-T_m AT A WORKPLACE. A PERSON WITH LOW MOVEMENT CAPABILITY (a) HAS A MORE LIMITED FREEDOM OF WORKPLACE CHOICE THAN A PERSON (b) WITH A HIGH CAPABILITY.

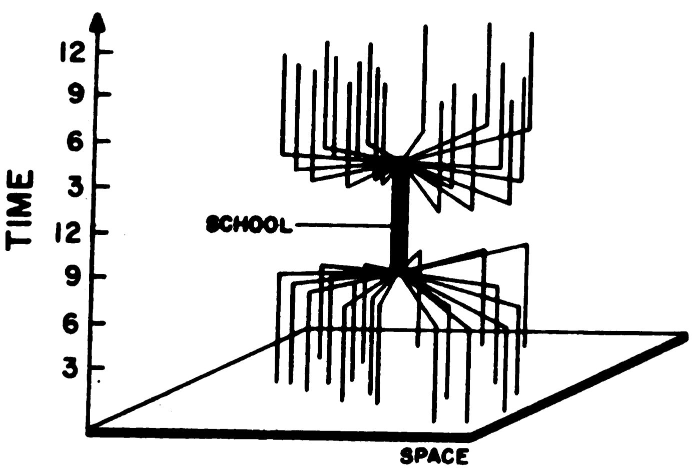

FIGURE 13.

ILLUSTRATION OF COUPLING CONSTRAINTS

THE COUPLING OF INDIVIDUAL PATHS (E.G., STUDENTS AND INSTRUCTORS) IN AN ACTIVITY BUNDLE (E.G., SCHOOL). SCHOOL ACTIVITIES ARE ASSUMED TO HAVE PREDETERMINED TIME-TABLES AND OCCUR AT A FIXED LOCATION IN SPACE.

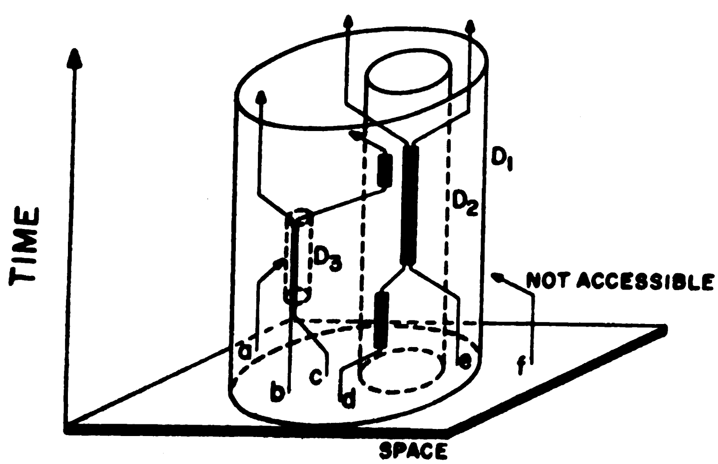

FIGURE 14.

ILLUSTRATION OF AUTHORITY CONSTRAINTS

HIERARCHY OF DOMAINS AND ITS IMPACT ON INDIVIDUAL PATHS. D_1 REPRESENTS A SUPERIOR DOMAIN (E.G., A MUNICIPALITY) AND D_2 AND D_3 ARE SUBORDINATE DOMAINS. ACTIVITIES WITHIN D_2 AND D_3 CAN TO A CERTAIN EXTENT BE REGULATED BY D_1. THIS MIGHT OCCUR IF SERVICE WAS RESTRICTED TO PERSONS RESIDENT IN D (b-e BUT NOT a AND f).

groups. Through segmentation, each aggregate is analyzed in isolation from the others. It was this particular problem that prompted Hägerstrand to write: "...one risks becoming lost in a description of how aggregate behavior develops as a sum total of actual individual behavior, without arriving at essential clues toward an understanding of how the system works as a whole." In order to discover these clues, he focuses on what may be termed the "time-space mechanics of constraints."[28]

Even if constraints are formulated as general and abstract rules of behavior, they can be provided with a "physical" shape in terms of location in space, areal extension, and duration in time. An individual's time-space path is constrained by a set of physiological and physical factors that arise in part from the social and/or private network of decisions and actions surrounding the individual. Hägerstrand suggests that these constraints are composed of three interacting groups: capability constraints (Figure 12), coupling constraints (Figure 13), and authority constraints (Figure 14).[29]

The individual is thus seen by Hägerstrand to operate within this complex of constraints which together constitute a "highly institutionalized power- and activity-system." Viewed from a time-space

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[28] Hägerstrand, "What About People in Regional Science?" loc. cit.

[29] Hägerstrand, "What About People in Regional Science?" op. cit., pp. 12-18; and, Hägerstrand, "A Socio-environmental Web Model," op. cit., pp. 20-25. These groups of constraints are also described in Chapter 2.

perspective, two recognizable, but diverse, systems of interaction are seen. One is primarily a time-oriented warp of individual paths which constitutes the population of an area and its capability constraints. The second is a set of constraints that domains impose (including within them coupling constraints) to which the individual may or may not have access according to his needs and wants.[30] Social scientists know very little of the interaction of constraints, expecially as viewed from the daily-path perspective. Hägerstrand suggests that at this stage of research into the interaction of constraints, a simulation approach would be the most appropriate method of analysis, until more general mathematical techniques become available. Reasonably solvent simulations may aid in surveying whole systems and help to reduce the trial and error component of empirical applications.[31]

Hägerstrand's conceptualization of constraints is instructive. Based upon his recommendation for a simulation methodology, it seems worthwhile to define the time-space mechanics of constraints which rule how paths are channeled, diverted, or even routinized. It is believed that such an approach will shed light on how decisions about one's time-space behavior interrelate. Some authors believe that such

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[30] Hägerstrand, "What About People in Regional Science?" op. cit., pp. 16-18. In a more recent paper Hägerstrand discusses the political aspects of entrance conditions attached to domains; see: Torsten Hagerstrand, "The Domain of Human Geography," Directions in Geography, ed. R.J. Chorley (London: Methuen and Co., Ltd., 1973), pp. 83-86.

[31] Torsten Hägerstrand, "The Impact of Social Organization and Environment upon the Time-use of Individuals and Households," Plan: Tidskrift för planering av landsbygd och tutorter, 26 (1972), pp. 29-30.

a negative determinants approach to social science may indeed be the safest and most productive.[32] In using this methodology, the simulation will attempt to construct each individual's day separately, generating the activities he performed and the sequence he adopted from generalized rules. The rules take the form of constraints or probability distributions which are estimated from a time-space budget data base. A technique for grouping constraints in time-space terms is formulated in order to collapse their considerable variety into a tractable number.

CONCEPTUALIZATION OF HUMAN BEHAVIOR AND CONSTRAINTS

The remainder of this chapter is devoted to a conceptualization of human behavior and constraints and the development of a methodology, including a time-space budget diary and associated survey. In accordance with the research strategy, the following chapters will develop analytical procedures to compress the survey data into a more comprehensible form (Chapter 4) necessary for modelling, via simulation techniques, the time-space mechanics of constraints (Chapter 5).

Time-space Behavior: The Search for Assumptions

Although the emergence and formal discussion of the "behavioral approach"[33] is rather recent, the employment of behavioral assumptions

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[32] Hägerstrand, "What About People in Regional Science?" op. cit., p. 11.

[33] For an overview of behavioral approaches in geography, the reader is referred to: J.M. Doherty, Developments in Behavioral Geography, Discussion Paper No. 35 (London: Department of Geography, London School of Economics and Political Science, November, 1969); and, Reginald G. Golledge, Lawrence A. Brown and Frank Williamson, "Behavioral Approaches in Geography: An Overview," The Australian Geographer, 12 (1972), pp. 59-79.

is not at all new. Harvey has noted that human geographers have almost always made assumptions about behavior—however, these assumptions have commonly been implicit in the analysis, rather than explicit in theoretical statements.[34] The most notable exception has of course been the case of the "Economic Man" assumption. This normative behavioral postulate has been used extensively by geographers in both implicit and explicit fashions--to the point where much of location theory bears a close relationship to classical economics. Thus Olsson and Gale have noted that most spatial theories rely on the same behavior assumptions as the theory of the firm.[35]

The well-known behavioral assumptions embodied in the Economic Man concept are reflected in the knowledge and goals attributed to the individual. Thus, it assumed that behavior is based on knowledge which is omniscient and perfect, and which precludes uncertainty from predictions. Behavior is oriented towards goals which optimize profits or utility. The extension of these goals into a spatial context results in the producer attempting to increase the size of his market area, while the consumer attempts to reduce purchasing costs by minimizing the expenses and effort associated with distance.[36] Similarly, the theory of route choice behavior--for whatever purpose—

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[34] David W. Harvey, "Behavioral Postulates and the Construction of Theory in Human Geography," Geographia Polonica, 18 (1970), p. 27.

[35] Gunnar Olsson and Stephen Gale, "Spatial Theory and Human Behavior: A Study of Anarchistic Vector Spaces," Papers of the Regional Science Association, 21 (1968), p. 230.

[36] Loc. cit.

is characterized by decisions which minimize distance, travel cost, or travel effort.

The fact that the above behavioral assumptions are unrealistic and inaccurate is well known. Economists, for example, have long been aware that producers rarely attain optimum profit levels. Non-normative economics, therefore, recognizes that business decision-makers possess imperfect knowledge and problem-solving ability, and that their goals under certain circumstances may be non-optimizing. The failure of real man to correspond with the actions of the firm have promoted various reformulations of the behavior assumptions. Simon, for example, has proposed the principle of "bounded rationality"--which emphasizes the limits to problem-solving capacities and the availability of knowledge.[37]

Geographers have widely criticized the Economic Man assumption in a spatial context. Particularly, spatial analysts have recognized the need for adjusting the distance optimizing function. Thus, linear distance has now been largely replaced in geographic models by "functional" measures such as accessibility or travel time. The use

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[37]In so doing, Simon relates the notion of "satisficing behavior"; see: Herbert Simon, Models of Man (New York: John Wiley & Sons, Inc., 1957). Wolpert recently reintroduced the concept into geography in writing of farmers in Central Sweden: "The concept of the spatial satisficer appears more descriptively accurate of the behavioral pattern of the sample population than the normative concept of Economic Man. The individual is adaptatively or intendedly rational rather than omnisciently rational." The satisficing notion assumes that in the absence of perfect knowledge, behavior is directed towards an alternative which is satisfactory, but not necessarily optimal. See: Julian Wolpert, "The Decision Process in a Spatial Context," Annals of the Association of American Geographers, 54 (December, 1964), pp. 537-558.

of surrogates in these adjustments, however, has not accounted for observed discrepancies between the normative-economic behavioral model and real-world locational and trip activity.[38] The widespread recognition of these discrepancies has prompted many geographers to seek reformulations or alternatives to the Economic Man concept.

Principle of Consistency and Recurrent Behavior Patterns

As an alternative, this research is committed to the fundamental principle of consistency in human behavior. The notion of consistency is not to be confused with assumptions of the rationality of behavior (i.e., Economic Man). The purposeful element in individual behavior varies in degree between individuals and among the different activities undertaken by an individual and, thus, some behavior seems to be virtually instinctive while other behavior is highly calculated. All behavior is purposeful to some degree. Whether spatial behavior is construed to be rational or not, depends on our depth of understanding the values, goals, and purposes towards which that behavior is directed. Moreover, what is rationality to one observer may not correspond to the interpretation of another observer; the assessment of rationality is a dubious process which varies with cultural, ideological, and personal biases.

In the conceptualization presented here, the notion of rationality is avoided in favor of the principle of consistency. In

[38] Ibid.; Marble, op. cit.; Clark, op. cit.; and W.A.V. Clark and Gerard Rushton, "Models of Intra-urban Consumer Behavior and Their Implications for Central Place Theory," Economic Geography, 46 (July, 1970), pp. 486-487.

so doing, an attempt is made to isolate that behavior which demonstrates recurrent patterns in time-space.[39] And, although behavior is not seen as consistently rational and well-informed in the classical economics sense, it is seen as containing highly organized episodes which give structure and pattern to the whole stream of behavior in time and space.

Given this interpretation of consistency, the claim is made that the concept of pattern can be meaningfully applied to any set, or sub-group, of time-space budgets and that this pattern is partly defined by the sequence in which activities are performed. This hypothesis will be validated if it can be demonstrated that, as individuals move through their days, the probabilities of their engaging in such activities as working, eating meals, relaxing, and sleeping vary significantly from one time period to another. The physiologically-determined activities tend to be those of a more routine nature. Although discretion may sometimes be exercised as to where the activity occurs, these activities occur in a day's sequence at about the same times. Working, attending classes, shopping, and homemaking--the culturally defined extensions of sustaining activities--tend to fall into a person's daily sequence at approximately the same time. The idea that activities differ significatnly from one time

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[39] Jiri Kolaja, Social System and Time and Space: An Introduction to the Theory of Recurrent Behavior (Pittsburgh: Duquesne University Press, 1969), pp. 48-51.

period to another is at least guaranteed by the fact that, historically, broad margins of choice over these matters has been institutionally removed.[40]

A similar assumption incorporated in the general idea of consistency is that the amount of time a person devotes to an activity follows a pattern over sub-groups of individuals just as much as does the position it occupies in that person's sequence. This is to say that the physiologically determined activities and their culturally defined extensions tend to have the same durations each day just as they tend to fall into a person's daily sequence with similar timing and frequency. Such simple patterns of activity must exist if simulation is to be a meaningful exercise.

Priorities and Opportunities

As was the case in Hägerstand's time-geography model, the individual in this conceptualization is seen to operate within a framework which is fundamentally structured by physical patterns and needs. This environmental structure is institutionalized to a considerable degree by the availability of services and by the norms, expectations, and habits of the individual.

Within the environmental structure, or budget-space, the individual selects from a set of opportunities that consists of possible activities. The order of selection is made after priorities have been assigned to the various activities in the opportunities set

[40]Hägerstrand, "The Impact of Social Organization and Environment," op. cit., pp. 24-25.

in accordance with their attributes. Several factors contribute to an individual's assessment and ranking of priorities. Perhaps the first consideration is the importance of the activity to the individual. A second consideration might be the presence of participants and their characteristics (e.g., their relationship to the decision-maker, their frequency of contact with the decision-maker, distance to be travelled or time spent travelling, etc.). Preferences will also produce a tendency for an individual to choose one kind of activity having a certain set of qualities over another activity having a different set; hence, preferences will enter into a person's ranking of alternatives.

The Interaction of Constraints: The Global View

Priorities, however, are only realized within the context of constraints. And whereas priorities are self-generated, most constraints are imposed externally (Figure 15). Daily activities are seen to possess a certain temporal rhythm defined by the manner in which physiological and culturally defined constraints impinge on human activity. Along with the temporal aspect of a person's activities, there is also the spatial dimension which has to do with the locations of his activities. Although some of the same constraints that regulate the timing are also involved, activity location is strongly influenced by environmental constraints.

The physiological, cultural, and environmental constraints operate differently on the activity sequence in different contexts. For example, the physiological needs of an individual (i.e., sleep and sustenance) constrain other activities in the daily activity cycle. They are activities in themselves, but they also serve as

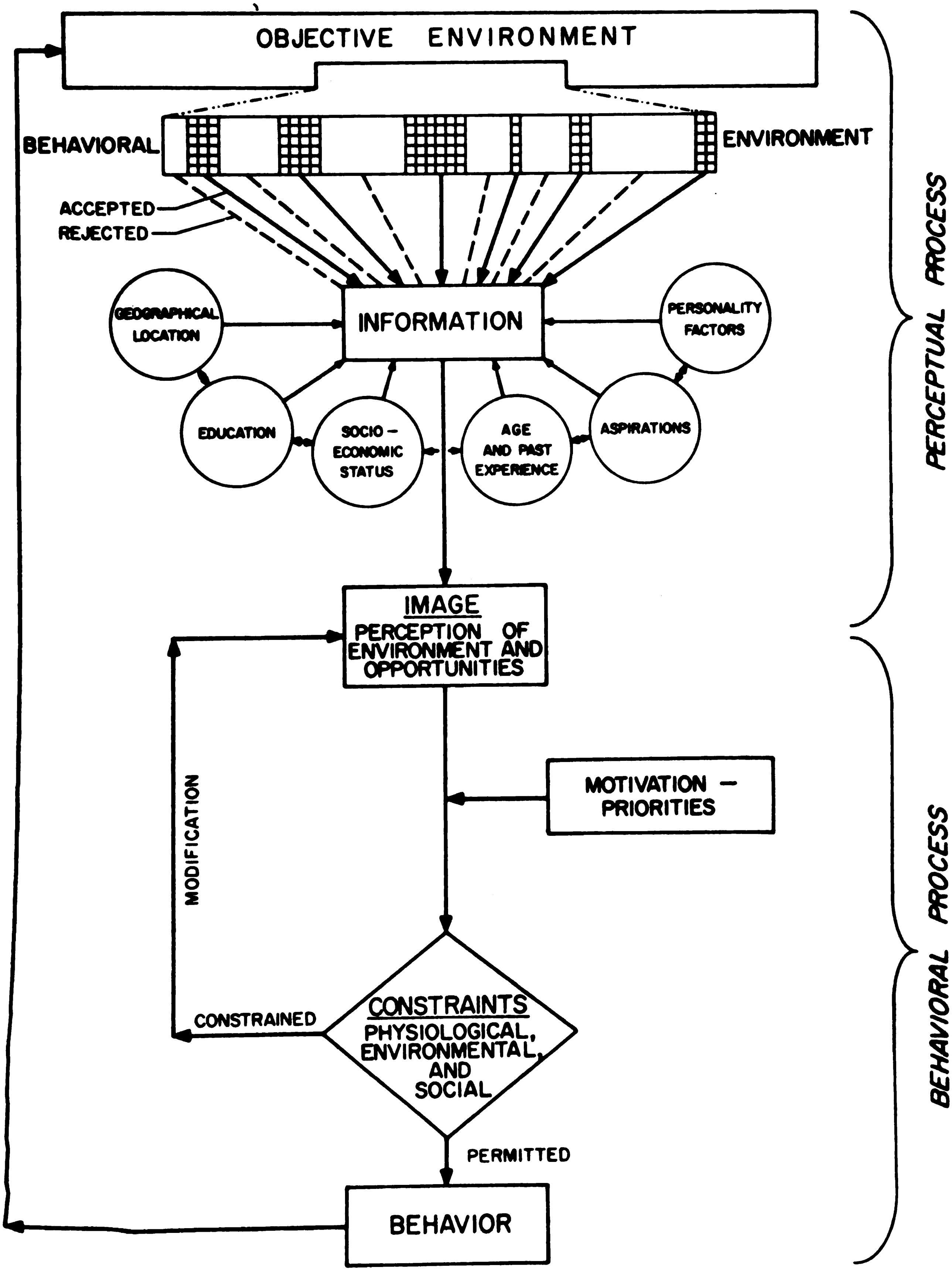

FIGURE 15.

FACETS OF THE BEHAVIORAL PROCESS.

constraints by affecting the timing of other activities. Similarly, the culturally defined extensions of these requirements (e.g., working, attending school, shopping, and homemaking) fall among the key activities in a person's day, but they also have an affect on other activities and, therefore, also serve as constraints. Indeed, all of these activities are considered to be so fundamental to an activity sequence, forming what may be termed a daily routine of an individual, that they structure the remainder of the activity sequence affecting not only the timing, but also the character of other activities in the sequence.

Environmental constraints are no less complex in the way they impinge on the flow of a person's activities. Individual activities may be directly influenced by the physical setting—the natural surroundings and the spatial configuration of the built environment—as well as the technical means with which to negotiate a path through the environment. Environmental constraints affect not only the spatial distribution, but also the timing of activity. The routines of urban residents must conform to the schedules of various institutional entities. In short, firms, organizations of various kinds, governments, and other institutional entities serve to constrain a person's activity simply by the schedules they set. For example, a person's place of employment maintains certain regular working hours, and stores are open only at certain times. Therefore, a person's routine is shaped by others, and the rest of his activity sequence is determined for him, to a considerable extent, by these constraints.

Objective and Subjective Constraints on Time-space Behavior

The next task is to refine, or simplify, this global view of physiological, cultural, and environmental constraints into a conceptualization more suitable for empirical work and eventual modelling. At the same time, I wish to incorporate and expand upon Hägerstrand's simple fixed/unfixed dichotomy of constraints to a much more elaborate range of flexibility as Cullen and others have proposed.[41] The simplification of the global view of constraints, along with the expansion of Hägerstrand's conceptualization, is reflected in the proposition that people are exposed to objective and subjective constraints.

Objective Constraints. The objective constraints on their behavior include those which are imposed by the environment. The notion of objective constraints is similar to Hägerstrand's idea of capability constraints. For example, a person at any given location may only move a certain distance away from that original station in a certain amount of time. The distance of this movement is determined by existing modes of transport and time available to him. Objective constraints tend to shape the potential "budget-space" available to an individual (Figure 12). To the extent that these constraints operate equally on groups of individuals, they frequently fix patterns of behavior, alluded to earlier in reference to the principle of consistency. Many of the movement constraints, however, operate quite independently on each individual (i.e., according to

[41] Cullen et al., op. cit.

one's capabilities, technical and otherwise, for movement through time-space). Despite their greater variation, or unfixed quality, they are essential in the development of a simulation model.

Subjective Constraints. Even more important than objective constraints is the considerable range of subjective ones which, to some degree, are self-imposed. Such constraints probably occur as a result of certain features of the individual's physical and social environment, but it is unlikely that there will be anything more than a contingent relationship between the objective facts and the subjective state associated with these.[42] In most contexts, a given environmental situation is subjectively perceived by different people as constraining choice to varying degrees. Although the peculiarities of the environmental context are important, an individual's response to that situation is critical. Any situation to which an individual reacts has at least three dimensions: a temporal position (e.g., in a day or sequence), a location in space, and a potential activities set. These dimensions interact to produce a feeling of constraint upon the individual.

One's evaluation of the way in which these dimensions interrelate is complex. But as a result of the priorities and constraints felt by an individual, any activity has a subjective fixity rating associated with it. This subjective fixity rating is proposed in place of Hägerstrand's fixed/unfixed dichotomy, since it permits a

[42]Ian G. Cullen and Vida Nichols, "A Micro-Analytical Approach to the Understanding of Metropolitan Growth" (paper read at the Seventh World Congress of Sociology, Varna, Bulgaria, 1970).

more elaborate range of flexibility defined by the degree of commitment to the activity and the extent to which it is constrained in time and space. These two dimensions of activity flexibility--commitment and time and space fixity—are highly correlated. Cullen, however, advises that such dimensions are theoretically independent aspects of the problem and may be treated separately.[43]

The degree of commitment affects the flexibility of activity choice. Cullen has distinguished four categories of commitment.[44]

1. Arranged activities. Such activities involve interaction with others, where time and place of the activity have usually been specified and, therefore, fixed.

2. Routine activities. These activities, which frequently recur at regular intervals, attain the status of virtually immoveable points in a person's day. Such routine activities may often have more stability and thus a greater degree of commitment, than is strictly necessary.

3. Planned activities. These include activities which an individual plans to perform at sometime in the future. Since planned activities are not usually coordinated with other individuals or groups, their degree of flexibility is generally greater.

4. Unexpected activities. Activities of this kind are commonly those which arise, or "just happen", while the individual is performing some other activity. Such activities as chance meetings, accidents, or

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[43]Cullen, et al., op. cit.

[44]Ibid.

some leisurely pursuits have no long-term planning perspective in the pursuit of one's everyday affairs, and are of the "spur of the moment" variety.

The remaining component of the subjective fixity rating is the degree to which activities are fixed with respect to particular times of day or to particular locations, or both. An individual schedules a variable proportion of his day according to these ratings of fixity, in order to facilitate synchronization and synchorization of activities and movements in time and space. Although much of the scheduling process is undoubtedly routine, the ordering of more complicated, unfamiliar, or crowded combinations of activities is objectively calculated. Activities to which the individual is strongly committed and which are space- and time-fixed or merely time-fixed, tend to act as points around which the ordering of activities, according to their flexibility, are scheduled.

Research Proposition. The central proposition of this research is that it is meaningful to view the constraints to which people feel subjected as relative to either a particular time of day or a certain activity, or both. It follows that for any particular time of day, it seems reasonable to ask a person whether or not he felt "tied down" either with respect to his current activity or his location. And for any given activity, it also seems reasonable to ask the individual whether or not he felt its timing or location to be similarly fixed. It would appear to be acceptable to fix on times of day at which one has to be at a particular location or at which one has to perform certain activities and to fix upon activities that must be undertaken at certain times or at specific locations. Alternatively, it would not appear acceptable to fix on locations since it seems unlikely that many people perceive many places to be either specific to a certain activity or a particular time of day, or both.[45] The basic hypothesis is, therefore, that the critical determinant of the structure of a person's day, given environmental forces (i.e., objective constraints), is the extent to which one feels constrained relative to certain activities, times, and locations. These fixes, or points, about which one's day tends to be organized will act as the crux of the simulation experiment.

RESEARCH STRATEGY

In order to substantiate or illuminate the preceding propositions, a survey was undertaken. The remainder of this chapter reports on a research design for the collection of pertinent data and includes: (1) a consideration of some methodological problems of time-space budgets, (2) the selection of a survey site, (3) the design of a sampling procedure, (4) the development of survey site, and (5) the administration of the survey.

Methodology of the Time-space Budget Diary

For any given group of people, a full set of time-space budget diaries provides a very comprehensive data base from which to approach an understanding of the problems that this research confronts. An individual's time-space budget can give spatial as

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[45]Cullen and Nichols, op. cit.

well as temporal coordinates of one's behavior in a given period. In most time-budget accounts, however, spatial coordinates have not been obtained or, if they have been obtained, they have not been used in the analysis. Where time spending has been considered explicitly in a spatial context, it usually has been given only partial treatment. For example, it has been used as a surrogate for distance to shops or workplaces, without reference to overall time-budgeting and spatial organization.[46]

Problems of Data and Analysis. Considerable difficulties confront the use of a time-space budget approach and in combining temporal and spatial analysis. Time-space budget data are expensive to collect and, for this reason, many studies are based on a short period of time such as a day or a week. Perhaps more as a matter of faith than of fact, this short time period is assumed to be typical. Activities which follow a longer time cycle may be neglected (e.g., seasonal ones),[47] thus altering the factual information. It is not easy to check for accuracy, or to check that recorded activities are in general typical of recurring behavior patterns. Therefore, it is frequently necessary to obtain information, via questionnaires, on

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[46]James Anderson, Time-budgets and Human Geography: Notes and References, Graduate Discussion Paper No. 36 (London: Department of Geography, London School of Economics and Political Science, 1970), p. 3. As an example, see: Chapin and Logan, op. cit.

[47]Mead is one of the few researchers to have concentrated on time-budgets and seasonal variations; see: W.R. Mead, "The Seasonal Round: A Study of Adjustment on Finland's Pioneer Fringe," Tijdschrift voor Economische en Sociale Geografie, 49 (July, 1958), pp. 157-162.

activities which occur irregularly or follow a longer cycle than the activity record period, although seasonal variability presents difficulties. Also, the willingness of respondents to record activities declines fairly rapidly, whether or not payment is involved. Anderson has found that about three days seems a critical limit for relatively comprehensive diary records.[48] However, a shorter activity record period can facilitate comprehensive treatment of important daily and weekly rhythms.

Linguistic Aspects of Time-space Budgets. Additional problems of the use of time-space budget data can perhaps be clarified by noting a distinction between substance language and coordinate language.[49] The semantic rules of a language must specify the manner of designating and identifying the objects in its domain of discourse, a process referred to as "individuation." The designation of objects commonly uses proper names, which is the mode for substance and thing languages, or positional coordinates, which characterize coordinate or time-space languages. The former, an aspatial language, describes characteristics or properties of individuals (e.g., incomes, occupations, life styles, types of activity, etc.), while their locations or positions are described in terms of a time-space language. The latter, a locational coordinate system of four dimensions (conventionally written as x, y, z, t), is associated with the so-called "physicalists"

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[48]Anderson, "Space-time Budgets and Activity Studies in Urban Geography and Planning," op. cit., p. 357.

[49]David W. Harvey, Explanation in Geography (New York: St. Martin's Press, 1969), pp. 191-229.

who advocated the unification of science through the language of physics.[50]

Wilson,[51] followed by Dacey,[52] suggests that "individuation" requires the use of time-space coordinates. Individuation of an individual may result either from attributes that the individual manifests or from the position one occupies. The individuals in the domain of most languages are commonly identified by a name or by presence of non-positional attributes and the time-space regions occupied by each individual are seldom explicitly taken into account. For this reason, the semantic rules of designation and individuation generally ignore spatial-temporal attritubes of individuals. And if individuals are defined only in substance terms (i.e., non-positional attributes), they lose part of their essence. Harvey points out that this is particularly essential to geographic study in that the ordering of geographic information "amounts to the difficult logical problem of working with two different language

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[50]The physicalists generally contend that the physical, cultural, and biological things considered by empirical science are largely time-space regions of the four dimensional time-space continuum: each thing occupies a definite region of space at a definite instant of time and occupies a temporal series of spatial regions during the whole history of its existence. Thus, all empirical science may be unified through the language of physics. See: Oscar Neurath, "Foundations of the Social Sciences," International Encyclopedia of Unified Science, Vol. 2 (Chicago: University of Chicago Press, 1944), pp. 1-51.

[51]N.L. Wilson, "Space, Time, and Individuals," Journal of Philosophy, 52 (1955), pp. 589-598.

[52]Michael F. Dacey, "Linguistic Aspects of Maps and Geographic Information," Ontario Geography, 5 (1970), p. 78.

systems in the same context";[53] a problem magnified by the fact that geographers usually deal with both discrete and continuous data.

The problem of using both languages lies at the heart of time-space budget analysis. The substance, or non-positional, language is itself multi-dimensional (e.g., different types of respondents and activities, attitudes, non-locational contraints), and adding the positional, or time-space, language further complicates the problem. Hägerstrand's use of computer simulation models, where activity schedules are sieved through a time-space environment in order to evaluate the constraints imposed by the environment, is perhaps the most complete answer to these linguistic problems.[54]

Data Requirements. All surveys which involve the collection of time-space budget diaries may be used to collect a set of activity modules which together may be taken as a definition of that individual's behavior over a fixed period of time. Each module contains information which has between two and four dimensions of variation. The most basic dimensions are those of activity, time, and location. Thus, each activity performed must have some descriptive title, a

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[53] David W. Harvey, Explanation in Geography (New York: St. Martin's Press, 1969), pp. 216-217; and for additional comments on the problem of individuation, see: David W. Harvey, Social Justice and The City, op. cit., pp. 38-40.

[54] Torsten Hägerstrand, "Tätortsgrupper som regionsamhällen: Tillgången til förvärvsarbete och tjänster utanför de större städerna," Regioner att leva i, Expertgruppen för Regional Utredningsverksamhet (Stockholm: AB Allmänna Forlaget, 1972), pp. 141-173.

rather precise location in time, including start and end times, and a spatial location. A final dimension that is sometimes included is relational; some information is collected about other individuals, if any, in whose company the event occurred. Furthermore, each of these four dimensions lend themselves to differing degrees of elaboration and integration. For example, if a respondent is watching television while eating dinner, a secondary activity might be recorded. And, if appropriate, an activity may be described in terms of the degree to which it was anticipated or unexpected, and further subjectively ranked according to the constraining effect of the major dimensions of time, space, and activity.

Survey Site

With this overview of the data requirements in mind, the first stage in the research design was the selection of a survey site and sampling procedures. The sample of respondents was drawn from the faculty, staff, and students of Michigan State University, located in East Lansing, Michigan. The university, a territorial enclave within the Lansing, Michigan metropolitan area, maintains a population of some 35,403 students, 3,463 faculty, and 4,703 staff.[55] Owing to its sheer size, in terms of population and areal extent, such an institution has often been referred to as "megaversity" or "multiversity." To many of its residents, the university is often viewed as a

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[55]These data are for the Fall Term of the 1973-74 academic year, and represent only full-time faculty, staff, and students; source: Department of Information Services, This is Michigan State University: 1974 Facts Book (East Lansing, Michigan: Department of Information Services, Michigan State University, 1974).

well-defined and self-contained entity. That is, within the confines of the institution, many of its members can satisfy almost all of their needs and wants in the conduct of their everyday affairs. These range from such physiologically defined needs as sleep and sustenance, to culturally defined extensions such as working, shopping, and home-making, and to a variety of leisure pursuits.

The spatial configuration of the university is in some ways analogous to that form commonly associated with the city, i.e., seen as a city in microcosm. It is characterized by a core of administrative and information-processing units that have important links and interdependencies necessary for personal communication and face-to-face contact. This core is ringed by classroom buildings and office structures in which the majority of business is transacted in the process of education and research. Also located in this zone is the majority of commercial establishments such as stores and restaurants. This zone is, in turn, engulfed by living quarters for the academic staff and students, ranging from high density dormitories to lower density apartment complexes as one moves toward the periphery. In terms of aggregate population shifts from core to periphery, and vice versa, during the course of a day, the diurnal movements of the university's population are not unlike those of a city's inhabitants. Also, the variety of transport modes available within this institutional complex rivals that common to the city.

There is, however, the danger of carrying the city/university analogy to extremes. Although the university may be thought of as an independent or semi-independent entity, it is in reality, quite dependent on its surroundings. This is borne out by the fact that, just as the linkages among the members of the university are numerous and complex, so too are the linkages it maintains with the surrounding environment.

The university is seen, therefore, as just one of a variety of subsystems of the larger urban system. Subsystems of the urban system can be distinguished in several ways. They can be described as spatially defined areas of the city; alternatively they can be delimited as operational units, for example, offices, organizations, industrial plants, or educational institutions. In each case, a more detailed knowledge of how these subsystems operate will assist in understanding the apparent complexity of the larger urban scene.[56]

In striving toward this understanding, geographers and planners are giving increased attention to subsystems, such as institutions and organizations and their internal and external linkages over space, rather than from sampling randomly from the larger urban population or from socio-economic strata.[57] In moving from the urban scale to that

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[56]Nicholas Bullock, Peter Dickens, and Philip Steadman, "The Modelling of Day to Day Activities," Urban Space and Structures, Cambridge Urban and Architectual Studies 1, eds. Leslie Martin and Lionel March (Cambridge: Cambridge University Press, 1972), p. 127. Equally of course, these parts or subsystems--such as, for example, the particular institution here chosen for investigation, the university--are deserving of study in their own right for the special geographic, planning, and architectural problems they present at their particular scale, besides as components of the larger urban problem.

[57]Some examples include: Vida Nichols, An Institution in Metropolis, Seminar Paper No. 12 (London: Joint Unit for Planning Research, University College, London, 1969); Britta Ohlsson, Inter-institutionella kontaktflöden, Urbaniserins-processen, rapport nr. 8 (Lund: Institutionen för kulturgeografi och ekonomisk geografi vid Lunds universitet, 1967); John Goddard, Office Linkages in Central London: Volume II (London: London School of Economics and Political Science, 1971); Gunnar E. Törnqvist, Contact Systems and Regional Development, Lund Studies in Geography, Series B, Human Geography, No. 35 (Lund: C.W.K. Gleerup, 1970); and, Olof Wärneryd, Interdependence in Urban Systems, Meddelanden från institutionen

of the institution, a much wider and more complex range of activities must be examined than just those distinctions that might be made for an urban model. For the university, the great variety of types of activity in which many of its members engage, and the relative freedom which they have to organize their time, make this perhaps an especially complicated case to consider, when compared with the more regular routine of the factory or office worker, or housewife.

In many respects, the sample of the population affiliated with a university might be expected to be a highly abnormal one, since university personnel generally are thought to have a degree of freedom governing their working hours far in excess of the working population. The general expectation would be that the greater the degree of freedom within this group, the greater the variation between individuals in the ways in which they structure their days. And this variation would be expected to be much larger than within other homogeneous groups of working people.[58] However, for these and other reasons, this population is particularly interesting and promising for study.

The complex range of activities open to members of the university institution leads one to expect a greater variety of subjective constraints in accommodating the greater range of activities in their

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kulturgeografiska, nr. 1 (Göteborg: Kulturgeografiska institutionen vids Göteborgs universitet, 1968).

[58]This problem, however, does not appear too serious since the research methodology is amenable to replication. Underlying this point is the conviction that a research event should be viewed as a single step in the context of a larger, continuing process.

daily routines. For example, the university institution depends, to a great extent, on personal and face-to-face contacts in the conduct of its everyday affairs. The commitments and time-space fixities assoćiated with such negotiations produces a great variety of subjective constraints operating on daily behavior. In this respect, the university institution is seen as a limiting case of a variety of tertiary and quaternary institutions.[59] Therefore, a model of the time-space mechanics of constraints operating on the daily activities of university personnel should have relevance to other subsystems or institutions in the larger metropolitan system, where the modelling may indeed be a more simple one.[60]

The emergence of clearly defined patterns of behavior among members of this group, despite their loosely structured budget-space, provides interesting information concerning people's habit of structuring their day in a standardized form regardless of the lack of direct constraints. In relation to this matter, Cullen and others note that:

> It must also be remembered that only about half the population is employed in any sort of regular job and that there are many housewives, old people, and children who have even fewer hard and fast commitments imposed upon them from outside than these supposedly unfettered students and dons. In some respects, university people, although abnormal, are perhaps quite middle-of-the-road in terms of the degree of freedom which they have to structure their own time.[61]

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[59] Cullen and Nichols, op. cit., p. 5; Nichols, op. cit., p. 14.

[60] Bullock et al., op. cit., p. 130.

[61] Cullen et al., op. cit., p. 11.

Sampling Design

As the first stage of the sampling design, one institution, the Michigan State University, was selected as a base for investigation. Although the rationale for its selection as one subsystem of the larger metropolitan system was discussed above, a few additional comments are necessary.

In order to adequately study the time-space mechanics of constraints operating on the formation of activity sequences, attention must be focused on the paths, or behavior of the individual through time-space. The instrument chosen for collecting this type of information is the time-space budget diary. The collection of diary information from a sample of people randomly selected from the entire metropolitan complex, or even from a number of its various subsystems (e.g., business or service organizations and institutions) would not be feasible in that responses would be spread so thinly among them as to make it virtually impossible to discern sequences or patterns of behavior. At this stage of research into the structuring of daily activities, more is to be gained through investigating the members of a single organization or subsystem in order to establish the pattern of linkages associated with one unit.

Once the first step in the sampling design is completed, the selection of the university institution, the procedure of sampling from among its members remains. When the problem of sampling elements from any universe arises, the issues of representativeness and reliability come to mind. Typically, these issues are important in the methodology of cross-sectional studies dealing with the aggregation and prediction of individual behavior.[62] In this research project, however, the focus is on the structuring effects that the interaction or mechanics of constraints have on daily behavior. It was in regard to these issues that Hägerstrand pointed out that, "a large sample survey of actual behavior is not essential since emphasis is laid on the working of constraints rather than the aggregation of their behavior patterns, the latter demanding a larger sample."[63] In a previous section of this chapter a distinction was made between choice- and constraint-oriented approaches to time-space behavior. Had the former methodology been adopted, the necessity of a large sample would have been a significant issue. With the issue of sample size relaxed, a survey population of some 200 individuals, or members of the university population was sought.[64]

The obvious sampling frame is the total university population, or, the list of all individuals who are affiliated with the institution. However, many who could be considered a part of this group seemed inappropriate to the purposes of the study. As a result, it

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[62]R.A. Carr-Hill and K.I. Macdonald, "Problems in the Analysis of Life Histories," Stochastic Processes in Sociology, ed. R.E.A. Mapes, The Sociological Review Monograph 19, ed. Paul Halmos (Keele, England: University of Keele, 1973), p. 58.

[63]Hagerstrand, "The Impact of the Environment and Social Organization," op. cit., p. ; Carr-Hill and Macdonald agree that studies with similar objectives have too often tried "to deploy the methodology of cross-sectional studies, using large samples when a few subjects would suffice for the discovery of a developmental sequence." See: Carr-Hill and Macdonald, loc. cit.

[64]Realizing the likelihood of non-response, the sample size was set at 200 (i.e., a sampling ratio of 0.5 to the survey population), so that the number of respondents, or, successfully interviewed persons would amount to at least 150.

was necessary to define the survey population in a somewhat more restricted fashion. The final definition included three general groups which are defined by university affiliation: (1) full-time students registered for the Fall Term, 1973, on the East Lansing campus of the university, (2) full-time faculty, including those in instructional and research programs, and administrative officers employed on the main campus during the Fall Term, 1973, and (3) full-time clerical-technical and labor staff employed during the Fall Term, 1973, on the East Lansing campus of the university.

The complete lists of individual's names and addresses were obtained for the Fall Term, 1973, and were stratified by type of affiliation as described previously.[65] Precautions were taken to ensure that no one individual's name appeared in more than one of the lists, so as to guarantee that all members of the survey population had an equal chance of being selected in the sample. Once the individuals' names had been arranged by affiliation, a systematic sample was selected across the entire list. The sample size for the study was set at 200 observation units. To achieve this sample, the sampling procedure employed a 1/200 sampling fraction, or a sampling ratio of 0.5. Thus, in using the systematic sampling method, every 200th individual in the list was chosen for inclusion in the sample. To guard against any

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[65]The data sources for the three groups included: (1) a roster of all full-time students enrolled during the Fall Term, 1973, on the main campus was obtained from the registrar's office; (2) a roster of all full-time faculty and administrative officers was obtained from the office of the executive vice president; and (3) a list of all clerical-technical and labor staff was received from the personnel office, Michigan State University, East Lansing, Michigan.

possible bias, the first element was chosen at random. The random start was made by generating a random number within the range of the sampling interval. The totals for the sample, stratified by type of university affiliation, are given in Table 1.

TABLE 1.

TARGET SURVEY POPULATION

AFFILIATION	TOTAL POPULATION	PROPORTION OF TOTAL	TARGET SURVEY POPULATION
STUDENTS: (full-time only)	35,403	81.2	162
FACULTY:	3,463	8.0	16
Instructional Programs	[2,229]		
Research Grants & Others	[557]		
Administrative-Professional	[657]		
STAFF:	4,703	10.8	22
Clerical-Technical	[2,128]		
Labor	[2,575]		
TOTAL:	43,569	100.0	200

The next step in the sampling design was to assign each individual in the sample to a weekday for survey. In other words, the sample was further stratified by weekday of participation. In order to counteract any possible bias in the stratification by weekday, the list of individuals in the sample was first randomized. After the reordering of elements, via random number techniques, the list was divided into quintiles; the first 40 individuals being assigned to a Monday survey date, the second quintile of individuals being assigned to a Tuesday survey date, and so on through the fifth quintile which was assigned a Friday survey date.[66]

Preliminary Survey

Before administering time-space budget diaries and supplemental questionnaires to the selected sample, several considerations made a preliminary survey advisable. Perhaps most important was the need to test several different methods of data collection pertaining to individuals' activities in time and space. In a preliminary survey conducted at Michigan State University, four survey formats were tested and compared. (See survey options 1-4 in Figure 16.) Each of the four options included a time-space budget diary and a supplemental questionnaire. The survey options differed according to two criteria: (1) the extent to which the survey relied upon interview techniques and (2) the degree to which the diary format was structured. The four alternatives were designed and implemented in such a way as to determine

[66]The survey was conducted over a continuous five-week period during the months of October and November, 1973. In the case of the first quintile of 40 individuals, for example, an equal number of eight individuals were assigned to each of the Mondays falling in the survey period. The same practice was followed for the remaining quintiles and their respective weekday of observation (Appendix E).

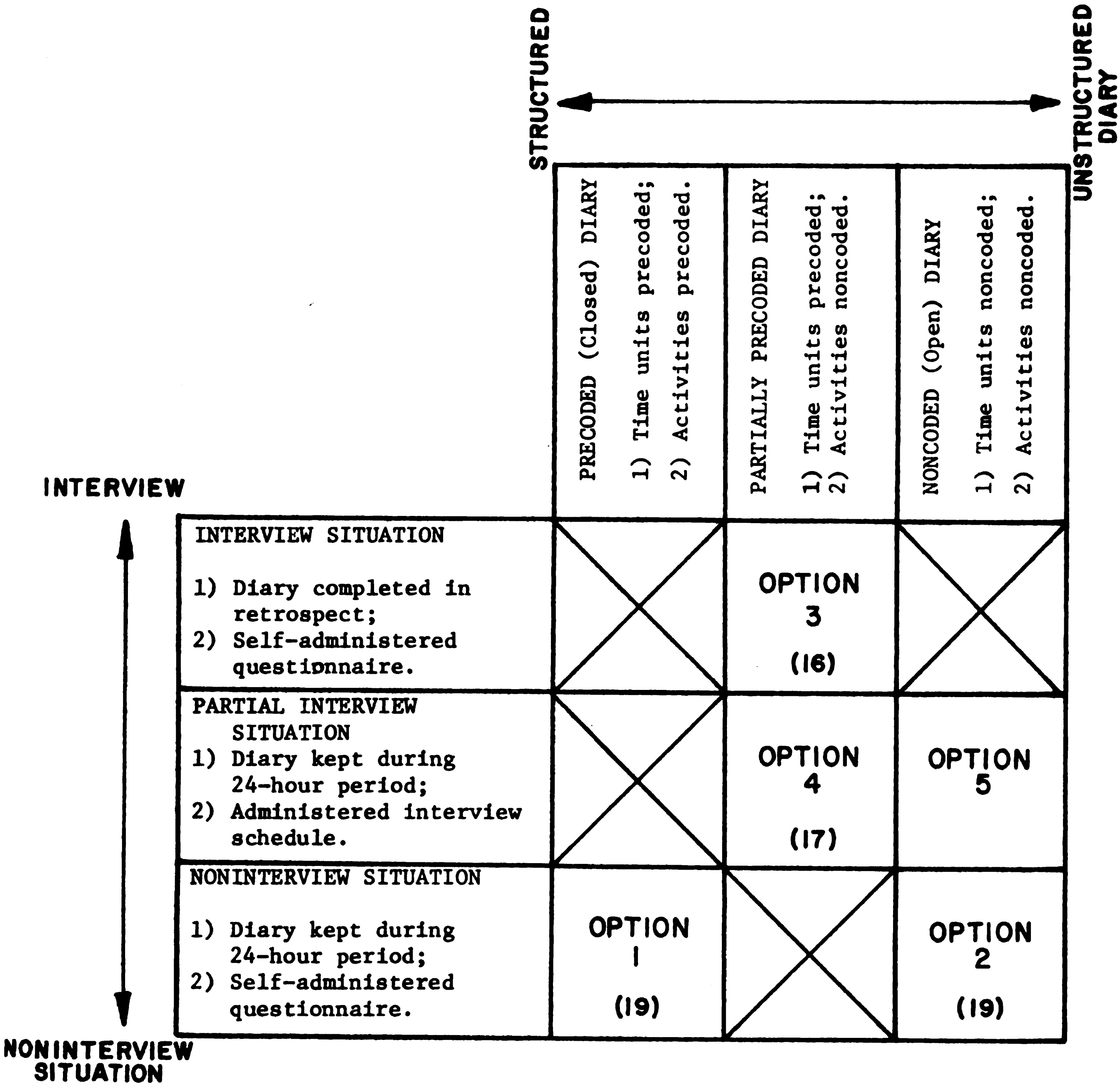

FIGURE 16

SURVEY FORMATS TESTED IN PRELIMINARY SURVEY

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*In the preliminary survey, a total of 20 individuals were asked on four occasions to complete diaries (options 1 through 4). The value within parentheses indicates the number of respondents completing this survey format.

**Format option chosen for the Michigan State University survey.

which method, or combination of methods, would produce the most reliable results, keeping in mind the time constraints of the survey as a whole, and the respondents in particular.

In selecting individuals for pretests, it was neither possible nor advisable to look for anything like a representative sample. Representativeness is no criterion in a pretest in which the objective is rather to test the degree to which variations in procedure affect the reporting of results. Given such an objective, the respondents need to be chosen in such a way as to represent a maximum variation with respect to whatever characteristics are likely to influence reactions to a particular data collection technique.[67] Also, the decision to use combinations of survey formats for describing the behavior of one individual presupposed that a stronger motivation to cooperate was needed than is necessary in a normal survey. The latter consideration resulted in an overrepresentation of persons in the student and faculty groups of the survey population. Accessibility was the main consideration in selecting cases for joint use of observational techniques, and to some degree the investigator was obliged to rely on networks of acquaintanceship.

Survey Formats. The first method (option 1), a noninterview, was designed to collect the desired survey information by mail. This method of self-reporting involved the respondent filling in a structured diary in which time units for the 24-hour period were precoded by fifteen minute intervals and classes of activity were predefined. For each

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[67]Earl R. Babbie, Survey Research Methods (Belmont, CA: Wadsworth Publishing Company, Inc., 1973), pp. 206-207.

activity at a given point in time, the respondent was asked to indicate its location, if anyone else was involved, and if the respondent was doing anything else at that time. In addition to the diary, the respondent was asked to complete a self-administered questionnaire that would provide the needed background information about the individual being surveyed. [For a similar questionnaire, see Appendix B.]

The second method (option 2) also relied on self-reporting in a noninterview situation. However, this alternative differed from the first in that the respondent was asked to complete an unstructured, or "open," diary. Here, the respondents were to describe in their own words their activities over the 24-hour period, giving their times and locations as exactly as possible. For each activity, the respondents were also asked to report any secondary activity and to indicate if anyone else was involved. In addition, the completion of a questionnaire, similar to that given in Appendix B, was required.

Unlike the previously mentioned alternatives, the third method relied on "yesterday interviews" in which the respondent was asked to provide an interviewer with an account of activities for the preceding day. The diary format used by the interviewer was partially precoded, in that only time units were defined by fifteen minute intervals. Otherwise, the remaining categories of response were open. These included: a description of the activity, its location, if anyone else was involved, and if the respondent was performing a secondary activity. The use of interview techniques permitted the interviewer to pose more detailed questions about activities, especially secondary ones, to be reported in the diary, and to administer an interview schedule.

The fourth and final survey format tested had the respondent keep a diary during the assigned day of observation (Figure 16). The diary format was partially structured, in that only time intervals of fifteen minutes duration were precoded, leaving the activities and their locations to be described in the respondents own words. The respondent was also instructed to record secondary activities where appropriate and other persons in whose company the activities were performed. On the following day, an interviewer administered an interview schedule and reviewed the diary with the respondent, probing for clarification in recorded activities, if necessary, and asking the commitment and fixity questions for all activities (Appendix B).

With all options, questions relating to one's degree of commitment to activities and their subjective fixity ratings were posed. In cases where the diary information was obtained via interviews, the questions were asked by the interviewer, whereas in noninterview situations, the questions were printed in the diary with space allocated for responses for each activity reported. In attempting to discern an individual's commitment to a given activity, the respondent was asked whether or not the activity had been planned. For information concerning the spatial and temporal fixity, the following questions were asked for each activity reported: (1) Could you have done this (activity) elsewhere? and (2) Could you have done this (activity) at another time?

It was thought that the use of precoded diaries in non-interview situations (option 1) would allow for a greater number of survey respondents than noncoded diaries, but with the risk that this information might be too sketchy or too innacurate to be of any use in modelling individuals' activities in detail. A diary in which both the activities and the time intervals are precoded would be simple to fill in and would thus guarantee a minimum level of detail. But by precoding, much of the detailed information would be forfeited. First, the range of activities would be greatly reduced, although space was provided for respondents to add further activities which did not fit within those categories listed. Secondly, by precoding the time units in intervals of fifteen or twenty minutes, it would become necessary either to disregard trips or activities of short durations or to round them off. Thus, much of this type of information would necessarily be inaccurate, particularly for trips around campus or in town, in which cases the majority are less than fifteen minutes. An additional disadvantage to the use of this kind of format is the ease with which fictitious activities might be entered into the diary.

The noncoded, or open, diary (option 2) used in a noninterview situation would not only make it possible to collect several times as many diaries as in the interview situation (options 3 and 4), but it would also preserve this information in a more detailed form than the precoded diary. The coding of activities could be undertaken after the survey and could thus take into account the actual range of activities described. Furthermore, the difficulty of choosing a fixed time unit would be overcome automatically. An additional advantage of this diary is that it would become very tedious to enter fictitious activities. However, an argument against this is that the quality of the diary might deteriorate over the 24-hour period.

It was thought that the interviews (options 3 and 4) would provide both reliable and detailed information of an individual's activities for a 24-hour period. Some advantages claimed for the interview were the possibility, with an experienced interviewer, of detecting if the interviewee were making up activities, and of prompting the respondent should he find it difficult to recall his activities or should he have difficulty interpreting the commitment and fixity questions.

Results of the Preliminary Survey. The results of the preliminary survey confirmed expectations that data on time and space use are very sensitive to even relatively minor variations in the procedures of data collection. This sensitivity affects both the reliability and the validity of the data. There is no obvious and absolute measure by which to judge the results of any of the techniques used during the pretests as "true"; the only basis for judgements are the variations among the techniques that record the behavior of the same person. However, if a particular technique consistently produces more complete and detailed records, then the technique that produced more complete records may reasonably be treated as "better."

The greatest difference between the various combinations of formats was observed with respect to activities that were incidental to other activities. Consequently, completeness of recording secondary activities was used as one means of judging the quality of data collection. Another noticeable difference among the various formats was the level of detail in recording the spatial locations of activity and movement between activity locations. The permutations of combinations allowed then a ranking of different techniques with respect to their completeness in recording behavior, and with regard to their suitability in reproducing various types of behavior. This procedure is analogous to the reasoning in using paired comparisons as a scaling procedure--each recording technique or survey format serves as a yardstick for every other technique.

No one technique with which the investigator is aware will result in "perfect" data. But among the techniques tested during the preliminary survey, a rather definite sequence in the reliability and validity of data collection procedures could be observed. The results of the survey showed that the partially precoded diary used in an interview situation yielded the best results (option 4 in Figure 16). Although it did not produce as many diaries as some other methods in a comparable amount of time, it did provide the best level of detail. Respondents were willing to complete these diaries in considerable detail and there was no consistent reduction in the number of entries toward the end of the day. The diaries completed in retrospect, the yesterday interviews with aided recall (option 3), consistently did not produce sufficient detail as those kept during the 24-hour period. It should be noted that the open diary method (option 2) provided an adequate level of detail. Considering that the open diary method was used in a noninterview situation, suggests that the method has even greater potential in an interview situation for providing greater detail.

The effects of an interview versus a noninterview situation were also noted. A comparison of the account of a given day in an interview with that from a noninterview revealed that much additional detail can be recovered from the use of diaries in interview situations. In the case of the total interview situation, the yesterday interview (option 3), the interviewer could aid recall, pose questions of clarification where appropriate, or probe for further detail. The interviews were particularly helpful for respondents and interviewers alike in clarifying ambiguities in the commitment and fixity questions.

The noncoded and partially precoded diaries were considerably more detailed than the precoded diaries in the number of entries and the range of activities described for both primary and secondary activities. Although provision was made for respondents to enter extra activities in the precoded diary, only the most obvious additions were made and these diaries were too unspecific about the type of activity. Unexpectedly, a number of respondents remarked that it appeared easier to fill in the noncoded diaries than the precoded ones, largely because with the latter it was difficult to find a suitable description for an activity in terms of the small number of categories provided and also because of the difficulties of rounding the duration of their activities to fit within the time period provided.

Choice of Survey Format

Of the four survey options tested, the second and fourth methods (Figure 16) yielded the best results. The primary advantage of the second method was its use of an unstructured, or open time-space budget in a noninterview situation. The only recognized weakness of the fourth method was that the diary format was partially precoded--time units being defined by fifteen minute intervals. The format chosen for the final survey was, therefore, a combination of the second and fourth methods. [See option 5 in Figure 16.]

Final Time-space Budget Diary. The fifth survey method involved the respondent keeping a diary during the assigned day of observation. Since the diary format was unstructured, the respondents were asked to describe their activities over the 24-hour period, giving their times and locations as exactly as possible. In addition to this information, the respondents were asked to further indicate for each activity the other persons present and whether or not a secondary activity occurred at the same time. Thus, all of the core information of the time-space budget diary would be recorded by the respondent without an interviewer present.

Since the remaining information of the time-space budget--the data on commitment to and fixity of activities--are particularly important to this research, they were obtained by interviewers on the day following the completion of the diary. The pretests were especially helpful in revealing the inadequacies of the questions relating to commitment and subjective fixity ratings of activities.

The pretests demonstrated that the response categories to the commitment question, planned and unplanned, were too limited. The decision was made, therefore, to expand the categories of response to include a broader range of flexibility, as discussed in an earlier part of this chapter. In attempting to discern one's degree of commitment to a given activity, the question--"To what extent was the activity planned?"--was changed to include four categories of response: (1) arranged with others, (2) routine, (3) planned independently, and (4) unexpected. Although some of the categories were thought to be self-evident, the interviewers were instructed to define each of the possible responses for the purposes of standardization. Interviewers were to advise respondents that routine activities were to be construed as those activities which almost invariably occur with a particular set of circumstances, even though the set of circumstances might only recur at intervals of a week or more. Hence, the degree of regularity of routine activities remained flexible. The degree to which an activity was planned, as in response categories 1 and 3, was similarly left open. If the respondent claimed to have planned to do a given activity at some time during the day, it was considered as planned.

The format of the subjective fixity questions was also altered to better match the conceptualization of the constraining effects that the dimensions of time, space, and activity have on the structuring of daily behavior. Only two of these dimensions were treated during the pretests. Following Cullen and Nichols' suggestion,[68] a four-part fixity question was included in the final time-space budget. Each of the four questions, designed to reveal subjective constraints, seeks simple yes/no responses (Table 2).

TABLE 2.

THE FOUR-PART SUBJECTIVE FIXITY QUESTION

	Subjective Fixity Question	Type of Constraint
(1)	Could you have done anything else at this time?	Activity choice fixity
(2)	Could you have done this (activity) at any other time?	Temporal fixity of activity
(3)	Could you have done this (activity) elsewhere?	Spatial fixity of activity choice
(4)	Could you have been elsewhere at this time?	Spatial fixity of activity location

The first question is phrased in such a way as to discover whether or not the individual had any choice of activity open to him. The second

[68]Cullen and Nichols, op. cit., p. 12.

question inquires about the timing of the chosen activity and is phrased in such a way that the respondent is forced to isolate the timing from the choice of activity.[69] The third and fourth questions seek information on the spatial fixity of a given activity. The third part is the direct spatial equivalent of the second in that it is similarly dependent on the choice of activity. The subject of the fourth question is the spatial fixity of the activity location. The fourth question is similar to the first in that the first focused on the choice of activity available to the individual during a given unit of time, while the fourth focuses on the same unit of time but on the individual's potential choice of location in it. Since the importance of this may not be immediately evident, consider the following example: A sequence of events may effectively tie a person to a particular place for short periods simply because there is not sufficient time to go elsewhere during the intervening period (e.g., successive meetings in the same office building).

A need arises for a standard of comparison for the detailed fixity question. Prior to answering the four-part fixity question (Table 2), the respondent was asked to review the day's activities as he had recorded them. While doing so, he was asked to isolate those activities or episodes which, in his opinion, were important in the sense of having had to be done at a fixed time or location and thus having been points about which he felt his day had to be organized. Once these activities had been isolated, the respondent was asked to further subjectively rank

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[69]Ibid. In order not to confuse the timing of an activity with the choice of a particular activity, Cullen and Nichols recommend two independent questions rather than the more direct question: Did you have to do this activity at this time?

the activities in order of their importance. This simple ranking, then, was to act as a measure against which to assess the detailed fixity question.

As a result of the pretests, further decisions were made regarding the format of the final survey. For example, the 24-hour weekday was retained as the unit of observation. Such a limited time span might have grave restrictions on research whose purpose is the quantitative analysis of aggregate behavior patterns, and where a typical day of observation is a significant issue.[70] However, the 24-hour observation period was not considered a restriction on this research. The objective focuses on the understanding of constraints, both objective and subjective ones, that affect the structuring of daily behavior, regardless of the typicality of the day of observation. However, it was observed during the pretests that a great many activities of considerable importance for the interviewees such as participating in sports, going to the theater or church, or meeting regularly with friends at a bar were quite infrequent during any one day. In order to have some idea of the relative frequency of such activities, in the event that such data might prove useful at some unforeseen stage of the research, data relating to these usually infrequent activities were collected in the interview schedule (Appendix B).

An additional problem in recording use of time derives from the fact that many people during a large portion of the day do more than one thing at a time. To catch this aspect of time use, a distinction was

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[70] Erwin K. Scheuch, "The Time-budget Interview," The Use of Time, ed. Alexander Szalai (The Hague: Mouton & Co., 1972), p. 75.

made between primary and secondary activities. A primary activity was defined as any act that was determined by a person's location, and/or his interaction partner plus his commitment response. A secondary activity was defined as an activity performed concurrently with primary activities. By and large, a primary activity represents the rough organization of a day, as a consequence of the institutionalization of society and the combination of duties that result from a person's configuration of roles; and, in general, a secondary activity represents the preferences of an individual. Although a number of respondents managed to do three things simultaneously such as eating, watching television, and conversing with others present, it was decided for practical reasons not to record more than two activities during any one time period.

While the term activity seems to be a notion which is clear enough, it became evident during the preliminary survey that a more formalized definition had to be adopted for recording and coding purposes. Activity, therefore, was defined as any behavior where any of the following conditions remained unchanged: the common sense term used by the respondent either for primary or secondary, the location; and the interacting partner. Or to define activity more positively: as soon as any one of the four dimensions characterizing behavior changed, this would mark the beginning of a new activity.

Interview Procedure. The standard interview procedure used during the final survey was as follows: 1. During the day t-3 (i.e., three days preceding the one during which the respondent kept records) an interviewer telephoned the respondent, briefly explaining the intent of the survey and asking for the respondent's cooperation. 2. During the day t-2 an interviewer visited the respondent's university address and familiarized the respondent with the self-recording procedure. 3. The respondent would fill out his diary for the day t (i.e., the assigned day of observation), either during the day or during the evening of this day. 4. During the day t+1 (i.e., the day following the one for which the respondent's diary was kept) the interviewer would return and conduct an interview based upon the diary of the respondent and an interview schedule.

The interview procedure in step 4 was as follows: 1. The interviewer carefully reviewed all entries that the respondent had recorded in the time-space diary, checking to see that: a) the reporting of activities had been accomplished at an acceptable level of detail; b) no portions of the respondent's diary remained unreported; c) activity locations were clearly indicated; d) the times spent travelling to and from activities were recorded as separate activities e) modes of travel were specified; and f) activities and associated information were reported sequentially. If the level of reporting was too general, the interviewer probed for more details about the activities. 2. After any probing for clarification, the interviewer asked the respondent to go through the diary and for each activity to provide an answer to the commitment question: To what extent was the activity planned? 3. The interviewer then instructed the respondent to review the day's activities as recorded. While doing so, the respondent was asked to pinpoint those activities or episodes which were important in the sense that they had to be done at a fixed time or location. Once these activities were selected, the respondent was asked to rank them in their order of importance. 4. Then, the respondent was asked the four-part fixity question for all recorded activities except sleep and travel. 5. Finally, the respondent was to answer the questions in the interview schedule (Appendix B), designed to collect certain socioeconomic background information about the respondent.

CHAPTER 4

BEHAVIOR PATTERN RECOGNITION: EMPIRICAL ANALYSIS FOR MODEL DEVELOPMENT

The purpose of this chapter is to evaluate the preliminary hypothesis regarding the principle of consistency in human behavior. The claim was made earlier that the concept of pattern can be applied not only to the sequencing of activities, but also to their durations. The recognition of pattern and consistency in the recorded behavior of the sample population is essential prior to the development of a simulation model.

Before testing the consistency hypothesis, the survey results are briefly summarized and the structure and coding of the resulting data are discussed. Several analytic approaches are then reviewed in order to determine how best to reduce the vast battery of survey data into a more manageable form for analysis and eventually simulation.

SURVEY RESULTS

The university survey generated 138 24-hour time-space budget diaries. Out of a total survey population of 200, this represents a response rate of 69.5 percent (Table 3 and Appendix E). Each of the diaries obtained in the survey was composed of an average of 35 activity modules. The description of any activity module entails a vector of 15 elements of information (Table 4). Although the survey is a modest one, it has yielded a final data set of about 80,000 elements.

TABLE 3

RESPONDENTS AND NONRESPONDENTS BY UNIVERSITY AFFILIATION

University Affiliation	Survey Population	Respondents	Nonrespondents	Response Rate
Students	162	105	57	64.8
Faculty	16	14	2	87.5
Staff	22	20	2	90.9
Total	200	138	62	69.5

TABLE 4

VECTOR OF INFORMATION DESCRIBING AN ACTIVITY MODULE*

Element	Description
1	Starting time of activity
2	Ending time of activity
3	X coordinate of activity location
4	Y coordinate of activity location
5	Two-digit primary activity code
6	Two-digit secondary activity code
7	One-digit activity location code
8	Two-digit social contact code
9	One-digit code for travel mode
10	Ordinal ranking of activity importance
11	Degree of commitment code
12	Subjective fixity code--(1) activity choice fixity
13	Subjective fixity code--(2) temporal fixity
14	Subjective fixity code--(3) spatial fixity
15	Subjective fixity code--(4) spatial fixity

*For more details on the organization and coding of activity modules, see Appendix C.

DATA STRUCTURE

In order to comprehend such a vast amount of information, the data must be represented in a compressed form. Regardless of the analytical strategy chosen to accomplish this compression, the use of a digital computer will be essential for anything more than the simplest exercise. The issue of how the data set is to be made more manageable and how comprehension may be achieved through collapsing the data set is the subject of the ensuing discussion.

The data set generated by the survey presents a variety of problems for analysis. The research propositions outlined earlier provide a comprehensive framework within which to perform analysis. They suggest a variety of questions, each of which might illuminate one or more facets of behavior which are considered important to this research. The problems that derive both from the complicated nature of the questions and from the structure of the data from which the answers are sought require that a decision be made as to the appropriate unit of study and an appropriate analytical procedure.

Unit of Analysis

In most survey research, the unit of analysis is not a problem since a sample of individuals is asked a battery of questions and responses are converted into a vector of information. The vector is of fixed length and the individual remains the unit of analysis throughout the study. However, this is not necessarily the case when information is taken from a time-space budget diary and associated questionnaire. There is only one vector of information of a fixed length. It contains socio-economic information about the respondent as well as some background information relevant to the interpretation of the diary.[1] But there is also the diary information which composes a vector of variable length. Actually, it can be regarded as a matrix of information, with the length of one dimension fixed, while the other dimension varies in length (Figure 17). The size of the first dimension is determined by the number of indices chosen to describe each activity module. The second dimension, however, varies with the actual number of activity modules or episodes performed. Each element of the array may be of cardinal, ordinal, or nominal form depending on the aspect of the activity module being described.

Inevitably, one is confronted with a choice in any analysis of behavior patterns as to which unit of analysis is most meaningful. In many instances, the research questions determine the unit of analysis, but this is not always the case. Consider, for example, the case where interest is focused on time allocations to various types of activity. For some activities which are performed by a few people, it may be best only to investigate those data describing the duration of activity episodes, i.e., an average amount of time that some aggregate of people devote each day to a particular activity. However, for other activities which tend to be undertaken by the majority of a population, especially activities spread throughout the day (e.g., work, eating, personal hygiene), the most appropriate unit of study is the individual. Thus, attention would not be focused on the data describing the duration of activities, but rather on that describing the amount of time that the individual allocates to activities of that type. In many cases the most

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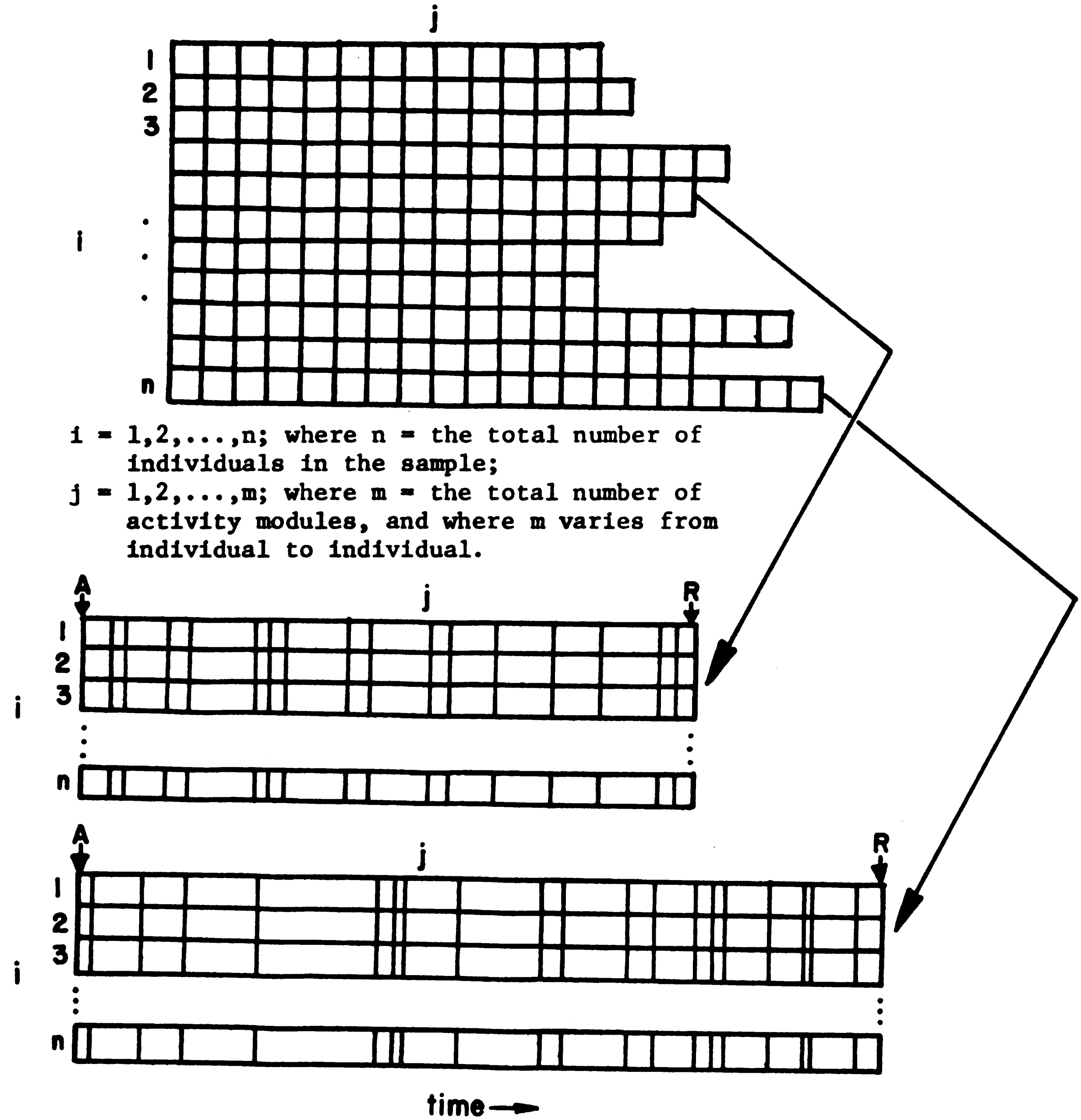
[1]See codebook for supplemental interview schedule and time-space budget diary in Appendix C.



i = 1,2,...,n; where n = the total number of individuals in the sample;

j = 1,2,...,m; where m = the total number of activity modules, and where m varies from individual to individual.

i = 1,2,...,n; where n = 15, the total number of dimensions describing activity module j;

j = 1,2,...,m; where m = the total number of activity modules for individual i;

A = the time an individual awakens at the beginning of the day;

R = the time at the end of the day at which the individual retires. The units along dimension j are of unequal length to represent the varying durations of activities.

FIGURE 17.

STRUCTURE OF TIME-SPACE DIARY INFORMATION meaningful unit of analysis may not be as obvious. For example, when the question involves comparing one measure of an activity with another --its location with the number of participants involved--the focus of interest is the episode that has these characteristics. But, in order to convert such ordinal or nominal data into a common cardinal measure for comparative purposes, one is forced to convert it into accounts of time spent in certain locations or with certain size groups by each member of the sample. That is, one has to transform the problem into one with the individual as the unit of study.

This phase of the research is concerned with the quantitative analysis of large numbers of sequences of temporally ordered observations as an observational unit. This will involve the analysis of a sequence of observations on an individual. The emphasis on the quantitative analysis of large numbers of sequences is not to deny the importance and validity of biographic or interpretive accounts of the lives of individuals. Indeed, it has been noted that these have been geographically more rewarding.[2] But on the continuum between biography and aggregate statistics is a "twilight zone" where common patterns of behavior among individuals can be discerned while preserving their individual identity.[3] If the problem of pattern recognition is to be adequately treated, it is this level of data representation that must be explored; a point that will become clearer in the subsequent discussion of analytical procedures.

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[2]Torsten Hägerstrand, "The Domain of Human Geography," Directions in Geography, ed. R.J. Chorley (London: Methuen & Co., 1973), p. 75.

[3]Torsten Hägerstrand, "What About People in Regional Science?" Papers of the Regional Science Association, 24 (1970), p. 8.

<u>Activity Modules</u>

All surveys which collect time-space budget diaries generate a set of activity modules which together define the individual's behavior over a fixed period of time. Each module varies according to several dimensions (Table 4). The most basic of these dimensions include activity, time, and location. Thus, the approach adopted in this inquiry conceives of the individual's day as an integrated n-dimensional unit. As a final stage in the comprehension of this unit, an attempt will be made to simulate the behavior of such an individual. Prior to the development of a simulation model, however, this chapter considers an intermediate stage of comprehension. Although attention must focus on the core of the inquiry, the respondents' behavior patterns, any simulation must proceed from an adequate understanding of the various factors involved. And since these factors and their integration are quite complex in the conception of time-space behavior, the techniques employed to achieve such understanding must be correspondingly comprehensive.

ANALYTICAL PROCEDURES FOR THE RECOGNITION OF BEHAVIOR PATTERNS

At the outset, it is mandatory to decide how to reduce the data set to a more comprehensible form. Univariate statistics and cross-tabulations are considered unsatisfactory since they are not sufficiently broad to cope simultaneously with even two or three of the closely related demensions involved in an individual's behavior pattern. Although these statistics can provide the analyst with a wealth of background information, they facilitate the comparison of no more than three variables simultaneously. And,,when used repeatedly to enable many such comparisons, this approach would result in some 1,200 tables and several thousands of summary indices even for this modest data set. The drawing of conclusions and generalizations from a full description of the data at this basic level would clearly be difficult given the unwieldy number of tables and summary statistics. This would also involve one in the dubious process of inferring individual behavior patterns from aggregate statistics. Even if one only considers portions of the data set, the tables and statistics at this level would require that they be treated individually since they defy rigorous consolidation.

Criteria for Pattern Recognition Analysis

The nature of the research problem defines the criteria to be employed in the selection or construction of an adequate analytical technique. First, a single analytic approach is considered insufficient, since the problem of describing and correlating a set of behavior patterns has two distinct levels. Initially, there are the data describing the set of activities which constitute each person's day. This set produces the series of activity modules which fully define what can be termed the time-space behavior pattern of the individual. In this case, only the time-space budget information is needed to satisfy the problem of pattern recognition. At a second but distinct level, are the data describing background characteristics of the respondents. Indeed, these background data are so different in form and substance from the diary data that it is difficult to imagine that an analytical procedure exists or could be formulated to treat both simultaneously. While attempting a solution to the problem of pattern recognition, the background information relative to each respondent, may be ignored. In the event that patterns can be identified, it may be possible to relate subsequently some index of the pattern for each individual such as membership in some behavior pattern group to one or more of the variables taken from the respondents' background data files.

Given the interest in pattern differentiation, a major problem is the vast amount of activity information relative to each individual in the sample. Some method must therefore be found by which all or part of these data may be condensed into a smaller, yet readily comprehensible, body of information. One should eventually be able to isolate a small set of faitly distinct behavior patterns, describe them in terms of the indices and variables which constitute them, and group individuals on a basis of the proximity of their behavior patterns to the generalized ones already described.

A Factor Analytic Approach

The use of a factor analytic technique might well be an ideal approach. Factor analysis would permit one to isolate the major dimensions of variation within a large data set defined by a considerable number of variables. In other words, factor analysis uncovers the independent sources of data variation. Because interdependencies may exist among the data, the technique would allow one to determine whether the same amount of variation in the data can be represented equally well by dimensions smaller in number than the columns necessary to tabulate the data.

The variables which make up an individual's activity pattern can be converted to cardinal form by treating each in terms of units of time.

Suppose one were to hypothesize that an individual's behavior pattern was constituted by the activities he performed, the degrees to which they were planned in advance and were treated as constraints, and the extent to which they involved other people. Then the cardinal measure in each of these sets of variables is the amount of time the person devoted (D) during the day to each variable category. Therefore, the total number of variables would be divided into three broad groups, and the activity pattern of the i-th individual, P_i, could be represented in the following vector form:

$$P_i = f(D_1,D_2,\ldots,D_j,D_{j+1},D_{j+2},\ldots,D_k,D_{k+1},D_{k+2},\ldots,D_m) \qquad (4.1)$$

where m is the total number of input variables, j is the total pertaining to the content or nature of activity, k-j is the total relating to degree of commitment or anticipation, and m-k is the total pertaining to numbers of participants. One should be able, then, to adopt a very detailed breakdown of behavior patterns (as in 4.1) as input to a factor analysis. The technique should produce a highly consolidated description which accounts for a high proportion of the variance within the data after the generation of a fairly small number of factors. The dimensions disclosed by a factor analysis can be interpreted as measures of the amount of ordered or patterned variation in the data. The degree to which such regularity or interdependency exists can be gauged by the number and strength of the dimensions.

Perhaps, some or all of the most important dimensions might be readily interpretable in terms of generalized activity patterns. For example, a pattern might result that would be typified by high factor loadings on on-campus activities such as attendence at classes and seminars, on variables representing a high level of commitment and constraint, and on variables describing large group activities. Such a dimension would then represent a day that is tightly ordered. By inspecting the factor scores, one would be able to identify the individuals that share this type of behavior pattern. Alternatively, another dimension might be characterized by low factor loadings on the above groups of variables, with higher loadings on independent study, socializing, or leisure, on smaller group size indices, and on the commitment and constraint items representing a much more loosely structured day.

Unfortunately, several problems confront the use of a factor analytic technique for the recognition of behavior patterns. Not the least of these is the fact that such a technique is based in parametric statistics. The analysis proceeds from a product-moment correlation matrix which is computed under the assumptions that all variables, commonly in cardinal form, are logically independent and have an underlying multinormal or near multinormal frequency distribution. Given a careful conceptualization of the research problem, the first assumption is relatively simple to ensure. The second assumption, that each variable is normally distributed about its respective mean, presents a more serious problem. Consider, for example, those variables which relate to the nature of the activities performed. The cardinal representation for such variables is the amount of time the i-th individual devotes to the j-th activity during the 24-hour period. In this research, activities have been coded according to a 98-way classification (Appendix C). Although the average number of activities performed per respondent per day in the university sample was found to be 35, the mean number of different activities performed was only 16. So even if the general assumption is made that types of activity are randomly distributed throughout the sample days, the probability that any one individual will perform any given activity at least once is only 0.163. Thus, the probability of a zero score occurring in any cell of the matrix, where columns are defined by the 98-way classification, is almost six times that of a non-zero score. It becomes apparent, therefore, that most of the activity variables of this form are heavily skewed to the right of the mean and are seriously distorted by the very large number of zero duration entries.

One possible solution to this problem would be to collapse the 98-way activity classification into, for example, the 37-way breakdown developed by Szalai and others in the Multinational Time-Budget Project.[4] If adopted, this would reduce the accuracy level to less than 38 percent of that attainable with the larger classification. The problem becomes much more complex that this, however. The claim was made earlier that the concept of pattern can be applied not only to the sequence in which activities are performed, but also to the duration of activities within the sequence. The assumption that activity types are not randomly distributed among individuals is critical to this hypothesis of activity pattern. Even at the increased level of activity aggregation, the 37-way classification, it was found that the activity variables remained heavily skewed to the right. This finding reinforces the belief that the zero values which produce skewness are fundamental in defining the patterns. Hence, the significant issue is that if one begins to search

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[4]Alexander Szalai, ed., The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries (The Hague: Mouton & Co., 1972), pp. 564-566.

for behavior patterns among individuals, one implicitly makes the assumption that people behave differently but do so in a non-random, predictable way. And if this is so, then some variables with a large number of zero entities will undoubtedly occur, and such variables may, in the end, be the most critical of all in defining generalized patterns. It appears just as important to know what activities are not performed by an individual as those that are. Thus, any attempt to satisfy the multinormal distribution of factor analysis would risk the loss of any regularity or pattern contained within the original data matrix.

To search for only variables with a large number of zero values would be dangerous for several reasons. First, it would be quite problematic to conclude a priori whether an activity type involved a large number of zero entries simply because it was that type of activity that no one performed very often or whether the zero and non-zero entries were systematically related to a characteristic of the particular sample or the environmental setting that was important. A second problem stems from the fact that there is a continuum of activities ranging from a high to a low number of zero entries. Thus, it would inevitably be difficult to decide what is to represent a high number.

Algorithmic Approach to Pattern Recognition Using a Non-Sequential Criterion

The problems of using any parametric multivariate statistical technique such as factor analysis seem too great to provide a satisfactory solution. It may be possible, however, to use it in conjunction with an algorithmic approach to the problem of pattern recognition. Thus, an algorithm might be formulated to partition the original data matrix so as to yield a set of paired matrices. A group of individuals' activity patterns, as defined by selected variables, would correspond to each pair. The variables would be maximally separated into two groups on the basis of performance or non-performance of activity. The variables included in the first of each pair would be those which either all, or at least a sufficient number, performed to guarantee a more or less normal distribution. And those in the second group would include the variables that were heavily skewed owing to the preponderance of zero values. Thus, as a first step toward the comprehension of behavior patterns, groups may be described in terms of the variables which differentiate them on the binary criterion of whether or not the activity is performed by a majority of the members of the group or not. The algorithm devised for describing distinct behavior patterns using a nonsequential criterion is described below.

1. Begin with one vector of information unique to each individual within the sample, as in (4.1).

2. Generate the basic data matrix, D_{ij}, where $i = 1,2, \ldots ,n$ (total number of individuals) and $j = 1,2, \ldots ,m$ (total number of variables). The ij-th element is some function of the amount of time the i-th individual devotes in total over a 24-hour period to all activities that come within the scope of the definition of the j-th variable. The definition in this case relates to the nature of activity, the participants involved, and the levels of commitment and constraint.

3. Create a binary matrix, B_{ij}, as a summary of the basic data matrix, by substituting each non-zero element of D_{ij} with a one.

4. Compute a symmetric matrix, S_{ik}, where $i = 1,2, \ldots ,n$ and $k = i+1,i+2, \ldots ,n-1$ (with the main diagonal entries deleted). The

ik-th element can vary between zero and m, and is the total number of variables which have non-zero values for both individuals i and k:

$$S_{ik} = \sum_{j=1}^{m} B_{ij} \mid B_{ij} = B_{kj} \tag{4.2}$$

5. Find the largest value of S_{ik} and assign individuals or groups i and k to a new group p.

6. Delete row i and k from B_{ij}, replacing them with a new composite row p in which each non-zero element represents corresponding non-zero elements in both old rows i and k:

$$B_{pj} = B_{ij} \mid B_{pj} = B_{kj} \tag{4.3}$$

where j = 1,2, ... ,m.

7. Replace the i-th and k-th rows and columns of S_{ik} with a new composite row and column p. The p-th element can vary between zero and $\sum_{j=1}^{m} B_{pj}$, and is the total number of variables which have non-zero values for both the newly created group p and any existing individual or group i:

$$S_{pi} = \sum_{j=1}^{m} B_{pj} \mid B_{pj} = B_{ij} \tag{4.4}$$

where i = 1,2, ... ,n'-1; i ≠ p; n' = n-1; and n = n'.

8. Test against criterion for termination of grouping procedure.[5] If this has not been reached, return to step 5.

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[5]The determination of this criterion should be something less than arbitrary. The limiting case would be the presence of no non-zero elements in matrix B. However, this might carry the algorithm to the point where

Once the grouping procedure has been terminated, the basic data matrix, D_{ij}, can be partitioned horizontally so that each consecutive set of rows relate to a homogeneous group of individuals created during steps five through eight above. Within each partition the columns could be rearranged in such a way that the total number of non-zero elements for each variable increase from right to left. The ranking of variables that results for each group would then form one possible description of the behavior pattern of that group.

For some of the larger groups generated by the algorithm the partitioning of the matrix might then be used as the basis for a factor analysis. The use of a factor analytic technique in this case would probably increase the sophistication of the description of the behavior patterns by emphasizing within-group variance. Thus, the set of variables for which non-zero values predominate would constitute the data base for a factor analysis. The factors produced and the scores for each individual might provide a basis for further differentiation and possibly the establishment of subgroups.

The preceding discussion demonstrates how one possible algorithmic approach, in conjunction with the multivariate technique of factor

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ambiguous groupings would result. This would undoubtedly be the case since the presence of just one variable with initially positive values for all records would mean that the criterion would never be reached and individuals would be continually grouped until only group remained. A more promising solution would be to set some "mini-max" value of the S matrix as a criterion. This would mean that, if the value was set at 5, then for every group there would have to be at least five variables that had non-zero scores relative to each individual in that group. Such a criterion as this would probably mean that some residual groups would be very small, and a few individuals might not be grouped at all. However, this would only occur to the extent that these groups or individuals had significantly unusual behavior patterns.

analysis, can be used for the recognition of behavior patterns. However, the way in which the variables were structured in this approach did ignore the sequential ordering of the individual's activities. Although each variable was expressed in time units, time was treated only as a summary measure of quantity rather than an index of temporal distribution. There appears to be no obvious way in which the variables might be structured so as to retain their important sequential property.

The Time-Space Map

One technique which does maintain the sequential ordering of events is the time-space map. This is similar in form to Hagerstrand's activity diagram (Figure 18),[6] in that it maps behavior onto a two-dimensional surface, where the vertical dimension represents movement through time and the horizontal dimension provides some definition of the activity performed. The maps are designed to illustrate in detail the manner in which a relatively small homogeneous group, such as a household, interacts over a period of time. The mapping technique is less valuable for a relatively large sample population such as the one treated here. A more productive use of the maps is to treat larger groups in a more generalized way. Thus, if a uniform symbol is used to represent one or more persons and if these symbols are plotted relative to the appropriate activity at each chosen time interval, a picture evolves of how people tend to distribute themselves throughout the day. The illustration in Figure 19 provides a crude summary of how

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T. Carlstein, Bo Lenntorp, and Solveig Martensson, Individers dygsbanor i nagra hashallstyper, Urbaniseringsprocessen, rapport nr. 17 (Lund: Institutionen for kulturgeografi och ekonomisk geografi vid Lunds universitet, 1968), pp. 27-30.

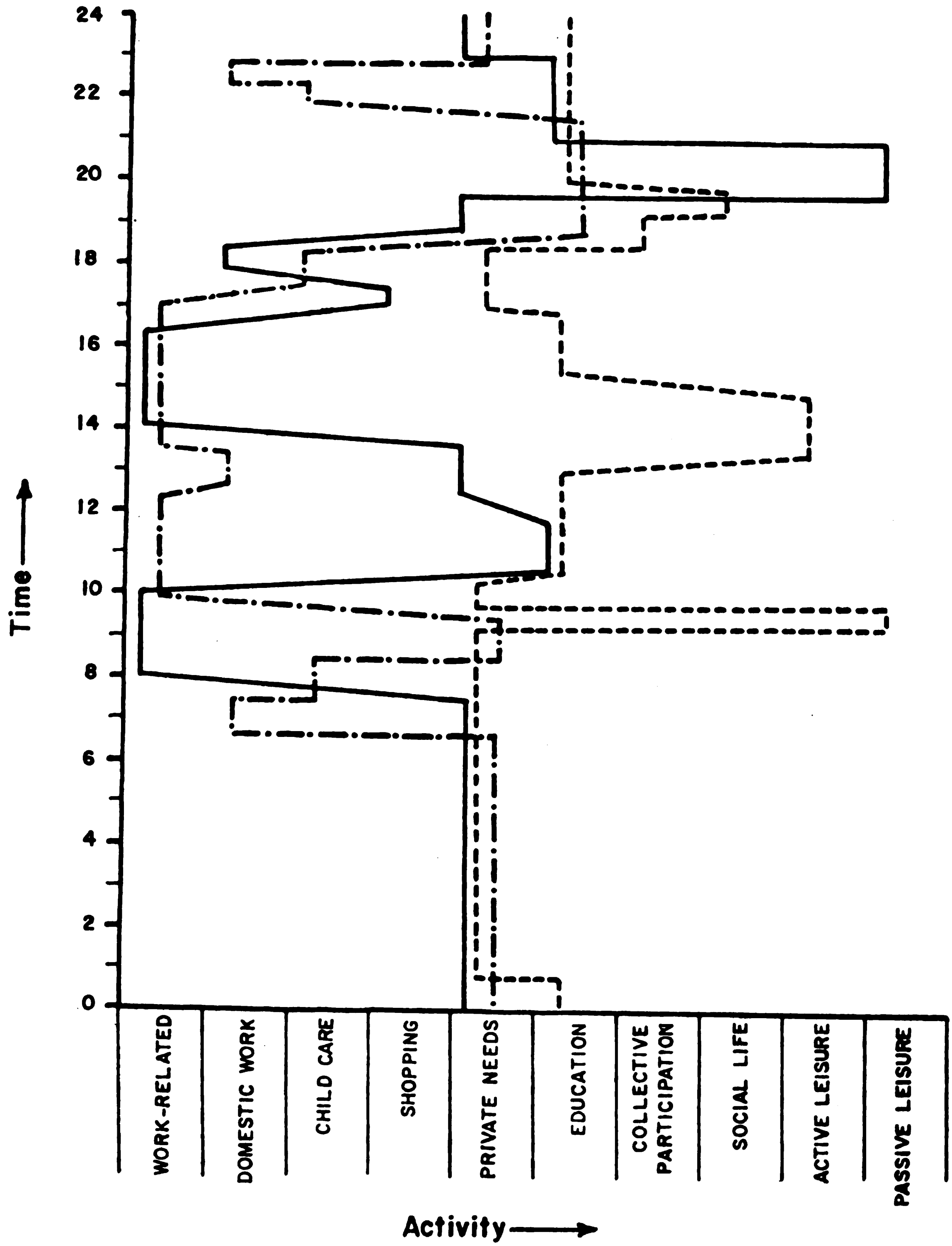

FIGURE 18.

DIAGRAM OF ACTIVITY SEQUENCES

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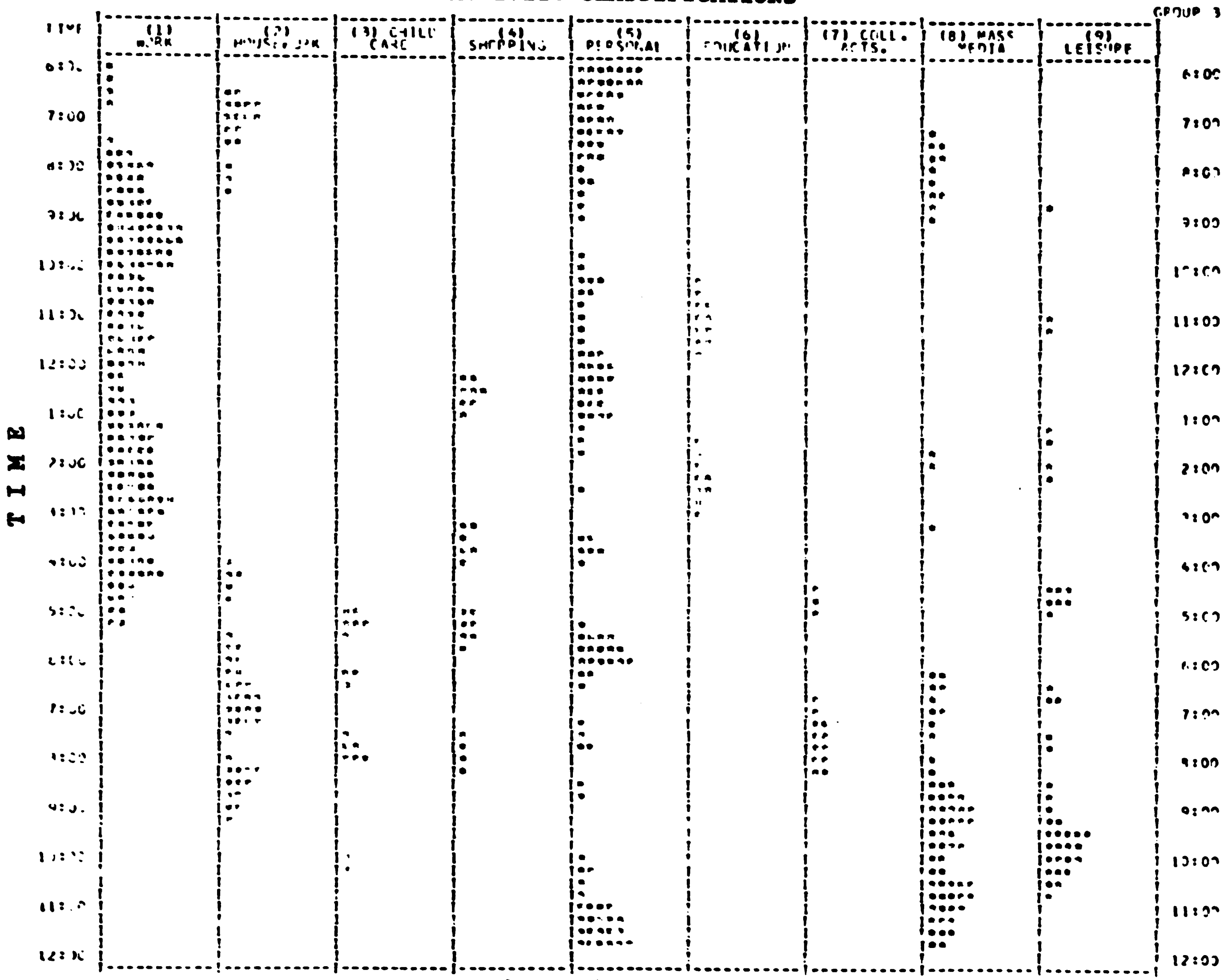
part of such a map would appear. If each asterisk represents, for example, graduate students in the university, the map (Figure 19) would provide a picture of how such a group behaves as a whole.

In general, the most noticeable weakness of this approach is that it does not maintain the spatial-temporal continuity of the individual. In other words, what any individual is doing between 9:30 and 9:45 is impossible to relate to what that same individual was doing between 9:00 and 9:15. The type of representation is somewhat analogous to a chronological record of a series of events using still photographs rather than a film where the continuity of events is preserved. However, one advantage of the technique is that it is a relatively simple way of generating ideas about the way in which people behave, albeit in a less rigorous fashion. At the very least, it might aid in the selection of background variables against which less constrained approaches to pattern recognition might be tested. This is to say that although the mapping technique requires that individuals be grouped a priori, as in the case of graduate students in Figure 19, it does permit simultaneous treatment of respondents' activity patterns and background data.

If a group defined by one or more background variables is fairly small, 35 or less, then it is relatively easy to maintain the continuity and individual identity of each member by simply using an array of alphameric symbols such as A,B, ... ,Z,1,2, ... ,9, instead of the uniform asterisk (Figure 20). Although the map produced using the new symbolization conveys more information, it does pose difficulties in

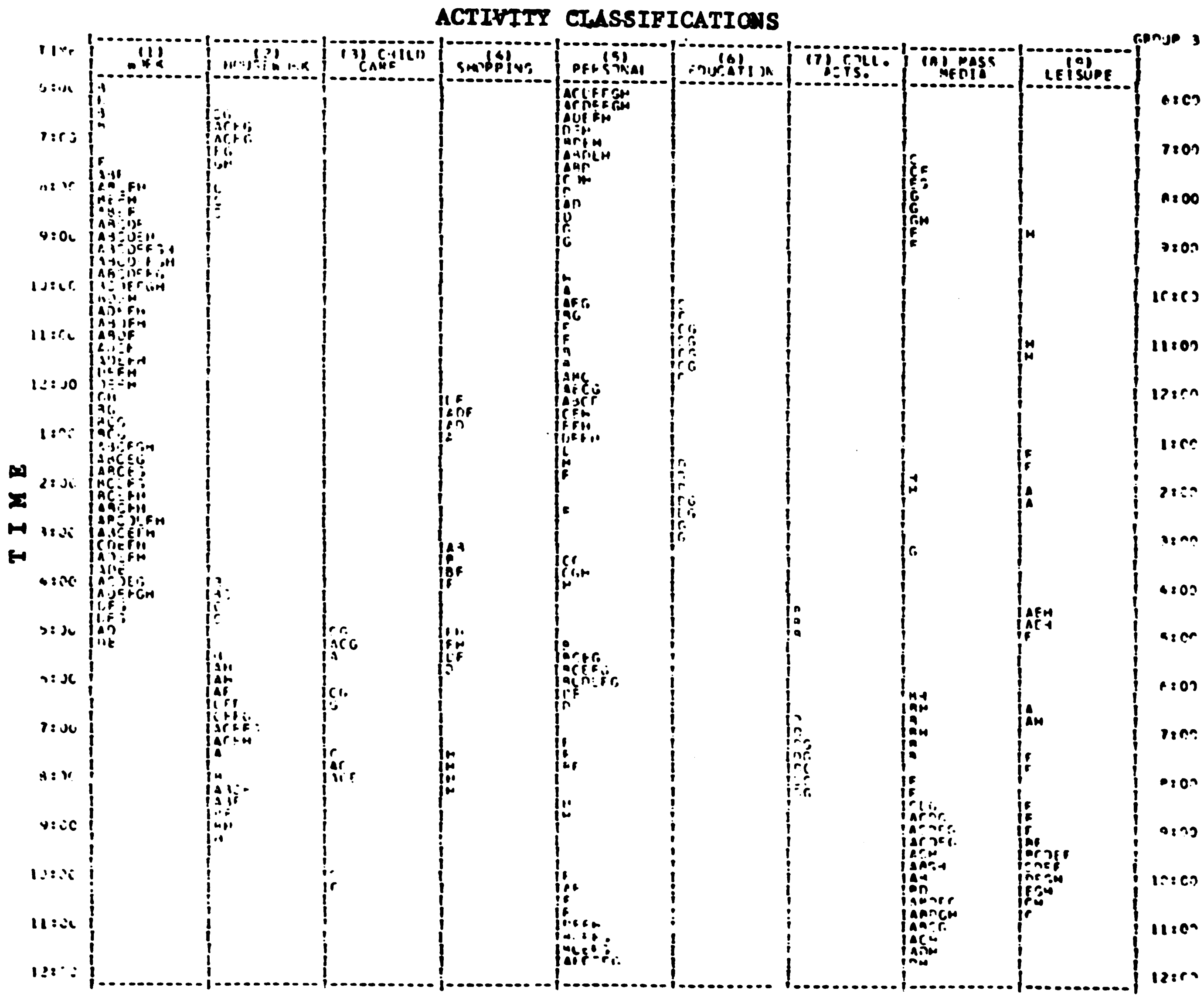
ACTIVITY CLASSIFICATIONS



* = Five Persons

FIGURE 19.

AGGREGATE TIME-SPACE MAP



One lette~ represents one person.

FIGURE 20.

DISAGGREGATED TIME-SPACE MAP

terms of computation and illustration.[7] There is the problem of how intelligible a map containing up to 35 records would be. In addition, there are very few groups within the sample population that can be regarded as sufficiently homogeneous to warrant such a laborious approach to the problem of retaining continuity, especially when the outcome is at most a general visual impression at a rather crude level of activity aggregation.

However, the time-space mapping technique would be of greater value if it were to be used as a visual illustration of the behavior pattern of a group whose membership had been previously defined in a more systematic manner. Therefore, some type of algorithm is required that groups individuals by maximally differentiating behavior patterns, while retaining as part of the definition of any pattern both its sequential nature and the spatial-temporal continuity of each individual involved.

Algorithmic Approach to Pattern Recognition Using a Sequential Criterion

An algorithm has been devised which groups individuals on the basis of a description of the amount of time which they spend on different activities and the order in which these are performed.

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[7]Even though it is most feasible to produce a quantity of time-space maps by use of the computer, it is a relatively uneconomical use of computer time since each map has to be retained in core memory in fine detail during one pass through the data. And since one map requires such a large number of computer words, this means that for each pass through the data, not more than about six maps can be readily generated. Moreover, by producing maps that represent a small number of individual records that may be spread randomly throughout the data set would make this approach even more uneconomical.

Thus, the analysis involves decomposing the sample population into groups based upon the sequential behavior patterns of individuals. These groups should maximize within-group similarities and between-group differentials. The rationale derives from the first research hypothesis. It has already been mentioned that when the concept of pattern cannot be applied, the simulation experiment becomes at best a trivial exercise. It is reasonable, then, to extract any patterns embedded within the data prior to an attempt at simulation. If this procedure is not followed and significantly different patterns do exist, then there would be a tendency to view the entire population as exhibiting purely random patterns of behavior. In all probability, this randomness would be due to the mistake of overlaying several distinct patterns on top of one another. Indeed, the possibility remains that the entire population would exhibit only one dominant pattern, making subdivision impractical, but this is the null hypothesis that must be tested.

It still must be decided what is to most precisely represent a constituent of a behavior pattern. Basically, the essential components are timing and duration of activities. For the purposes of simulation, there are two parallel ways of classifying each activity episode or point in a person's day. The first is the objective description of the activity type. Secondly, there is the subjective assessment of the degree to which the respondent was committed to a given activity and the extent to which the respondent felt constrained relative to that time of day or activity performed.

Cullen[8] has suggested a method whereby individuals are grouped on the basis of a description of the amount of time they devote to different activities and the sequence in which these are performed. Cullen's approach proceeds by dividing the day into equal time intervals. For each individual every time period is labelled with a predominant activity index and a value representing the duration of the activity within that interval. The population is then grouped on a basis of the maximum time overlap between any pair of individuals or previously grouped subsets. Based upon Cullen's recommendation, an algorithm has been formulated to differentiate behavior patterns defined by a sequential criterion.

Data Organization. It is not difficult to understand the basic form of the data matrix from which the algorithm will work. First, there must be one vector of information unique to each individual within the sample. Within each vector every data element must be labelled in two distinct ways: (1) with a sequence index and (2) with a content index. In order to maintain comparability among individuals, given that each one performed a different number of activities and thus each has a different length sequence (Figure 17), the sequence will have to be preserved by creating a uniform subdivision of the day (15-minute intervals) for all individuals. Then for all respondents the information recorded at sequence position 60, for example, represents what occurred between 15:00 and 15:15 hours. The context index,

[8] Ian G. Cullen, Algorithmic Approaches to the Recognition of Activity Patterns, Joint Unit for Planning Research, Seminar Paper No. 19 (London: University College, London, 1969), pp. 15-16.

describing exactly what was occurring at the time, presents some problems, since it has to relate closely to the form of the information that is indexed. An obvious and difficult problem is the method of referring to what a person was doing during any given 15-minute interval. Since it would be theoretically possible for one to do as many as 15 different activities during that time, it would appear that the only reasonable summary would be the code of that activity which he performed for the greatest length of time during the 15-minute period (Figure 21). Then the weighting could be maintained by using the cardinal duration (between 1 and 15 minutes) as the base information of the vector, indexed both as to its sequential position and the nature of the activity performed. Thus, if A^t_{ij} is the amount of time the i-th individual devotes to the primary activity i during time period j, then the individual's sequential behavior pattern, S_i, can be represented by a vector:

$$S_i = (A^t_{i1}, A^t_{i2}, \ldots , A^t_{ij}, \ldots , A^t_{im-1}, A^t_{im}) \qquad (4.5)$$

where: $i = 1,2, \ldots ,n$ (the total number of individuals); $j = 1,2, \ldots ,$ m (the total number of subdivisions of the day); and $t = 1,2, \ldots ,k$ (the total number of activity categories).

Two problems relating to the organization of the data matrix arose when the algorithm was first tested. The first problem relates to the number of subdivisions of the day. The 1,440 minutes of the day were divided into a total of 96 15-minute intervals ranging from midnight to midnight. However, since each 15-minute interval receives equal weight in the analysis, any grouping procedure would be dominated by the

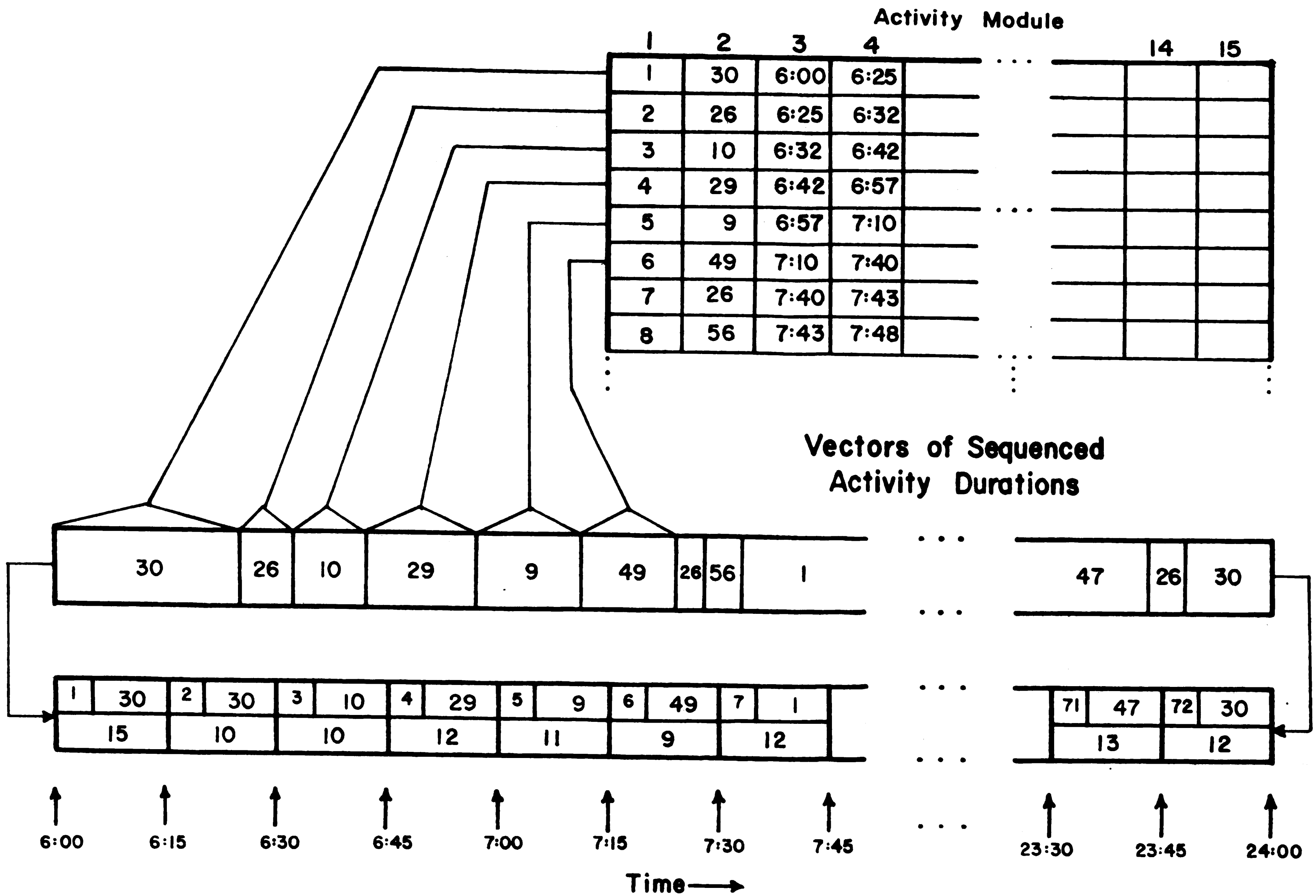

FIGURE 21.

UNIFORM SEQUENCING OF ACTIVITY VECTORS

uniformity of behavior patterns occurring between midnight and about 7:00 a.m., during which period most people are sleeping. When first tested, the outcome of the algorithmic procedure was one large group composed of 96 percent of the respondents in the sample, with the remaining four percent of respondents constituting one-member groups. Since the majority of individuals shared a common activity between about midnight and 8:00 a.m., this pattern so dominated the grouping that it was impossible to break out any patterns based upon daytime activities. For this reason, the decision was made to begin each sequence at 6:00 a.m. and continuing through midnight, the end of the recorded period. Therefore, all data prior to 6:00 a.m. were disregarded.

The second problem relates to the index of content for each position in the sequence. It is by no means obvious how much detail is feasible in the activity description. As already noted, the 98-category activity classification developed by the Multinational Time-Budget Project[9] was adopted because presumably it is the most widely recognized scheme and described activities at a fine level of detail.[10] However, the sample population treated here is considerably more homogeneous than the populations surveyed in the Multinational Project. Given this greater degree of homogeneity, the activities which were coded using the 98-way classification were considered too detailed for analysis. In fact, as many as nine activity types were not even performed by

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[9]Szalai, loc. cit.

[10]Although clearly beyond the scope of this inquiry, the adoption of such a well-known classification system would provide the necessary standardization to allow for comparisons with other research using a similar system.

individuals in the sample population. If the 98-way scheme is adopted, the probability for any individual that one activity occurs in one's day is 16/98 or 0.163, given a random distribution of different activities between persons, with a mean of 16. However, once the day is divided into time periods, the probability of any one activity occurring in any one time period is inversely proportional to the number of time periods in total and directly proportional to the mean number of those periods occupied by that one activity. If the mean duration of activities is constant, then the probability p of activity x occurring at time t is:

$$p(x_t) = (\frac{a}{b}) \cdot (\frac{y}{z}) \cdot (\frac{z}{ay}) \quad (4.6)$$

where a is the mean number of different activities performed, b is the size of the classification, y is the size of the time interval, and z is the length of time. Thus, in this case the probability is 1/98 or 0.0102; and for any given activity and time period, one can only expect about 1 out of 138 people to be doing this at the same time.

Alternatively, if the 98-way classification is condensed into a 65-category scheme, such as that given in Appendix C, little detail would be forfeited. In fact, when using the collapsed activity classification, the mean number of activities performed was about 33, only two less than with the larger categorization. And the mean number of different activities performed was 15, only one less than the total using the larger classificatory scheme. Thus, by using the formula (4.6), the probability of activity x occurring at time t is 1/65 or 0.0155. Given the slight increase in the probability, therefore, one can now expect about two out of the 138 respondents to be doing the same thing at the same time.

Very little detail is lost by collapsing the classification of activities to 65 categories. Moreover, the reduction should make the prediction of activities more manageable in the simulation phase. Even though the probability of a number of individuals performing the same activity at the same time of the day is very small, the likelihood of the null hypothesis (i.e., a random distribution of activities) being rejected remains high. For example, at 12:30 p.m. the probability of finding people eating lunch is very high, and at 6:00 a.m. the probability of finding people asleep is, likewise, high. Although the theoretical probabilities of establishing patterns may be very low owing to the potentially wide variety of possible activities, the actual probabilities are fairly high despite this variety, since people do behave in a predictable manner. It remains to be seen whether the practical variety of activities generated by the 65-way classification tends to obscure or clarify behavior patterns.

The Algorithm. Given a matrix of sequenced durations, each indexed according to the activity performed, S_i (4.5), the matrix can be partitioned horizontally to group individuals with similar patterns. The algorithm designed to accomplish this task focuses on those points in an individual's sequence, or vector, where the activity performed is the same as that performed by another individual. Consequently, it is possible to sum this total "overlap time" over individuals. The total overlap time is the linking index to be used as a basis for grouping; i.e., the greater the overlap time the greater the similarity in behavior patterns. The steps in the algorithmic approach are briefly outlined below.

1. Generate the basic data matrix, $[A^t_{ij}]$, where i=1,2, ... ,n (the total number of individuals); j=1,2, ... ,m (the total number of subdivisions of the day); and, t=1,2, ... ,k (the total number of activity categories). Each row vector of information unique to each respondent in the sample is given in (4.5). Each cell entry in the matrix represents a sequenced activity duration. If the main activity during a given time interval was "attending class," then the cell entry is its numeric code (33) indexed to its duration (15 minutes), or 33.15.

2. Create a symmetric overlap totals matrix, $[O_{pq}]$, where p=1,2, ... ,n and q=1,2, ... ,n (the total number of individuals). Delete the main diagonal entries so that for the p-th individual there is a single figure relative to each other individual q representing the total amount of "activity overlap time":

$$O_{pq} = \sum_{t=1}^{k} [\mathrm{Min}(A^t_{pj}, A^{t'}_{qj}) \mid t=t'] \tag{4.7}$$

3. Select the maximum value of O_{pq} and collapse the appropriate individuals or groups p and q into a new group g.

4. Construct an amalgamated time series vector, A^t_{gj}, to represent the activity pattern of individuals p and q by selecting only those elements of each individual vector (4.5) which overlap:

$$A^t_{gj} = [\mathrm{Min}(A^t_{pj}, A^{t'}_{qj}) \mid t=t'] \tag{4.8}$$

$$A^t_{gj} = [O(A^t_{pj}, A^{t'}_{qj}) \mid t \neq t'] \tag{4.9}$$

where t=1,2, ... ,k.

5. Delete rows p and q from A_{ij}^{t} and rows and columns p and q from O_{pq}.

6. Replace rows and columns p and q of O_{pq} with a new row and column g, so that relative to each existing individual or group there is a figure for activity overlap time for a new group g:

$$O_{gp} = \sum_{t=1}^{k} [\mathrm{Min}(A_{gj}^{t}, A_{qj}^{t'}) \mid t=t']; \quad n' = n-1. \tag{4.10}$$

7. Test against criterion for termination of grouping procedure. If this has not been reached, return to step 3.

Computational Problems. When inspecting the overlap totals matrix generated by (4.7), several elements of the matrix were found to obtain identical or tied values. The problem of tied values presents considerable difficulty, especially in step 3. If the maximum, value of O_{pq} is obtained by more than one element in the matrix, then, given the computational procedure of the algorithm, the first of the tied values is selected as the maximum value. This method of treating tied values is unsatisfactory, since it might seriously misrepresent the predominant structure of interrelationships in the overlap matrix.

Alternative Algorithmic Approach Using the LAWS Modification

In an attempt to solve this problem, the algorithm was modified to include an alternative approach to grouping based upon the Largest Average Within-group Similarity (L.A.W.S.).[11] The modification would

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[11] Leighton A. Price, Hierarchical Clustering Based on a Criterion of Largest Average Within-cluster Similarity, Research Report (East Lansing, MI: Computer Institute for Social Science Research, Michigan State University, March, 1969).

allow for all the relationships between pairs of elements to be processed in order of decreasing similarity. Thus, the procedure of processing interrelationships by rank order was chosen in preference to the reciprocal pairs approach described above. This was done because it may be demonstrated that reciprocal methods, which proceed by combining elements and forming estimates of the relationship of the combination of other elements, are merely approximations of a rank order approach.

Reciprocal Pairs and Typal Analysis. The purpose of the following discussion is to demonstrate that a reciprocal pairs approach deviates from an otherwise comparable method which processes relationships by order of magnitude. It deviates to the extent that procedures for estimating the similarity between a combination of elements and other elements (or groups) have the effect of distorting and misrepresenting the nature of the original relationships. This demonstration will be made using McQuitty's typal analysis[12] and the reciprocal pairs method, of which the algorithm above is but one example. Table 5a presents a 5x5 matrix of overlap totals and Table 5b shows a rank ordering of the off-diagonal relationships.[13] This small data set will be used for comparison in lieu of the larger survey data set.

In performing a typal analysis, the group consisting of elements 1 and 2 is formed first since {1,2} is the highest ranked pair in

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[12] L.L. McQuitty, "Typal Analysis," Educational and Psychological Measurement, 21 (1961), pp. 677-696.

[13] The tables are after Price, op. cit.

TABLE 5

SAMPLE SET OF OVERLAP RELATIONSHIPS

a. Matrix Form

	1	2	3	4	5
1	-	10	1	2	4
2	10	-	9	3	5
3	1	9	-	8	6
4	2	3	8	-	7
5	4	5	6	7	-

b. Rank-order Form

Pair	Value
1,2	10
2,3	9
3,4	8
4,5	7
3,5	6
2,5	5
1,5	4
2,4	3
1,4	2
1,3	1

FIGURE 22

TYPAL ANALYSIS OF OVERLAP TOTALS IN TABLE 5

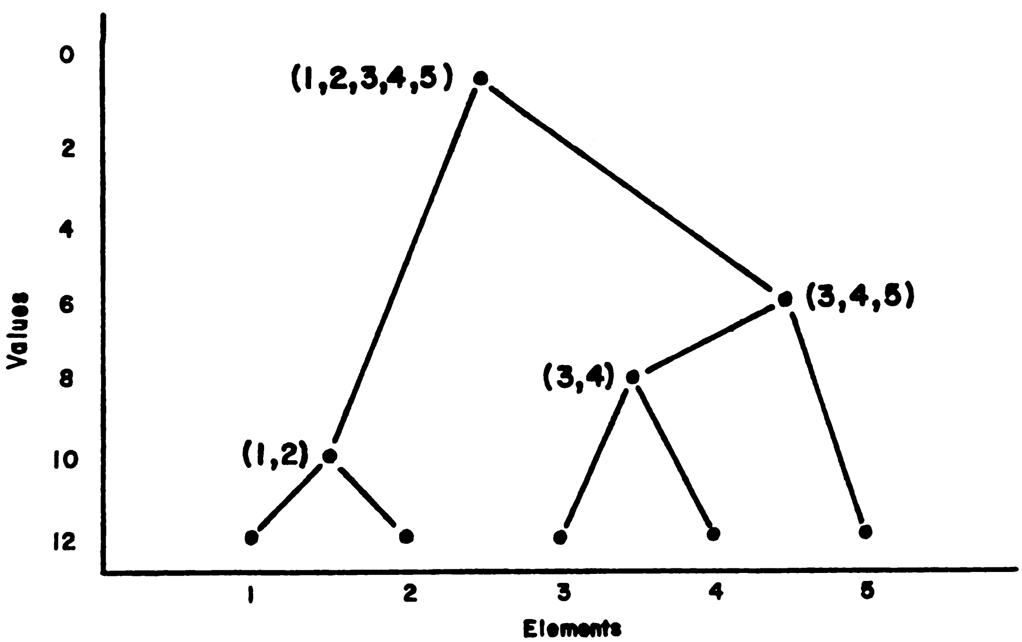

Table 5b. Because the second ranked pair overlaps with group {1,2}, the second group formed is {1,2,3}. Other groups are formed in the same manner in arriving at the final structure (Figure 22).

The reciprocal pairs analysis is performed as follows. Given that a reciprocal pair is defined as two elements having a higher relationship to one another than to any other elements, the first reciprocal pair in Table 5a is {1,2}. Once the reciprocal pair is identified, the first and second rows and columns are replaced by a single row and column, as in (4.10) of the preceding algorithm. Within the new row and column are estimates of the relationships of the other elements (or groups) to the first group. As conveyed by (4.10), these estimates are based on the assumption that the relationship of an element (or group) to a newly formed group cannot be greater than the smaller relationship with the two components of the new group. This has been termed the classification assumption.[14]

The process is repeated until pairs of rows and columns can no longer be replaced. The matrices resulting at each step are given in Table 6 while the resulting structure is shown in Figure 23.

The structures in Figures 22 and 23 obviously do not match. The classification assumption has the effect of eliminating a number of relationships before they would be encountered during typal analysis. In other words, reciprocal pairs analysis is equivalent to a typal analysis which ignores some values instead of processing all of them in order of magnitude.

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[14]McQuitty, op. cit.

TABLE 6

REDUCED MATRICES FROM RECIPROCAL PAIRS ANALYSIS OF OVERLAP TOTALS IN TABLE 5

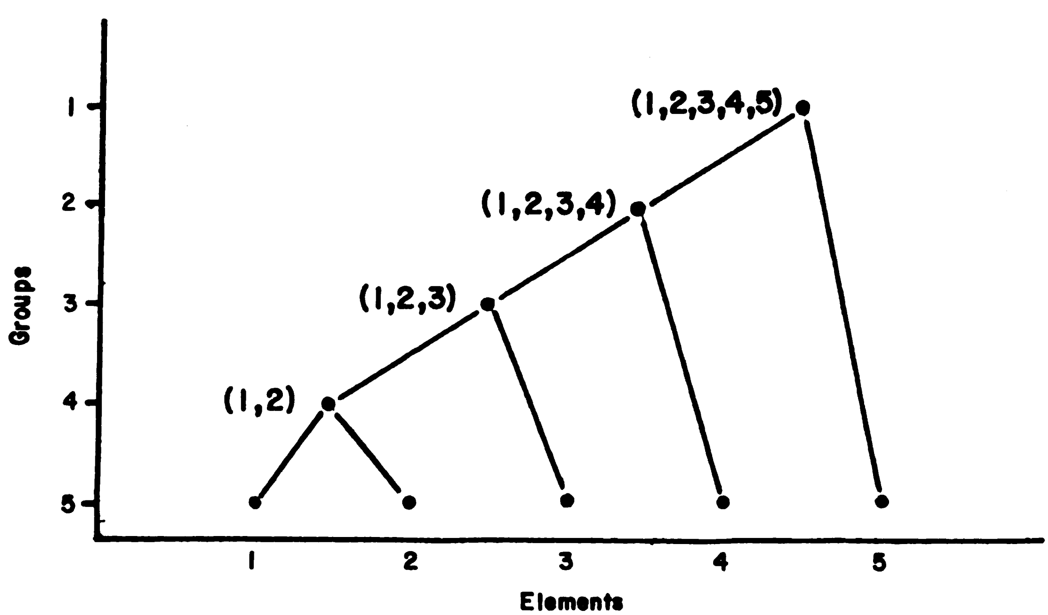
	1,2	3	4	5
1,2	-	1	2	4
3	1	-	8	6
4	2	8	-	7
5	4	6	7	-

	1,2	3,4	5
1,2	-	1	4
3,4	1	-	6
5	4	6	-

	1,2	3,4,5
1,2	-	1
3,4,5	1	-

FIGURE 23

RECIPROCAL PAIRS ANALYSIS OF OVERLAP TOTALS IN TABLE 5



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Given in Table 7 are the values which were not eliminated by combining rows and columns in the reciprocal pairs analysis. When a typal analysis is performed with these values, the outcome is identical to the results of the reciprocal pairs analysis. Therefore, these results clearly demonstrate that the reciprocal pairs method is merely an approximation of the solution which would have been obtained had all relationships been processed in order of magnitude.

The discrepancies between typal analysis and a reciprocal pairs analysis can be further clarified by a substitution procedure. As a first step, a list is created in which all pairwise relationships in a matrix are ranked. Then following each step in a reciprocal pairs analysis, the estimate of the relationship between the new group and another element (or group) is substituted in place of the pairwise relationships between each of the elements included in the new group and the other element (or all elements of the other group). This procedure is repeated for each new estimated value. The results of a typal analysis and a reciprocal pairs analysis will be identical if and only if, at each step in a reciprocal pairs analysis, the substitutions do not alter the original pairwise ordering of relationships prior to when they would be encountered in a typal analysis. As long as the substitutions merely yield tied values where ties already existed, the ordering may be regarded as unaltered.

The problem is that any method which condenses a matrix by replacing pairs of rows and columns with a single row and column will almost inevitably misrepresent the relationships in the original matrix. It is impossible to force such a collapse without a considerable loss in

TABLE 7

THE RELATIONSHIPS (IN TABLE 5) NOT ELIMINATED DURING RECIPROCAL PAIRS ANALYSIS

Pair	Value
1,2	10
3,4	8
3,5	6
1,3	1

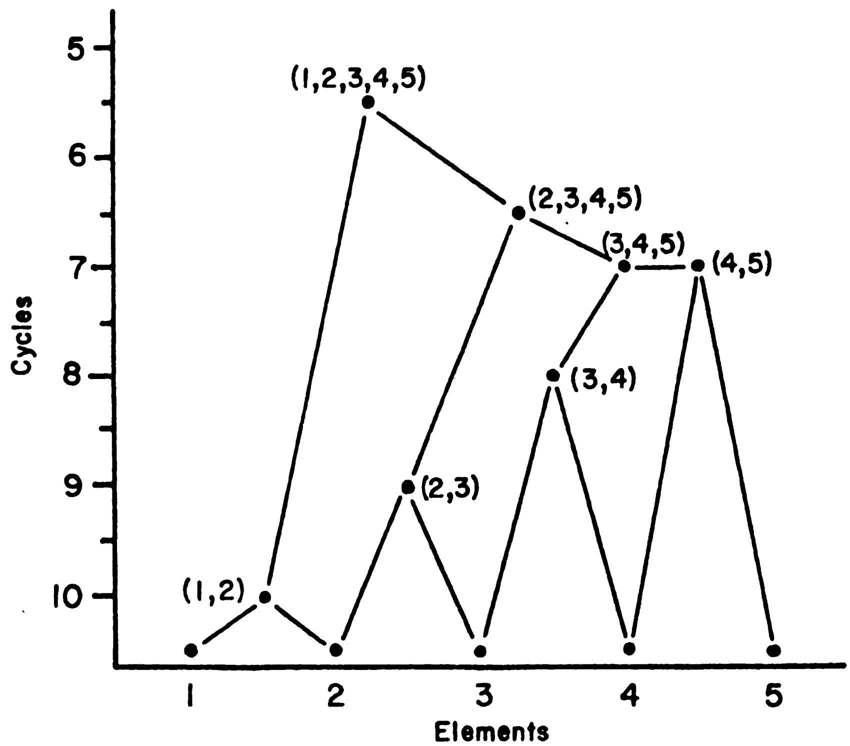

FIGURE 24

LAWS ANALYSIS OF THE OVERLAP TOTALS IN TABLE 5 information. Thus, replacement procedures will often have the effect of eliminating relationships before they would be encountered if processed in order of rank. Moreover, the larger groups generated by a replacement approach may not adequately describe predominant groupings in a matrix.[15]

The LAWS Modification. The LAWS method incorporated in the algorithm focuses upon within-group characteristics. Typal analysis also has a similar focus, but with the latter method, a larger group is automatically formed whenever a pair is encountered that overlaps with a group already accepted. Therefore, grouping decisions do not consider any between-group calculations. In the LAWS approach, this consideration of within-group charactertistics is represented in calculations of average within-group similarity which are computed from the original matrix values throughout the analysis. Furthermore, these indices of within-group similarity are also used in making decisions regarding the acceptance or rejection of some possible new groups. The decision rule is, basically, that among a set of tentative groups, only those having the largest average within-group similarity should be accepted. Hence, larger groups are not formed necessarily at the first point of overlap (Figure 24).

Most reciprocal pairs and typal analysis methods tend to yield groups which might have been quite different had the relative magnitude

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[15]This was clearly the case when the overlap totals matrix was partitioned by the algorithm, prior to the incorporation of the LAWS method. Moreover, this will almost always be the case for grouping algorithms which arrive at a one group termination in N-1 cycles.

of a few rather similar pairwise interrelationships been ordered differently. There appears to be two reasons for this sensitivity. First, the matrix collapsing procedures used in reciprocal pairs methods may, in effect, cause relationships to be eliminated. Second, all reciprocal pairs and typal analysis methods impose grouping restrictions which may misrepresent the nature of the original relationships in a matrix. The primary restriction is, therefore, that once a set of elements has been accepted as a group, subsequent groups including any of these elements must include all of them.

In the LAWS approach, the first form of sensitivity is eliminated by processing all element interrelationships by order of magnitude. The second restriction is treated by introducing a decision rule whereby tentative groups are accepted if and only if the average within-group similarity is greater than the value for the pair indicating that these groups should be considered.

The LAWS method is based on the idea that estimates of average within-group similarity provide excellent indices upon which to base grouping decisions. The formulation of such a decision criterion is necessary in that the operational characteristics of the method do not automatically lead to the formation of larger groups, as is the case with all reciprocal pairs and typal analysis methods.[16]

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[16]This is due to the fact that the LAWS method may yield overlapping groups. Partial overlap may result from the method's ties solution or from application of the criterion of largest within-group similarity, which will sometimes reject a larger group in favor of a pair of elements. Moreover, pairwise relationships are processed in order of magnitude, and once overlapping groups have been accepted subsequent pairs may overlap with more than one group or link more than one pair of groups (Figure 24). The frequency and nature of the overlaps which may result depends upon the complexity of the original relationships. Therefore, the number of cycles needed to arrive at a one-group solution is determined by the relationships within the data and not by the grouping algorithm.

The values of the relationships between all pairs of elements are processed in order of decreasing similarity. All the pairs of elements having a given index value are compared with groups that may already have been accepted and which are not completely included in some larger group. For each pair associated with a particular index value, a record is made of all non-included groups in which one, or both, of the elements of the pair can be found. At this point, all pairs in the set are processed. On the basis of the overlap information for a given pair of elements, some new group possibilities are formed. Whenever more than one possibility results, some decisions must be made before groups may be accepted. These decisions derive from the general rule of accepting groups that have the largest average within-group similarity. After all pairs in a set have been processed, the procedure is repeated for the next set, and so on, until all the data have been examined. The decision to build upon only the non-included groups can be regarded as an attempt to satisfy the objectives of reflecting the predominant structure of interrelationships while keeping the number of groups as small as is reasonable.[17]

For each pair in the ordered list, four decision situations may be encountered. The situations and their rules are as follows:

1. Situation: Neither element of the pair appears in any of the groups that are in the list of final groups. Rule: If so, add the pair to the list of groups which have been accepted thus far.

2. Situation: One element of a pair is included in one or more of the existing groups and the other included in none. Rule: This

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[17]Price, op. cit., p. 18.

being the case, tentatively form larger groups by expanding overlap groups to include the non-overlapping element of the pair. Then, determine whether any of these groups have greater average within-group similarity than the pair. If so, accept the largest ones among those having greatest average within-group similarity. Otherwise, add only the pair to the list of groups already accepted (rule 1).

3. Situation: The pair of elements links previously accepted groups (i.e., one element in some group and the other is another group). Rule: If so, tentatively form all groups which result from combining the indicated pairs of groups. Then determine which groups are the largest ones among those having greatest average within-group similarity and add them to the list of groups already accepted.

4. Situation: Both elements of the pair already appear in some group(s). Rule: If this is the case, proceed to the next pair in the ordered relationships.

Two additional decision rules not directly associated with the processing of pairs in the ordered list are as follows:

5. Situation: The average within-group similarity associated with an accepted group reflects lower average similarity than a group in which it is included. Rule: If this occurs, which is seldomly the case, then eliminate the included group from the set of accepted groups.

6. Situation: The element pairs associated with a block of tied values include all possible pairs for some set(s) of elements. Rule: If so, identify all sets which are not subsets of others. Then, add each of these to the list of accepted groups, provided that none of its

elements are included in the groups accepted prior to processing the block of pairs.[18]

The present method should do a better job in producing groups with higher within-group similarity than the algorithm first proposed. As a result, group differentiation, or pattern recognition should be greatly facilitated.

RECOGNITION OF BEHAVIOR PATTERN GROUPS

The algorithm, incorporating the LAWS modification, was then used to partition the matrix of sequenced activity durations (Figure 21). A major consideration in the analysis was how to arrive at a meaningful termination to the grouping procedure. Clearly, the termination criterion should be something less than arbitrary.

Termination Criteria for Group Formation

Chi-square (χ^2) was considered a suitable technique for establishing a realistic termination to the grouping procedure. Thus, as pattern groups were formed, they were tested for significance against the set of background variables (Appendix B) using the chi-square statistic. The use of chi-square served two purposes. First, it provided a test for the significance of pattern groups at various stages of group formation. And secondly, it provided a method whereby one could assess the importance of background variables in describing specific attributes of behavior pattern groups.

Chi-square is considered the most useful univariate test of group membership since much of the data obtained through the interview schedule (Appendix B) is nominal or at best ordinal in nature, which

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[18] Price, op. cit., pp. 20-23.

precludes the use of parametric tests. The technique tests the null hypothesis that k independent samples have been drawn from the same population or from k identical populations.[19] When pattern group membership is tabulated against any background variable, the problem arises of determining whether the distributions associated with each group differ significantly from those that might have been expected had each group been drawn randomly from the population.

The chi-square statistic is calculated as follows:

$$\chi^2 = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \qquad (4.11)$$

where $i = 1,2, \ldots ,n$ (the total number of categories generated by the background variable), $j = 1,2, \ldots ,m$ (the total number of pattern groups generated by the previously applied algorithm). Then, O_{ij} is the number of people in the variable category i and group j. The degrees of freedom are given by the rule:

$$d.f. = (n-1)(m-1) \qquad (4.12)$$

The higher the value of chi-square derived for any variable, the greater is the probability that a given variable is of significance in defining the activity pattern groups.

Ten background variables were chosen for tests of significance against pattern group membership (Table 8). Prior to the chi-square tests, however, all cycles of grouping analysis were arrayed in order of the amount of loss in the average within-group similarity index between

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[19] Hubert M. Blalock, Jr., Social Statistics (New York: McGraw-Hill Book Co., 1960), pp. 214-219.

one cycle and the next.[20] Within the first quartile of the ordered list, the cycles were further ordered according to a second criterion. Cycles were arranged in descending order according to the number of individuals

TABLE 8.

BACKGROUND VARIABLES CHOSEN FOR TESTS OF SIGNIFICANCE

No.	Variable Name	Variable Description	Categories of Response
1	AGE	Age	5
2	SEX	Sex	2
3	CIVIL	Civil Status	4
4	UAFFIL	University affiliation	7
5	YAFFIL	Years associated with the institution	4
6	OEMPLY	Employed elsewhere	2
7	INCOME	Annual income	5
8	HOUSE	Housing type	7
9	TRAVLM	Common mode of travel	6
10	LOC	Residential location	5

[20]Before reordering the cycles according to this criterion, the final 42 cycles (out of a total of 286) were eliminated since only one group existed. It was during these final cycles that the remaining two-member residual groups were added one by one until only one group of all elements remained.

who had membership in a group whose size was greater than two members.[21] The results of the rankings are given in Table 9 for the first quartile of the reordered list.[22]

In order to determine which one cycle of those given in Table 9 is to be chosen as the termination of the grouping procedure, chi-square tests were performed. Ten cross-classification tables were prepared for each of the nine cycles where the rows of the tables were defined by the number of response categories in a given background variable (Table 8) and the columns of the tables were defined by the number of groups formed during the cycle. The calculated chi-square statistics for each of the cycles, over all variables, are given in Table 10.

<u>Results of the Grouping Procedure: Behavior Pattern Groups</u>

The highest calculated values of χ^2 are most consistently obtained by the second ranked cycle in Table 10. At the 99 percent confidence level, four variables were found to be significant: civil status (CIVIL), years of affiliation with the institution (YAFFIL), secondary employment (OEMPLY), and location of residence (LOC). The variables of age (AGE), sex (SEX), type of affiliation with the institution (UAFFIL), annual

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[21]The method for seeking a realistic termination to the grouping procedure was developed through consultation with the originator of the LAWS method. Person communication, Leighton A. Price, Computer Institute for Social Science Research, Michigan State University, August 24, 1974.

[22]The resulting quartile originally included eleven cycles. However, the last six of the eleven cycles do not appear in Table 9 since they had to be deleted. The cycles were ignored due to restrictions on tabular cell frequencies for calculating χ^2. Given the larger number of groups formed during these cycles, the dimensions of the tables increased substantially with a similar increase in the number of zero cell frequencies. For restrictions on zero cell frequencies, see: Blalock, op. cit., pp. 220-221.

TABLE 9

GROUPING CYCLES ORDERED BY TERMINATION CRITERIA

Rank No.	Cycle No.	No. of Groups*	Total Population within Groups	Total AWS+	Overall Loss in AWS+ Between This Cycle & Next	Individuals Having Multiple Group Memberships	No. of Residual Groups**
1	236	2	104	46.321	4.665	26	41
2	231	3	101	55.642	4.773	44	45
3	224	5	94	63.820	3.521	49	50
4	211	6	87	89.056	3.286	63	61
5	189	8	81	119.189	3.893	71	78
6	156	69	69	178.342	3.258	51	105

+Average within-group similarity.

*Only for groups with memberships greater than two.

**Residual groups are those containing only two members.

TABLE 10

CHI-SQUARE STATISTICS FOR SIGNIFICANCE OF PATTERN GROUP MEMBERSHIPS

Ranked Cycle No.	No. of Groups	(1) AGE	(2) SEX	(3) CIVIL	(4) UAFFIL	(5) YAFFIL	(6) OEMPLY	(7) INCOME	(8) HOUSE	(9) TRAVLM	(10) LOC
1	2	9.64*	3.62	14.89*	9.41	9.56*	12.38**	8.23	13.93*	23.37**	6.77
2	3	19.06*	6.15*	24.29**	24.67*	17.37**	11.31**	28.92*	18.17	22.96*	20.91**
3	5	17.37	9.63*	33.58**	21.39	19.05	13.92**	35.80**	23.72	27.99	22.49
4	6	15.53	11.20*	31.45**	26.84*	26.64*	17.96**	37.88**	26.67	25.37	30.25
5	8	24.36	16.47*	35.06*	37.62	33.11	16.19*	31.16	40.05	34.62	31.78
6	10	32.28	31.93**	41.67*	61.22	68.18	28.64**	47.55**	59.01	48.91	52.30

*Significant at the 0.95 confidence level.

**Significant at the 0.99 confidence level.

income (INCOME), and common mode of travel (TRAVLM) obtained significance at the 95 percent confidence level. The only variable not found to be significant at the 95 percent confidence level was that of housing type (HOUSE).

The observed and expected cell frequencies are given for all variables in Table 11. Some general impressions may be gleaned from the tables regarding the attributes of the three behavior pattern groups. For example, the first pattern group, more than double the size of any other, is composed primarily of students who are generally the younger members of the population. The group is also constituted by a majority of females and single persons. Generally, the members of the group have had fewer years of affiliation with the institution and a lower yearly income than expected. Finally, the majority have no secondary employment, reside in close proximity to the institution, and largely use private means of transport (e.g., walking, bicycling, or driving their own cars) for various travel purposes.

The general attributes pertaining to the second group are more difficult to discern due to a smaller membership (Figure 25). However, within the group there is almost a two to one ratio of men to women, a generally older population, relative to the first group, and a slight majority who are married. There is also a smaller proportion of students and a greater proportion of faculty and staff than expected. The members of this group tend toward longer association with the institution and a higher income level than the first group. Unlike the previous group, however, the members rely on a greater variety of travel modes.

TABLE 11.

TABLES OF OBSERVED AND EXPECTED FREQUENCIES FOR SELECTED VARIABLES OVER PATTERN GROUPS

(a)

AGE	1	2	3	
	24/18.2	1/ 6.7	2/ 2.1	27
20-24	26/22.9	7/ 8.4	1/ 2.7	34
25-29	8/13.5	9/ 5.0	3/ 1.6	20
30-39	7/ 8.1	4/ 3.0	1/ 1.0	12
40	3/ 5.4	4/ 2.0	1/ 1.0	8
	68	25	8	101

χ^2 = 19.06* d.f. = 8

(b)

SEX				
M	26/29.6	16/10.9	2/ 3.5	44
F	42/38.4	9/14.1	6/ 4.5	57
	68	25	8	101

χ^2 = c.16* d.f. = 2

(d)

CIVIL	1	2	3	
Singl	56/47.1	10/17.3	4/ 5.5	70
Marr	8/15.5	13/ 5.7	2/ 1.8	23
Di-Se	3/ 4.0	2/ 1.5	1/ 0.5	6
Wid	1/ 1.4	0/ 0.5	1/ 0.1	2
	68	25	8	101

χ^2 = 24.29** d.f. = 6

(c)

UAFFIL	1	2	3	
Fac	3/ 8.1	7/ 3.0	2/ 1.0	12
Stf	8/10.8	5/ 4.0	3/ 1.3	16
Gr	8/10.1	6/ 3.7	1/ 1.2	15
Sr	9/ 8.1	2/ 3.0	1/ 1.0	12
Jr	15/12.1	3/ 4.5	0/ 1.4	18
So	13/10.1	1/ 3.7	1/ 1.2	15
Fr	12/ 8.8	1/ 3.2	0/ 1.0	13
	68	25	8	101

χ^2 = 24.67* d.f. = 12

TABLE 11.--Continued

(e)

YAFFIL	1	2	3	
1	18/14.1	2/ 5.2	1/ 1.7	21
1-2	34/30.0	7/10.6	2/ 3.4	43
3-5	10/13.5	7/ 5.0	3/ 1.6	20
5	6/11.5	9/ 4.2	2/ 1.4	17
	68	25	8	101

$\chi^2 = 17.37$** d.f. = 6

(f)

OEMPLY	1	2	3	
Y	9/13.5	6/ 5.0	5/ 1.6	16
N	59/54.5	19/20.1	3/ 6.4	85
	68	25	8	101

$\chi^2 = 11.31$** d.f. = 2

(g)

INCOME	1	2	3	
2	31/24.2	4/ 8.9	1/ 2.9	36
2-5	20/18.9	6/ 6.9	2/ 2.2	28
5-10	10/10.1	3/ 3.7	2/ 1.2	15
10-15	6/ 6.1	2/ 2.2	1/ 0.7	9
15	1/ 8.8	10/ 3.2	2/ 1.0	13
	68	25	8	101

$\chi^2 = 28.92$* d.f. = 8

(h)

HOUSE	1	2	3	
Si-Fm	5/10.1	7/ 3.7	3/ 1.2	15
S-Apt	11/ 8.8	1/ 3.2	1/ 1.0	13
L-Apt	10/11.5	6/ 4.2	1/ 1.4	17
F/M-H	7/ 6.1	1/ 2.2	1/ 0.7	9
R-H	30/26.3	8/ 9.7	1/ 3.1	39
S/F-Coop	4/ 3.4	1/ 1.2	0/ 0.4	5
Other	1/ 2.0	1/ 0.7	1/ 0.2	3
	68	25	8	101

$\chi^2 = 18.17$ d.f. = 12

TABLE 11.--Continued

(i)

TRAVLM	1	2	3	
O-Car	29/27.6	9/10.2	3/ 3.3	41
N-Car	1/ 4.0	3/ 1.5	2/ 0.5	6
Bike	18/15.5	4/ 5.7	1/ 1.8	23
Bus	1/ 3.4	3/ 1.2	1/ 0.4	5
Walk	19/16.2	4/ 5.9	1/ 1.9	24
Other	0/ 1.4	2/ 0.5	0/ 0.2	2
	68	25	8	101

χ^2 = 22.96* d.f. = 10

(j)

LOC	1	2	3	
Camp	37/32.3	9/11.9	2/ 3.8	48
E-L	25/22.9	8/ 8.4	1/ 2.7	34
Lan	3/ 6.7	4/ 2.5	3/ 0.8	10
O-Met	3/ 4.7	3/ 1.7	1/ 0.6	7
Out-Met	0/ 1.4	1/ 0.5	1/ 0.2	2
	68	25	8	101

χ^2 = 20.91** d.f. = 8

Groups	1	2	3	R	t
1	(49)	5	3	11	68
2	5	(13)	1	6	25
3	3	1	(3)	1	8
R	11	6	1	(29)	47
t	68	25	8	47	138

TABLE 12.

TOTAL AND OVERLAPPING GROUP MEMBERSHIP FOR BEHAVIOR PATTERN GROUPS

TABLE 13.

SUMMARY STATISTICS FOR BEHAVIOR PATTERN GROUPS

Group No.	Average Within-group Similarity	Within-group Variability of Element Pairs
1	46.763	893.767
2	70.321	1182.609
3	99.189	799.837

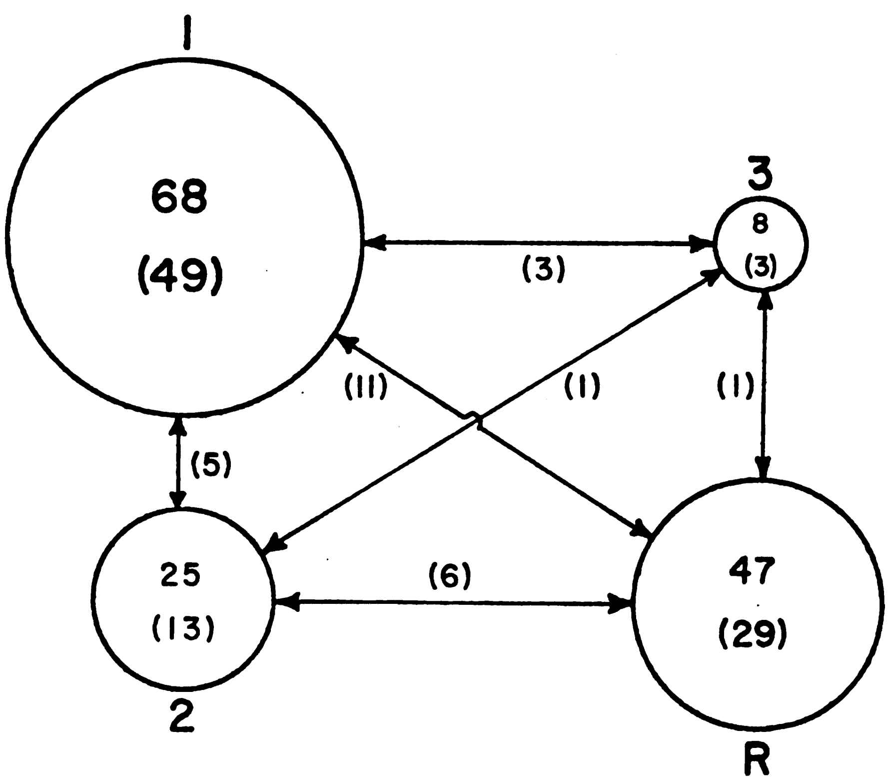

FIGURE 25.

GROUP MEMBERSHIP CONFIGURATION OF DATA IN TABLE 12

Due to a comparatively small membership of the third group, it is difficult to extract any general impressions. The few distinguishing characteristics include a longer affiliation with the institution, a more sizeable number than expected in the faculty and staff categories, and a greater than expected number having secondary employment.

Consistency Hypothesis. All calculated values of χ^2 in Table 11, with one exception, exceed their respective, critical values of χ^2 at the 95 percent confidence level (i.e., with the table of critical χ^2 values being entered with the appropriate number of degrees of freedom, as computed by 4.12). The 95 percent confidence level has been chosen because the researcher wishes to avoid making a Type I error,[23] which would be very easy to do in this instance because all but one calculated values of χ^2 lie between the critical values of χ^2 at the 95 and 99 percent confidence levels. The lower limit is chosen because the sample is so small, relative to the total population of the institution, that it would be unwise to be overconfident and accept a hypothesis that would have interesting theoretical implications concerning the distinctiveness of the behavior pattern groups. Thus, at the 95 percent confidence level the null hypothesis of purely random behavior is rejected and the hypothesis regarding the consistency of behavior pattern groups is inferred.

Patterned variations do, therefore, exist between subgroups of the population, where the concept of pattern is construed in terms of sequence and duration of daily activities. Recognition of distinct

[23] Ibid., pp. 93-95.

patterns is faciliated not only by the χ^2 statistics (Tables 10 and 11) but also by the index of largest average within-group similarity (Table 13).

The total populations of the three pattern groups and the residual group[24] are given in Table 12 and displayed graphically in Figure 25. Some overlap in memberships exists among the three groups. However, this reflects the solution obtained by the LAWS method whereby the predominant interrelationships within the overlap totals matrix are retained through the calculation of largest average within-group similarity (Table 13). Although 36 percent of the grouped individuals have dual membership, the groups were considered as independent entities for the chi-square analysis.[25]

<u>Activity Sequences of Pattern Groups</u>. The pattern of a group's activities during the course of a day can be displayed through the medium of the time-space map. These maps (Figures 19, 20, 26 and 27) depict the sequence and frequency of activities performed by members of each pattern group during the 24-hour period.

It is clear, even at this aggregate level of mapping the sequence of activities, that the time-space maps differ markedly. The majority of daytime activities for Group 1 (Figure 26) are devoted to educational pursuits. And, these are interspersed with other less frequent

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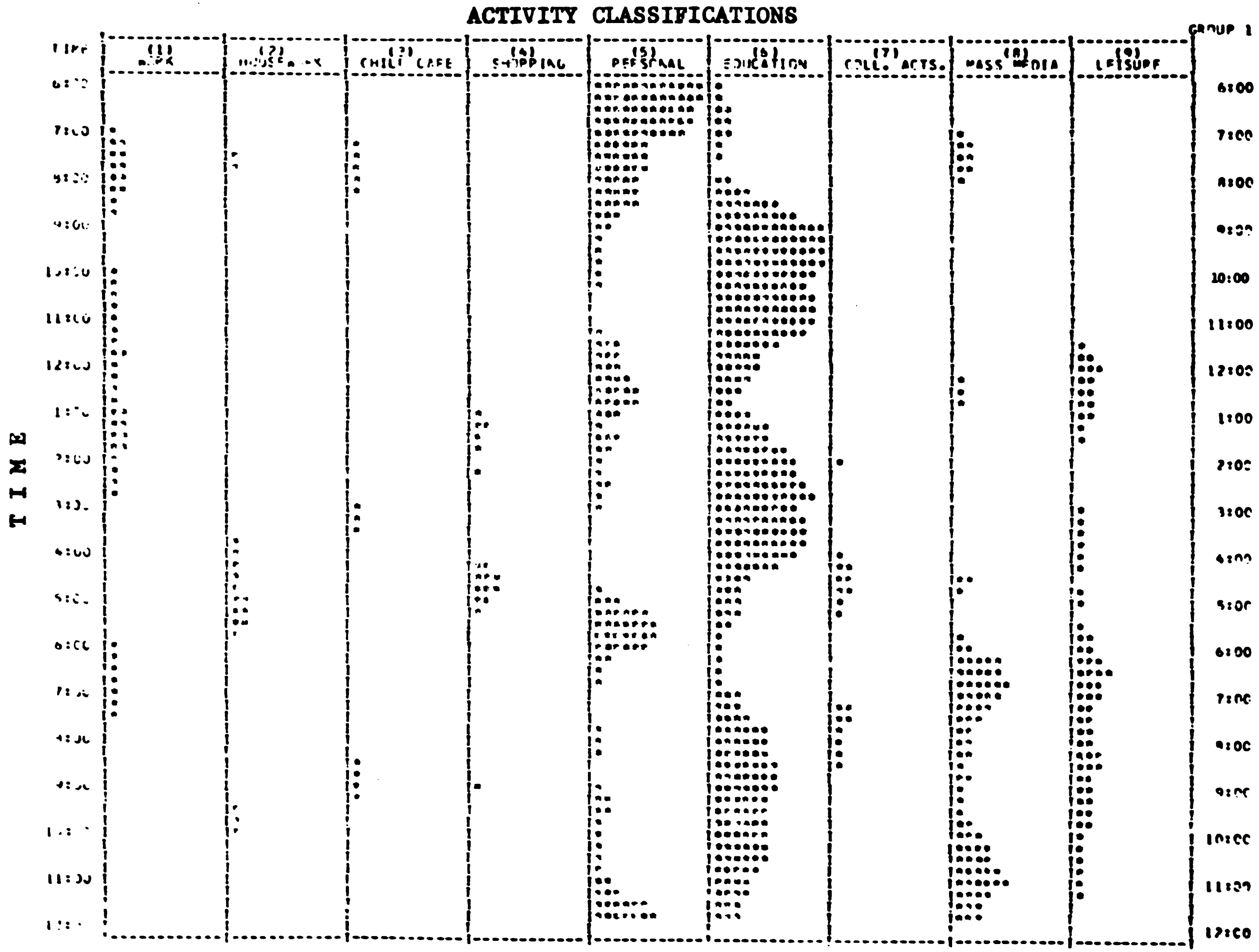
[24]Group R (Table 12 and Figure 25) represents the aggregate of two member residual groups that were among the non-included pairs during this cycle of the algorithm (Table 9). The residual pairs are not to be construed as a coehesive group, but rather, have been designated as Group R for tabular and diagrammatic purposes only.

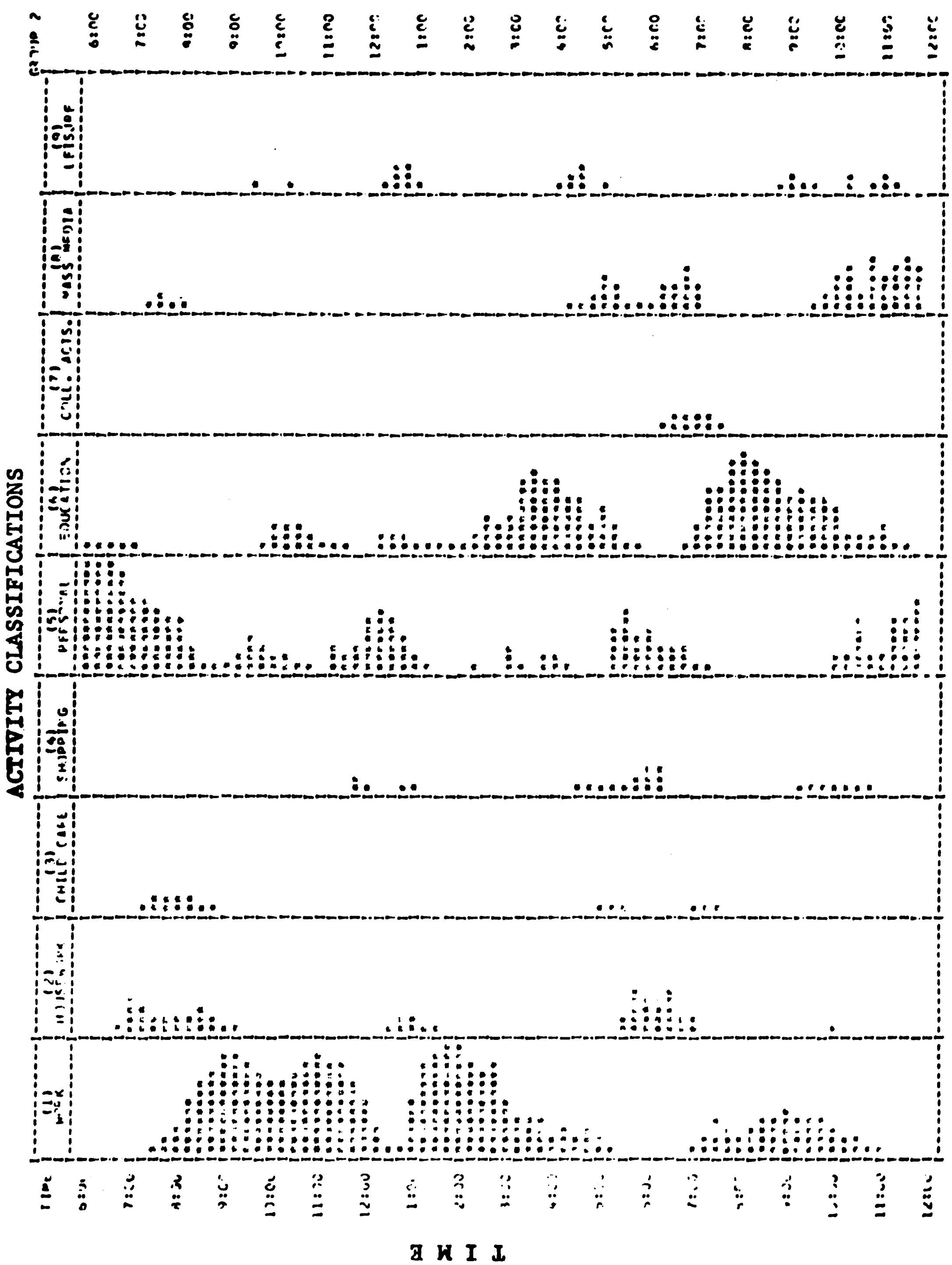
[25]Personal communication, Leighton A. Price, Computer Institute for Social Science Research, Michigan State University, August 23, 1974.



* = Two Persons

FIGURE 26.

TIME-SPACE MAP OF PATTERN GROUP I



* = Five Persons

FIGURE 27.

TIME-SPACE MAP OF PATTERN GROUP II

activities such as leisure, mass media, and personal needs. Following approximately 6:00 p.m. the pattern of activities for Group 1 is not as clear, however. Throughout the late afternoon and evening the only noticeable patterns that evolve relate to personal needs (mainly eating meals) and education-related activities.

The map for Group 2 (Figure 27) differs from the first in that work-related activities predominate throughout much of the day. Educational activities also attain a high frequency, especially during the daytime and early evening hours. Presumably, then, the similarities in time use among members of each group for daytime activities provided the greatest amount of overlap time, and this considerable degree of overlap was the basis for the grouping decisions.

The time-space maps for the third group (Figures 19 and 20) exhibit a totally different configuration. One appreciable difference is the reduction in time devoted to educational activities. Although the smallest group, it is perhaps the most homogeneous in terms of the sequence and frequency of activities. The variety of activities throughout the entire time period is considerably less than for the other groups. The daytime hours are dominated by work-related activities, while work, mass media, and leisure constitute the greatest frequencies during the evening.

The recognition of these distinct behavior pattern groups satisfies the criteria for simulation that were established by the research strategy. If the null hypothesis--that the population exhibited random behavior--had been accepted, then simulation would have been a trivial exercise. However, having identified behavior pattern groups, the simulation of individuals' time-space paths would appear to be a worthwhile exercise.

Before considering the simulation model, additional insights into the structuring of activity sequences for both groups may be gained from a number of graphic and tabular summaries. These include: (1) the configuration of subjective constraints throughout the observation period (Figures 28 and 29), (2) the distribution of individuals' commitment to activities during the day (Figures 30 and 31), (3) the pattern of objective constraints as measured by aggregate travel times, and (4) tables summarizing the degree to which the most highly constrained episodes, or pegs, fix the choice, timing, and location of activities that precede and follow them (Tables 14 and 15).

For the first pattern group (Figure 28), the choices of activity appear to be most constrained during the late morning and mid-afternoon with a lesser peak occurring during the early evening. Compared to Figure 28, the time-space map for the first group (Figure 26) indicates that these constraints are realized within the context of education-related activities. Constraints to the timing of activities follow a similar trend to that of activity choice with a more noticeable period of fixity occurring during the morning hours. The first category of spatial fixity (Figure 28) deviates considerably from the preceding distributions in that the early morning and late evening hours represent the greatest degrees of constraint relative to one's location. This pattern can be partially understood by the fact that home-centered (personal) activities, which generally occur at these times, cannot be performed elsewhere, thereby being fixed at one's residence. The second distribution of spatial fixity reflects responses to the question--

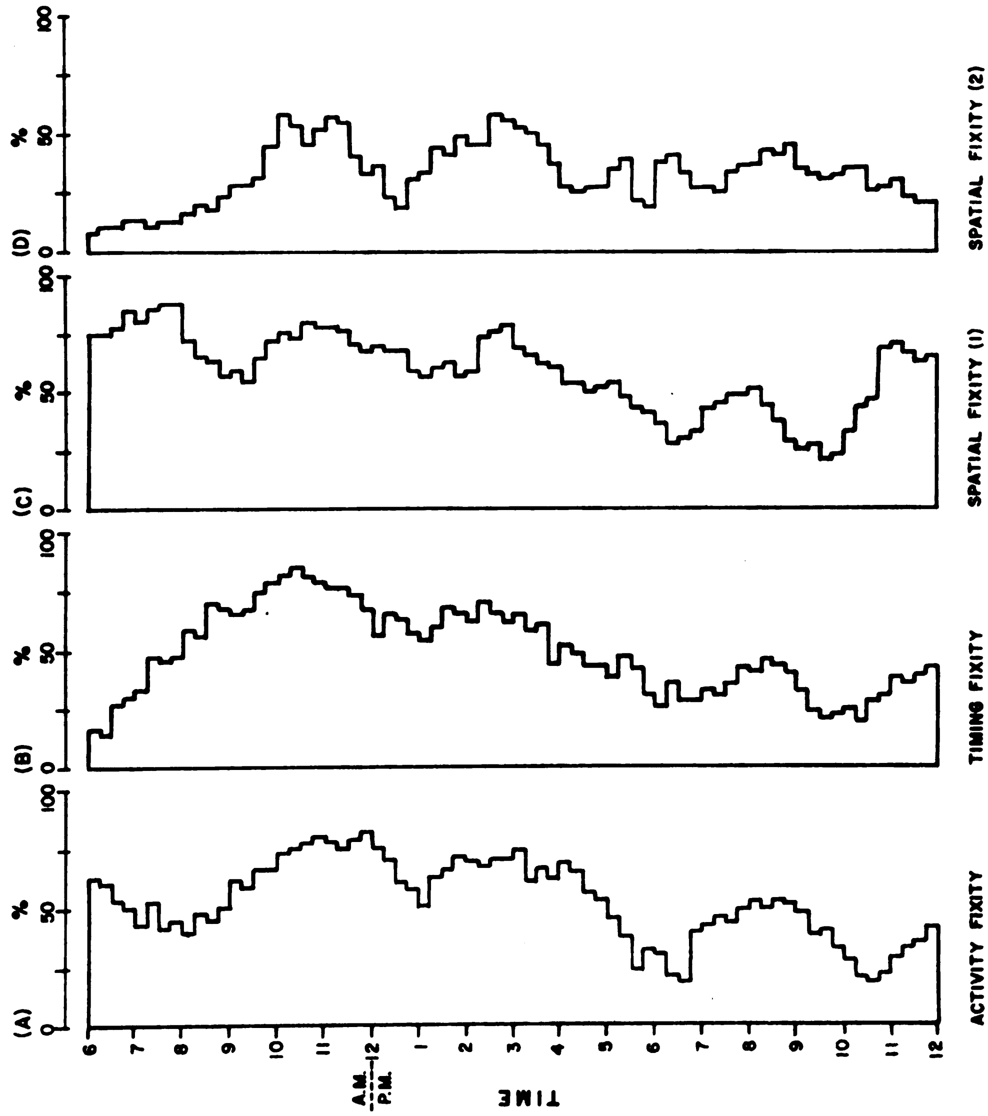


FIGURE 28.

CONSTRAINT CONFIGURATION OF PATTERN GROUP I

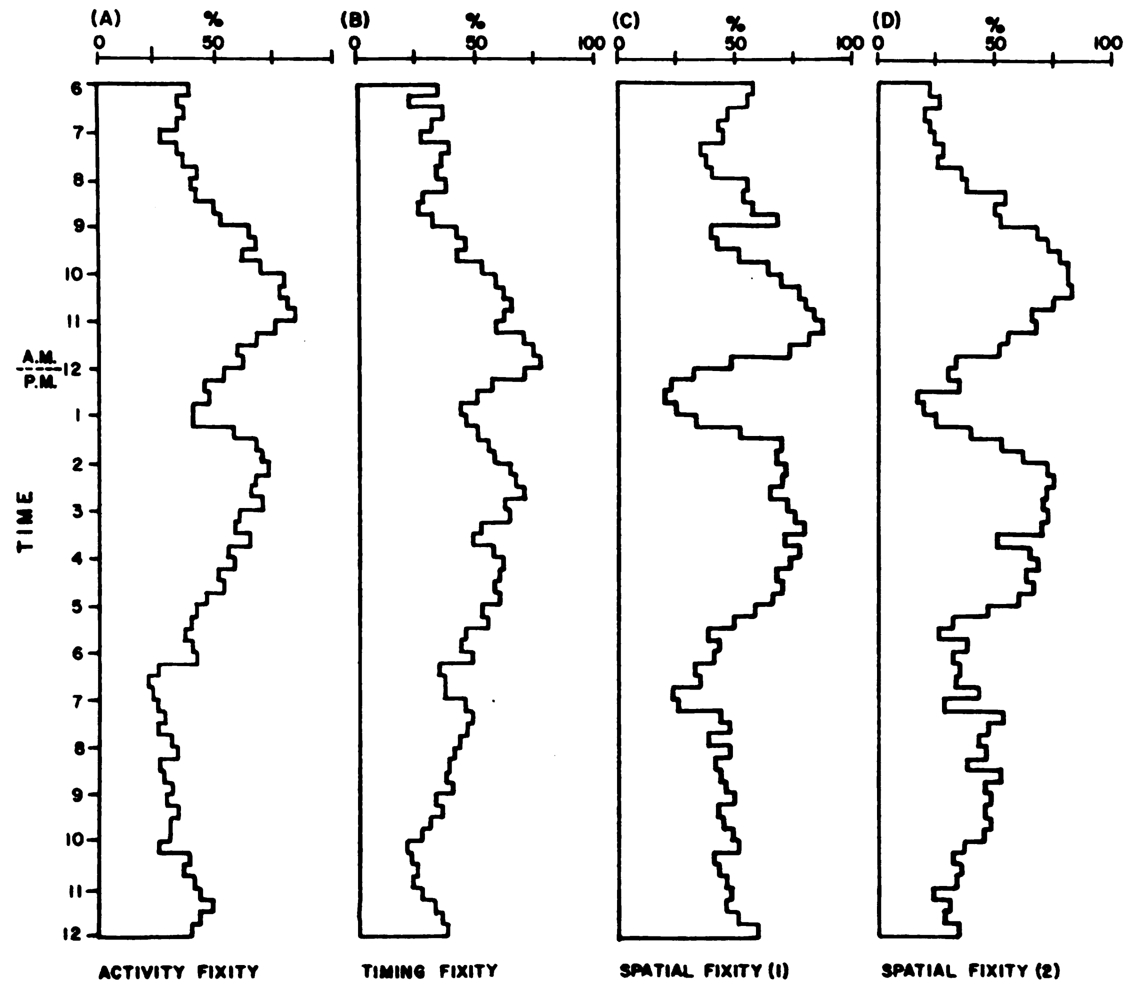


FIGURE 29.

CONSTRAINT CONFIGURATION OF PATTERN GROUP II could you have been elsewhere at this time? Comparatively, this category of fixity appears to have the least constraining effect. Despite the consistently smaller proportion of "yes" responses throughout the day, this distribution of spatial fixity corresponds to the peaks of activity choice and timing fixities (Figure 28).

Additional information may be obtained by examining the pattern of degrees of commitment to various activities (Figure 30). Coincidental with the periods of maximum activity, time, and location fixities are activities that are routine in nature or involve coordination with others. Once again, these activities are primarily educational (Figure 26). Activities which are either planned independently or occur unexpectedly reach their maximum proportions during the late afternoon and evening. According to the time-space map (Figure 26), the types of activity associated with these forms of commitment are education, mass media, and leisure.

The graph of aggregate travel times (Figure 32) displays the average amount of time that group I members devote to travel during a given 15-minute interval of the day. Sizeable shifts in location can be observed during the morning and late afternoon. However, the overall pattern of aggregate travel times suggests that this group is highly mobile over short distances during the working day and early evening.[26]

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[26]For group I the average distance separating an individual's residence from his workplace (i.e., location of work, classes, seminars, etc.) is 0.943 miles. The modes of travel common to the majority of group I members include walking and bicycling. Therefore, the aggregate travel times displayed in Figure 32 measure the effects of objective constraints (i.e., modes of travel) in overcoming distance.

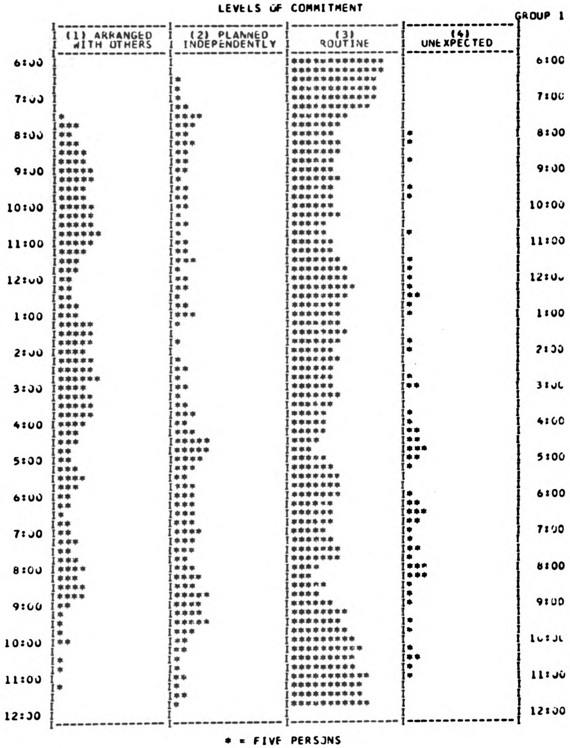

FIGURE 30.

DISTRIBUTION OF ACTIVITY COMMITMENTS
FOR PATTERN GROUP I

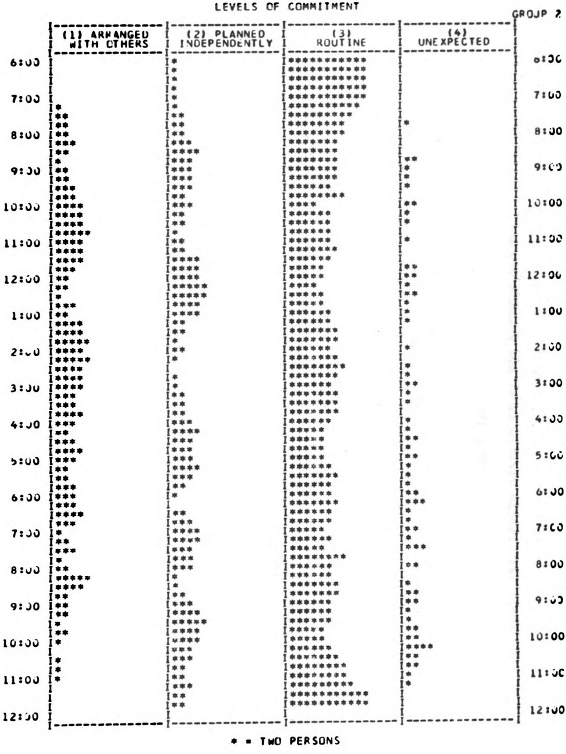

FIGURE 31.

DISTRIBUTION OF ACTIVITY COMMITMENTS

FOR PATTERN GROUP II

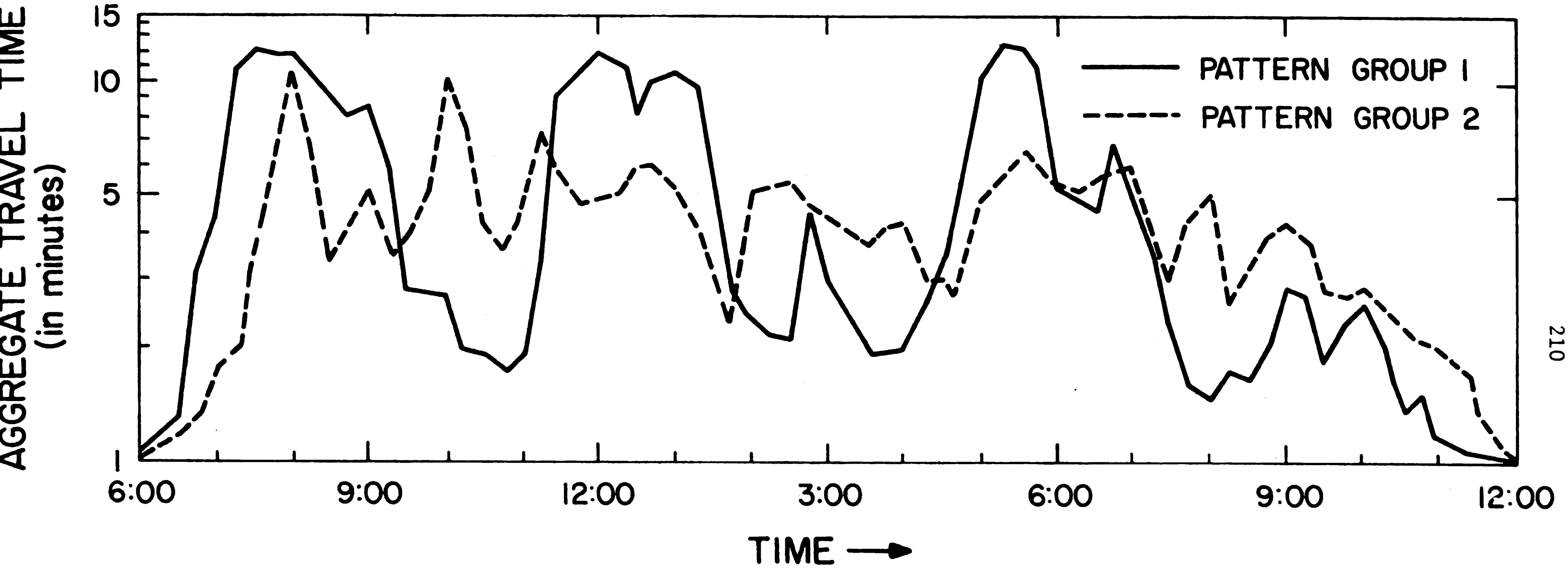

FIGURE 32.

AGGREGATE TRIP LENGTH DISTRIBUTIONS FOR PATTERN GROUPS

Since full-time students represent the majority of group membership, it is not surprising that moderately high and fluctuating rates of mobility result. The pattern of geographical mobility reflects a group in constant transit among a concentrated set of class, study, work, and home locations. Generally, it can be observed that periods of considerable mobility occur during times of least constraint (Figure 26).

The general picture that results from comparisons among Figures 26, 28, 30, and 32 is that educational pursuits dominate the activity pattern of group I. These activities reach their maximum frequency during the morning but peak again in the afternoon and late evening. The times at which the majority of individuals are moving from place to place occur between these peaks. The maximum frequencies of education-related activities correspond to the time intervals which are most constrained with respect to the choice, timing, and location of activities. These are also the times at which group members undertake activities to which they are routinely committed or involve planned interaction with others.

The graphic information pertaining to the first group suggests that one or more educational-related activities represent the pegs about which most of their days are structured and which influence the constraints governing the choice, timing, and location of preceding and subsequent activities. In order to evaluate this assertion, the types of activity which respondents declared as pegs are summarized in Table 14. The table presents information regarding the effects of constraints upon the structuring of activity sequences; information which cannot be inferred by visual inspection of Figure 28.

The data contained in Table 14a describe the degree to which the choices of activity, preceding and following a peg, are fixed. For example, of those who declared a work-related activity as a peg, 80 percent indicated that their choices of activity during the 15 minutes preceding work were fixed by it. Similarly, 60 percent indicated that for as long as 30 minutes prior to an important work activity, activity choices were constrained. In looking across the rows of the table, it becomes apparent that activity choices are fixed for the greatest amount of time before and after important educational activities.

Similarly, Table 14b summarizes the structuring effect that a particularly important activity has on the timing of preceding and subsequent events. The entries in the table indicate that activities leading to a peg generally cannot be performed at any other time. Conversely, activities which follow a peg are not as time-specific as those which precede it. Activities occurring before an all-important education-related event experience the greatest time fixity for the longest period of time.

The data contained in Table 14c pertain to the degree to which activities were fixed at particular locations. Events that occur prior to activity pegs tend to be more place-specific than subsequent ones. Both work- and education-related activity pegs are preceded by activities that are more noticeably fixed with respect to particular activity locations.

Finally, the second category of spatial fixity describes the degree to which individuals are tied to locations at given points in time. For the time periods preceding a peg, the relative magnitudes of the data are moderate in comparison with the other tables. And of the time

TABLE 14.

RATINGS OF ACTIVITY, TIME, AND LOCATION FIXITY--GROUP I

	←---- PRECEDE ----→ (in minutes)						←----- FOLLOW -----→ (in minutes)				
Category of Peg	60 - 90	45 - 59	30 - 44	15 - 29	0 - 14	No. of Members	0 - 14	15 - 29	30 - 44	45 - 59	60 - 90
Work	20	20	60	60	80	(5)	40	20	20	0	20
Personal	25	50	50	63	75	(8)	50	25	13	0	0
Education	25	42	65	83	92	(48)	71	58	29	40	35

a. Activity Choice Fixity: Could you have done anything else at this time?

Work	20	60	60	80	100	(5)	80	60	20	20	40
Personal	25	25	50	63	75	(8)	40	25	25	13	25
Education	40	54	88	65	83	(48)	69	63	44	25	27

b. Timing Fixity: Could you have performed this activity at any other time?

Work	60	60	60	60	100	(5)	80	20	40	20	40
Personal	38	50	25	50	75	(8)	63	25	25	38	25
Education	44	58	69	65	83	(48)	67	38	42	42	13

c. Spatial Fixity: Could you have performed this activity elsewhere?

Work	0	40	40	60	40	(5)	40	20	0	0	20
Personal	25	13	38	25	50	(8)	38	13	13	38	13
Education	17	33	29	60	73	(48)	38	40	23	19	21

d. Spatial Fixity: Could you have been elsewhere at this time?

intervals following a peg, the proportion of individuals affected is quite low. Again, activity pegs that are education-related stand out as having the most profound effect on the spatial fixity of activities that precede them.

In turning attention to the second pattern group, Figure 29 suggests that maximum constraint over activity choice is confined to working hours (i.e., 8:00 to 11:30 a.m. and 1:00 to 4:30 p.m.). The time-space map for group II (Figure 27) shows that primarily work-related activities coincide with these time intervals. Activities that cannot be performed at any other time (Figure 29b) occur most frequently during the hours of work and, to a lesser extent, during the early evening. The categories of spatial fixity generally conform to the preceding distributions but differ in one important way. The relative proportion of group members experiencing constraint with respect to location is much greater. Individuals appear to regard work-related activities as specific to particular locations more so than to particular times of day. This suggests that of all activities undertaken during working hours, the majority cannot be performed elsewhere, and the individuals find it impossible to be elsewhere at these times. Unlike the distributions for pattern group I (Figure 28), the shapes of the constraint histograms for the second group tend to conform to one another. The greatest frequencies over all categories of fixity are recorded during the late morning and afternoon. On the other hand, periods of lowest frequency transpire at midday and during the early evening. Overall, the group is quite homogeneous with reference not only to activity sequences (Table 13), but also to temporal patterns of constraint.

Corresponding to the periods of maximum activity, time, and location fixity are activities that are overwhelmingly routine in nature (Figure 31).[27] Again, these activities are commonly work-related and educational. Activities which are either arranged with others or planned independently occur most frequently during late afternoon and evening. The types of activity associated with these forms of commitment include education, work, and mass media (Figure 27).

The distribution of aggregate travel (Figure 32) reveals that the mobility of members of the second group is restricted to certain clearly defined periods of the day. Major changes in location take place in early morning, midday, and late afternoon, while intervening time periods obtain only modest rates of movement from place to place. This pattern is understandable since at these times individuals are noticeably tied to particular locations (Figures 29c and 29d).[28]

Membership in group II represents a mixture of university faculty, staff, and graduate students. For these individuals, employment and educational pursuits dominate the activity patterns. Work-related activities reach maximum frequency throughout the morning and early afternoon. Educational activities, on the other hand, peak during

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[27]In this case, there may have been a tendency on the part of the respondents to consider activities such as meetings, work sessions, classes, seminars as routine simply because they recur frequently and on a regular basis. In so doing, the label (routine) may have masked activities planned well in advance and arranged with others.

[28]The average residence-to-workplace distance for group II is 1.284 miles. Modes of travel common to the majority of members include private automobile and walking. The aggregate travel times shown in Figure 32 represent the degree to which objective constraints, or available means of transport, limit movement over space.

late afternoon and early evening. The maximum frequencies of work-related activities correspond to the time intervals which record the maximum amount of constraint. Degree of commitment at these times is decidedly routine.

The types of activity which members of group II reported as pegs are given in Table 15. Work- and education-related events constitute the majority of these pegs. The entries in Table 15a show that one's choice of activity is more highly constrained prior to an important activity than following it. However, the data pertaining to fixity over the timing of activities (Table 15b) suggest that activities preceding a peg are as time-specific as those following it. Many activities performed before and after an important educational peg are those which cannot be undertaken at any other time.

Table 15c describes the extent to which activities are fixed at particular locations. Events occurring before and after activity pegs are noticeably place-specific. In fact, the span of time over which this category of spatial fixity is recorded is greater than all other types of fixity. All-important work activities, however, appear to have the greatest impact on the locations where preceding and subsequent activities take place.

The second category of spatial fixity identifies the extent to which individuals are tied to specific locations. A sequence of events may effectively tie a person to a particular place for short periods simply because there is not time to go elsewhere in the period between, for example, two classes in the same place or a number of interdependent work obligations at the same location. It can be observed in Table 15d that a large number of individuals have limited choice of location for

TABLE 15.

RATINGS OF ACTIVITY, TIME, AND LOCATION FIXITY--GROUP II

←---- PRECEDE ----→ (in minutes) ←---- FOLLOW ----→ (in minutes)

Category of Peg	60 - 90	45 - 59	30 - 44	15 - 29	0 - 14	No. of Members	0 - 14	15 - 29	30 - 44	45 - 59	60 - 90
Work	31	31	46	46	69	(13)	62	31	15	31	23
Personal	25	50	50	50	100	(4)	75	25	50	50	0
Education	13	38	50	75	75	(8)	50	38	13	0	13

a. Activity Choice Fixity: Could you have done anything else at this time?

Work	13	54	39	69	92	(13)	62	39	39	31	23
Personal	0	25	50	100	100	(4)	75	100	25	50	25
Education	38	25	50	50	88	(8)	50	25	0	0	13

b. Timing Fixity: Could you have performed this activity at any other time?

Work	39	62	77	85	92	(13)	69	62	46	31	54
Personal	25	0	75	50	100	(4)	100	100	50	50	25
Education	25	25	38	75	88	(8)	75	38	38	13	25

c. Spatial Fixity: Could you have performed this activity elsewhere?

Work	46	23	54	69	77	(13)	54	31	46	31	39
Personal	0	25	75	75	75	(4)	75	50	50	75	50
Education	25	50	50	63	63	(8)	63	38	25	13	13

d. Spatial Fixity: Could you have been elsewhere at this time?

activities. Potential choice of location is most restricted before and after personal activities and especially prior to important work activities. In comparing the data for both categories of spatial fixity, it would appear that the first (Table 15c) has the more constraining effect and for a greater duration both before and after activity pegs. This trend can be partially understood by realizing that the location of activity at a given time is dependent upon activity choice. Thus, activity pegs are considered to have a direct influence on the location of activities which precede and follow them.

Tables 14 and 15 provide considerable information about levels of fixity over limited portions of the day. But for the entire day, is the mean time spent on activities regarded as totally fixed in both time and space greater or less than that regarded as totally free? The results for both pattern groups indicate that the amount of time which is totally free exceeds the amount of time being totally fixed. Table 16a shows the mean amounts of time over which the four categories of fixity prevail. The greatest average amount of time which is fixed corresponds to the first category of spatial fixity. Therefore, activities throughout the day are, on the average, slightly more place-specific than time-specific.[29] Deviations about the means of timing and spatial fixity (i.e., the first category) are comparatively small suggesting, among other things, that there is a concensus in the sample's interpretation of these subjective constraints.

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[29]For group I, approximately ten percent more time is spent doing things where location is a more critical factor than timing of activities. Alternatively, 18 percent more time is devoted to space fixed activities than to time fixed ones for members of group II.

TABLE 16.

SUMMARY STATISTICS FOR CONSTRAINT AND COMMITMENT INDICES.

a. FIXITIES	Pattern Group I			Pattern Group II		
		s^2	s		s^2	s
Activity Choice	437.63	56012.69	236.67	451.89	19254.34	138.76
Timing	446.28	13354.11	115.56	488.12	6840.91	82.71
Location (1)	478.67	28361.93	168.41	538.26	9377.99	96.84
Location (2)	292.14	107118.74	327.29	497.33	14239.65	119.33

b. COMMITMENT	Pattern Group I			Pattern Group II		
		s^2	s		s^2	s
Arranged with others	388.64	32811.70	181.14	351.26	132678.06	364.25
Planned independently	568.50	18790.93	137.08	479.48	57544.46	239.07
Routine	508.37	13973.60	118.21	642.04	25153.96	158.60
Unexpected	294.22	53805.44	231.96	111.67	92561.98	304.24

The most obvious discrepancy between groups occurs with respect to the second category of spatial fixity. For an average of about eight hours (approximately 500 of a total 1,080 minutes during the observation period), members of group II were tied to particular locations. However, group I members recorded a mean of only 296 minutes for this type of location fixity. A very high deviation about the mean suggests considerable variation among individuals.

Table 16b gives the average amounts of time devoted to planned and unplanned activities. Degree of commitment to planned activities is considered to increase from activities which involve routine planning, to those which are planned independently, and finally to those which are arranged with other persons. Activities that are planned independently register the greatest average amount of time for group I members. The average duration for which individuals are routinely committed is also large. Deviations about these means are comparatively small indicating a modest degree of correspondence among group I members.

The average amount of time devoted to activities that are planned independently and routine also obtain the largest means for pattern group II. The mean time for routine commitments, however, is significantly larger than the average for those which are planned independently. The standard deviation for the mean of routine activities is relatively small. This implies that for an average of about ten hours a day, give or take two hours, members of group II are involved in recurrent, or strictly routine, events.

The degree of commitment to activities represents one measure of subjective constraint. The means, variances, and standard deviations presented in Table 16b show that members of group II have more highly

structured days. For example, the average amount of time which is not planned (i.e., unexpected) is considerably less than that of the first group. Also, the mean times for activities which are either routine or arranged with others tend to be greater than those for group I.[30]

It would be incorrect to assert that one type of fixity is more important than another in structuring activity sequences in time and space. However, respondents in the survey have indicated that there are certain points, or pegs, about which much of the remaining portions of their days are anchored. The graphic and tabular data presented reinforce the contention that activity, time, and location constraints play an integral role in the sequencing of activity in general, and the sequencing of events before and after pegs in particular. Tables 14 and 15 demonstrate that ratings of fixity are usually greater preceding a peg, and decline in severity with increasing time following it. The configurations of constraint (Figures 28 and 29) show that peaks of activity, time, and spatial fixities decline as the day moves on. Figures 30 and 31 show a general decrease in level of commitment with increasing time. The schematic representation in Figure 33 relates the combined effect of the data presented in the preceding tables and figures.[31] This simplified view suggests an oscillating pattern to the

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[30]The mean time devoted to activities arranged with others (for group II) is quite possibly an underestimation. Many of the activities which respondents in group II classified as routine took place at work-specific locations. However, several of these routine events were pre-arranged with others, suggesting a higher degree of commitment. It is, perhaps, the routine location of certain events that lead people to classify activities, to which they are otherwise highly committed, as routine.

[31]The graph measures constraint on the vertical axis as ranging from zero ("yes" responses to all subjective fixity questions) to an upper limit of one ("no" responses to all questions). The horizontal line represents the average combined fixity rating.

increases and decreases in the impacts of constraints throughout the day. Moreover, the extent of oscillations tends to narrow with increasing time. Amplifications of the wave represent the most highly constrained episodes, while deamplifications, or troughs, depict the periods of least constraint.

The generalized pattern of constraints (Figure 33) will constitute a large portion of the data input to the simulation model. The simulation experiments described in the following chapter adhere to the methodology of the time-space mechanics of constraints that was outlined in the previous chapter. In accordance with this methodology, each of the pattern groups must be treated separately. Membership in the first and second groups (Figure 25 and Table 10) is sufficiently large to permit the simulation of their constituents. The membership of the third group is too limited for a meaningful simulation of its

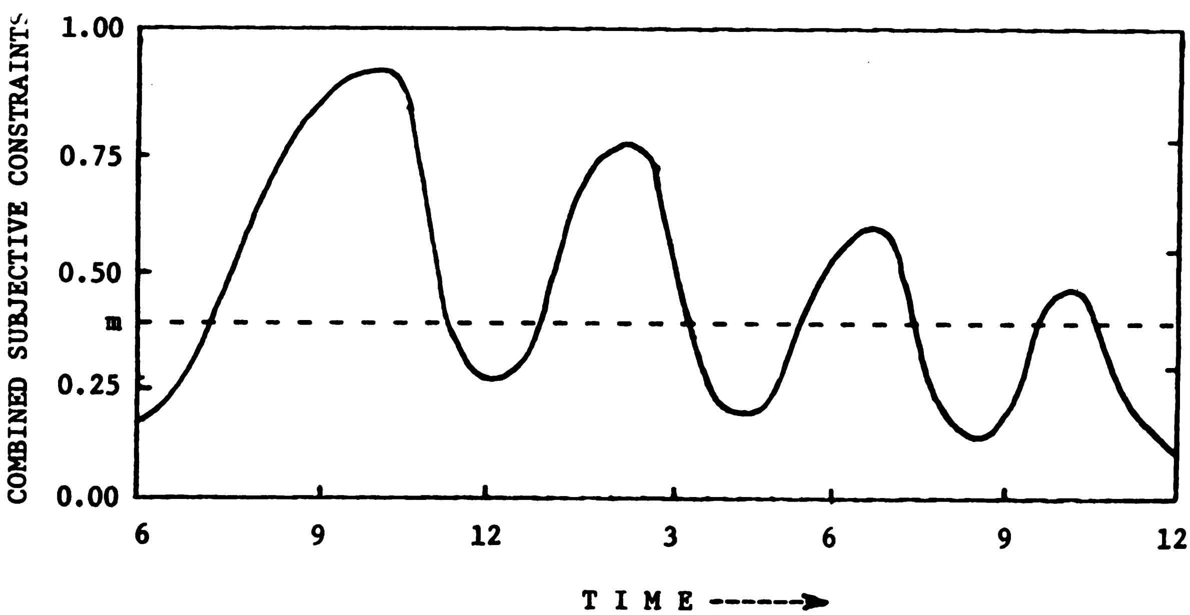

FIGURE 33.

GENERALIZED PATTERN OF TIME-SPACE CONSTRAINTS members. Therefore, it will not be considered in the simulation experiments. However, because of its comparatively small size, the third group will serve as the data base for calibrating the simulation model.

CHAPTER 5

SIMULATION MODEL OF TIME-SPACE PATHS AND THE MECHANICS OF SOCIO-ENVIRONMENTAL CONSTRAINTS

The results of the preceding analysis were three relatively homogeneous behavior pattern groups. The groups were defined as having a high degree of within-group similarity on the basis of the sequence and duration of activities performed over a 24-hour period. Having recognized these behavior pattern groups, the central research hypothesis can now be evaluated. The hypothesis states that the critical determinant of the structure of a person's day is the extent to which one feels constrained relative to certain activities, times, and locations. These fixes, or points, about which one's day tends to be organized will act as the basis of the following simulation experiments.

The chapter is divided into five main sections. First, the context in which the method of simulation is applied is established. Second, the data requirements are reviewed and the method by which the data are organized for input to the model are discussed. The third section establishes the objectives, simplifying assumptions, and procedural rules of the model. Fourth, the design of the simulation model and experiments is outlined together with some comments on preliminary verification of the modelling approach. The results of the individual simulation experiments are then treated. In the fifth and final section, the modelled results are critically evaluated against the observed behavior of the pattern groups. A method is developed whereby the research hypothesis is either inferred or rejected based upon the statistical significance of the correspondence between the observed and the simulated results.

SOLUTION, MODEL-BUILDING AND SIMULATION

The emergence of simulation methods has undoubtedly had a profound impact on the social sciences. These methods offer the social scientist the opportunity to investigate the properties of complex systems, featuring qualitative as well as quantitative relationships, non-linearities, and ill-defined structures.[1]

From a research point of view, it is useful to define simulation as a model-solving technique based on the experimental as opposed to the analytic approach. This definition stresses the fact that simulation is a tool for solving abstract models of some real system, rather than being a model-building technique, as implied by a substantial segment of the simulation literature.[2] Although the intended use of simulation may bear upon the approach adopted to model-building, and upon the structure of the model, there are no universal features distinguishing such models from any others. The so-called "simulation models" usually differ from others in complexity or size, but not necessarily in structure, as is the difference between linear and non-linear

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[1]Michael Inbar and Clarice S. Stoll (eds.), Simulation and Gaming in Social Science (New York: The Free Press, 1972), pp. 40-41.

[2]This distinction is reflected in the writing of the Gullahorns; see: John T. Gullahorn and Jeanne E. Gullahorn, "Simulation and Social System Theory: The State of the Union," Simulation and Games, 1 (March, 1970), pp. 19-42.

system of equations.

The definition outlined above emphasizes the experimental, as opposed to the analytic approach to model solution. Only a general and somewhat vague distinction can be made between the structure of a model solved by simulation and a model solved analytically. In order to avoid structural complications which could render the model mathematically unsolvable, it is often necessary to postulate a number of restrictive assumptions. These assumptions may further remove the model from the real system it represents. In this respect, there is more freedom in constructing a simulation model. In the modelling stage, the investigator is able to introduce structural relationships which are amenable to the computer's step-by-step procedure for arriving at a numerical answer. Otherwise, such structures would, in all probability, be too complicated for solution.

This freedom has a definite pitfall. Cyert has eloquently stated:

> A tendency which is sometimes displayed in the formulation of simulation models is to embed as much of the real world as possible in the models. This is motivated by the feeling that the more complicated the model is, the better able it is to describe special cases, and hence better will be its predictions.
>
> However, the model may become almost as complex as the real world, and, therefore, the model may become almost as difficult to understand.[3]

Fortunately for the investigator, no rules--not even rules of thumb--exist to tell one where the model should end and the real world begin. The extent to which one should proceed in abstracting and simplifying

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[3]R. M. Cyert, "A Description and Evaluation of Some Firm Simulations," Proceedings of the IBM Scientific Symposium on Simulation and Gaming. White Plains, N.Y.: IBM Corporation, Data Processing Division, 1966, pp. 16-17.

reality is part of the art of model-building--any model at that, simulation or others.

The experimental approach to model solution is particularly relevant to the present research, since the prime objective is one of testing a particular methodology. In essence, the methodology posits that constraints, both objective and subjective, are critical determinants of one's behavior in time and space. Thus, an attempt is made to simulate the unknown variables, the timing, sequencing and location of activities, in terms of the parameters, or known variables, the objective and subjective constraints.

DATA REQUIREMENTS

The outcome of the preceding analysis was three relatively homogeneous groups which could act as the basis for simulation. The simulation will have to deal with each group separately.[4] Since the third group is composed of so few individuals, the following simulation experiments will focus on only the two major groups resulting from the previous analysis (Table 12).

As a first step in preparing the data for the simulation experiments, it is necessary to discover the way in which the daily pattern of each group is organized. The organization must be more detailed than was the case in Figures 26 and 27. First of all, for each activity in the 65-way classification, two sorts of distribution must be derived:

[4]Since it was demonstrated in the preceding chapter that particular sequences of activity and patterns of constraint correspond to each group, it follows that two simulations should be performed independent of one another. To do otherwise would render the estimation of unknown parameters meaningless.

(1) the frequency of occurrence of every activity at each time interval throughout the day and (2) the probable duration of each activity (Figure 34).

The next distribution that must be derived relates to the commitment and subjective constraint indices. For each possible combination of responses to the subjective constraint questions, sixteen in all, a distribution may be drawn up describing its frequency of occurrence relative to each activity in the 65-way classification. The distribution may be further defined by individuals' degrees of commitment to these various activities. These distributions can then be organized into a three-dimensional array where the dimensions represent activities, degrees of commitment, and subjective constraint indices (Figure 34).

A fourth distribution that must be created prior to the execution of the simulation relates to the probable location of activities. Thus, it is necessary to discover the probability of activities occurring at specified locations (Appendix C) at each time interval throughout the day. These data can then be represented by an array having the dimensions of time, activity, and location (Figure 34).

The fifth and final probability distribution derived for each group was a matrix of activity linkages. In preparing this distribution it was necessary to tabulate from each individual's activity module the frequency of links between all sequential pairs of episodes. These frequencies were then transformed into a matrix of linkage coefficients which take the form of transition probabilities. Therefore, a matrix P_{ij} of transition probabilities is derived where p_{ij} represents

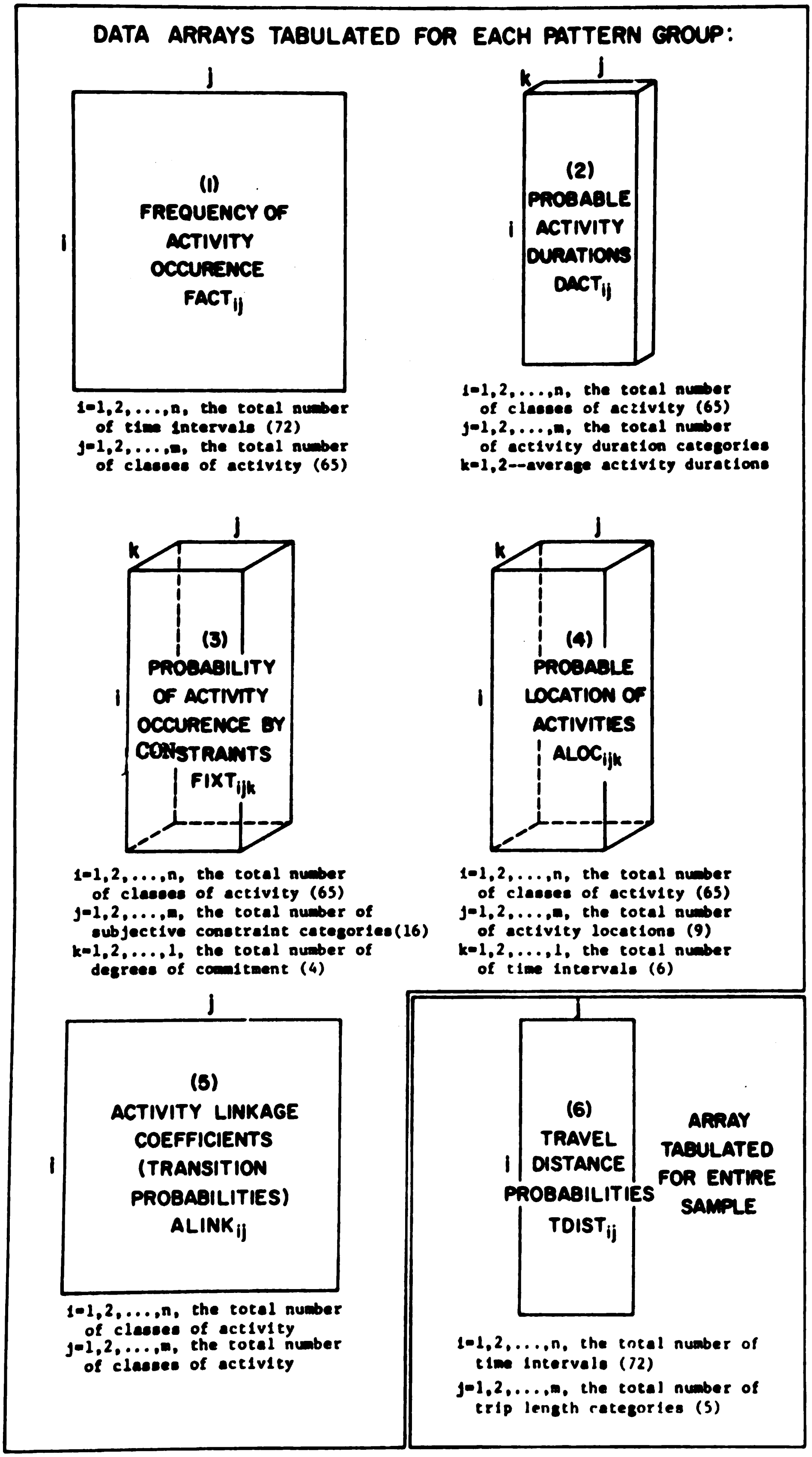

FIGURE 34.

DATA REQUIREMENTS OF THE SIMULATION MODEL.

the probability of activity i leading to activity j. The matrix P_{ij} summarizes the structure of activity linkages for the particular group in question (Figure 34).[5]

The next distribution that was developed relates to what will, in effect, take the form of environmental or objective constraints in the final model. It will be essential to constrain where people go to perform activities or at least determine how long it will take for them to get there. The procedure necessary in developing such constraints involved computing a trip length distribution relative to each of a range of physical distances by grouping each travel episode encountered in the activity modules. This distribution, unlike the previous ones, is calculated from the entire sample of time-space budget diaries (Figure 34).

MODELLING OBJECTIVES, ASSUMPTIONS AND RULES

It has been hypothesized that the critical determinant of the structure of a person's day is the extent to which the individual feels constrained relative to certain activities, times, and locations. The objective of the simulation model is to model the daily paths of individuals in time-space based upon the individual's response to the subjective fixity questions (Table 2 and Appendix B) for each activity performed. It seems reasonable, therefore, that the first input to

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[5]Examples where matrices of transition probabilities are similarly interpreted as activity linkage coefficients include: George C. Hemmens, The Structure of Urban Activity Linkages (Chapel Hill, N.C.: Center for Urban and Regional Studies, University of North Carolina, 1966), and Brian P. Holly, "Urban Life Styles and Environment: The Effects of Location and Behavior in a Time-space Framework" (unpublished Doctor's dissertation, Michigan State University, 1974).

the simulation model should be the subjective constraints for each person. Once the sequence of constraints has been established, the model will then simulate the manner in which the individual relates his behavior to these constraints.

As a first step, the individual selects an activity to perform at some time during the day. Once the individual has selected an activity, how does he choose a location for that activity? Following the principle of least effort, the individual chooses the nearest location. The choice of activity and location is limited by certain constraints. The timetable is an obvious limitation. If the individual has a fixed commitment in an hour's time, he cannot choose an activity for which the nearest location is more than an hour away. This need to take account of any points in the person's day that are fixed in time and/or space requires a "look-ahead" mechanism.

It is assumed that the individual selects an activity first, either at random or from a set of transition probabilities (i.e., linkage coefficients), and then a location, which is assumed to be the nearest. This process is then repeated at fifteen-minute intervals until the entire day is completed. By repeating the procedure for as many times as there are members of a group, a complete pattern of activities can be built up for the whole group for a day.

Limiting Assumptions

For any model that tries to approximate reality, a number of limiting assumptions must usually be established. The first assumption of the model presented here is that the proportion of time spent in various activities and the sequencing of these activities remains the same over the day for each group of individuals. A second assumption is that the groups identified by these criteria are fairly homogeneous and should be treated independently. The timetable of activities common to the members of each group forms the backbone of the simulation. It is further assumed that the individual organizes the pattern of his day around certain fixed events in his daily timetable. Moreover, it is assumed that activities which are fixed in time and space determine the overall structure of one's day. An activity, therefore, which is felt to have a high degree of fixity determines the sequence of events that precede and follow it.

The model is designed to simulate the daily time-space behavior of individuals over an 18-hour time period. The decision to restrict the simulated time period to 18 hours, 6:00 a.m. to 12:00 midnight of the same day, was twofold. First, the computer storage requirements of the data arrays, shown in Figure 34, imposed serious limitations when the data were tabulated for the 24-hour period. Second, the recognition of behavior pattern groups was limited to an 18-hour observation period. If the simulated activity sequences are to be compared with the observed, then the time periods, both simulated and observed, must be of equal length.

Procedural Rules

Another requirement of the simulation model is that the rules regulating its flow of operations be unambiguously defined.

The first rule relates to the manner in which activity labels are assigned to time intervals. Those episodes during the day which are considered as pegs about which one's day is anchored are first assigned activities. The order in which a set of pegs is assigned a set of activities depends upon their rank order of importance to the individual.

Following the activity assignments to pegs, the model then considers the category of episodes which are termed fixes.[6] Once the fixes are identified, they are assigned activities in their chronological order throughout the day. Following the completion of this task, the program, through iterative procedures yet to be described, then fills in the remaining unidentified time intervals by assigning activities, durations, and locations. As such, these are the rules governing the order of activity assignments taken by the simulation.

A second rule pertains to successive activities that are spatially separated. Successive activities that occur at different locations can only be accomodated if there is sufficient intervening time for travel between them.

A third rule governs the number of activities that can be performed by an individual at any given time. Although in reality some persons can perform several activities simultaneously, the model limits an individual to performing only one activity at a time. Moreover, this activity is assumed to be a primary activity as defined earlier (Chapter 3).

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[6]A useful distinction can be made between pegs and fixes. Pegs constitute a first order of constrained episodes. They are seen by the individual (or respondent) as those episodes around which much of one's day is thought to be anchored. Fixes, on the other hand, are of second order and are determined internally by the program. Any episodes, other than the pegs, in which the responses to the fixity questions are affirmative and have been planned in advance are interpreted as fixes. Together the fixes and pegs represent the most highly constrained events in the person's day.

DESIGN OF THE SIMULATION MODEL AND EXPERIMENTS

The focus here is on a micro-level simulation approach, which sees the model in terms of a computer program focusing on real-world decision processes. In order to describe the computer simulation, the following discussion will proceed on a level one step removed from the actual programming (Appendix F) by developing a generalized block diagram of the simulation model (Figure 35).

Model Design

The first step in the simulation is to derive six probability distributions (Figure 34). The nature of these distributions will differ depending on the behavior pattern group being treated. Given these probability vectors as real-world approximations of activity structure, a Monte Carlo method is then used to select activities, durations, and locations. These vectors are treated as discrete cumulative probability distributions, and uniform random numbers bounded by zero and one are drawn to determine the activities, durations, and locations. Thus, the time-space path of each individual's day is built up by assigning random numbers in accordance with the calculated probabilities, and by comparing numbers drawn for every time period or activity with these distributions.

The structure of the model is necessarily tied to the conceptual framework developed earlier. Therefore, an attempt is first made to establish the major constraints in each person's day, and then, how one relates his behavior to these constraints.

The simulation first isolates the most important episodes, or pegs, about which one's day is organized. These have been defined by

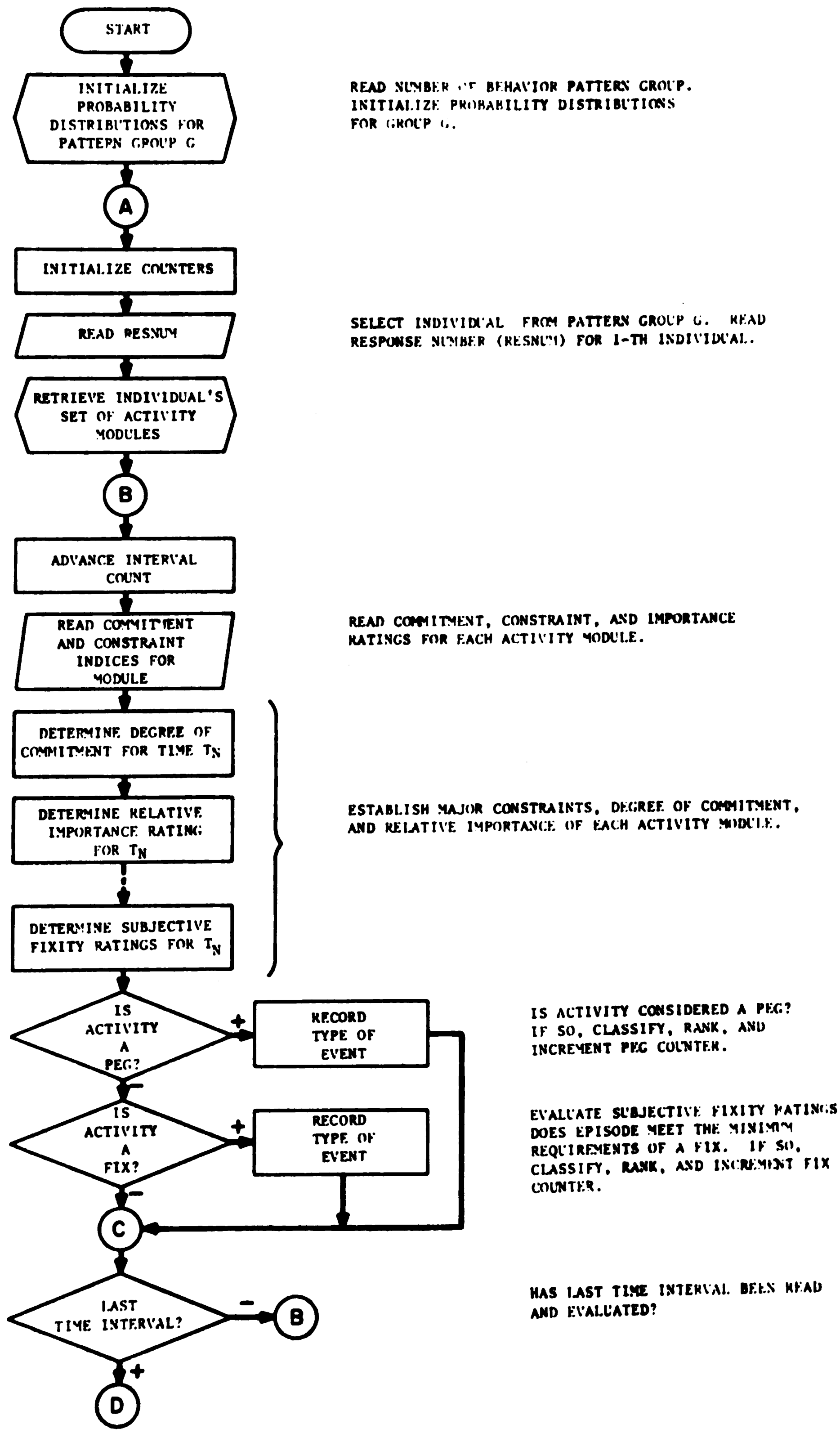


FIGURE 35.

FLOWCHART OF THE SIMULATION MODEL

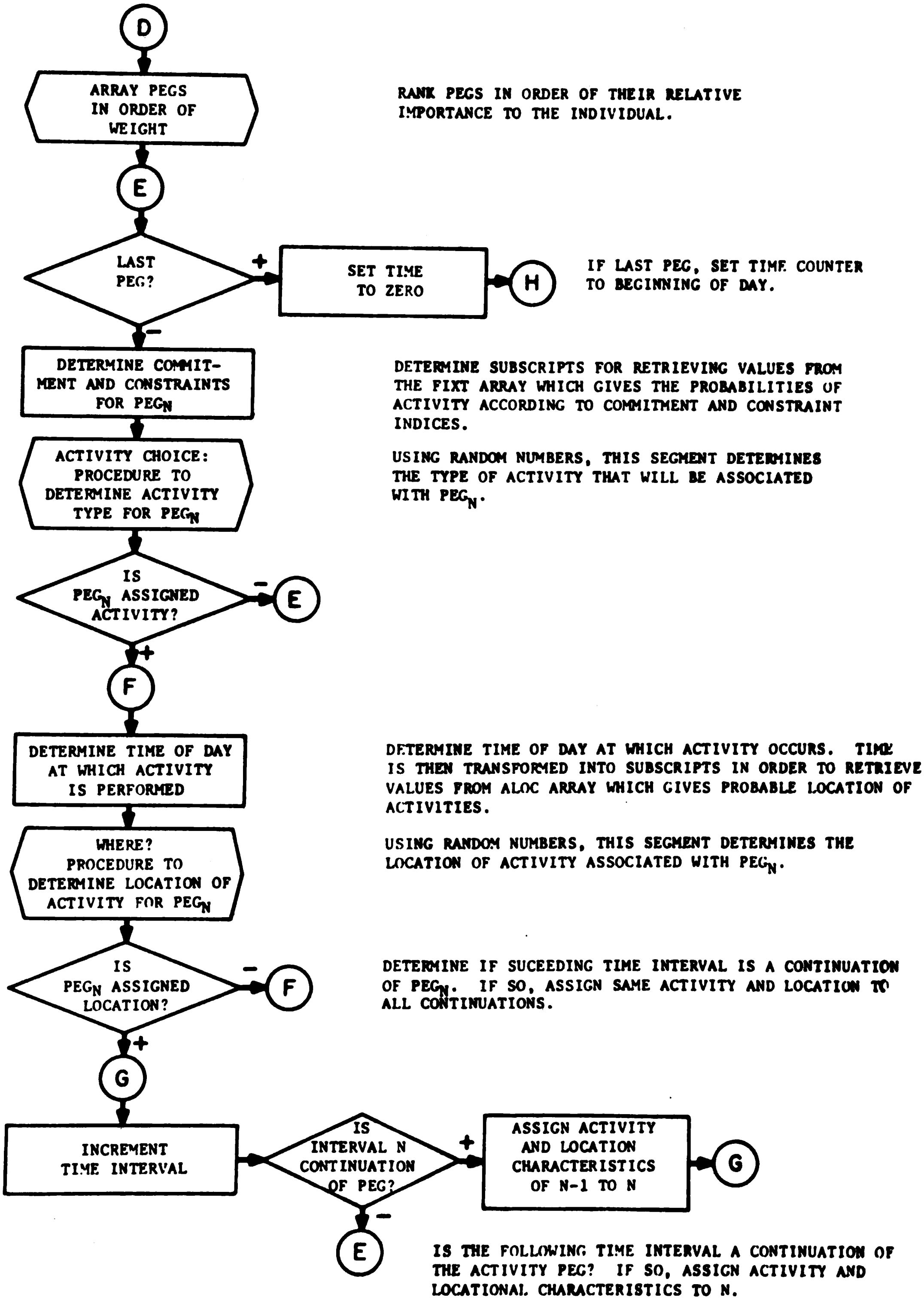


FIGURE 35--CONTINUED

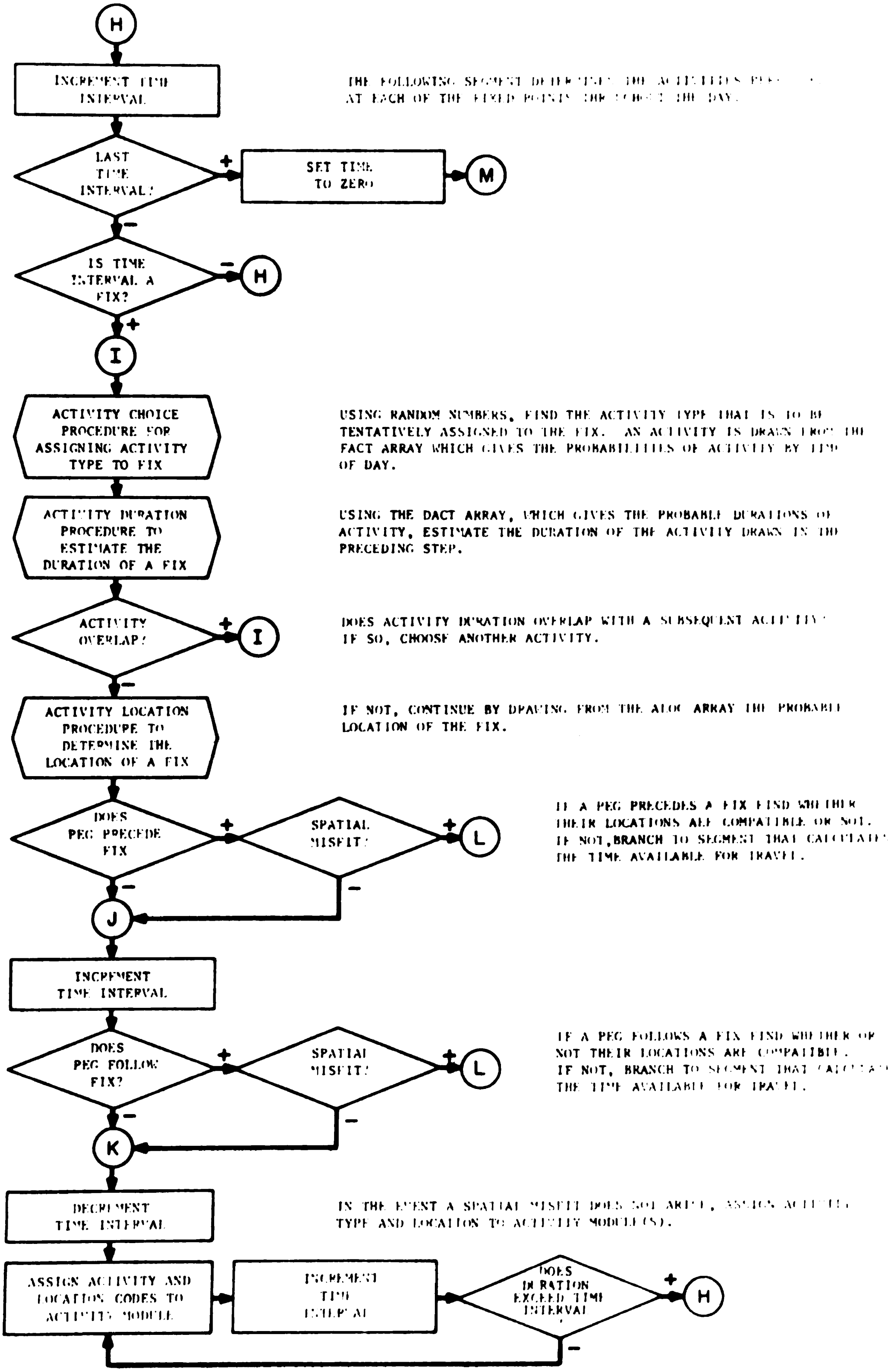
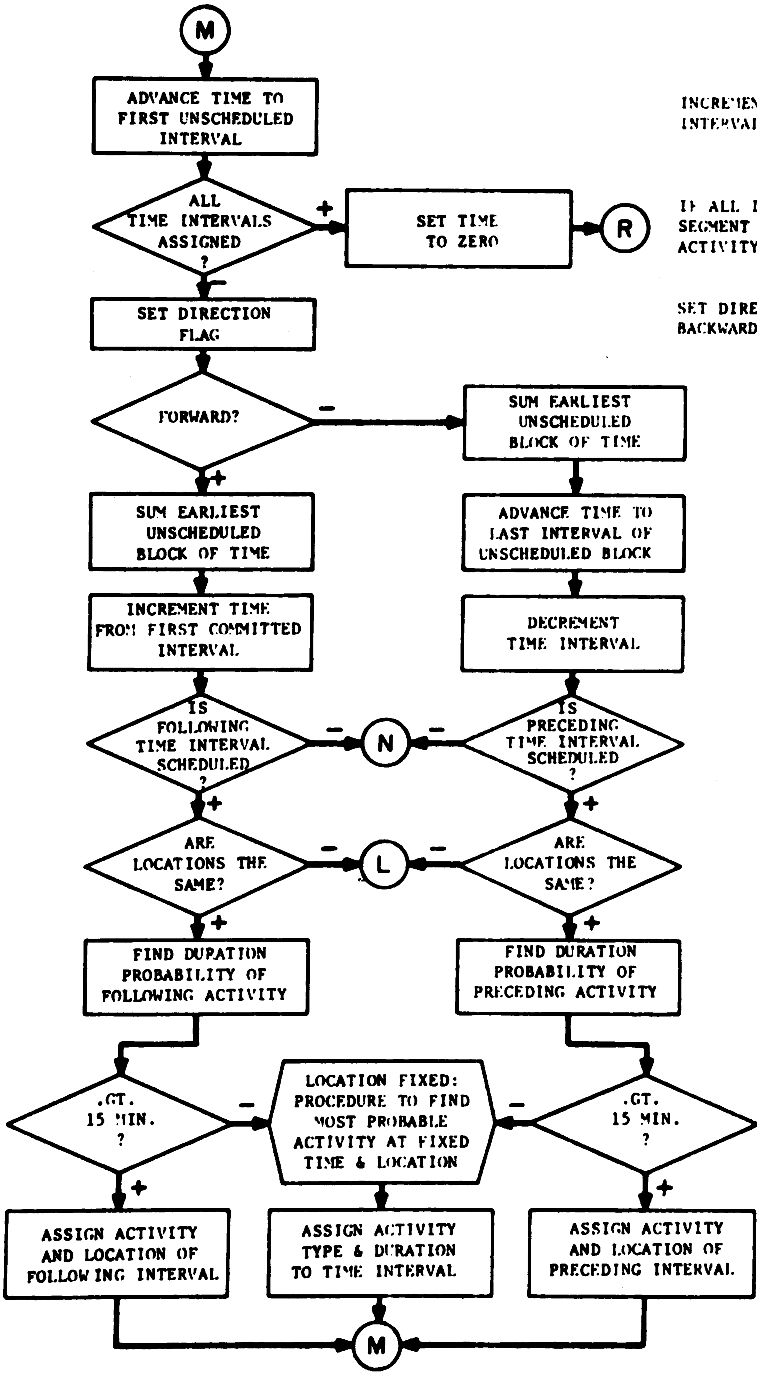


FIGURE 35--CONTINUED



INCREMENT TIME TO FIRST UNSCHEDULED INTERVAL.

IF ALL INTERVALS ARE ASSIGNED BRANCH TO SEGMENT THAT OUTPUTS VECTOR OF SEQUENCED ACTIVITY DURATIONS.

SET DIRECTION FLAG FOR FORWARD OR BACKWARD ITERATION.

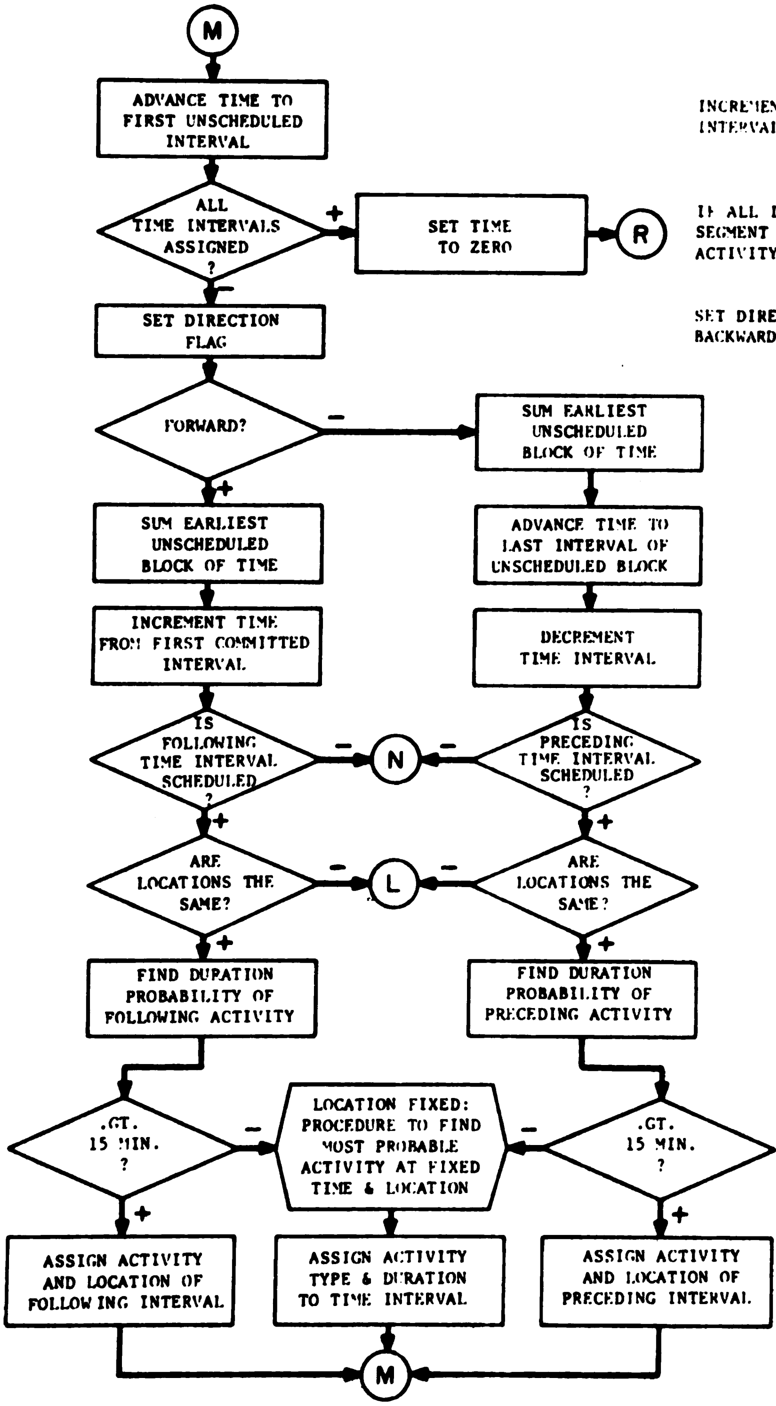
DEPENDING UPON DIRECTION, FIND EARLIEST UNSCHEDULED BLOCK OF TIME.

IF LOCATIONS OF ACTIVITY DIFFER, BRANCH TO TRAVEL TIME SEGMENT.

IF ACTIVITY DURATION IS LESS THAN TIME INTERVAL, FIND MOST PROBABLE ACTIVITY FOR BALANCE OF TIME.

IF DURATION EXCEEDS TIME INTERVAL, ASSIGN ACTIVITY CHARACHTERISTICS TO PRECEDING OR FOLLOWING INTERVAL.

FIGURE 35--CONTINUED



INCREMENT TIME TO FIRST UNSCHEDULED INTERVAL.

IF ALL INTERVALS ARE ASSIGNED BRANCH TO SEGMENT THAT OUTPUTS VECTOR OF SEQUENCED ACTIVITY DURATIONS.

SET DIRECTION FLAG FOR FORWARD OR BACKWARD ITERATION.

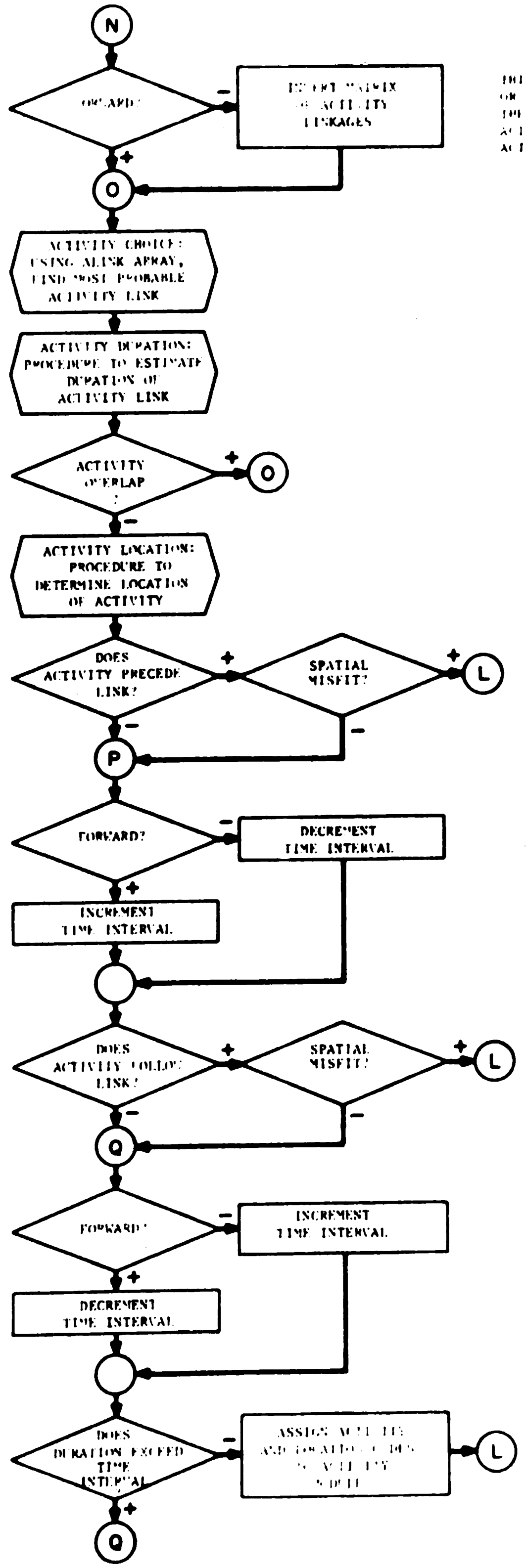
DEPENDING UPON DIRECTION, FIND EARLIEST UNSCHEDULED BLOCK OF TIME.

IF LOCATIONS OF ACTIVITY DIFFER, BRANCH TO TRAVEL TIME SEGMENT.

IF ACTIVITY DURATION IS LESS THAN TIME INTERVAL, FIND MOST PROBABLE ACTIVITY FOR BALANCE OF TIME.

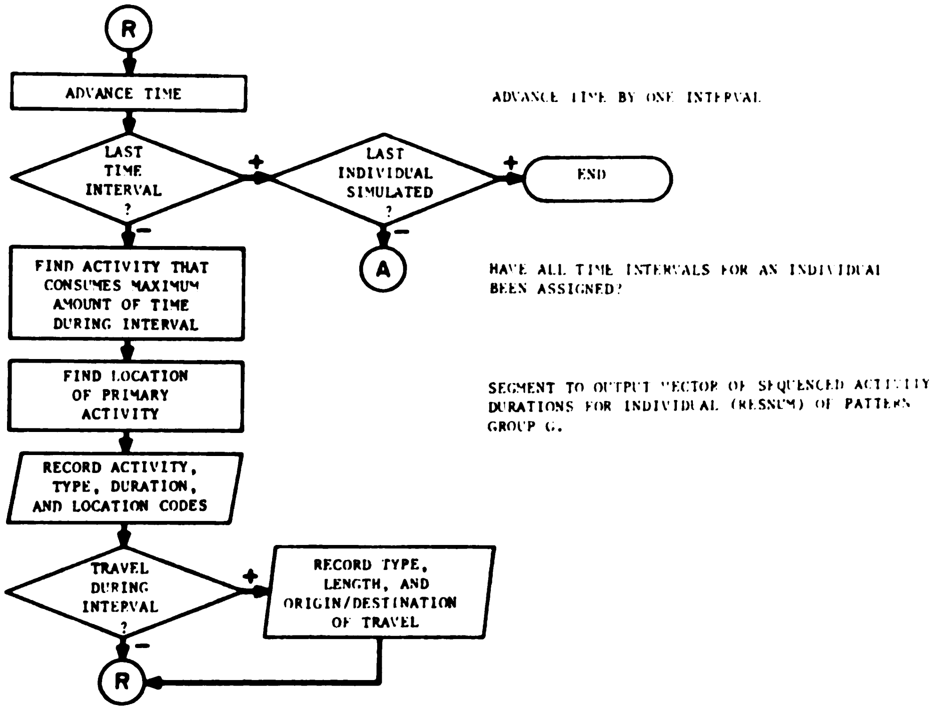
IF DURATION EXCEEDS TIME INTERVAL, ASSIGN ACTIVITY CHARACHTERISTICS TO PRECEDING OR FOLLOWING INTERVAL.

FIGURE 35--CONTINUED



[illegible] SEGMENT, [illegible] MECHANISMS, [illegible] CHOICE, DURATION, AND [illegible] THAT [illegible]

FIGURE 35--CONTINUED



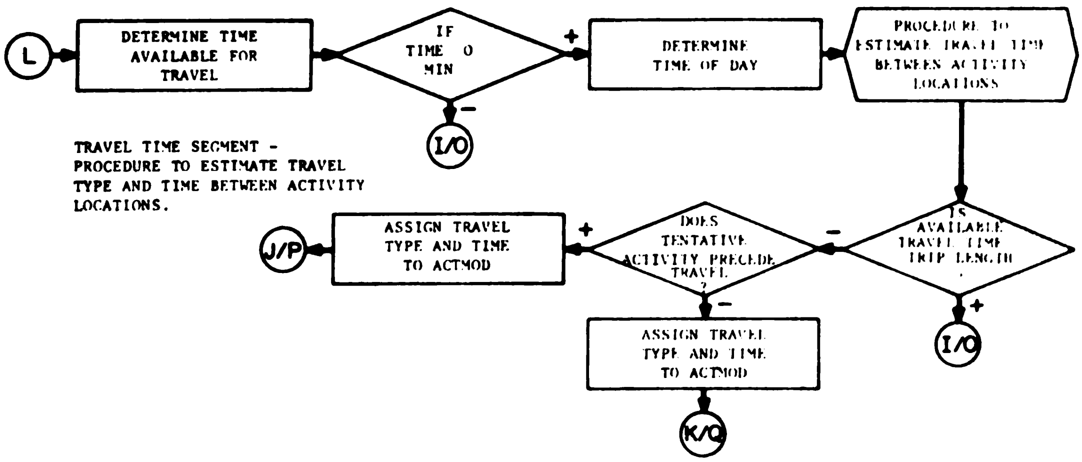


FIGURE 35--CONTINUED

the respondent's importance ranking and his degree of commitment. Once a peg has been established, uniform random numbers are drawn in order to determine the activity, duration, and location to be associated with it.

During the next step of the simulation a second pass is made through the data. Those activities having the highest subjective fixity ratings are then isolated.[7] Consistent with the conceptual framework, these fixed points in the day, the fixes, are assigned activities. For each combination of commitment and constraint indices, there is associated with it a cumulative probability distribution defining the frequency of activity occurrence. A uniform random number is then drawn to determine the type of activity to be assigned to a given fix. In a similar fashion, random numbers are generated to determine the probable activity duration and location for each fix.

Once an activity, its duration and location have been tentatively assigned to a given fix, the program then determines whether or not another fix or peg immediately precedes or follows it. This being the case, it is then necessary to determine whether the two successive activities have compatible locations. If a spatial misfit does not arise, the activity, duration, and location assignments are retained. In the event of different locations for successive activities, the program checks to see if there is any intervening time available for

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[7]For instance, if the responses to the four subjective fixity questions were no for a given activity, then that activity would be assigned the highest degree of fixity or constraint. Activities for which three of the responses were no would be next in order of fixity, and so on.

travel between the two locations. If not, the tentative activity assignments for the fix in question are rejected and the procedure for selecting an activity, duration, and location is reactivated. If, on the other hand, some time is available for travel, a travel time is estimated by sampling a discrete probability distribution of trip lengths while taking into consideration the travel modes (objective constraints) available to the individual. If the trip length is less than the time available for travel, then the travel time and mode are retained; otherwise, they are rejected along with the tentative activity, duration, and location of the fix preceding the trip.

In simulating around the major fixes in a person's day, it became necessary to employ look-ahead and look-back mechanisms.[8] Beginning with the first fix in an individual's timetable the program looks back in time in order to determine the amount of time available for activity. If a fix occurs at time t then the program iterates backward to interval t-1. An activity j is already associated with interval t. Therefore, it is possible to enter the table of activity linkage coefficients (Figure 34) until reaching the j-th column vector. This vector represents a cumulative probability distribution of linkages to all of the i activities. A uniform random number is then drawn to determine the activity that is tentatively to be assigned to the preceding time interval, t_i-1. In a similar fashion, random numbers are

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[8]The look-ahead and look-back procedures were chosen in favor of the introduction of a Markovian property to the model. The Markovian property would unfortunately require that the performance of an activity at sequence t+1 or t-1, as the case may be, be independent of the activity performed at time t. The data recorded in the original time-space budgets indicate that activities preceding and following a highly constrained activity are not independent of one another (Tables 14 and 15).

generated in order to determine the probable activity duration and location of activity i while still looking back in time. If intervals t and t-1 are compatible in terms of activity and location, i.e., $t_i - 1 = t_i$, then the data describing the type, duration, and location of activity i are assigned to interval t-1. If two successive activities differ in type, are incompatible with respect to their locations, and no time is available for travel between them, then the solution to this instance of a spatial misfit is identical to that described earlier for successive fixes. If, on the other hand, a spatial misfit does not arise or the activities occurring at t-1 and t allow for travel between their respective locations, then the data pertaining to type, duration, and location of activity are assigned to interval t-1.

The simulation then looks ahead to time interval t+1 and performs the same operations. Following the look-back and look-ahead operations around the first fix or fixes, the program then advances through the day until reaching the next fix. At that time, the same backward and forward iterations are performed until a solution to the assignment of activity, duration, and location is reached. This procedure is repeated for as many passes through the day as are necessary to build up a continuous, unbroken sequence of events that describe the simulated time-space behavior of an individual.

Verification

The third stage of model development was that of verification. The procedure involved comparing the model's responses with those which would be anticipated if indeed the model's structure were programmed as intended.

The third group resulting from the pattern recognition analysis consisted of only eight members (Figure 25 and Table 12). This relatively small data set was employed during the verification phase. The data pertaining to such a small number of individuals made it possible to hand tabulate many segments of the computer simulation model. The following paragraphs describe some problems of model design revealed during verification.

It is central to the simulation procedure that what people feel to be the major constraints upon their day should be established first and the remainder of the day built up around these. But the actual manner in which they are ascribed a substantive label is highly problematic. This is because the way in which an episode may be regarded as constraining differs from occasion to occasion. At some times a constraint is felt to be relative to a particular activity--a person could not have done this activity at any other place or time. And yet other times, it is felt to be totally independent of the activity performed--he could not have been elsewhere at that time. To deal with both sorts of constraint in the same way seems somewhat unreasonable. Further, even when the fixes have been established, there remains the problem of simulating around them. This involves specifying the manner in which they affect both preceding and subsequent activities. For instance, it is reasonable to expect that a fix which involves being at a certain location at a particular time will operate in a different way from one which just involves doing something at a certain time, independent of location.

It was realized during the verification phase of model development that the various combinations of constraint had to be treated differently. The decision was made, therefore, to include a three-dimensional data array that would define the probability of activity occurrence according to the types of constraint that described a particular fix during the course of a day (see FIXT array in Figure 34).

A second decision made during the verification phase was that the array containing the trip length distributions (TDIST in Figure 34) should be composed of the entire sample. If the TDIST array contains the trip length distribution relative to only the members of one group, then trip lengths are too limited by time of day.

Simulation Experiments

Deriving numerical values of the endogeneous variables from a single simulation run constitutes an experiment. The parameters, which are varied from one run to another, are the factors of the experiment; each factor can be assigned several values or levels. A single simulation run, or experiment, involves a given assignment of values to all the parameters manipulated in the investigation.

The steps of the simulation as described above and depicted in Figure 35 were repeated as many times as there were members of a behavior pattern group. Before the completion of each experiment, i.e., simulated activity sequence, a final check was made to ensure that all time intervals in the day had been assigned the necessary information to describe an activity module.[9] Each module in a sequence contains the data elements 1, 2, 5, and 7 (Table 4), and for those episodes that

[9]The possibility of an unassigned activity module exists. If after five attempts a spatial misfit is unresolved, all data elements of the activity module in question are coded as being void of activity. This precautionary measure was taken in order to avoid excessive use of computer time.

were fixes or pegs the activity module contains the additional data elements 10-15 (Table 14).

The data modules describing the simulated activity sequences were then transformed into vectors of sequenced activity durations (Figure 21). The vectors were computed in the same way as that described in Chapter 4. For each of the 72 15-minute time intervals, the type of activity which was performed for the greatest length of time was entered. Weighting was maintained by using the cardinal duration (between 1 and 15 minutes) as the base information of the vector and it was indexed both according to its sequential position and the nature of the activity performed. If E_{ij}^{t} is the estimated amount of time the i-th individual devotes to main activity j during time period t, then the individual's simulated activity sequence, P_i, can be represented by the vector:

$$P_i = (E_{i1}^{t}, E_{i2}^{t}, \ldots, E_{ij}^{t}, \ldots, E_{im-1}^{t}, E_{im}^{t}) \qquad (5.1)$$

where: i = 1,2,...,n (the total number of individuals); j = 1,2,...,m (the total number of subdivisions of the day); and t = 1,2,...,k (the total number of activity categories).[10]

EVALUATION OF THE MODEL

The simulated activity sequences may be aggregated by behavior pattern groups and summarized in the form of time-space maps (Figures

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[10]Each element in the vector represents a sequenced activity duration. If the main activity code during a given time interval is 47, then the element is represented by that numeric code indexed to its duration (e.g., 10 minutes), or 47.10.

36 and 37). When comparing the observed time-space maps (Figures 26 and 27) with the simulated ones, it becomes difficult to accurately determine the degree of correspondence between them. For instance, it is obvious, when comparing the observed (Figure 26) and simulated (Figure 36) maps for pattern group I, that considerable discrepancies occur following 6:00 p.m. Similarly, observed differences can be noted between the actual (Figure 27) and simulated (Figure 37) maps of the second pattern group, especially during the mid-afternoon and evening hours. For example, during the mid-afternoon there is a noticeable under-estimation of education-related activities, while during the evening hours a serious over-estimation of educational activities occurs.

It is difficult to measure, by visual comparison alone, the departures of the simulated from the observed patterns. Moreover, it is impossible to discern individual differences between the actual and the predicted time-space paths. A more reliable measure of correspondence must be sought.

Correspondence Between Estimated and Observed Results

Once the activity sequences for members of a pattern group have been simulated (5.1), it is necessary to compare these results against the observed sequences. The tests for evaluating the ability of the chosen methodology to replicate the observed time-space paths must satisfy two criteria. First the tests should measure at the micro-scale the degree of correspondence between the actual and predicted time-space paths of individuals. Second, and more importantly, the tests should measure the goodness-of-fit between the actual and

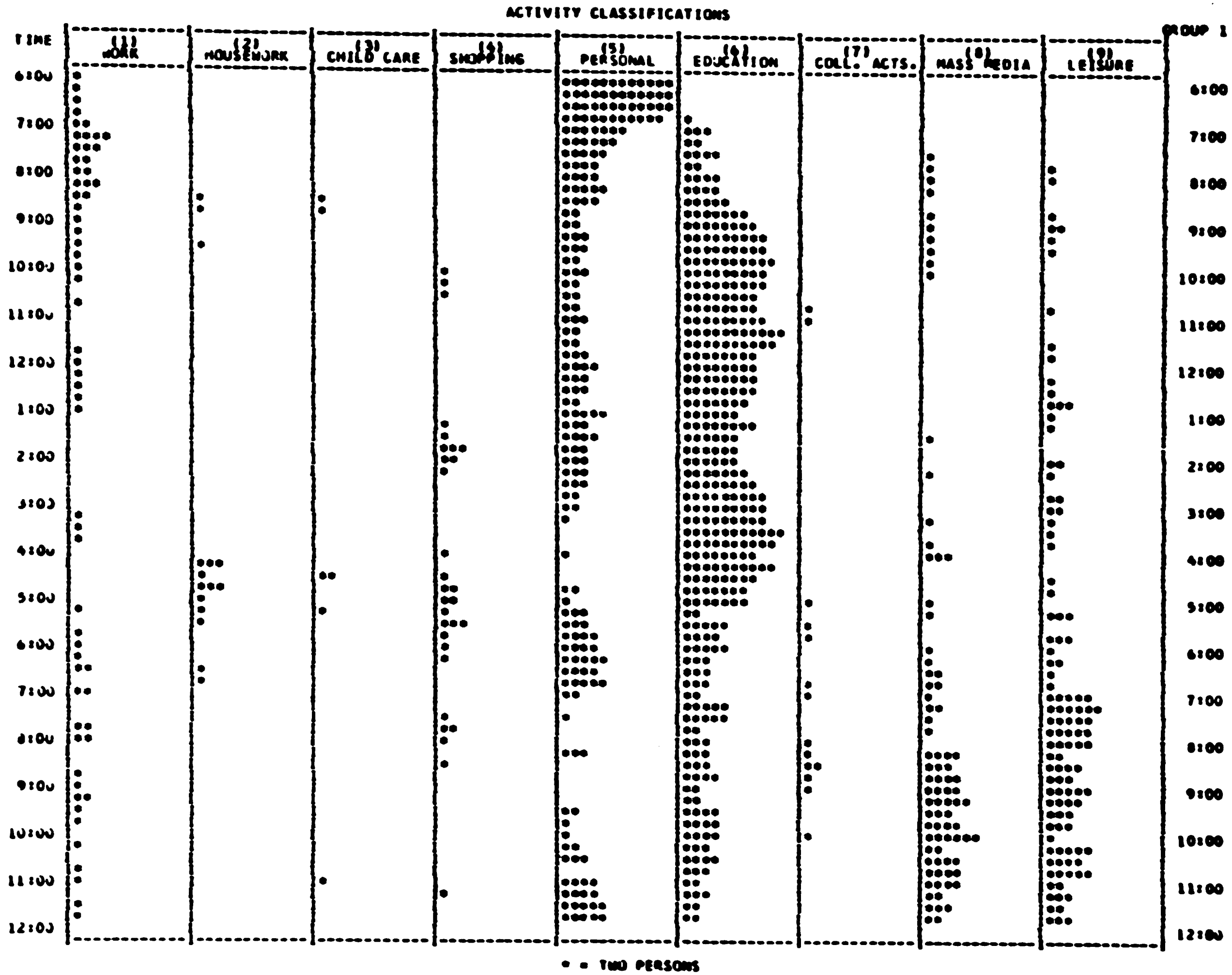

FIGURE 36.

SIMULATED TIME-SPACE MAP OF PATTERN GROUP I

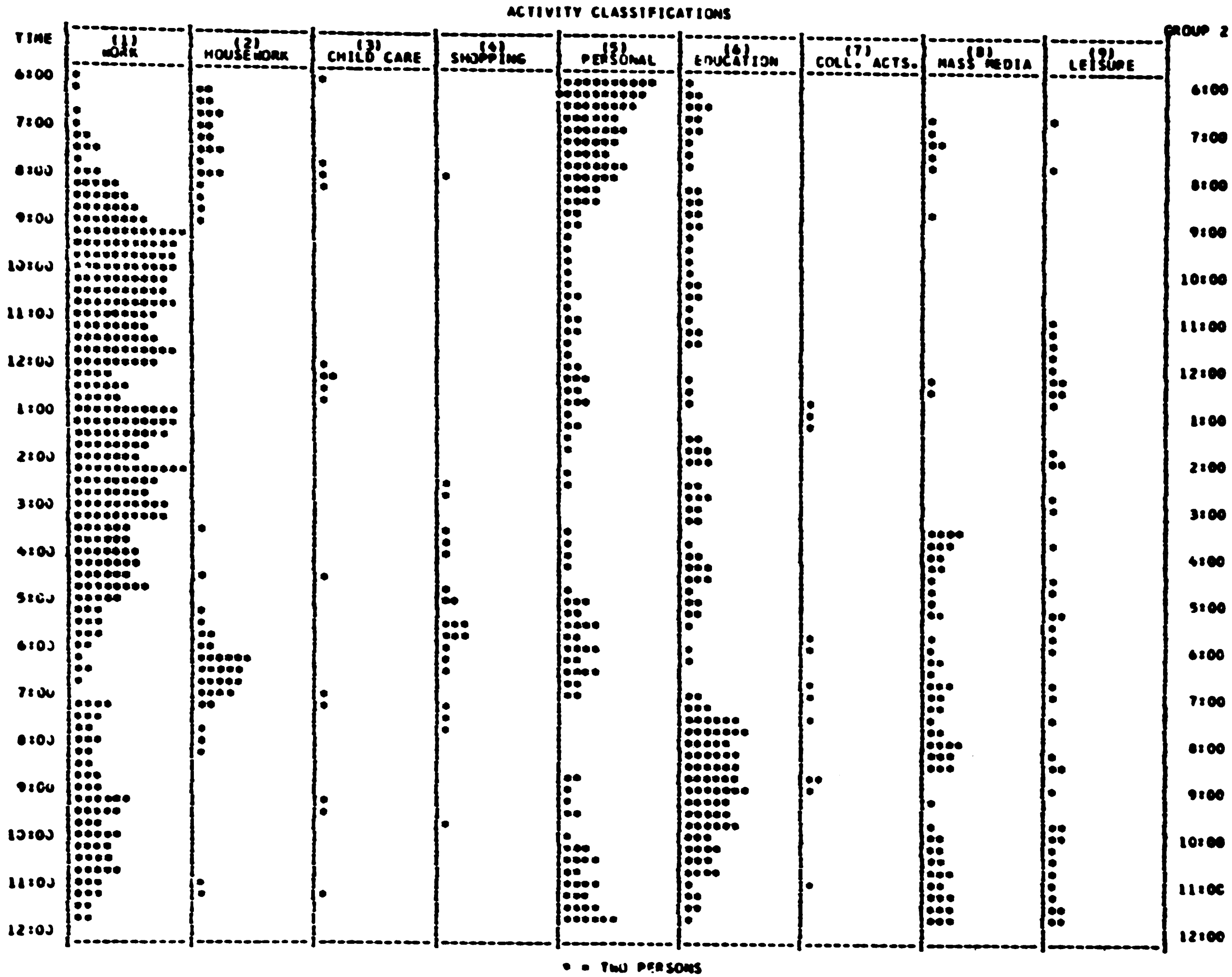

FIGURE 37.

SIMULATED TIME-SPACE MAP OF PATTERN GROUP II the predicted activity sequences of behavior pattern groups. By satisfying these criteria, it is possible to assess the effectiveness of the overall methodology in simulating the time-space paths of individuals based upon the mechanics of constraints.

A test which satisfies the criteria is the Kolmogorov-Smirnov (K-S) test.[11] The technique is based on the principle that one expects the cumulated frequency distributions of two samples to be similar if they are random samples drawn from the same population. The test takes advantage of the situation in which there can be some logical ordering of intervals so that the profiles of the frequency distributions can be compared. In this application, the logical ordering of intervals is clear--the 36 sequential time intervals throughout the observation period (Table 17).[12] The two profiles are represented by: (1) the actual distribution, where each entry in the list is a frequency (in minutes) for the major activity performed during a given time interval and (2) the predicted distribution, where each entry represents a frequency (in minutes) for the same activity recorded in the actual distribution. If a predicted activity is different from the actual, or observed, activity during the same time interval, then

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[11]The method of construction and relative advantage of this statistic may be indicated most clearly for the data presented in Table 17, where the minimum frequency restriction of the X^2 test made that test inappropriate. For additional information pertaining to the K-S test, see: Hubert M. Blalock, Social Statistics (New York: McGraw-Hill Book Co., 1960), pp. 203-206.

[12]In order to assess the goodness-of-fit between the actual and predicted time series, the 72 15-minute time intervals were condensed into a sequence of 36 30-minute intervals. Thus, interval 1 represents the time period 6:00-6:29 a.m., interval 2--the time period 6:30-6:59 a.m., through interval 36--the time period 11:30-11:59 p.m.

TABLE 17.

ACTUAL AND PREDICTED ACTIVITY SEQUENCES

Time Interval	Actual Frequency	Actual Proportion	Actual Cum.	Predicted Frequency	Predicted Proportion	Predicted Cum.	Difference
1	30	.036	.036	30	.051	.051	.015
2	30	.036	.072	30	.051	.102	.030
3	30	.036	.108	30	.051	.153	.045
4	22	.027	.135	30	.051	.204	.069
5	12	.015	.150	0	.000	.204	.054
6	10	.012	.162	24	.041	.245	.083
7	30	.036	.198	17	.029	.274	.076
8	24	.029	.227	0	.000	.274	.047
9	30	.036	.263	12	.021	.295	.032
10	30	.036	.299	30	.051	.346	.047
11	12	.015	.314	5	.009	.355	.041
12	18	.022	.336	20	.035	.390	.054
13	20	.024	.360	0	.000	.390	.030
14	16	.019	.379	0	.000	.390	.011
15	22	.027	.406	0	.000	.390	.016
16	30	.036	.442	15	.026	.416	.026
17	25	.030	.478	4	.007	.423	.055
18	10	.012	.490	23	.040	.463	.027
19	14	.017	.507	0	.000	.463	.044
20	25	.030	.537	0	.000	.463	.074
21	30	.036	.573	17	.029	.492	.081
22	15	.018	.591	30	.051	.543	.048
23	23	.028	.619	8	.014	.557	.062
24	30	.036	.655	12	.021	.578	.077
25	30	.036	.691	0	.000	.578	.113*
26	21	.025	.716	22	.038	.676	.040
27	14	.017	.733	30	.051	.667	.066
28	30	.036	.769	30	.051	.718	.051
29	30	.036	.805	30	.051	.769	.036
30	15	.018	.823	30	.051	.820	.003
31	14	.017	.840	0	.000	.820	.020
32	21	.025	.865	0	.000	.820	.045
33	30	.036	.901	30	.051	.871	.030
34	27	.033	.937	11	.019	.890	.047
35	30	.036	.973	30	.051	.941	.032
36	30	.036	1.000	30	.051	1.000	.000

$N_A = 830$ $N_P = 580$ $D = .113$

$X^2 = 17.438$

the actual duration is recorded while the predicted duration is denoted by a zero frequency (Table 17).[13]

Once both sets of data are ordered in an internally logical sequence (Table 17), each frequency is then expressed as a proportion of N, which in the case of the actual (A) distribution, $N_A = 830$, and in the case of the predicted (P) distribution, $N_P = 580$.[14] The proportions are then accumulated. Finally, the absolute values of the differences between the accumulated proportions for each row are calculated. The largest of these is designated D and, in the example of the first member of pattern group I, this is 0.113 (interval 25 in Table 17).

When the samples, N_A and N_P, are large and unequal in size, a significance test which pools the two sample sizes must be employed. This test makes use of the fact that the sampling distribution of D can be transformed into the chi-square (X^2) distribution as follows:

$$X^2 = 4\ D^2 \frac{N_A N_P}{N_A + N_P} \qquad (5.2)$$

where the degrees of freedom associated with chi-square are two.[15]

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[13] As an example, see interval 15 in Table 17. The observed activity which occupied the majority of time (22 minutes) during this interval is "eating." However, the predicted activity for the same time interval was "study consultation" for a duration of 18 minutes. Since the activity of eating was not predicted to occur for any duration during the time interval, a zero frequency registers in the predicted time interval. This means, therefore, that no amount of activity overlap, or correspondence, exists between the observed and the predicted.

[14] As would be expected, the sizes of N_A and N_P vary among individuals as well as between pattern groups.

[15] Blalock, op. cit., p. 205.

In the example for one member of pattern group I (Table 17), the maximum difference (D) value is 0.113. The chi-square which results from substituting the value for D in expression 5.2, is 17.438. In consulting the chi-square distribution, it is found that for two degrees of freedom the value 9.21 corresponds to the .01 level. This means that if the null hypothesis were actually true, a chi-square this large or larger would result by chance less than one percent of the time. Since a chi-square of 17.438 was obtained, the null hypothesis must be rejected. That hypothesis stated that there is no significant difference between the actual and predicted activity sequences. Since the chi-square value for the individual represented in Table 17 was larger than the critical value of X^2 at the 99 percent confidence level, the null hypothesis must be rejected, meaning that patterned variations do exist between the actual and predicted sequences of activity. Hence, it must be inferred that the simulation model, based on the time-space mechanics of constraints, does not accurately predict the observed time-space behavior of the first member of pattern group I (Table 17).

The decision to accept or reject the research hypothesis based solely on the results of one experiment is quite obviously incomplete. Rather, the K-S test must be applied to all experiments of a simulation run. Once the differences between the actual and predicted activity sequences are computed, the maximum difference statistic (D) may be calculated for each individual in a pattern group. The D and the X^2 statistics are given in Appendix G for members in each of the two pattern groups.

Of the 68 experiments conducted for pattern group I, only the predicted results for two individuals were significant at the .01

level. This means that for all but three percent of the experiments, the null hypothesis was rejected. Rejecting the null hypothesis infers that the majority of actual and predicted activity sequences were significantly different. These results relate specifically to the ability of the simulation model to predict activities and their sequencing.

In looking at the ability of the model to predict activity locations and their sequence, the results are slightly improved (Appendix G). For all but five experiments, the null hypothesis was rejected, meaning that significant variations exist between the actual and the predicted sequences of activity locations.

Table 18 gives the overall X^2 statistics for pattern group I. Since both chi-square values exceed the critical value of X^2 at the 99 percent confidence level, the null hypothesis must be rejected. Thus, for the majority of experiments, actual and predicted locational sequences are dissimilar.

A total of twenty-five experiments resulted from the second simulation run. The results are slightly more significant. For eight percent of the experiments, the null hypothesis was accepted, suggesting that the predicted types, durations, and sequencing of activity closely approximated those originally recorded in the time-space budgets. When looking at the aggregate result for group II (Table 18), however, the null hypothesis must be rejected since the departures of the predicted from the observed activity sequences are too great to have occurred by chance.

A second means for evaluating the model's results is to inspect the predicted sequences of activity location (Appendix G), which

TABLE 18.

CHI-SQUARE STATISTICS FOR PATTERN GROUPS

	D	N_A	N_P	X^2
PATTERN GROUP I				
Activity Sequences	.244	876.8	529.4	78.542
Locational Sequences	.207	933.6	721.3	69.710
PATTERN GROUP II				
Activity Sequences	.191	797.2	462.9	42.743
Locational Sequences	.122	958.0	776.4	25.521

incorporates type of location, time-stay at a particular place, and sequencing of movements from one location to another. Sixteen percent of the experiments for group II predicted locational sequences which were not significantly different from the actual patterns. In fact, there were additional chi-square statistics that hovered about the critical value of X^2. Although the actual and predicted locational sequences in these instances were significantly different statistically, the closeness of the results suggests that they should not be totally discounted.

Table 18 gives the overall X^2 statistics for pattern group II. As was the case for group I, both chi-square values exceed their respective critical value at the 99 percent confidence level. Therefore, the null hypothesis must again be rejected because the deviations of the predicted from the observed locational sequences for group II are too great to have occurred by chance.

Since the model is unable to accurately predict the observed time-space paths of individuals, it is necessary to examine the weaknesses of the model. How accurate is the model in estimating activities for episodes having differing levels of commitment? Table 19 summarizes the number of correct activity assignments for episodes ranging from planned to totally unexpected. The best rates of prediction occur for those activities which are planned while the poorest predictability is associated with activities which have not been planned in advance. More specifically, those activities which are either routine or planned in advance with others obtain the best rates of prediction for both

TABLE 19.

SIMULATED ACTIVITY ASSIGNMENTS BY LEVELS OF COMMITMENT

GROUP I:	(Observed) Actual No. of Episodes	(Simulated) Correct Activity Assignments	Prediction Rate (%)
Arranged with Others	658	321	48.8
Planned Independently	583	206	35.3
Routine	744	413	55.5
Unexpected	236	67	28.4
GROUP II:			
Arranged with Others	240	115	47.9
Planned Independently	186	81	43.5
Routine	281	166	59.1
Unexpected	124	40	32.3

simulation runs. It is important to note that activities having these types of commitment (Figures 30 and 31) are also the activities having the greatest fixity in terms of activity choice, timing, and location (Figures 28 and 29).

The preceding observation raises the question, how accurate is the model in estimating activities for episodes having not only different levels of commitment, but also different degrees of constraint? Table 20 presents information pertaining to the various combinations of commitment and constraint, ranging from planned activities fixed in both time and space to unplanned activities having a low degree of constraint. Column A of Table 20 gives the sum of all observed activity durations common to a particular category. The values of $\bar{a}$ indicate the average amount of time a member of group I engages in activities having a given combination of commitment and constraint. The final column of percentages indicate the relative proportion of time devoted to activities in each of the six categories.

In the second part of Table 20, the values under P represent the sum of all predicted activity durations for each category while $\bar{p}$ values indicate the predicted average amount of time group I members perform activities having the various commitment and constraint characteristics. Finally, percentage values describe the simulated amount of time devoted to activities in each of the six categories.

The data in Table 20 were subjected to a K-S test in order to determine whether any significant difference exists between the actual and predicted sequenced activity durations as classified by degree of commitment and level of constraint. The null hypothesis states that there is no significant difference between the observed and simulated

TABLE 20.

SIMULATED ACTIVITY ASSIGNMENTS BY COMMITMENT AND FIXITY RATINGS--

PATTERN GROUP I

PATTERN GROUP I COMMITMENT AND FIXITY RATING	A	$\bar{a}$	%	P	$\bar{p}$	%
Planned, High Constraint	9112	134	15.31	7480	110	20.70
Routine, High Constraint	11968	176	20.10	8976	132	24.86
Unplanned, High Constraint	4216	62	7.11	1292	19	3.55
Planned, Low Constraint	10268	151	17.20	5101	75	14.08
Routine, Low Constraint	14280	210	23.95	10132	149	28.01
Unplanned, Low Constraint	9724	143	16.34	3128	46	8.61
GROUP I	59568	876	100.00	37401	531	100.00
		N_A			N_P	
		D = .102		X^2 = 19.890		

patterns. The X^2 value obtained as a result of the K-S test is 19.890. This value clearly exceeds the critical value for X^2 at the .01 level indicating that for group I there exists a significant difference between the actual and predicted sequenced activity durations. Again, the model falls short in estimating activities, including type, sequence, and duration, based upon activity commitment and time-space constraints.

Despite the rejection of the null hypothesis, valuable information may be drawn from the data contained in Table 20 pertaining to the operation of the model. Episodes having the highest ratings of commitment and time-space fixity attain the best prediction rates. That is, categories having the highest ratings of fixity and commitment also have the smallest difference between the actual and predicted sequenced activity durations. This suggests that the model is better able to determine the choice, duration, and location of activities to which individuals are highly committed and which are highly constrained in time and space. Alternatively, activities which are unexpected and have low ratings with respect to activity choice, timing, and location fixities, obtain the maximum difference between actual and simulated patterns.

Similar trends may be observed in the tabulation of data for group II (Table 21). The null hypothesis which states that no significant difference exists between the observed and simulated sequenced activity durations for group II, must also be rejected as the X^2 value exceeds the critical limit at the .01 level. However, the best prediction rates are associated with activities having a high level of constraint (i.e., activities fixed in time and space) which are either planned or routine.

TABLE 21.

SIMULATED ACTIVITY ASSIGNMENTS BY COMMITMENT AND FIXITY RATINGS--

PATTERN GROUP II

PATTERN GROUP II COMMITMENT AND FIXITY RATING	A	$\bar{a}$	%	P	$\bar{p}$	%
Planned, High Constraint	3825	153	19.22	3074	123	25.55
Routine, High Constraint	4624	185	23.27	3177	127	27.39
Unplanned, High Constraint	1325	53	6.62	306	12	2.57
Planned, Low Constraint	1997	80	9.99	1548	63	8.79
Routine, Low Constraint	4628	185	23.21	3856	154	21.89
Unplanned, Low Constraint	3526	141	17.68	1498	60	12.81
GROUP II	19925	796	100.00	11629	464	100.00
		N_A			N_P	
		$D = .114$		$X^2 = 24.375$		

For both groups, the smallest differences between the actual and predicted activity sequences correspond to episodes having the highest ratings of fixity and commitment. This observation suggests that the model is better able to estimate the type of activity, its timing, and location for time periods which are considered activity pegs and fixes than for others having a less constraining effect. When the sequenced activity durations, both actual and simulated, are classified by activity pegs, activity fixes, and all others, as in Table 22, the relationship becomes clearer.

In Table 22 the actual values represent the total amount of time devoted to activities which are considered as pegs, fixes, and all others. The predicted values represent the total amount of time (sequenced activity durations) for which the model was able to accurately match, or predict, the observed activity, timing, and location. Those points around which one's day is thought to be organized, the pegs and fixes, obtain the best prediction rates in contrast with all other activities having differing levels of subjective constraint. Comparatively, the model better estimates the activity, timing, and location parameters for the second group. This is perhaps partially understood by its smaller size. The smaller the group size the greater the probability of accurately estimating the parameters.

The simulation model, based upon the interrelationships between activity commitment and time-space constraints, is not capable of estimating with a high degree of precision the observed daily sequences of activity and location. However, those particular segments of the day to which members of both groups are highly committed and involve a considerable degree of fixity are more accurately predicted than others.

TABLE 22.

MODEL PERFORMANCE BY CATEGORIES OF TIME-SPACE CONSTRAINT

a. GROUP I

CATEGORIES OF TIME-SPACE CONSTRAINT*	A	$\bar{a}$	%	P	$\bar{p}$	%
Pegs	7756	114	13.01	5778	85	15.99
Fixes	11910	175	19.94	8302	122	22.99
All Others	40051	589	67.05	22037	324	61.01
GROUP I	59717	878	100.00	36117	531	100.00

b. GROUP II

CATEGORIES OF TIME-SPACE CONSTRAINT	A	$\bar{a}$	%	P	$\bar{p}$	%
Pegs	3197	128	16.09	2071	83	17.81
Fixes	5411	217	27.05	4317	172	37.08
All Others	11326	453	56.86	5206	208	44.74
GROUP II	19934	797	100.00	11594	463	100.00

*Categories of time-space constraint are the same as those defined in footnote 6.

At a disaggregated level, this trend in model prediction may be observed in the time-space paths of individuals. Figure 38 displays the actual and simulated time-space paths for selected members of group I.[16] Each diagram incorporates the dimensions of activity

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[16]The individual experiments graphically represented in Figures 38 and 39 are those whose amount of correctly simulated activity time, in the first case, approximate the mean of a group and, in the second case, fall one standard deviation below the mean. The examples are intended to show the problems of matching the simulated with the observed time-space paths.

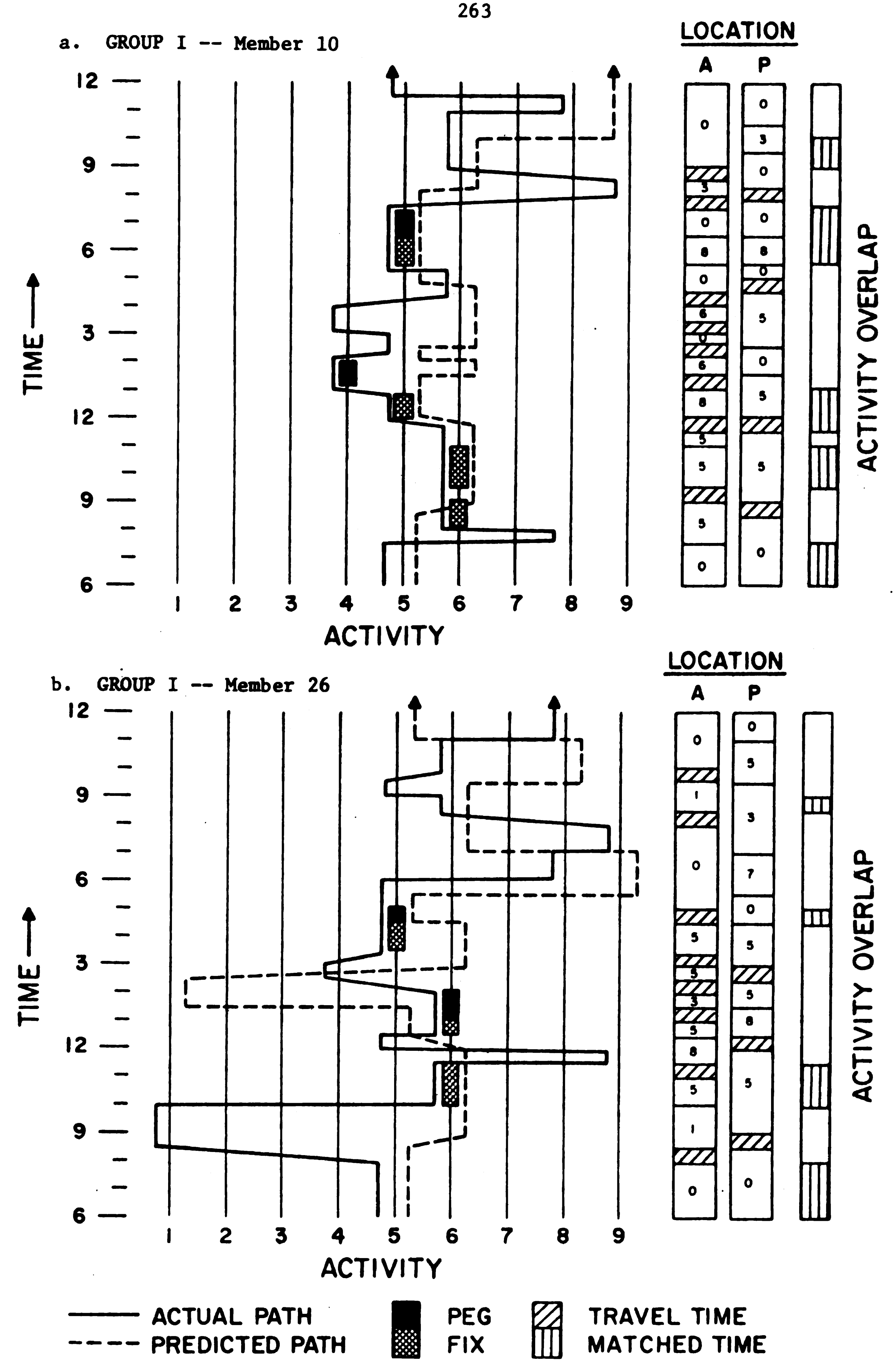

FIGURE 38. TIME-SPACE DIAGRAMS FOR PATTERN GROUP I

(where the primary categories are given at the bottom), time, and location (where codes of activity location are given to the right). The extent of matching, or overlap, of the actual and simulated paths is given to the right of each diagram.

It is evident for the individual paths portrayed in Figure 38 that the greater the time distance from activity pegs or fixes, the greater the inability of the model to accurately simulate the characteristics of activity. However, those time periods which are designated as an activity peg or fix obtain a considerable degree of overlap, or matching, between the actual and the predicted. In addition, the simulated activity locations for pegs and fixes correspond, more often than not, to the observed locations. One noticeable difficulty in the simulated results pertains to the estimation of travel times between activity locations. Poor correspondence exists between the actual and predicted locational sequences with respect to travel times (see also Figure 40).[17]

While the time-space paths for group II (Figure 39) are quite different from group I in terms of activities performed, a similar relationship exists between prediction rates and activity pegs and fixes. Those time periods during the day for which fixity ratings

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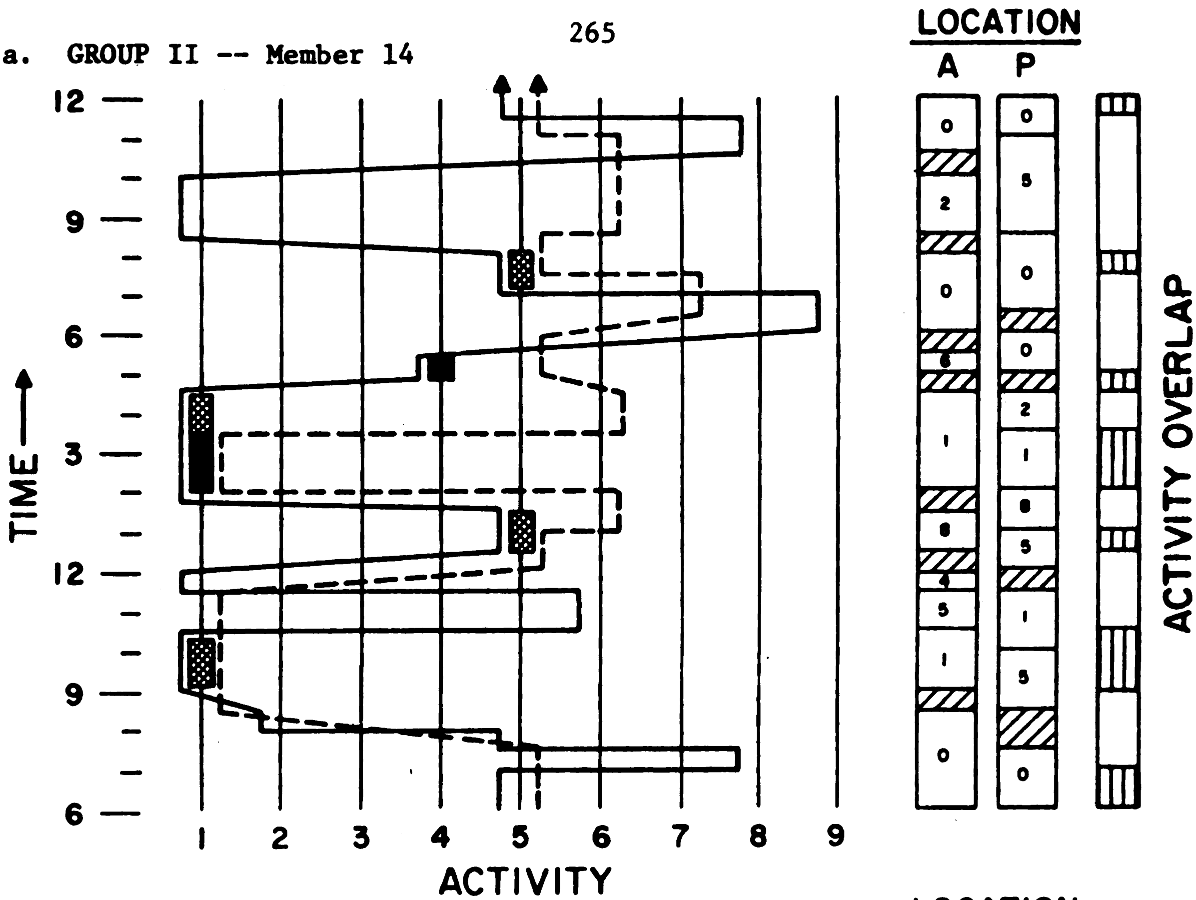
[17]For many changes between simulated activity locations (see predicted locational sequences in Figures 38 and 39), no intervening travel time is recorded. In many cases the problem is with the method for recording a major activity during a time interval. For instance, if travel within a given interval had a duration of only five minutes, then it is unlikely that travel would be recorded as the major activity and, thus, would not appear on the diagram. This technical problem, however, may not be that critical since Figure 40 shows that simulated travel times are seriously underestimated when compared with the observed travel times (Figure 32) throughout the observation period.

a. GROUP II -- Member 14



b. GROUP II -- Member 21

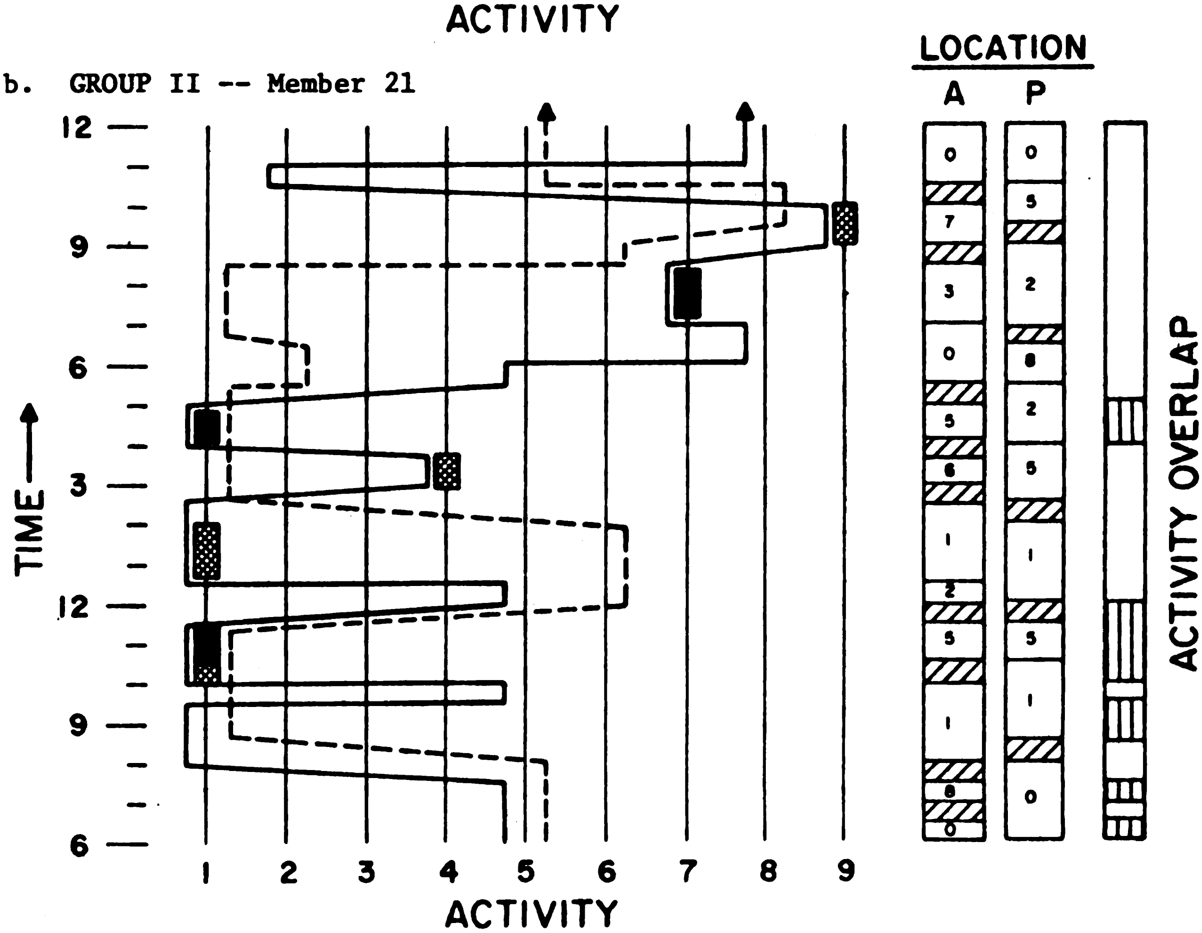


FIGURE 39.

TIME-SPACE DIAGRAMS FOR PATTERN GROUP II

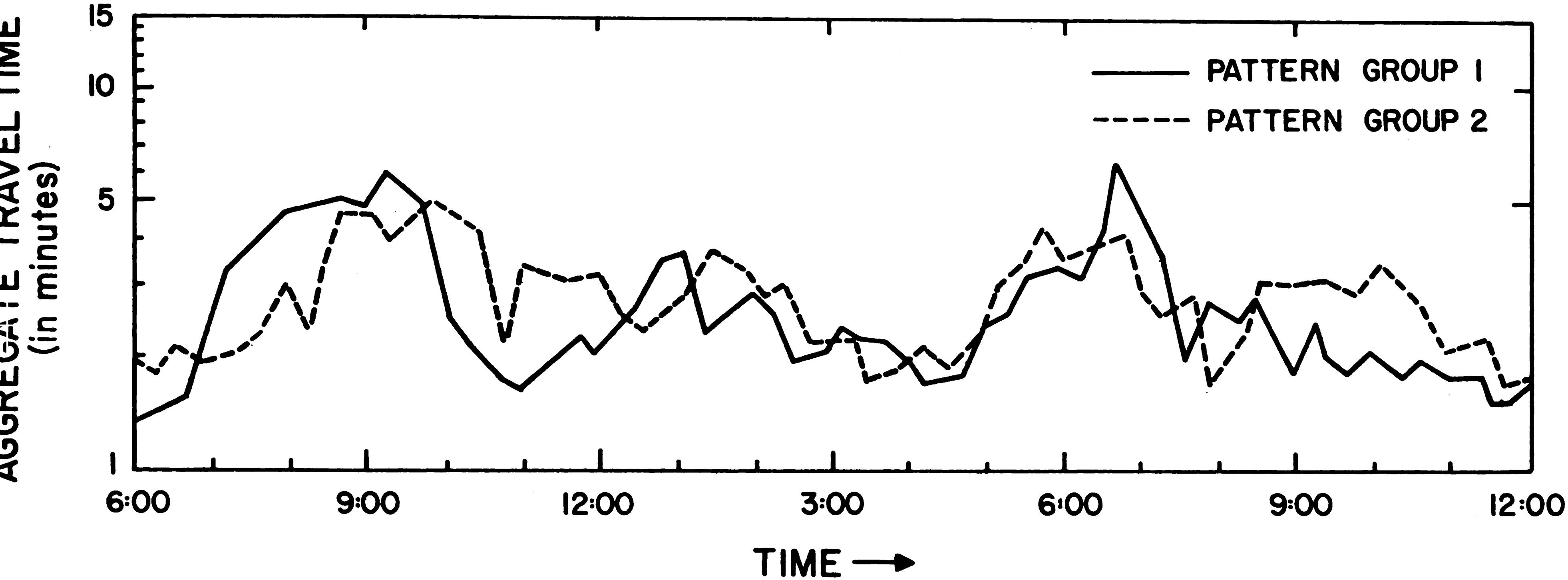


FIGURE 40.

SIMULATED TRIP LENGTH DISTRIBUTIONS FOR PATTERN GROUPS are highest obtain the greatest degree of correspondence between the actual and predicted activity and location characteristics. Those episodes which have lower fixity ratings consistently have poorer matching of the simulated with the observed. Once again, the examples shown in Figure 39 point out the inability of the model to cope with travel time estimation. The problem of accurately predicting travel between activity locations is also evident in the aggregate results for both groups (Figure 40).

Research Hypothesis

The central research hypothesis of this investigation is that the critical determinant of the structure of a person's day, given environmental forces (i.e., the objective constraints), is the extent to which one feels constrained relative to certain activities, times, and locations. A methodology has been formulated which is built around the idea that subjective constraints are the critical determinants of one's behavior in time and space. The vehicle used to examine this hypothesis is that of simulation. Thus, an attempt has been made to simulate the unknown variables, the timing, sequencing, and location of activities, in terms of the parameters or known variables, the subjective constraints.

The findings from the modelling experiments demonstrate that the subjective constraints acting on the choice, timing, and location of activities are modestly important in attempting to understand the formation of activity sequences and the paths people follow through time and space. The statistical results of the model's output suggest that they are not as significant as they were hypothesized to be.

Based upon these tests of validation, the research hypothesis must be rejected. The rejection infers that subjective constraints alone are not the critical determinants which structure time-space paths at a daily scale.

It is the conclusion of this researcher that the limitations of the methodology rest mainly with the conceptualization of constraints in relation to the phenomena to be explained--the structuring of daily behavior in time-space. Necessary but simplifying assumptions were made as part of the modelling strategy that precluded a more direct concern for the objective constraints. This set of constraints includes the peculiarities of the environment in which action takes place. Objective constraints also vary from person to person in the form of available transport media. These differentials in transport modes for overcoming distances in time-space were not directly addressed. The distinction of subjective from objective constraints was designed to simplify the research problem and to facilitate the investigation.

The divorce of the two categories of constraint is not altogether realistic. As was suggested earlier, constraints circumscribe man's actions. In support of the chosen research methodology, it was stated that choices of activity can only be realized within the context of constraints. Therefore, the investigation of constraints, or negative determinants, might prove to be a more fruitful line of research than the focus on positive factors that lead to activity choices. This contention is still held. However, as a result of this investigation it is concluded that subjective constraints can only be understood in the context of objective constraints. In any further research dealing with the structuring of time-space paths, it is recommended that the two categories of constraint remain distinct but not divorced from one another in the analysis.

Some specific comments must be made with regard to the value of the computer simulation model. Simulation has been employed as a descriptive technique and not a predictive one. The simulation model was developed in order to answer the question--to what extent are subjective constraints descriptive of one's behavior in time-space? Relying upon Monte Carlo procedures, the simulation generates time-space paths of individuals which describe the choices, timing, and location of activity. Moreover, it permits a degree of random variation to represent the uncertainty in man's actions. Monte Carlo simulation is not a powerful explanatory technique, but its simplicity, its heuristic value, and its dynamic nature have made it extremely useful in exploring the research hypothesis. Furthermore, simulation procedures are necessary in that the highly complex processes in question preclude purely analytical solutions.

The results of the simulation experiments suggest that we cannot reproduce the complexities of daily behavior, seen as an unbroken sequence of actions in time and space, solely on the basis of subjective constraints. However, the model is capable of rather accurately describing the type of activity chosen, its timing and location for certain periods of the day which are considered to have the most constraining effect. Thus, activity pegs, those points around which much of the remainder of the day was organized, were most accurately described by the model. Activities having high subjective fixity ratings were also rather accurately described by the model. These are generally activities in which the individuals had little or no choice in their timing, duration, and location. In fact, a relationship has evolved suggesting that the more constrained the event, in terms of commitment and time-space fixity, the better the model's estimation of the activity performed at that time as well as its sequence and location.

As with the use of most simulation models, more problems arise than can be solved. First, the problem of matching the two major dimensions of the model--the subjective fixes and the objective descriptions (i.e., activity choice, timing, and location)--require much more thought and investigation. It is central to the present methodology that what people feel to be the major constraints upon their days should be input first and the simulation of the rest of the day built up around these. But the actual manner in which they are assigned activities, times, and locations is highly problematic. This is primarily because the way in which an episode may be regarded as constraining differs from occasion to occasion. Sometimes a constraint is felt relative to a particular activity (e.g., a person could not have performed this activity at any other time) and sometimes it is felt to be totally independent of the activity performed (e.g., a person could not have been elsewhere at that time). At other times a constraint is felt relative to a particular activity location (e.g., a person could not have performed this activity at any other place) while at many times it is felt to be totally independent of spatial location (e.g., a person could have been elsewhere at the same time). To deal with all types of constraint in exactly the same way seems somewhat unrealistic.

Further, even when fixes have been established, there remains the problem of simulating around them. This involves specifying the manner in which they affect preceding and subsequent activities. The model has proven to be particularly weak in this regard since it was observed that time periods with lower fixity ratings had the poorest prediction rates.

Perhaps the most glaring weakness of the model is its inability to cope with travel episodes. Spatial locations are only treated implicitly by the model. That is to say, exact geographical locations of activity recorded in the time-space budgets were grouped into categories of activity locations (Appendix C), for instance, workplace, one's own residence, somebody else's residence, etc. As a result, distance between activity locations was measured by the surrogate variable--trip length (i.e., travel time). Geographical distance and direction of movement were not treated explicitly due to the simplifying assumptions of the model.

These and many more difficulties will have to be remedied before a full-fledged simulation can be fully operationalized.

CHAPTER 6

SUMMARY AND CONCLUSIONS: RETROSPECT AND PROSPECT

The principal aim of this research has been to develop a methodology for investigating how individuals' decisions about their time-space behavior interrelate. What determines where, when, for how long, and in what sequence activities are performed? In attempting to understand more clearly the structuring of everyday behavior this research adopted a methodology based on the time-space mechanics of constraints.

SUMMARY

Conceptually, the behavior, or activities, of an individual can be viewed as a series of discrete episodes occurring in a sequence through some specified period of time. These episodes have meaning at different temporal and spatial scales. Those that relate to a day's activities, such as work, housekeeping, or eating, were chosen for investigation. Events in the daily sequence are seen to possess an essential order in the sense that certain types of events occur in fairly predictable cycles or routines and take place in a space of fairly predictable locus. Activities, therefore, occur in a time-space continuum: there are temporal regularities inherent in spatial regularities, and temporal rhythms obviously vary over space.

Two general approaches to the study of time-space behavior were considered. One orientation, the more common in geographical literature, focuses on choices of activity that are manifest in behavior.

A second approach, and the one chosen for this research, focuses on the constraints which circumscribe man's actions. Since choices of activity can only be realized within the context of constraints, the second approach is more general and more likely to lead to a discovery of how the decisions regarding one's time-space behavior interrelate.

Two broad groups of constraint were identified. First, objective constraints are those which are imposed by the environment. These constraints tend to shape the "niches" of possible action open to an individual. The pattern of niches formed by objective constraints describes a map of potential events. These potential events can be more narrowly defined by a second group, the subjective constraints, which are to a great extent self-imposed. Such constraints arise as a result of the individual's social and physical environment. Thus, a given environmental situation is subjectively perceived by different people as constraining choice to varying degrees. Although the uniqueness of the environmental context is important, the individual's reaction to it is crucial. Any situation to which an individual reacts has at least three dimensions: a temporal position, a location in space, and a potential activities set. These dimensions interact to produce a feeling of constraint upon the individual.

One's evaluation of the way in which these dimensions interrelate is complex. But as a result of the priorities and constraints perceived by an individual, any activity has a subjective fixity rating associated with it. The subjective fixity rating is defined by the degree of commitment to the activity and the extent to which it is constrained in time and space. It is thought that an individual schedules a variable proportion of his day according to these ratings of fixity, in order to facilitate synchronization of activities and movement in time and space. Although much of the scheduling process is undoubtedly routine, the ordering of more complicated, unfamiliar, or crowded combinations of activities is objectively calculated. Activities to which the individual is strongly committed and which are space- and time-fixed tend to act as points around which the ordering of activities, according to their flexibility, are scheduled.

The major research hypothesis is that the critical determinant of the structure of a person's day, given environmental forces (i.e., objective constraints), is the extent to which one feels constrained relative to certain activities, times, and locations. The term structure is interpreted to mean not only the types and sequences of activities, but also their location and duration.

In order to adequately test this hypothesis it was first necessary to isolate a sample population and to develop survey instruments for obtaining the needed data. The sample population was drawn from the faculty, staff, and student populations of Michigan State University, located in East Lansing, Michigan. A systematic random sample, stratified by university affiliation, resulted in a target survey population of 200 persons, of which there were 138 respondents.

In order to study the time-space mechanics of constraints operating on the formation of activity sequences, attention must be focused on the paths, or behavior, of the individual through time-space. The instrument chosen for collecting this type of information is the time-space budget. The time-space budget, which is very central to this research, incorporates the sequence, linkage, timing, duration, and frequency of activities, as well as the spatial and temporal coordinates of one's behavior. Time-space budgets focus on two related aspects: people's overt behavior and the perceptions of their physical and social environment. The time-space budget can, therefore, record spatial behavior (moving and stationary), and it can be indirectly related to environmental perceptions (via questionnaire techniques) as these interact with overt activities.

Perhaps the primary attribute of time-space budgets is that they record behavior patterns which are not directly observable due to their spatial and temporal extent. Furthermore, this method of activity accounting is unique in that, as far as their activities for the sampled time span are concerned, individuals are treated as totalities, and the entire sequence or pattern of activities can be analyzed. The time-space budget, when carefully completed, makes available data which describe the behavior of an individual as a sequence of unbroken actions in time-space. This does not mean that the activity sequences are fully explained as understood by the persons who create them, but at least the totality is there for examination.

Based upon the conceptualization of constraints, a simulation methodology was developed in order to define the time-space mechanics of constraints which are thought to rule how individual paths are channeled, diverted, or even routinized. It was hoped that such an approach would shed light on how decisions about one's time-space behavior interrelate. At this stage of research into the organization of daily behavior, a negative determinants approach was considered to be the safest and, perhaps, most productive.

As a first step toward the goal of developing a simulation model, an attempt was made to isolate that behavior which demonstrates recurrent patterns in time-space. Hence, a preliminary hypothesis regarding the principle of consistency in human behavior was tested using a sample of time-space diaries. The claim was made that the concept of pattern could be meaningfully applied to any set, or sub-group, of time-space budgets and that this pattern is partly defined by the sequence in which activities are performed. A second assumption of the consistency hypothesis stated that the amount of time a person devotes to an activity follows a pattern over sub-groups of individuals just as much as does the position it occupies in that person's sequence. Such simple patterns of activity are necessary conditions for the development of a simulation model.

In order to test this hypothesis, an algorithm was devised which groups individuals on the basis of the amount of time which they spend on different activities and the order in which they are performed. The algorithm focuses on those points in an individual's sequence where the activity performed is the same as that performed by another individual. Consequently, it was possible to sum this total "overlap time" over individuals. The total overlap time was the linking index used for grouping; the greater the overlap time, the greater the similarity in behavior patterns. The algorithm decomposed the sample population into groups based upon the sequential behavior patterns of individuals. The groups maximize within-group similarities and between-group differentials. Three distinct groups emerged as a result of the grouping of time-space budgets. Therefore, the hypothesis dealing with the consistency of behavior patterns was accepted. Patterned variations do exist between subgroups of the university population, where the concept of pattern is construed in terms of sequence and duration of daily activities.

As a result of the grouping analysis, it was discovered that "typical" workdays encompassed a variety of forms. But two clearly discernable archetypes were the highly structured day (Group II) normally including numerous work and social commitments, and a more loosely structured day (Group I), spent largely at one's residence and involving non-formalized work, leisure, and routine activities. When looking more closely at the patterns which emerged, especially as people described the priorities and constraints which they associated with the individual episodes in their days, it was learned that basically three levels of commitment could be related to normal work activities. First, there were formalized work episodes--classes, seminars, committee meetings, and staff duties--which were regarded as by far the most important fixing or structuring events, both with respect to specific locations and particular times of day. Next came less formalized work phases of longer duration and not normally involving interaction. They were only regarded as shaping the respondent's day in the sense that they were often tied to particular times, but flexible as to location. It seemed reasonable to conclude that they were fixed to certain times largely because they were related to future deadlines (e.g., preparing reports, assignments, or lectures). Finally, there were threshold activities which appeared to mark the end of the working day--for instance, in the afternoon an increase in loosely structured activity was still classified as work by the majority.

Leisure activities were of two dominant forms. On the one hand, there were the special occasions such as social events which were arranged in advance with others and involved a fairly high degree of perceived constraint. Alternatively, there were the unplanned time-filling episodes. Two major types of punctuating activities were also evident. These were short in duration and normally peripheral to the major features of behavioral sequences. First, there were routine (personal) and domestic chores which were not felt to be of structuring significance, but were commonly considered as tied to particular locations. Second, shopping activities, for some, were also punctuations. They were normally short and undertaken by many on the way home from work or classes in the evening.

Patterns of behavior, insofar as they relate to the structuring importance of certain perceived constraints, are revealed at least as significantly through the sequences of activity which people perform, as through the amount of time people devote to them. In the algorithm used, individuals were grouped together not only on the basis of the activities performed, but also on the basis of the order, or sequence, in which they were undertaken. The analytic approach permitted the identification of different groups of activity sequences nested within the basic diurnal cycle. Not surprisingly, the basic waking-sleeping and mealtime-to-mealtime cycles were found to be of overriding importance in dictating the overall structure of the day. However, within, and to some extent independent of, this structure certain other important sequence patterns were found. Two of these are of particular interest in that they indicate how key episodes--whether formalized work, social events, or routine activities--are integrated into the overall structure of the day. First, if they are important work activities it is often the case, as suggested in Chapter 4, that they are immediately preceded by other work activities which involve preparation for the major event. Second, the important fixes are dispersed throughout the working hours. A typically important activity, tied to a particular time and place gives way to less important social or routine behavior which is also place-fixed, simply because it follows an activity that was fixed with respect to location. This, in turn, leads to even more relaxed behavior, often merely passing time, which precedes the build-up toward the next major fix in the day. This build-up, just as the previous decline, involves activity tied to the location of the forthcoming event, but otherwise relatively unimportant. The pattern is one of oscillation (Figure 33). Thus, the working day, for members of the university population at least, may be considered as a process which oscillates between active committed high priority phases and passive uncommitted low priority ones.

Can activities and their timing and location be associated with this oscillating pattern of commitment and time-space constraints throughout the day? This is the question that the simulation model addresses. In conjunction with this problem it was hypothesized that time-space constraints and levels of activity commitment are the critical determinants of behavior, or activity sequences, in time-space. This hypothesis derives from the studies of Hagerstrand who suggests that people's consumption of time and space is largely fixed and routinized. In practice most people have little choice about where or when they sleep, eat, work, or relax--at least from a day-to-day perspective. Therefore, Hagerstrand suggests that human activity may best be understood in terms of the constraints rather than the incentives of activity. This research in general, and the simulation methodology in particular, are seen as extensions of Hagerstrand's basic model. In lieu of Hagerstrand's fixed-unfixed dichotomy of activity, this research has envisaged the individual's day as an integrated function of a more extensive range of flexibility, defined by one's level of commitment to each activity and by the time and space constraints to which one feels subject. This information which was collected in the time-space budgets is only descriptive of the constraints people experience. Nevertheless, it was used as the base information of the simulation model.

Given the data pertaining to levels of commitment and time-space constraints for all activities, the model attempts to simulate, in an integrated sense, the daily behavior of a given individual. The unknowns, or the simuland, includes the types of activity performed as well as their timing, duration, and locations.

The simulation performed reasonably well in estimating the activities to be associated with periods of high commitment and constraint. But the model failed in its ability to accurately estimate activity sequences over the day as a whole and for periods of low commitment and constraint in particular. The inability of the model to simulate daily behavior applies not only to the estimation of activities and transitions between activities, but also to the accurate description of their location in time and space. Thus, it was concluded that subjective constraints alone are not the critical determinants of time-space behavior at the daily scale.

CONCLUSIONS: RETROSPECT AND PROSPECT

In retrospect, several conclusions can be drawn as a result of this research. First, the data for the research came from the members of one institution, a university, in a sizeable metropolitan area. In many ways this might be expected to be a highly unique sample since those affiliated with a university are generally thought to have a greater degree of freedom governing their days than the majority of the working population. The variation between individuals in the ways they structure their days would be expected to be much larger than within other homogeneous groups of working people. However, clearly defined patterns of behavior among this group emerged which suggests that people, through habit, structure their days in a standardized form regardless of the lack of direct constraints. One general conclusion resulting from the analysis of these behavior pattern groups is that the sequence of a day's activities is "pegged" around key structuring episodes (e.g., work, eating, studying, etc.) that are interspersed with relaxed forms of behavior which serve to give the day's events balance and continuity.

The principal aim of the present inquiry has been to develop a methodology for investigating how an individual's decisions about his time-space behavior interrelate. The approach adopted was based on the time-space mechanics of constraints. More specifically, the methodology is founded on the premise that subjective constraints determine the structuring of paths of behavior in time-space. The adequacy of the methodology has been evaluated on its ability to replicate observed behavior. As a result of the simulation experiments, the methodology has been judged to be inadequate.

The findings of the modelling experiments demonstrate that the subjective constraints acting on the choice, timing, and location of activities do not accurately describe the activity sequences, or paths, people follow in time-space. The statistical results of the model's output indicate that they are not as significant as they were hypothesized to be. These results cast doubt on the validity of the research methodology and modelling strategy. Hence, it must be concluded that subjective constraints alone are not the critical determinants which structure time-space paths at a daily scale.

Another conclusion of this research is that the limitations of the methodology are due primarily to the conceptualization of constraints. Necessary but simplifying assumptions of the modelling strategy deemphasized the role of objective constraints. In fact, it was the aspiration of the research methodology to develop general rules concerning the formation of activity sequences in time-space regardless of the peculiarities of the environment in which behavior was observed. That is, can we develop general rules of time-space constraints which underlie behavior patterns, irrespective of the particular environment in which the behavior has been observed? As a result of the research effort, this goal is still a distant one.

Observed behavior is partly determined by the structure of the environment in which it occurs. Therefore, the set of objective constraints describe the peculiarities of the environment in which action takes place. Although the distinction of subjective from objective constraints was designed to simplify the research problem and to facilitate the investigation, the divorce of the two categories is not altogether realistic.

In support of the chosen research methodology, it was stated earlier that choices of activity, with its temporal and spatial ramifications, can only be realized within the context of subjective constraints. In light of the research results, the idea is now advanced that subjective constraints can only be understood in the context of objective constraints. Thus, in future research which explores the structuring of time-space paths, it is recommended that the two categories of constraint remain distinct but not divorced from one another in the conceptualization.

One suggestion made in this paper is that the most fruitful course for the development of a time-space framework in geography is to try as simply and rigorously as possible to devise conceptualizations and methods of basic calculation before going on to the greater complexities of large-scale empirical applications. However, a considerable amount of methodological and empirical research will have to be conducted in order to better develop a model for describing the relationship between objective and subjective constraints and time-space paths of individuals. Before doing so, at least three problem areas which have arisen as a result of this research need to be resolved.

The first problem area relates to the way we organize our data in geographical analysis. We must have a minimum of spatial and temporal precision in the location of our data. The time-space budget is only a means toward this end; without a well organized time-geographic information system the data resulting from the budgets will be of limited value. As far as the time dimension is concerned, a useful conventional system of reference based on solar or astronomic time (e.g., days and years) exists. By contrast, when it comes to space, we have to cope with regions of all sorts of odd sizes and shapes, which is quite problematic.

A solution to this problem has been suggested and described by

Hagerstrand, and is based on a co-ordinate square grid system covering a whole country.[1] It provides for a regular and standardized framework suited to all kinds of localized data regarding population, activities and different social, economic, and natural variables. The adoption of a co-ordinate grid system would allow for data organization at various spatial scales from a micro-scale at the intra-urban level to a regional scale, however defined. This is the type of matrix needed for efficient handling of time-geographic information and for the identification of objective constraints.

A second problem area concerns the methods of analysis used to investigate the research problem. Simulation has been employed as a descriptive technique to illuminate the relationship between subjective constraints and individual sequences of behavior in time-space. Relying upon Monte Carlo procedures, the simulation has generated time-space paths of individuals which describe the choices, timing, and location of activity. Admittedly, Monte Carlo simulation is not a powerful explanatory technique, but its simplicity and heuristic value have made it useful in exploring the research hypothesis. Although the model is deemed inadequate in simulating observed behavior, this is not to suggest that the modelling strategy should be totally abandoned. As a result of the simulation experiments, additional information has been obtained regarding the relationship between constraints and the choice, timing, and location of activities. It is recommended that the Monte Carlo procedures, which permit a considerable degree of random variation

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[1]Torsten Hagerstrand, "The Computer and the Geographer," Transactions, Institute of British Geographers, 42 (1967), pp. 27-34.

to represent the uncertainty of man's actions, be replaced by a more systematic approach that can better accomodate the oscillating pattern of constraints and commitment. A goal for future simulations would be to broaden the scope of the model (e.g., better treatment of the spatial dimension and objective constraints) while at the same time relaxing a greater number of limiting assumptions.

A third problem area concerns the unit of analysis used in this investigation. The research has sampled from one institution, a university. The writer has thereby been in a position to describe the daily routines and patterns of time-space constraint associated with only the members of that institution. However, the study of individuals as institution members focuses upon their lives in only one of their roles. Every person has many roles and the logical implication is to look at the individual in what for most is the primary reference group, the nuclear family or household. Other important secondary roles will be revealed by a record of one's daily activity cycles, and the performance of any one of these is so integrated with the performance of others, that no one can be understood completely on its own.

Carlstein has also made suggestions regarding the unit of analysis problem.[2] His focus is at an aggregate or group level. In order to survive, work exchange information, socialize, and so on, individuals must continually come together in time and space. It is not for the geographer to take the group for granted but it should be regarded as an assembly kit rather than as a finished product. Although most

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[2]Tommy Carlstein, Regional or Spatial Sociology? Lund, Sweden: Department of Social and Economic Geography, University of Lund, 1972.

people wake up each morning among members of a household, the primary group, there are still other groups in which individuals usually participate that are still unformed as people have their breakfast. For most people, each day is begun by making an investment in a time-consuming movement before other groups take shape. In other words, there is a cost of forming groups which is paid by other groups which cannot be formed at the same time. The costs can be conveniently viewed in terms of subjective and objective constraints.

For the geographer who takes movement as an integral component in group formation, the whole set of spatial origins and destinations inherent in a settlement pattern becomes a very important social subsystem. The observation explains why so much emphasis has been placed on the concept of accessibility in geography, whether measured in time, distance, or monetary units. In using the concept of accessibility, geographers often look at potential group formation in the population of an area rather than at which groups are actually formed. It follows logically that many of the applications of geography to planning are a matter of facilitating group formation by improving transport and by rearranging elements in the spatial pattern. Such applications would include planning the relative location of the origins and destinations in space such as work places, shops, administrative offices, hospitals, and other public facilities.

In conclusion, the methodology of time-space constraints might better be operationalized if the unit of analysis were adjusted to the level of a group with attention given to potential rather than actual group formation. What is the nature of time-space constraints that limit the potential for group formation? What are the distributional impacts of public facilities on various social groups? To what extent do perceived as well as objective constraints interact so as to actually disrupt the activity patterns of social groups? These are just a few examples of important questions which might be examined through an extension of the time-space constraint methodology developed in this research.

APPENDICES

APPENDIX A.

THE TIME-SPACE BUDGET DIARY*

*The diary presented on the following pages is only a portion of actual diary used in the survey. In order to minimize repetion, only the first six pages of the form are reproduced here.

Interviewer No. ______
Respondent No. ______
Date(s) of time-space diary: ______ ______
______ ______
______ ______
Date of interview: ______________

TIME SPACE Budget Survey

TIME-SPACE DIARY

Investigator: *J. D. Stephens*
Department of Geography
and the
Computer Institute for
Social Science Research

MSU

October, 1973

To the Survey Participant:

We would like to use the information from this diary to build up a picture of the way in which you spend your time and the kind of facilities that you use both in the university and in the city. For one day we would like to know, as accurately as possible, what you do and where and when you do it. Therefore, we are asking you to record for us on the pages that follow all of the activities that you engage in on the NEXT WEEKDAY, from the time you get up in the morning until the time you go to bed. In a sense, you will be keeping a diary of that day's activities. Although you may wait until the end of the day, or even until the next day to complete the diary, we would prefer that you fill this out as you do the activities throughout the day.

The contents of the individual diaries will, of course, be treated confidentially. Each diary is identified by a number only and the list of names of those participating will be destroyed as soon as the survey is complete.

We would like to thank you for your participation in the survey. For additional information about this survey or the nature of the research for which these survey data will be used, please contact John Stephens in the Department of Geography (MSU - 355-4649) or at the Computer Institute for Social Science Research (MSU - 353-9367). Again, thank you for your cooperation.

Diary Instructions

To explain how we would like you to fill in the diary, here are some notes and an example showing a typical day and how it should be recorded in the diary:

Beginning at the time you get up, enter in the left-most column the time at which you start an activity. In the second column describe the activity, and in the third column enter the location. If you are entering the location for an activity at a university site, please enter both the name of the building and a description or number of the room. For all other locations, simply enter the address. If you are moving from one place to another please indicate how you travel [e.g., walking, bicycle, car (driver), car (passanger), etc.]. In the fourth and fifth columns please enter the following information for each activity: in column four--whether or not anyone else was with you at the time of the activity (e.g., friends, colleagues, classmates, relatives, etc.) and in column five--whether or not you were doing anything else at the same time of the reported activity (if so, please describe that activity).

Please describe your activities in as much detail as possible. For example, we would like to know, when you go to the library, if you are there because you need to refer to particular books, or if you go there simply to read a thriller or as a place to spend half-an-hour before your next class. Please use as many lines as you need to describe an activity.

When you record where each off-campus activity takes place in column 3, indicate the location to the nearest intersection, street, or landmark. If you are not sure of the location's address, record the general area (e.g., Okemos, West Lansing, etc.). Remember that the time spent travelling to or from an activity is a separate activity and should not be included with that activity. A trip to or from an activity such as class, committee meeting, shopping, work, etc., is a separate activity and should be recorded as such. When reporting the activity of travelling from one place to another, indicate how you travelled from one place to another in column 3 (e.g., car (passanger, car (driver), bus, walking, etc.).

To know how we would like the diary filled in, we illustrate on the next pages (pp. 3-4) a portion of a typical day for one individual, showing the level of detail at which to describe your activities. When keeping your diary for the designated 24-hour period, please do not record any information in columns 7-12.

Date for which this form applies: EXAMPLE ONLY

1 Time	2 Activity	3 Location	4 Who else was with you (or involved)?	5 Doing anything else at same time?	7	8	9	10	11	12	13	6
					← Do not write here →							
7:10am	Got up — personal hygiene	Home					3	2	1	2	2	
7:30	Prepared and ate breakfast	Home	wife	Watching news on TV			3	2	2	2	2	
7:45	Drove car	to Seven-eleven store Corner of Ann + Grove Sts, E.L.	wife				1					
7:50	Purchasing batteries	Seven-eleven store Corner of Ann + Grove Sts., E.L.	wife				1	2	1	1	2	
7:55	Drove to Pinecrest School	1811 Pinecrest Dr., E.L.	wife	Taking wife to work			1					
8:00	Drove car	to East Lansing School District Off.					2					
8:10	Waiting to pick up insurance forms	East Lansing School District Off. 507 Burcham Dr., E.L.		Reading magazines			1	1	2	2	2	
8:30	Filling in insurance forms	" " " "	Secretary	Phone call to wife for information	X	4	1	2	2	2	2	✓2
8:45	Drove car	to Dentist's office		Listening to radio			2					
9:00	Waiting for dental appointment	Okemos Professional Center		Reading magazines			1	1	2	2	1	
	↓ ↓	2248 Mt. Hope Rd., Okemos										
9:25	Dental appointment	" " " "	Dentist and Assistant		X	2	1	2	2	2	2	
10:15	Drove car	to Men's IM parking lot at University		Listening to radio			2					
10:30	Walked	to Computer Center, MSU					3					
10:40	Read newspaper	Office, Rm. 506 Computer Center		Had coffee and a phone call			3	1	1	1	1	✓3
11:00	Working at office (typing)	" " " " "	Staff member	Informal meeting with staff member	X	3	3	2	2	1	2	✓2
	↓ ↓		Students	2 phone conversations			4					
12:15pm	Walked	to Student Union Bldg.	Friend	Talking with friend			3					
12:30	Lunch	Student Union Cafeteria		Reading			3	1	1	1	2	
1:10	Walked	to Wells Hall					3					
1:25	Foreign Language Practice	Language Lab., 102-B Wells Hall	Graduate Assistant		X	6	1	2	2	2	2	
2:30	Talked with classmate after class	" " " " "	Classmate				4	2	1	1	2	

3 For each entry, put the time, the activity, and in the 'location' column, the room name or number and building name (for on-campus sites), or the address (for off-campus sites).

Where you are recording a journey, put the mode of travel in the 'activity' column, and the destination in the 'location' column. 4

Date for which this form applies:

1	2	3	4	5	7	8	9	10	11	12	13	6
Time	Activity	Location	Who else was with you (or involved)?	Doing anything else at same time?	← *Do not write here*							→

5 For each entry, put the time, the activity, and in the 'location' column, the room name or number and building name (for on-campus sites), or the address (for off-campus sites).

Where you are recording a journey, put the mode of travel in the 'activity' column, and the destination in the 'location' column. 6

APPENDIX B.

THE SUPPLEMENTAL INTERVIEW SCHEDULE

TIME SPACE Budget Survey

MSU

Investigator: J. D. Stephens

(1) Your Interview Number ______________

(2) Date ______________

(3) Length of 1st Interview ______________ (minutes)

(4) Length of 2nd Interview ______________ (minutes)

(5) Respondent Number ________(12-14) / / / /

(6) Address of Residence: ______________________________

____

______________________________(21-25) / / / / / / (26-30) / / / / / /

(7)

CALL NUMBER	1	2	3	4	5	. . .
Interview Number						
Hour of the Day						
Date						
Day of Week						
Results						

→ *If an interview is taken, complete the items immediately below and attach this cover sheet to the Interview Schedule and the Time-space Diary.*

(8) Date of completed time-space diary. ______________ / // / // / / (31-35)

→ *By observation of interviewer!*

(9)
- ☐ Male
- ☐ Female

(10)
- ☐ Caucasian
- ☐ Negro
- ☐ Other ______________
- ☐ Don't know

(36) / /

(37) / /

→ *If NO interview is taken, complete NONRESPONSE FORM below and on back side of page.*

NONRESPONSE FORM

(1) NONINTERVIEW AND NONSAMPLE FORM: *(Fill out for cases where no interview was obtained)*
INTERVIEWER: check one:

- ☐ Respondent absent. Someone at university address, but respondent absent. Describe on back side of page
- ☐ No one at location (university address).
- ☐ No such address. Invalid university address.
- ☐ No eligable respondent.
- ☐ Refusal. Give detailed description on back side of this page.
- ☐ Other. No interview obtained for reason other than above. Explain fully on back side of this page.

→ *INTERVIEWER: Please supply as much of the following information as you can without making inquiries of others present.*

(2) Sex of probable respondent.
- ☐ Male
- ☐ Female
- ☐ Don't know

(3) Race of probable respondent.
- ☐ Caucasian
- ☐ Negro
- ☐ Other (specify) ______________
- ☐ Don't know

(4) Civil status of probable respondent.
- ☐ Single
- ☐ Married
- ☐ Divorced or Separated
- ☐ Widowed
- ☐ Don't know

1

→ *INTERVIEWER: Please supply as much of the following information as you can without making inquiries of others present.*

(5) Age of probable respondent:

- ☐ 19 yrs. or less
- ☐ 20 - 24 yrs.
- ☐ 25 - 29 yrs.
- ☐ 30 - 39 yrs.
- ☐ 40 - 64 yrs.
- ☐ 65 yrs. and over
- ☐ Don't know

(6) Location of probable respondent's address:

- ☐ Residence Hall
- ☐ Faculty or Married Housing
- ☐ East Lansing
- ☐ Lansing
- ☐ Other (specify) ______________
- ☐ Don't know

(7) University position of probable respondent: ☐ Don't know

☐ Faculty

- ☐ Full-time ☐ Part-time
  - ☐ Professor
  - ☐ Associate Professor
  - ☐ Assistant Professor
  - ☐ Instructor
  - ☐ Other (specify) ______________

☐ Student

- ☐ Full-time ☐ Part-time
  - ☐ Graduate Student (______)
  - ☐ Senior
  - ☐ Junior
  - ☐ Sophomore
  - ☐ Freshman
  - ☐ Other (specify)______________

☐ Staff

- ☐ Full-time ☐ Part-time
  - ☐ Administrative
  - ☐ Clerical
  - ☐ Food Service
  - ☐ Maintenance/Custodial
  - ☐ Secretarial
  - ☐ Skilled tradesman
  - ☐ Other (specify)______________

(8) Address of non-interview location: ______________________________

____

→ *INTERVIEWER: Space for comments on either interview or non-interview situation.*

2

TIME SPACE Budget Survey ·MSU·

Investigator: J. D. Stephens

Interview Number______ **Respondent Number**______

(11) What is your age (as of your last birthday)? ________yrs. (38-39) / / /

(12) What is your marital status? (40) / /

☐ Single ☐ Separated
☐ Married ☐ Widowed
☐ Divorced

(13) Please indicate your current position at the university. (41-43) / / / /

☐ Faculty
- ☐ Full-time ☐ Part-time
  - ☐ Professor
  - ☐ Associate Professor
  - ☐ Assistant Professor
  - ☐ Instructor
  - ☐ Other (specify) ________

☐ Student
- ☐ Full-time ☐ Part-time
  - ☐ Graduate Student (________)
  - ☐ Senior
  - ☐ Junior
  - ☐ Sophomore
  - ☐ Freshman
  - ☐ Other (specify)________

☐ Staff
- ☐ Full-time ☐ Part-time
  - ☐ Administrative
  - ☐ Clerical
  - ☐ Food Service
  - ☐ Maintenance/Custodial
  - ☐ Secretarial
  - ☐ Skilled Tradesman
  - ☐ Other (specify)________

(14) For how many years have you been associated, in one way or other, with Michigan State University? ________yrs. ________mos. (44-47) / / / / /

→ *If NON-STUDENT, go to Q17b; if STUDENT, continue below with Q15*

(15) For how many credits are you enrolled this term? ________crs. (48-49) / / /

(16) What is your major (program of study) at the University? (50-53) / / / / /

College ________ Major ________

(17) Are you employed in any capacity by the University? ☐ Yes ☐ No (54) / /

→ *If response to Q17 is NO, go to Q18; otherwise, continue below*

a. Please describe your position ________ (55) / /

____

b. Approximately how many hours do you work at this job per week? (56-58) / / / /
________hrs.

→ *NOTE: For faculty and graduate teaching assistants, ask:* (59-63) / / / / / /
Approximately how many contact hours do you have per week? (64-68) / / / / / /

c. Where is your place of work on campus? ________

____

(18) Are you employed in any job outside the University? ☐ Yes ☐ No (69) / /

→ *If response to Q18 is NO, go to Q19; otherwise, continue below*

a. Please describe your position ________ (70) / /

____

b. Approximately how many hours do you work per week? ________hrs. (70-73) / / / /

c. Where is your place of work off-campus? ________

____

Card 2: (21-25) / / / / / / (26-30) / / / / / /

3

(19) Would you please check the box of the group on this card that indicates how much total income you (and your family, if applicable) received in the calander year 1972--that is, before taxes?

→ *NOTE: For students, please include your grants (scholarships, fellowships and awards), income from vacation jobs, part-time employment, allowances from parents, wife's earnings, etc.*

(31) __/

☐ under $2,000	☐ $ 6,000 - 7,999	☐ $12,500 - 14,999
☐ $2,000 - 3,999	☐ $ 8,000 - 9,999	☐ $15,000 - 24,999
☐ $4,000 - 5,999	☐ $10,000 - 12,499	☐ $25,000 and over

(20) On this card would you please check the box of the type of housing structure in which you currently reside?

☐ Own ☐ Rent (32) __/

☐ Single family	☐ Faculty or married housing
☐ Duplex	☐ Residence Hall
☐ Trailor	☐ Sorority/Fraternity house or cooperative
☐ Small apartment building (≤5 units)	☐ Other (specify) ______
☐ Large apartment building (>5 units)	

(33) __/

(21) How long have you lived at your present address?

______yrs. ______mos. (34-37) / / / /

→ *NOTE: Include summer vacation period if, for example, respondent was living at the same address before and after the vacation.*

(22) How long have you lived in the Lansing metropolitan area (including tri-county area)?

______yrs. ______mos. (38-41) / / / /

(23) Before moving to the Lansing area, where did you live?

(Town/City)____________________ (State)______________

What was the approximate size (i.e., total population) of that town/city? (42) __/

→ *NOTE: If rural location, ask for total population of nearest village, town or city.*

☐ less than 2,500	☐ 25,000 - 50,000	☐ 250,000 - 500,000
☐ 2,500 - 10,000	☐ 50,000 - 100,000	☐ 500,000 - 1,000,000
☐ 10,000 - 25,000	☐ 100,000 - 250,000	☐ 1,000,000 and over

(24) About how many times have you changed your residence since being associated with Michigan State University? ______ (43-44) / / /

→ *NOTE: Do NOT include temporary/summer vacation residences outside of the Lansing area.*

(25) How many adults (>18 yrs. of age) live at your residence (or household)?

______ (45-46) / / /

NOTE: If living in RESIDENCE HALL--the number of adults sharing room or suite.

(26) Do you live with your family? ☐ yes ☐ no (47) __/

→ *If response to Q26 is NO, go to Q29; otherwise, continue below*

(27) How many children (<18 yrs. of age) do you have in your family (and living at home)? ______ (48-49) / / /

(28) IF MARRIED, does your spouse work outside the home? ☐yes ☐no (50) __/

(29) About how far (in miles and fraction of miles) is your residence located from where you most frequently go on the campus? ____.____ miles (51-54) / / / /

(30) How many cars do you own? ______ (57) __/

→ *NOTE: If living in FAMILY SITUATION, the number of cars owned by household.*

4

TIME SPACE **Budget Survey** MSU

Investigator: J. D. Stephens

Interview Number______ **Respondent Number**______

(31) How many cars are owned by others living at your residence that are sometimes available for your use (either driver or passanger)?

__________ (58-59) / / /

(32) On this card you will see four categories of travel (A through D along the top side of card) together with nine modes of transportation (along left-hand side of card). Using the frequence-of-use codes (given at the bottom of the card), would you please indicate for each travel purpose (A through D) the frequencies to which you use the various modes of transportation.

		A	B	C	D
		Means of transportation to and from University (classes, employment, work-related activities).	Means of transportation for shopping (i.e., for food and other everyday activities).	Means of transportation for *local* leisure activities.	Means of transportation to and from non-university employment (if any).
1)	Car (your own)				
2)	Car (friend's or neighbor's)				
3)	Motorcycle (or motorbike)				
4)	Bicycle				
5)	Bus				
6)	Taxi				
7)	Walking				
8)	Hitch-hiking				
9)	Other (specify) ________				

Frequency-of-use codes: *0 - not applicable* *1 - never* *2 - seldom* *3 - sometimes* *4 - frequently* *5 - very frequently*

Card 2: A (60-69) / / / / / / / / / / / B (70-79) / / / / / / / / / / /

Card 3: C (21-30) / / / / / / / / / / / D (31-40) / / / / / / / / / / /

(33) From the list of activities on this card, would you please indicate about how often you engage in each. For those that are seasonal activities, indicate how often you take part in them when they are in season. Circle the number which best fits you: *1 - never; 2 - seldom; 3 - sometimes; 4 - frequently; 5 - very frequently.*

1)	1 2 3 4 5	Visiting relatives
2)	1 2 3 4 5	Visiting neighbors and friends
3)	1 2 3 4 5	Going to plays, concerts, or movies
4)	1 2 3 4 5	Reading, studying, listening to music
5)	1 2 3 4 5	Going to church or religious activities
6)	1 2 3 4 5	Going to classes or lectures (extracurricular)
7)	1 2 3 4 5	Watching television
8)	1 2 3 4 5	Shopping (except for groceries)
9)	1 2 3 4 5	Going to watch sports events
10)	1 2 3 4 5	Playing cards, and other indoor games
11)	1 2 3 4 5	Playing active sports
12)	1 2 3 4 5	Going to nightclubs, bars, restaurants
13)	1 2 3 4 5	Working on hobbies, painting, music
14)	1 2 3 4 5	Participating in club meetings and club activities
15)	1 2 3 4 5	Working in and around the house, yard, or building
16)	1 2 3 4 5	Other (specify) __________
17)	1 2 3 4 5	Other (specify) __________

Card 3: (46-62) / / / / / / / / / / / / / / / / / /

5

Interview Number _______ Respondent Number _______

Supplementary Questions to Time-space Diary

INTERVIEWER: *Briefly, but carefully, review all entries that the respondent has recorded in the time-space diary, checking to see that:*

(1) the reporting of activities has been accomplished at an acceptable level of detail;

(2) no portions of the respondent's day remain unreported;

(3) activity locations are clearly indicated;

(4) modes of travel are specified;

(5) the times spent travelling to or from activities are recorded as separate activities;

(6) activities and associated information are reported sequentially.

If the level of reporting is too general, probe for more details about the activities. After any probing for clarification, administer the following supplementary questions.

(1) We would now like you to go through the diary of activities as you have recorded them. For each activity, would you please record (in column 9 of the diary) your answer to the question:

TO WHAT EXTENT WAS THE ACTIVITY PLANNED?

You may choose from the four possible responses given on this sheet that best answers the question.

1 - arranged with other people
2 - planned independently
3 - routine
4 - unexpected

(The respondent should repeat this procedure for each activity entry in the diary).

(2) Now would you please review the day's activities as you have recorded them. While doing so, try to pinpoint those activities or 'episodes' which, in your opinion, are important in the sense of having had to be done at a fixed time or location. You might think of these activities as having been 'pegs' about which you feel your day had to be organized.

(a) Please indicate these activities by placing a check (or 'X') in column 7 on the lines corresponding to these activities.

(b) Now, in column 8 would you please rank those (N) activities in order of their importance (1,2, ... ,N). A '1' would indicate the most important, a '2', the next most important, and so on.

(3) Finally, I would like to ask you four simple questions for each of the activities that you have recorded in the diary (except for sleep and travel). These questions seek only yes/no answers.

(a) Could you have done anything else at this time? [Column 10]

(b) Could you have done this (activity) at any other time? [Column 11]

(c) Could you have done this (activity) elsewhere? [Column 12]

(d) Could you have been elsewhere at this time? [Column 13]

[*Repeat this questionning procedure for each activity entry in the diary (with the exception of sleep and travel)*]

6

APPENDIX C

DATA CODEBOOK FOR INTERVIEW SCHEDULE AND TIME-SPACE BUDGET DIARY

DATA RECORD 1[1]

Card Columns	Item Number[2]	Data Item and Code(s)
1		Deck number (1)
2 - 4	5	Respondent number (i.e., unique number assigned to respondent by interviewer)
5 - 7		Sequence identification number (001,002, ... ,n; where n=total number of respondents)
8 - 9		Card number (01)
10		blank
11 - 15	6	X geocoded grid coordinate of respondent's residence
16 - 20	6	Y geocoded grid coordinate of respondent's residence
21	8	Weekday of completed time-space diary: 1-Sunday, 2-Monday, 3-Tuesday, 4-Wednesday, 5-Thursday, 6-Friday, 7-Saturday
22 - 23	8	Day of month (1,2, ... , 31)
24 - 25	8	Month: 10-October; 11-November
26	9	Sex of respondent: 0-no response; 1-male; 2-female
27 - 28	11	Age of respondent (as of last birthday)

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[1]Data records 1 through 3 contain information obtained from the supplemental interview schedule (Appendix B).

[2]Item numbers that appear under this heading correspond to those item numbers in the interview schedule (Appendix B).

29 12 Civil status:
- 0-no response
- 1-single
- 2-married
- 3-divorced
- 4-separated
- 5-widowed

University status (or position)--

30 13 University affiliation:
- 0-not reported
- 1-student
- 2-faculty (instructional and research programs and administrative officers)
- 3-staff (clerical, technical, and labor classes)

31 13 Subdivision of university affiliation:

If student (1):
- 0-not reported
- 1-doctoral level
- 2-master's level and specialists
- 3-senior
- 4-junior
- 5-sophomore
- 6-freshman
- 7-other

If faculty (2):
- 0-not reported
- 1-professor
- 2-associate professor
- 3-assistant professor
- 4-instructor
- 5-research associate
- 6-administrative officer
- 7-other

If staff (3):
- 0-not reported
- 1-administrative
- 2-clerical/technical
- 3-labor
- 4-other

32 13 Part-time/full-time affiliation:
0-not reported; 1-full-time; 2-part-time

Length of time associated with university--

33 - 34 14 Number of years: 00-not reported; otherwise, actual number of years

35 - 36 14 Number of months: 00-even number of years or not reported; otherwise, the actual number of months (01,02 ... ,12)

37 - 38 15 Number of credit hours for which respondent is enrolled this term (for students only)

Major program of study (for students only)--

39 - 40 16 College in which enrolled (university classification codes)

41 - 42 16 Major program within college (university classification codes)

43	17	Is respondent employed by university (for students only): 0-no response; 1-yes; 2-no
44	17a	Occupational classification codes (for university-employed students only): 0-not reported 1-instruction and research 2-clerical/secretarial/technical 3-food service/labor 4-other
45 - 47	17b	Number of work hours per week: For students--hours devoted to university-employment per week; For faculty--contact hours per week; For staff--average number of work hours per week
48 - 52	17c	X geocoded grid coordinate of respondent's university work location
53 - 57	17c	Y geocoded grid coordinate of respondent's university work location
58	18a	Is respondent employed outside the university? 0-not reported; 1-yes; 2-no
59 - 61	18b	Number of work hours per week (for those employed outside the university)
62 - 66	18c	X geocoded grid coordinate of respondent's non-university work location
67 - 71	18c	Y geocoded grid coordinate of respondent's university work location
72	19	Annual income classification codes: 0-not reported 1-under $2000 2-2000-3999 3-4000-5999 4-6000-7999 5-8000-9999 6-10000-12499 7-12500-14999 8-15000-24999 9-25000 and over
73	20	Housing classification codes: 0-not reported 1-single family 2-duplex 3-trailor 4-apartment 6-sorority/fraternity house or cooperative 7-residence hall 8-faculty or married housing
74	21	Does respondent own or rent residence? 0-not reported; 1-own; 2-rent

		Length of time at present address--
74 - 76	22	Number of years
77 - 78	22	Number of months: 00-even number of years or not reported; otherwise, the actual number of months

DATA RECORD 2

1 - 7		Same information as coded on data record 1
8 - 9		Card number (02)
		Length of time (as resident in Lansing metropolitan area--
10 - 11	23	Number of years
12 - 13	23	Number of months: 00-even number of years or not reported; otherwise, the actual number of months
14	24	Size of place in which respondent lived before moving to the Lansing area: 0-not applicable 1-less than 2,500 2-2,500-10,000 3-10,000-25,000 4-25,000-50,000 5-50,000-100,000 6-100,000-250,000 7-250,000-500,000 8-500,000-1,000,000 9-1,000,000 and over
15 - 16	25	Number of changes of residence since affiliated with the university
17 - 18	26	Number of adults living at respondent's address
19	27	Does respondent live with family? 0-not reported; 1-yes; 2-no
20 - 21	28	Number of children in family and living at home (for respondent living in family situation only)
22	29	Is respondent's spouse, if any, employed outside the home? 0-not reported; 1-yes; 1-no
23 - 26	30	Distance (in miles) from residence to campus (distance in miles and decimal fraction of miles to two decimal places)
27	31	Number of cars owned by respondent

28 - 29	32	Number of cars owned by others living at residence (i.e., how many are available for respondent's use)
	32a	Modes of transportation to and from university (i.e., for classes, university employment, and work-related activities):[3]
30		car (respondent's)
31		car (friend's or neighbor's)
32		motorcycle (or motorbike)
33		bicycle
34		walking
35		bus
36		taxi
37		hitch-hiking
38		other
	32b	Means of transportation for shopping (i.e., for food and other everyday needs):
39		car (respondent's)
40		car (friend's or neighbor's)
41		motorcycle (or motorbike)
42		bicycle
43		walking
44		bus
45		taxi
46		hitch-hiking
47		other
	32c	Means of transportation for local leisure activities:
48		car (respondent's)
49		car (friend's or neighbor's)
50		motorcycle (or motorbike)
51		bicycle
52		walking
53		bus
54		taxi
55		hitch-hiking
56		other
	32d	Means of transportation for non-university employment:
57		car (respondent's)
58		car (friend's or neighbor's)
59		motorcycle (or motorbike)

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[3]Legal codes for items 32a, 32b, 32c, 32d, and 33: 0-not reported; 1-never; 2-seldom; 3-sometimes; 4-frequently; 5-very frequently.

60		bicycle
61		walking
62		bus
63		taxi
64		hitch-hiking
65		other
	33	Frequency of involvement in leisure activities:
66		visiting relatives, neighbors, and friends
67		going to plays, concerts, or movies
68		reading, studying, listening to music
69		going to church or religious activities
70		going to classes or lectures (extra curricular)
71		watching television
72		shopping, except for groceries
73		going to watch sports events
74		playing cards, and other indoor games
75		playing active sports
76		going to nightclubs, bars, and restaurants
77		working on hobbies, painting, music
78		participating in club meetings and activities
79		working in and around the house, yard, building
80		other

DATA RECORDS 3→N[4]

1		Deck number (2)
2 - 4		Respondent number (i.e., unique number assigned to respondent by interviewer)
5 - 7		Sequence identification number (001,002), ... ,n; where n=total number of respondents)
8 - 9		Card number (i; where i=03,04, ...N)[5]
11 - 14	1	Start time of activity (time given in hours and minutes)

[4]The number of activity modules needed to describe the behavior of an individual over a 24-hour period varies from respondent to respondent. Two activity modules can be coded on one data record. Therefore, N=2 (background data record) + respondent's total number of activity modules / 2.

[5]Item numbers that appear under this heading correspond to those item numbers in the time-space budget diary.

15 - 18	1	End time of activity (time given in hours and minutes)
19 - 23	3	X geocoded coordinate of activity location
24 - 28	3	Y geocoded coordinate of activity location
29 - 30	2	Primary activity code (see classification of activity codes below)
31 - 32	5	Secondary activity code (see classification of activity codes below)
33	3	Type of activity location (see activity location codes below)
34 - 35	4	Others present or involved in activity (see social contacts codes below)
36	2	Travel mode: 0-not reported 1-car (respondent's) 2-car (friend's or neighbor's) 3-motorcycle (or motor-bike) 4-bicycle 5-walking 6-bus 7-taxi 8-hitch-hiking 9-other
37	8	Subjective ranking (relative to respondent) of important activities: 0-not applicable 1-first important activity 2-second important activity . . . . 9-ninth important activity
38	9	Degree of respondent's commitment to activity: 0-no response 1-arranged with others 2-planned independently 3-routine 4-unexpected
		Four-part subjective fixity question--
39	10	part 1--activity-choice fixity part 2--temporal fixity of activity part 3--spatial fixity of activity part 4--spatial fixity of activity 0-no response; 1-yes; 2-no

43 - 44		blank
45 - 76	1-13	Repeat data format above (columns 11-42) for data describing the second activity module to be coded in columns 45-76[6]

THE CODING OF ACTIVITIES

Activities listed in the respondents' diaries were coded into 98 activity categories using a two-digit system.[7] The first digit divided activities into ten main groups: work (0), housework (1), child care (2), shopping (3), personal needs (4), education (5), organizational activity (6), entertainment (7), active leisure (8), and passive leisure (9). The complete two-digit activity code is presented in Table C-1 together with their abbreviations.

Several activities may take place simultaneously, and provision was made in the coding procedure for the recording of two simultaneous activities. In order to accomplish this, one activity had to be designated as the primary activity and the other as secondary. The distinction between the primary and the accompanying or secondary activity depended on how the respondent described his behavior.

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[6]Repeat the format of this data record as many times as necessary in order to describe the respondent's behavior (sequence of activity modules) over the 24-hour period.

[7]Perhaps the most widely recognized system, and the one adopted here with minor modifications, is the one developed by the 12-nation consortium of social scientists. See Alexander Szalai, "The Multinational Comparative Time-Budget Research Project," <u>The American Behavioral Scientist</u>, 10 (December, 1966), appendix.

TABLE C-1

TWO-DIGIT ACTIVITY CODE

CODE	ACTIVITY DESCRIPTION	ABBREVIATION
00-09	WORKING TIME AND TIME CONNECTED TO IT	
00	Normal professional work (outside home)	Regular work
01	Normal professional work at home or brought home	Work at home
02	Overtime if it can be specifically isolated from 00	Overtime
03	Work-related discussion or meeting	Work meeting
04	Any waiting or interruption during working time if it can be isolated from work (e.g., due to supply shortage, breakdown of machines, etc.)	Waiting, delays
05	Undeclared, auxiliary, etc. work	Second job
06	Meal at workplace	Meals at work
07	Time spent at the workplace before starting or after end work	At work, other
08	Regular breaks and prescribed non-working periods during worktime	Work breaks
09	Travel to and return from workplace, including waiting for means of transport	Travel to job
10-19	DOMESTIC WORK	
10	Preparation and cooking of food	Prepare food
11	Washing up and putting away dishes	Meal cleanup
12	Indoor cleaning (sweeping, washing, bed-making)	Clean house
13	Outdoor cleaning (sidewalk, disposal of garbage)	Outdoor chores
14	Laundry, ironing	Laundry, ironing

TABLE C-1--Continued

CODE	ACTIVITY DESCRIPTION	ABBREVIATION
15	Repair or upkeep of clothes, shoes, etc.	Clothes upkeep
16	Other repairs and home operations	Other upkeep
17	Gardening, animal care	Gardening, animal care
18	Heat and water supplies--upkeep	Heat, water
19	Others (e.g., dealing with bills and various other papers, usual care to household members, etc.)	Other duties
20-29	CARE TO CHILDREN	
20	Care to babies	Baby care
21	Care to older children	Child care
22	Supervision of school work (exercises and lessons)	Help on homework
23	Reading of tales or other non-school books to children, conversations with children	Talk to children
24	Indoor games and manual instruction	Indoor playing
25	Outdoor games and walks	Outdoor playing
26	Medical care (including visits to doctor or dentist, or other activities related to health of children)	Child, health
27	Others	Other, babysit
28	Not used	Blank
29	Travel to accompany children including waiting for means of transport	Travel with child
30-39	PURCHASING OF GOODS AND SERVICES	
30	Purchasing of everyday consumer goods and products	Marketing
31	Purchasing of durable consumer goods	Shopping

TABLE C-1--Continued

CODE	ACTIVITY DESCRIPTION	ABBREVIATION
32	Personal care outside the home	Personal care
33	Medical care outside the home	Medical care
34	Administrative services, offices	Administrative service
35	Repair and other services	Repair service
36	Waiting, queueing for the purchase of goods and services	Waiting in line
37	Others	Other service
38	Not used	Blank
39	Travelling connected to the above mentioned activities, including waiting for means of transport	Travel, service
40-49	PRIVATE NEEDS: MEALS, SLEEP, PRIVATE AND NONDESCRIBED ACTIVITIES	
40	Personal hygiene, dressing (getting up, going to bed, etc.)	Personal hygiene
41	Personal medical care at home	Personal medical
42	Care given to adults, if not included in household work	Care to adults
43	Meals and snacks at home	Meals, snacks
44	Meals outside the home	Restaurant meals
45	Night sleep (essential)	Night sleep
46	Daytime sleep (incidental)	Daytime sleep
47	Nap or rest	Resting
48	Private activities, non-described, others	Private, other
49	Travelling connected to the above mentioned activities, including waiting for means of transport	Travel, personal

TABLE C-1--Continued

CODE	ACTIVITY DESCRIPTION	ABBREVIATION
50-59	EDUCATION AND PROFESSIONAL TRAINING	
50	Full-time attendance to classes, lectures, seminars (under-graduate or post-graduate student), studies being the principle activity	Attend classes
51	Attendence to special lectures (occasionally) or special training courses	Other classes
52	Homework (e.g., private study, writing, reading) for different courses and lectures, including related research work and self-instruction	Homework
53	Talking or consultation with instructional staff or tutor	Study consultation
54	Discussion of course-related matters with others, if it can be isolated from 53	Informal consultation
55	Waiting for or looking for member of instructional staff or tutor	Waiting for staff
56	Reading or reviews or books for personal instruction	Read to learn
57	Tutorial, supervised study, research, or independent study	Tutorial, supervision
58	Others	Other study
59	Travelling connected to the above mentioned activities, including waiting for means of transport	Travel, study
60-69	CIVIC AND COLLECTIVE PARTICIPATION ACTIVITIES	
60	Participation as member of a party, union, etc.	Union, politics
61	Voluntary activity as an elected official of a social or political organization	Work as officer
62	Participation in meetings other than those covered by 60 and 61	Other participation

TABLE C-1--Continued

CODE	ACTIVITY DESCRIPTION	ABBREVIATION
63	Non-paid collective civic activity (e.g., volunteers)	Civic activities
64	Participation in religious organizations	Religious organization
65	Religious practice and attending religious ceremonies	Religious practice
66	Participation in various university councils (committees, commissions)	University councils
67	Participation in other associations (family, parent, military, etc.)	Misc. organizations
68	Others	Other organization
69	Travelling connected to the above mentioned activities, including waiting for means of transport	Travel, organization
70-79	SPECTACLES, ENTERTAINMENT, SOCIAL LIFE	
70	Attending a sports event	Sports events
71	Circus, music-hall, dancing, show, night-club	Mass culture
72	Movies	Movies
73	Theater, concert, opera	Theater
74	Museum, exhibition	Museums
75	Receiving visit of friends or visiting friends	Visiting with friends
76	Party or reception with meal offered to or offered by friends	Party, meals
77	Cafe, bar	Cafe, bars
78	Attending receptions (other than those mentioned above)	Other social
79	Travelling connected to the above mentioned activities, including waiting for means of transport	Travel, social

TABLE C-1--Continued

CODE	ACTIVITY DESCRIPTION	ABBREVIATION
80-89	SPORTS AND ACTIVE LEISURE	
80	Practice a sport and physical exercise	Active sports
81	Excursions, hunting, collections	Fishing, hiking
82	Walks	Taking a walk
83	Technical hobbies, collections	Hobbies
84	Needle work, sewing, knitting, etc.	Sewing hobbies
85	Artistic creations (painting, sculpture, literature, etc.)	Art work
86	Playing a musical instrument, singing	Making music
87	Society games	Parlor games
88	Others	Other pastime
89	Travelling connected to the above mentioned activities, including waiting for means of transport	Travel, pastime
90-99	PASSIVE LEISURE	
90	Listening to the radio	Radio
91	Watching television	TV
92	Listening to records	Play records
93	Reading books	Read book
94	Reading reviews, periodicals, pamphlets, etc.	Read magazine
95	Reading newspaper	Read paper
96	Conversations, including telephone conversation	Conversation
97	Writing private correspondence	Letters, private
98	Relaxing, reflecting, thinking, planning, doing nothing, no visible activity	Relax, thing
99	Travelling connected to the above mentioned activities, including waiting for means for transport	Travel, leisure

CODING OF ACTIVITY LOCATIONS

In addition to locations of activity being identified by spatial coordinates, types of activity locations were also coded qualitatively. The following one digit coding scheme was used:

0 - in and around one's own residence
1 - workplace (at university)
2 - workplace (elsewhere)
3 - at somebody else's residence
4 - outdoors (on campus, in streets, public places)
5 - inside university buildings (classrooms, meeting rooms, offices)
6 - inside building where one receives public or private services (e.g., doctor's office, shop, bank)
7 - establishment for leisure, cultural, sport, etc. activities
8 - eating and drinking establishments
9 - others

CODING OF SOCIAL CONTACT DATA

Respondents recorded for each activity in their diaries with whom or the individual's present while it was performed. This social contact information was coded into two single columns as shown in Table C-2. If no social contact occurred, the code was 00; and if only one contact took place, the second column was 0.

As Szalai notes,[8] the coding scheme generates a possible total of 82 categories. These are, however, collapsed into 12 exhaustive but not mutually exclusive groups for use in the analysis (Table C-3).

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[8]Alexander Szalai ed., The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries (The Hague: Mouton & Co., 1972), pp. 773-774.

TABLE C-2

SOCIAL CONTACT CODES

FIRST COLUMN	SECOND COLUMN
0 - alone	0 - no other individuals
1 - spouse	1 - many unidentified people, a crowd
2 - children at respondent's residence	2 - children at respondent's residence
3 - other adults at the respondent's residence	3 - other adults at respondent's residence
4 - relatives, friends outside the respondent's residence	4 - relatives, friends outside the respondent's residence
5 - co-workers or fellow students	5 - co-workers, fellow students, faculty
6 - members of an organization	6 - members of an organization
7 - neighbors or other children	7 - neighbors or other children
8 - administrative personnel, students, clients	8 - administrative personnel, students, clients
9 - others, unidentified	9 - others, unidentified

TABLE C-3

COLLASPSED CODING SYSTEM FOR SOCIAL CONTACTS

1. all alone
2. alone in a crowd
3. with children only, spouse not present
4. with children and spouse
5. with spouse, children not present
6. other adults at residence
7. friends and relatives
8. neighbors
9. work colleagues, fellow students
10. organization members
11. administrative personnel, staff
12. all other persons

APPENDIX D

TABLE D-1

TWO-DIGIT ACTIVITY CODE:
COLLAPSED FORM

NEW CODE	NEW ACTIVITY CATEGORY (abbreviation)	OLD CODE	OLD ACTIVITY CATEGORY* (abbreviation)
01-09	WORK-RELATED		
01	Regular work	00	Regular work
02	Work at home	01	Work at home
03	Overtime	02	Overtime
04	Work meeting	03	Work meeting
05	Waiting, delays	04	Waiting, delays
06	Second joy	05	Second job
07	At work, other	07	At work, other
08	Work breaks	08	Work breaks
09	Travel to job	09	Travel to job
10-14	HOUSEWORK AND HOUSEHOLD OBLIGATIONS		
10	Prepare food	10	Prepare food
11	Home chores	11	Meal cleanup
		12	Clean house
		13	Outdoor chores
12	Laundry	14	Laundry, ironing
		15	Clothes, upkeep
13	Garden, animal care	17	Gardening, animal care
14	Other house	16	Other, upkeep
		18	Heat, water
		19	Other duties
		42	Care to adults
15-17	CHILD CARE		
15	Child care	20	Care to babies
		21	Care to older children
		26	Child, health

*For descriptions of original activity categories, see Appendix C.

TABLE D-1--Continued

NEW CODE	NEW ACTIVITY CATEGORY (abbreviation)	OLD CODE	OLD ACTIVITY CATEGORY (abbreviation)
16	Other child	22	Help on homework
		23	Talk to children
		24	Indoor playing
		25	Outdoor playing
		27	Other, babysit
17	Travel, child	29	Travel with child
18-23	SHOPPING		
18	Marketing	30	Marketing
19	Shopping	31	Shopping
20	Administrative service	34	Administrative service
21	Repair and other service	35	Repair service
		37	Other service
22	Waiting in line	36	Waiting in line
23	Travel, service	39	Travel, service
24-32	SHOPPING		
24	Personal care	32	Personal care
25	Medical care	33	Medical care
26	Personal hygiene	40	Personal hygiene
27	Personal medical	41	Personal medical
28	Private, other	48	Private, other
29	Eating	06	Meals at work
		43	Meals, snacks
		44	Restaurant meals
30	Night sleep	45	Night sleep
31	Daytime sleep	46	Daytime sleep
32	Travel, personal	49	Travel, personal
33-42	EDUCATION AND TRAINING		
33	Attend classes	50	Attend classes
34	Other classes	51	Other classes
35	Homework	52	Homework
36	Study consultation	53	Study consultation
37	Informal consultation	54	Informal consultation
38	Waiting for staff	55	Waiting for staff
39	Read to learn	56	Read to learn
40	Tutorial, supervision	57	Tutorial, supervision

TABLE D-1--Continued

NEW CODE	NEW ACTIVITY CATEGORY (abbreviation)	OLD CODE	OLD ACTIVITY CATEGORY (abbreviation)
41	Other study	58	Other study
42	Travel, study	59	Travel, study
43-45	COLLECTIVE PARTICIPATION		
43	Religion	64	Religious organization
		65	Religious practice
44	Organization	60	Union, politics
		61	Work as officer
		62	Other participation
		63	Civic activities
		66	University councils
		67	Misc. organizations
		68	Other organization
45	Travel, organization	69	Travel, organization
46-52	MASS MEDIA		
46	Radio	90	Radio
47	TV (at residence)	91	TV**
48	TV (elsewhere)	91	TV***
49	Read paper	95	Read paper
50	Read magazine	94	Read magazine
51	Read books	93	Read book
52	Movies	72	Movies
53-65	LEISURE		
53	Social (at residence)	75	Visiting with friends**
		76	Party, meals**
		87	Parlor games**
54	Social (elsewhere)	75	Visiting with friends***
		76	Party, meals***
		87	Parlor games***
		78	Other social

**For location codes 0 or 2 (see activity location codes in Appendix C).

***For all location codes other than 0 and 2 (see activity location codes in Appendix C).

TABLE D-1--Continued

NEW CODE	NEW ACTIVITY CATEGORY (abbreviation	OLD CODE	OLD ACTIVITY CATEGORY (abbreviation)
55	Cafe, bars	77	Cafe, bars
56	Conversation	96	Conversation
57	Active sports	80	Active sports
58	Outdoors	81	Fishing, hiking
		82	Taking a walk
59	Entertainment	70	Sport events
		71	Mass culture
60	Cultural events	73	Theater
		74	Museums
61	Resting	98	Relax, think
		47	Resting
62	Play records	92	Play records
63	Letters, private	97	Letters, private
64	Other leisure	83	Hobbies
		84	Sewing hobbies
		85	Art work
		86	Making music
		88	Other pastime
65	Travel, leisure	79	Travel, social
		89	Travel, pastime
		99	Travel, leisure

APPENDIX E

SURVEY SAMPLE DESIGN AND RESPONSE RATES

FIGURE E-1

RESPONSE RATES BY WEEK AND WEEKDAY OF THE SURVEY PERIOD*

*The Figure presents information concerning the response rate for each (1) survey date, (2) weekday, and (3) week of the survey period. Since the sample was stratified by university affiliation, as well as weekday of survey, the figure gives for each survey date the response by three categories: (1) students (upper left), (2) faculty (lower left), and (3) staff (lower right). Within each block, the size of the target sample appears to the left while the actual number of respondents successfully completing the survey appears to the right.

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		Weekly Response Rates		
WEEK 1	7/3	OCTOBER 15	8/4	16	5/2	17	6/4	18	5/1	19	31/14	WEEK 1	$RR_1 =$ 52.5
	-/-	1/0	-/-	-/-	1/0	2/2	1/1	1/1	-/-	3/3	2/1	4/6	
WEEK 2	7/3	22	6/5	23	4/4	24	8/6	25	8/5	26	33/23	WEEK 2	$RR_2 =$ 75.0
	1/1	-/-	1/1	1/1	3/3	1/1	-/-	-/-	-/-	-/-	5/5	2/2	
WEEK 3	6/5	29	8/7	30	8/5	31	5/5	NOVEMBER 1	6/4	2	33/26	WEEK 3	$RR_3 =$ 80.0
	1/1	1/0	-/-	-/-	-/-	-/-	1/1	2/2	1/1	1/1	3/3	4/3	
WEEK 4	8/5	5	7/6	6	7/5	7	6/5	8	6/3	9	34/24	WEEK 4	$RR_4 =$ 75.0
	-/-	-/-	-/-	1/1	-/-	1/1	1/1	1/1	-/-	2/2	1/1	5/5	
WEEK 5	7/5	12	6/3	13	5/2	14	7/5	15	6/3	16	31/18	WEEK 5	$RR_5 =$ 65.0
	1/0	-/-	1/1	1/1	2/2	1/1	1/1	-/-	-/-	2/2	5/4	4/4	

Daily Response Rates	35/21	MONDAY	35/25	TUESDAY	29/18	WEDNES-DAY	34/25	THURSDAY	31/16	FRIDAY	162/105	TOTAL SURVEY	
	3/2	2/0	2/2	3/3	6/5	5/5	4/4	4/4	1/1	8/8	16/14	22/20	$RR_T =$
	$RR_M =$ 57.5		$RR_{Tu} =$ 75.0		$RR_W =$ 70.0		$RR_{Th} =$ 82.5		$RR_F =$ 62.5				69.5

APPENDIX F

THE COMPUTER SIMULATION PROGRAM*

---

*The following simulation is programmed in FORTRAN 6000 Extended and was implemented on a CDC 6500 computer in the Computer Laboratory of Michigan State University.

```
C        SIMACT:  PROGRAM TO SIMULATE THE CHOICE, DURATION, AND
C                 LOCATION OF ACTIVITIES SEQUENTIALLY.
      COMMON /A1/ SED,RESNUM,GNUM
      COMMON /B2/ FACT(72,65),ALINK(9,9),FIXT(65,16,4),ALOC(65,9,6)
      COMMON /C3/ ACTMOD(73,10),DACT(65,10,2),TDIST(72,5)
      DIMENSION FIXRAT(16), TR(7), T(5), DUR(10), SC(4)
      LOGICAL FLAG,TRIP,OK
      INTEGER RESNUM,GNUM
      DATA (FIXRAT(I),I=1,16)/2222.,2221.,2212.,2211.,2122.,2121.,2112.,
     12111.,1222.,1221.,1212.,1211.,1122.,1121.,1112.,1111./
      DATA (T(J),J=1,5)/5.,10.,20.,30.,60./
      DATA (TR(J),J=1,7)/9.,17.,23.,32.,42.,45.,65./
      DATA (DUR(J),J=1,10)/5.,10.,15.,30.,45.,60.,90.,120.,180.,300./
      SED=100.
      N=0
C
C        READ CUMULATIVE PROBABILITY DISTRIBUTIONS
C
      CALL INPUTS (N)
      IF (N.GT.0) GO TO 1010

C        READ RESPONDENT NUMBER OF I-TH INDIVIDUAL IN PATTERN GROUP
C
20    READ (9,1040) RESNUM,GNUM
      IF (RESNUM.EQ.99999) GO TO 1020
C
C        ZERO OUT ACTMOD ARRAY
C
      DO 30 I=1,72
      DO 30 J=1,10
30    ACTMOD(I,J)=0.0
      ACTMOD(73,7)=30.
```

```
      ACTMOD(73,8)=1.
      ACTMOD(73,9)=15.
C
C        ON TAPE9 FIND SET OF SEQUENCED ACTIVITY MODULES FOR INDIVIDUAL
C        IDENTIFIED BY RESNUM
C        READ RELATIVE IMPORTANCE, COMMITMENT, AND FIXITY RATINGS,
C        THEREBY RECORDING THE CONSTRAINT CONFIGURATION FOR EACH TIME
C        INTERVAL THROUGHOUT THE DAY.
C
      II=1
      JJ=8
      DO 40 K=1,9
      READ (9,1050) ((ACTMOD(I,J),J=1,7),I=II,JJ)
      II=II+8
      JJ=JJ+8
40    CONTINUE
C
C        SET PEG AND FIXITY COUNTERS TO ZERO
C
      PEGS=0.0
      FIXS=0.0
C
C        CALL UNIFRM FUNCTION TO RETURN UNIQUE SEED FOR RANSET
C
      A=(UNIFRM(0)+0.005)*100.0
      CALL RANSET (A)
C
C        EVALUATE THE DEGREE OF IMPORTANCE, COMMITMENT, AND CONSTRAINT
C        FOR EACH TIME INTERVAL
C
      DO 80 I=1,72
C
```

```
C        CHECK IMPORTANCE RANKING; IF NON-ZERO, COUNT AS PEG              SIM  640
C                                                                         SIM  650
      IF (ACTMOD(I,1)) 50,60,50                                           SIM  660
50    PEGS=PEGS+1.0                                                       SIM  670
      GO TO 80                                                            SIM  680
C                                                                         SIM  690
C        IF ACTIVITY PERFORMED DURING TIME INTERVAL IS SLEEP OR TRAVEL,   SIM  700
C        SKIP                                                             SIM  710
C                                                                         SIM  720
60    IF (ACTMOD(I,7).EQ.0.0) GO TO 70                                    SIM  730
      ACTMOD(I,7)=0.0                                                     SIM  740
      GO TO 80                                                            SIM  750
C                                                                         SIM  760
C        CHECK COMMITMENT RATING; IF 1,2, OR 3, TENTATIVELY COUNT AS FIXSIM  770
C                                                                         SIM  780
70    IF (ACTMOD(I,2).LT.1.0.OR.ACTMOD(I,2).GT.3.0) GO TO 80              SIM  790
C                                                                         SIM  800
C        CHECK FOR OCCURRENCE OF ACTIVITY, TIME, AND LOCATION FIXITIES    SIM  810
C                                                                         SIM  820
      IF (ACTMOD(I,3).LT.2.0) GO TO 80                                    SIM  830
      IF (ACTMOD(I,4).LT.2.0) GO TO 80                                    SIM  840
      IF (ACTMOD(I,5).LT.2.0.OR.ACTMOD(I,6).LT.2.0) GO TO 80              SIM  850
C                                                                         SIM  860
C        IF ACTIVITY, TIME, AND LOCATION ARE FIXED, RECORD MAJOR CON-     SIM  870
C        STRAINT INDEX AND ADD TO TOTAL FIXES                             SIM  880
C                                                                         SIM  890
      ACTMOD(I,1)=-1.0                                                    SIM  900
      FIXS=FIXS+1.0                                                       SIM  910
80    CONTINUE                                                            SIM  920
C                                                                         SIM  930
C        SEGMENT TO COMPUTE A SUBJECTIVE CONSTRAINT INDEX FOR EACH TIME SIM  940
C        INTERVAL THAT HAS A NON-ZERO IMPORTANCE RANKING                  SIM  950
```

```
C
      DO 110 I=1,72
C
C        IS TIME INTERVAL A PEG OR A FIX
C
      IF (ACTMOD(I,1).EQ.0.0) GO TO 110
C
C        COMPUTE SUBJECTIVE CONSTRAINT INDEX FOR TIME INTERVAL
C
      K=3
      DO 90 J=1,4
      SC(J)=ACTMOD(I,K)
      K=K+1
90    CONTINUE
      CALL SCON (SC,S)
C
C        TEMPORARILY STORE INDEX VALUE IN ACTMOD(I,9)
C
      DO 100 IND=1,16
      IF (S.EQ.FIXRAT(IND)) ACTMOD(I,9)=IND
100   CONTINUE
110   CONTINUE
C
C        THE FOLLOWING SEGMENT (115 LOOP) DETERMINES THE ACTIVITIES
C        PERFORMED AT EACH OF THE FIXED POINTS (PEGS) THROUGHOUT THE
C        DAY.  THE DURATION AND LOCATION OF ACTIVITY IS ALSO ASSIGNED
C        FOR EACH PEG.
C
      IPEG=PEGS
      DO 230 IP=1,IPEG
      IA=0
      PEG=IP
```

```
C                                                                       SIM 1280
C        DETERMINE SUBSCRIPTS FOR RETRIEVING VALUES FROM THE FIXT ARRAY SIM 1290
C                                                                       SIM 1300
120   IA=IA+1                                                           SIM 1310
      IF (ACTMOD(IA,1).NE.PEG) GO TO 120                                SIM 1320
      KM=ACTMOD(IA,2)                                                   SIM 1330
      KN=ACTMOD(IA,9)                                                   SIM 1340
      K=1                                                               SIM 1350
C                                                                       SIM 1360
C        GENERATE RANDOM NUMBER FOR DETERMINING ACTIVITY PERFORMED      SIM 1370
C                                                                       SIM 1380
      CALL RNUM (R,VAL,OVL)                                             SIM 1390
C                                                                       SIM 1400
C        FIXT ARRAY GIVES THE PROBABILITIES OF ACTIVITY ACCORDING TO    SIM 1410
C        COMMITMENT AND CONSTRAINT INDICES                              SIM 1420
C                                                                       SIM 1430
130   VAL=VAL+FIXT(K,KN,KM)                                             SIM 1440
C                                                                       SIM 1450
C        IN WHICH CELL OF THE CHOSEN COLUMN VECTOR DOES THE RANDOM      SIM 1460
C        NUMBER FALL                                                    SIM 1470
C                                                                       SIM 1480
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 140                              SIM 1490
      OVL=OVL+VAL                                                       SIM 1500
      K=K+1                                                             SIM 1510
      GO TO 130                                                         SIM 1520
C                                                                       SIM 1530
C        ASSIGN THE K-TH ACTIVITY CODE TO THE IA-TH INTERVAL OF THE     SIM 1540
C        INDIVIDUAL'S DAY                                               SIM 1550
C                                                                       SIM 1560
140   ACTMOD(IA,7)=K                                                    SIM 1570
C                                                                       SIM 1580
C        DETERMINE SUBSCRIPTS FOR RETRIEVING VALUES FROM THE ALOC ARRAY SIM 1590
```

```
C
      INT=12
      L=1
150   IF (IA.LE.INT) GO TO 160
      L=L+1
      INT=12*L
      GO TO 150
160   KT=L
      KK=1
C
C        GENERATE RANDOM NUMBER FOR DETERMINING ACTIVITY LOCATION
C
      CALL RNUM (R,VAL,OVL)
C
C        ALOC ARRAY GIVES PROBABLE LOCATION OF ACTIVITIES
C
170   VAL=VAL+ALOC(K,KK,KT)
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 180
      OVL=OVL+VAL
      KK=KK+1
      GO TO 170
C
C        ASSIGN THE KK-TH ACTIVITY LOCATION TO THE IA-TH INTERVAL
C
180   ACTMOD(IA,8)=KK
      ACTMOD(IA,9)=15.
      IG=1
C
C        CHECK SUBSEQUENT TIME INTERVAL; IF PEG IS THE SAME, ASSIGN SAME
C        ACTIVITY AND LOCATION CODES
C
190   IA=IA+1
```

```
      IF (ACTMOD(IA,1).NE.PEG) GO TO 230
      ACTMOD(IA,7)=K
      ACTMOD(IA,8)=KK
      IG=IG+1
      IB=IA+1
      IF (ACTMOD(IB,1).NE.PEG) GO TO 200
      ACTMOD(IA,9)=15.
      GO TO 190
200   DURM=IG*15
      L=1
210   IF (DURM.LE.DUR(L)) GO TO 220
      L=L+1
      GO TO 210
220   ACTMOD(IA,9)=DACT(K,L,2)
230   CONTINUE
C
C        THE FOLLOWING SEGMENT ASSIGNS AN ACTIVITY, DURATION, AND
C        LOCATION TO EACH OF THE FIXES DETERMINED IN LOOP 65.  APART
C        FROM THE PEGS, THE FIXES ARE THOSE EPISODES THOUGHT TO HAVE THE
C        MOST CONSTRAINING EFFECT ON THE STRUCTURE OF ONE'S DAY.
C
      IF=0
C
C        INCREMENT TIME INTERVAL; DOES NEW EPISODE CONTAIN A FIX
C
240   IB=IB+1
      IF (IB.GT.72) GO TO 520
      NI=IB
      IF (ACTMOD(IB,1).NE.-1.0) GO TO 240
C
C        COMPUTE TOTAL SUBJECTIVE FIXITY RATING FOR TIME INTERVAL
C
```

```
      K=3
      DO 250 J=1,4
      SC(J)=ACTMOD(IB,K)
      K=K+1
250   CONTINUE
      CALL SCON (SC,TC)
      DO 260 IN=1,16
      IF (TC.EQ.FIXRAT(IN)) KN=IN
260   CONTINUE
      KM=ACTMOD(IB,2)
270   K=1
C
C        GENERATE RANDOM NUMBER FOR DETERMINING ACTIVITY PERFORMED
C
      CALL RNUM (R,VAL,OVL)
280   VAL=VAL+FIXT(K,KN,KM)
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 290
      OVL=OVL+VAL
      K=K+1
      GO TO 280
C
C        ASSIGN THE K-TH ACTIVITY TO THE IB-TH TIME INTERVAL
C
290   JT=0
      AK=K
      DO 300 J=1,7
      IF (AK.EQ.TR(J)) JT=1
300   CONTINUE
      IF (JT.GT.0) GO TO 270
      ACTMOD(IB,7)=K
C
C        GENERATE RANDOM NUMBER FOR DETERMINING DURATION OF ACTIVITY
```

```
C
      KK=1
      CALL RNUM (R,VAL,OVL)
C
C        DACT ARRAY CONTAINS PROBABLE ACTIVITY DURATIONS
C
310   VAL=VAL+DACT(K,KK,1)
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 320
      OVL=OVL+VAL
      KK=KK+1
      GO TO 310
C
C        TENTATIVELY ASSIGN KK-TH ACTIVITY DURATION TO IB-TH INTERVAL
C
320   IK=DUR(KK)/15.
      IF (IK.LT.1) IK=1
C
C        LOOK AHEAD TO DETERMINE IF ACTIVITY DURATION (IBK) OVERLAPS
C        WITH ANY FUTURE ACTIVITY
C
      IBK=IB+IK
330   IB=IB+1
      IF (IBK-IB) 360,360,340
340   IF (ACTMOD(IB,7).EQ.0.0) GO TO 330
C
C        IF ACTIVITY DURATION EXTENDS BEYOND ONE THAT HAS ALREADY BEEN
C        ESTABLISHED (I.E., A PEG), RETURN TO 125 AND TRY AGAIN.
C
      IF (IBK-IB.LE.1) GO TO 350
      IB=(IBK-KK)-1
      ACTMOD(IB,7)=0.0
      GO TO 270
```

```
350   MU=1                                                          SIM 2880
      GO TO 370                                                     SIM 2890
360   MU=0                                                          SIM 2900
C                                                                   SIM 2910
C        DETERMINE SUBSCRIPTS FOR RETRIVING VALUES FROM THE ALOC ARRAY  SIM 2920
C                                                                   SIM 2930
370   INT=12                                                        SIM 2940
      L=1                                                           SIM 2950
380   IF (IB.LE.INT) GO TO 390                                      SIM 2960
      L=L+1                                                         SIM 2970
      INT=12*L                                                      SIM 2980
      GO TO 380                                                     SIM 2990
390   KT=L                                                          SIM 3000
C                                                                   SIM 3010
C        GENERATE RANDOM NUMBER FOR DETERMINING ACTIVITY LOCATION   SIM 3020
C                                                                   SIM 3030
      K3=1                                                          SIM 3040
      CALL RNUM (R,VAL,OVL)                                         SIM 3050
C                                                                   SIM 3060
C        ALOC ARRAY GIVES PROBABLE LOCATION OF ACTIVITIES           SIM 3070
C                                                                   SIM 3080
400   VAL=VAL+ALOC(K,K3,KT)                                         SIM 3090
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 410                          SIM 3100
      OVL=OVL+VAL                                                   SIM 3110
      K3=K3+1                                                       SIM 3120
      GO TO 400                                                     SIM 3130
C                                                                   SIM 3140
C        DOES ANOTHER ACTIVITY FOLLOW THE K-TH ACTIVITY AT TIME IB  SIM 3150
C                                                                   SIM 3160
410   IF (MU) 460,460,420                                           SIM 3170
420   B=K                                                           SIM 3180
      B3=K3                                                         SIM 3190
```

```
      JB=IB+1                                                           SIM 3200
C                                                                       SIM 3210
C        ARE DIFFERENT ACTIVITIES ASSIGNED AT TIMES IB AND IB+1         SIM 3220
C                                                                       SIM 3230
      IF (B.EQ.ACTMOD(JB,7)) GO TO 460                                  SIM 3240
C                                                                       SIM 3250
C        ARE DIFFERENT LOCATIONS ASSIGNED TO ACTIVITIES                 SIM 3260
C                                                                       SIM 3270
      IF (BB.EQ.ACTMOD(JB,8)) GO TO 460                                 SIM 3280
C                                                                       SIM 3290
C        CALCULATE TIME AVAILABLE FOR TRAVEL                            SIM 3300
C                                                                       SIM 3310
      DURM=IBK*15                                                       SIM 3320
      L=1                                                               SIM 3330
430   IF (DURM.LE.DUR(L)) GO TO 440                                     SIM 3340
      L=L+1                                                             SIM 3350
      GO TO 430                                                         SIM 3360
440   ACTMOD(IB,9)=DACT(K,L,2)                                          SIM 3370
      MX=1                                                              SIM 3380
450   FLAG=.TRUE.                                                       SIM 3390
      CALL TTIME (FLAG,IB,K,BB,OK,TR,T,DUR)                             SIM 3400
      IF (OK) GO TO 460                                                 SIM 3410
      IF (MX.GT.2) GO TO 270                                            SIM 3420
      MX=MX+1                                                           SIM 3430
      GO TO 450                                                         SIM 3440
C                                                                       SIM 3450
C        UPDATE INDIVIDUAL'S ACTIVITY MODULE WITH ACTIVITY, TIME, AND   SIM 3460
C        LOCATION INFORMATION FOR THE DURATION OF THE IX-TH FIX.        SIM 3470
C                                                                       SIM 3480
460   IB=NI                                                             SIM 3490
      DMIN=DACT(K,KK,2)                                                 SIM 3500
      IF ((IBK-1)-IB) 470,470,480                                       SIM 3510
```

```
470   ACTMOD(IB,9)=DMIN                                                         SIM 3520
      ACTMOD(IB,8)=K3                                                           SIM 3530
      ACTMOD(IB,1)=0.0                                                          SIM 3540
      GO TO 240                                                                 SIM 3550
480   IBK=IBK-1                                                                 SIM 3560
      DO 510 IBB=1,IBK                                                          SIM 3570
      ACTMOD(IB,7)=K                                                            SIM 3580
      ACTMOD(IB,8)=K3                                                           SIM 3590
      ACTMOD(IB,1)=0.0                                                          SIM 3600
      IF (IBB.EQ.IBK) GO TO 490                                                 SIM 3610
      ACTMOD(IB,9)=15.0                                                         SIM 3620
      GO TO 500                                                                 SIM 3630
490   ACTMOD(IB,9)=DMIN                                                         SIM 3640
500   IB=IB+1                                                                   SIM 3650
510   CONTINUE                                                                  SIM 3660
      GO TO 240                                                                 SIM 3670
520   CONTINUE                                                                  SIM 3680
C                                                                               SIM 3690
C        THE FOLLOWING SEGMENT SIMULATES THE CHOICE, TIMING, AND LOCA-          SIM 3700
C        TION OF ACTIVITIES FOR THE REMAINING, UNSCHEDULED PORTIONS OF          SIM 3710
C        THE DAY                                                                SIM 3720
C                                                                               SIM 3730
      IF (ACTMOD(1,7)-0.0) 540,540,530                                          SIM 3740
C                                                                               SIM 3750
C        SET DIRECTION FLAG                                                     SIM 3760
C                                                                               SIM 3770
530   FLAG=.TRUE.                                                               SIM 3780
      GO TO 550                                                                 SIM 3790
540   FLAG=.FALSE.                                                              SIM 3800
550   IT=0                                                                      SIM 3810
      DO 1000 I=1,72                                                            SIM 3820
      IA=0                                                                      SIM 3830
```

```
      IB=0                                                              SIM 3840
      IF (ACTMOD(I,7).GT.0.0) GO TO 560                                 SIM 3850
C                                                                       SIM 3860
C        SUM EARLIEST UNSCHEDULED BLOCK OF TIME                         SIM 3870
C                                                                       SIM 3880
      IT=IT+1                                                           SIM 3890
      GO TO 1000                                                        SIM 3900
560   IC=I+1                                                            SIM 3910
      IQ=ACTMOD(IC,7)                                                   SIM 3920
      IF (IT.EQ.0.AND.IQ.GT.0) GO TO 1000                               SIM 3930
      IF (FLAG) GO TO 570                                               SIM 3940
C                                                                       SIM 3950
C        DECREMENT/INCREMENT TIME INTERVAL                              SIM 3960
C                                                                       SIM 3970
      IA=I-2                                                            SIM 3980
      IF (IA.LT.1) IA=1                                                 SIM 3990
      GO TO 580                                                         SIM 4000
570   IA=I+2                                                            SIM 4010
      IF (IA.GT.72) IA=72                                               SIM 4020
580   IF (ACTMOD(IA,7).EQ.0.0) GO TO 750                                SIM 4030
C                                                                       SIM 4040
C        IF LOCATIONS OF ACTIVITY DIFFER, BRANCH TO TRAVEL TIME SEGEMNT SIM 4050
C                                                                       SIM 4060
      K=ACTMOD(IA,7)                                                    SIM 4070
      AL=ACTMOD(IA,8)                                                   SIM 4080
      IF (ACTMOD(IA,8).EQ.ACTMOD(I,8)) GO TO 600                        SIM 4090
590   CALL TTIME (FLAG,IA,K,AL,OK,TR,T,DUR)                             SIM 4100
      IF (OK) GO TO 980                                                 SIM 4110
      GO TO 590                                                         SIM 4120
600   KK=1                                                              SIM 4130
C                                                                       SIM 4140
C        FIND DURATION PROBABILITY OF PRECEDING/FOLLOWING ACTIVITY      SIM 4150
```

```
C
      CALL RNUM (R,VAL,OVL)
610   VAL=VAL+DACT(K,KK,1)
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 620
      OVL=OVL+VAL
      KK=KK+1
      GO TO 610
620   IF (KK-3) 660,660,630
630   KD=TR(KK)
      IF (KD.GT.15) KD=15
      IF (FLAG) GO TO 640
      IB=I-1
      GO TO 650
640   IB=I+1
650   ACTMOD(IB,9)=KD
C
C        ASSIGN ACTIVITY AND LOCATION OF PRECEDING/FOLLOWING TIME
C        INTERVAL
C
      ACTMOD(IB,8)=ACTMOD(IA,8)
      ACTMOD(IB,7)=ACTMOD(IA,7)
      GO TO 930
C
C        WHEN LOCATION IS FIXED BETWEEN TWO SCHEDULED INTERVALS, THE
C        FOLLOWING SEGMENT FINDS MOST PROBABLE ACTIVITY AT FIXED TIME
C        AND LOCATION.
C
660   IF (FLAG) GO TO 670
      IB=I-1
      GO TO 680
670   IB=I+1
680   INT=12
```

```
      L=1                                                               SIM 4480
690   IF (IB.LE.INT) GO TO 700                                          SIM 4490
      L=L+1                                                             SIM 4500
      INT=12*L                                                          SIM 4510
      GO TO 690                                                         SIM 4520
700   KT=L                                                              SIM 4530
      K=ACTMOD(IA,8)                                                    SIM 4540
      K3=1                                                              SIM 4550
      CALL RNUM (R,VAL,OVL)                                             SIM 4560
710   VAL=VAL+ALOC(K3,K,KT)                                             SIM 4570
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 720                              SIM 4580
      OVL=OVL+VAL                                                       SIM 4590
      K3=K3+1                                                           SIM 4600
      GO TO 710                                                         SIM 4610
C                                                                       SIM 4620
C        ASSIGN ACTIVITY, DURATION, AND LOCATION TO TIME INTERVAL.      SIM 4630
C                                                                       SIM 4640
720   ACTMOD(IB,7)=K3                                                   SIM 4650
      ACTMOD(IB,8)=ACTMOD(IA,8)                                         SIM 4660
      KK=1                                                              SIM 4670
      CALL RNUM (R,VAL,OVL)                                             SIM 4680
730   VAL=VAL+CACT(K3,KK,1)                                             SIM 4690
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 740                              SIM 4700
      OVL=OVL+VAL                                                       SIM 4710
      KK=KK+1                                                           SIM 4720
      GO TO 730                                                         SIM 4730
740   KD=TR(KK)                                                         SIM 4740
      IF (KD.GT.15) KD=15                                               SIM 4750
      ACTMOD(IB,9)=KD                                                   SIM 4760
      GO TO 980                                                         SIM 4770
C                                                                       SIM 4780
C        THIS SEGMENT, EMPLOYING LOOK-AHEAD OR LOOK-BACK PROCEDURES,    SIM 4790
```

```
C          DETERMINES THE CHOICE, DURATION, AND LOCATION OF ACTIVITIES    SIM 4800
C          THAT PRECEDE OR FOLLOW AN ACTIVITY PEG OR FIX                  SIM 4810
C                                                                         SIM 4820
750   IF (FLAG) GO TO 760                                                 SIM 4830
      IP=I                                                                SIM 4840
      IU=I-IT                                                             SIM 4850
      GO TO 770                                                           SIM 4860
760   IP=I                                                                SIM 4870
      IU=I+IT                                                             SIM 4880
770   IF (FLAG) GO TO 780                                                 SIM 4890
      IP=IP-1                                                             SIM 4900
      IF (IP.LT.IU) GO TO 980                                             SIM 4910
      GO TO 790                                                           SIM 4920
780   IP=IP+1                                                             SIM 4930
      IF (IP.GT.IU) GO TO 980                                             SIM 4940
C                                                                         SIM 4950
C          SEGMENT TO FIND MOST PROBABLE ACTIVITY LINK                    SIM 4960
C                                                                         SIM 4970
790   CALL TRAN (IP,FLAG,IT,Q)                                            SIM 4980
      K=Q                                                                 SIM 4990
      KK=1                                                                SIM 5000
C                                                                         SIM 5010
C          FIND DURATION PROBABILITY OF ACTIVITY                          SIM 5020
C                                                                         SIM 5030
      CALL RNUM (R,VAL,CVL)                                               SIM 5040
800   VAL=VAL+DACT(K,KK,1)                                                SIM 5050
      IF (R.GT.CVL.AND.R.LE.VAL) GO TO 810                                SIM 5060
      CVL=CVL+VAL                                                         SIM 5070
      KK=KK+1                                                             SIM 5080
      GO TO 800                                                           SIM 5090
810   IK=KK/15                                                            SIM 5100
      IF (IK.GT.IT) GO TO 790                                             SIM 5110
```

```
      RK=KK/15
      IR=(RK-FLOAT(IK))*15.
      IF (FLAG) GO TO 920
      IBF=IP-IK
      IF (IBF-IU.GE.1) GO TO 840
      GO TO 830
820   IBT=IP+IK
      IF (IBT-IU.LE.1) GO TO 840
830   TRIP=.FALSE.
      GO TO 850
840   TRIP=.TRUE.
C
C        PROCEDURE TO DETERMINE THE LOCATION OF ACTIVITY
C
850   INT=12
      L=1
860   IF (IP.LE.INT) GO TO 870
      L=L+1
      INT=12*L
      GO TO 860
870   KT=L
      K3=1
      CALL RNUM (R,VAL,OVL)
880   VAL=VAL+ALOC(K,K3,KT)
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 890
      OVL=OVL+VAL
      K3=K3+1
      GO TO 880
890   AL=K3
      IF (ACTMOD(I,3).EQ.AL) GO TO 910
      IF (TRIP) GO TO 900
      GO TO 790
```

```
900   CALL TTIME (FLAG,IP,K,AL,OK,TR,T,DUR)
      IF (OK) GO TO 910
      GO TO 790
910   ACTMOD(IP,7)=Q
      ACTMOD(IP,8)=K3
      ACTMOD(IP,9)=15
      IF (FLAG) GO TO 920
      IP=IP-1
      IF (IP.LT.IBF) GO TO 930
      GO TO 910
920   IP=IP+1
      IF (IP.GT.IBT) GO TO 930
      GO TO 910
930   IF (RK.EQ.0.0) GO TO 960
      IF (FLAG) GO TO 940
      IM=IP-1
      GO TO 950
940   IM=IP+1
950   ACTMOD(IM,7)=Q
      ACTMOD(IM,8)=K3
      ACTMOD(IM,9)=RK
960   IF (FLAG) GO TO 970
      IF (IU.GE.IBF) GO TO 980
      IP=IBF
      GO TO 770
970   IF (IU.LE.IBT) GO TO 980
      IP=IBT
      GO TO 770
980   IT=0
      IF (FLAG) GO TO 990
      FLAG=.TRUE.
      GO TO 1000
```

```
999   FLAG=.FALSE.
1000  CONTINUE
      CALL OPUT (N)
      GO TO 20
1010  WRITE (6,1060) N
      GO TO 1030
1020  WRITE (6,1070) GNUM
1030  STOP
C
C        FORMAT STATEMENTS
C
1040  FORMAT (2I5)
1050  FORMAT (8(1X,7F1.0,1X))
1060  FORMAT (*1*,10X,*ERRORONDATAINPUT*/*0*,11X,*SEEDATAARRAY*,I2)
1070  FORMAT (*1*,10X,*NORMALTERMINATIONOFSIMULATIONFORPATTERNGROUP*,I2)
      END
      SUBROUTINE INPUTS (N)
      COMMON /A1/ SEED,RESNUM,GNUM
      COMMON /B2/ FACT(72,65),ALINK(9,9),FIXT(65,16,4),ALOC(65,9,6)
      COMMON /C3/ ACTMOD(73,10),DACT(65,10,2),TDIST(72,5)
      INTEGER RESNUM,GNUM,FIN
      DATA FIN/99999/
C
C        READ CUMULATIVE PROBABILITY DISTRIBUTIONS FOR SIMULATION
C
      L=0
      DO 20 I=1,72
20    READ (8,190) (FACT(I,J),J=1,65)
      READ (8,210) M
      L=L+1
      IF (M.EQ.9999) GO TO 30
      N=L
```

```
      RETURN
   30 DO 40 I=1,72
   40 READ (8,200) (TDIST(I,J),J=1,5)
      READ (8,210) M
      L=L+1
      IF (M.EQ.9999) GO TO 50
      N=L
      RETURN
   50 DO 60 I=1,65
   60 READ (8,220) (DACT(I,J,1),J=1,10)
      DO 70 I=1,65
   70 READ (8,230) (DACT(I,J,2),J=1,10)
      READ (8,210) M
      L=L+1
      IF (M.EQ.9999) GO TO 80
      N=L
      RETURN
   80 DO 100 K=1,4
      DO 90 I=1,65
   90 READ (8,190) (FIXT(I,J,K),J=1,16)
  100 CONTINUE
      READ (8,210) M
      L=L+1
      IF (M.EQ.9999) GO TO 110
      N=L
      RETURN
  110 DO 140 K=1,6
      DO 130 I=1,65,2
      IF (I.EQ.65) GO TO 120
      II=I+1
      READ (8,240) (ALOC(I,J,K),J=1,9),(ALOC(II,J,K),J=1,9)
      GO TO 130
```

```
120   READ (8,240) (ALOC(I,J,K),J=1,9)
130   CONTINUE
140   CONTINUE
      READ (3,210) M
      L=L+1
      IF (M.EQ.9999) GO TO 150
      N=L
      RETURN
150   DO 160 I=1,9
160   READ (5,250) (ALINK(I,J),J=1,9)
      RETURN
C
      ENTRY OPUT
C
C        OUTPUT DATA DESCRIBING EACH ACTIVITY MODULE IN AN INDIVIDUAL'S
C        ACTIVITY SEQUENCE ON TAPE 10
C
      DO 180 I=1,72
      I1=ACTMOD(I,7)
      I2=ACTMOD(I,8)
      I3=ACTMOD(I,9)
      IF (ACTMOD(I,10).EQ.0.0) GO TO 170
      J=ACTMOD(I,10)
      IDUR=(ACTMOD(I,10)-FLOAT(IDUR))*100.
      IF (IDUR.LT.8) GO TO 170
      I1=J
      I2=99
      I3=IDUR
170   WRITE (10,260) RESNUM,GNUM,I,I1,I2,I3
180   CONTINUE
      WRITE (10,270) FIN
      RETURN
```

```
C
C        FORMAT STATEMENTS
C
190   FORMAT (10X,25F3.0)
200   FORMAT (5X,5F5.0)
210   FORMAT (I5)
220   FORMAT (10X,10F5.0)
230   FORMAT (10X,10F5.1)
240   FORMAT (13X,9F3.0,23X,9F3.0)
250   FORMAT (12X,9F5.0)
260   FORMAT (6I5)
270   FORMAT (I5)
      END
      SUBROUTINE RNUM (R,VAL,CVL)
      COMMON /A1/ SED,RESNUM,GNUM
      IR=(SED-1.0)*RANF(-1)+1.0
      R=IR
      VAL=0.0
      CVL=0.0
      RETURN
      END
      SUBROUTINE SCON (SC,T)
C
C        SCON COMPUTES THE TOTAL SUBJECTIVE CONSTRAINT INDEX (T) FOR A
C        TIME INTERVAL
C
      DIMENSION SC(4)
      P=1000.
      Q=2000.
      T=0.0
      DO 40 J=1,4
      IF (SC(J).EQ.2.0) GO TO 20
```

```
      T=T+P
      GO TO 30
20    T=T+Q
30    P=P/10.
      Q=Q/10.
40    CONTINUE
      RETURN
      END
      SUBROUTINE TTIME (FLAG,IP,K,AL,OK,TR,T,DUR)
C
C        TTIME:  PROCEDURE TO ESTIMATE TRAVEL TYPE AND TIME BETWEEN
C        ACTIVITY LOCATIONS
C
      COMMON /C3/ ACTMOD(73,10),DACT(65,10,2),TDIST(72,5)
      DIMENSION TR(7), T(5), DUR(10)
      LOGICAL FLAG,MV,OK
      DATA (TR(J),J=1,7)/9.,17.,23.,32.,42.,45.,65./
      DATA (T(J),J=1,5)/5.,10.,20.,30.,60./
      DATA (DUR(J),J=1,10)/5.,10.,15.,30.,45.,60.,90.,120.,180.,300./
C
C        DETERMINE TIME AVAILABLE FOR TRAVEL
C
      KP=IP
      T4T=0
      T4T=T4T+(15.-ACTMOD(KP,9))
      GO TO 30
20    T4T=T4T+15.
30    IF (FLAG) GO TO 40
      KP=KP-1
      GO TO 50
40    KP=KP+1
50    IF (KP.LT.1.OR.KP.GT.72) GO TO 60
```

```
      IF (ACTMOD(KP,7).EQ.0.0) GO TO 20
      IF (ACTMOD(KP,8).EQ.AL) GO TO 190
C
C        GENERATE RANDOM NUMBERS TO DETERMINE TRIP LENGTH ACCORDING TO
C        TIME OF DAY
C
60    MV=.FALSE.
70    CALL RNUM (R,VAL,OVL)
      L=1
80    VAL=VAL+TDIST(IP,L)
      IF (R.GT.OVL.AND.R.LE.VAL) GO TO 90
      OVL=OVL+VAL
      L=L+1
      GO TO 80
90    IF (T4T.GE.T(L)) GO TO 100
      IF (MV) GO TO 240
      MV=.TRUE.
      GO TO 70
C
C        IF TIME AVAILABLE FOR TRAVEL IS GREATER THAN TRIP LENGTH,
C        ASSIGN TRAVEL TYPE AND TIME TO ACTIVITY MODULE.
C
100   JK=1
110   IF (FLAG) GO TO 120
      IF (ACTMOD(IP,7).LT.TR(JK)) GO TO 140
      GO TO 130
120   IF (ACTMOD(KP,7).LT.TR(JK)) GO TO 140
130   JK=JK+1
      GO TO 110
140   TT=15.-ACTMOD(IP,9)
      TTT=T4T-TT
      TT=TT/100.
```

```
      ACTMOD(IP,10)=TR(JK)+TT
      ACTMOD(IP,7)=K
      ACTMOD(IP,8)=AL
150   IF (FLAG) GO TO 160
      KP=KP-1
      GO TO 170
160   IF (TTT.LE.0.0) GO TO 230
      KP=KP+1
170   TQ=TTT/15.
      IF (TQ.LT.1) GO TO 180
      ACTMOD(KP,10)=TR(JK)+0.15
      ACTMOD(KP,7)=TR(JK)
      TTT=TTT-15.
      GO TO 150
180   ITQ=TQ
      TQ=TQ-FLCAT(ITQ)
      TT=(TQ*15.)/100.
      ACTMOD(KP,10)=TR(JK)+TT
      IF (TT.GT.0.07) ACTMOD(KP,7)=TR(JK)
      GO TO 230
190   IF (FLAG) GO TO 200
      KP=KP-1
      GO TO 210
200   KP=KP+1
210   IF (ACTMOD(IP,9).EQ.0.0.AND.ACTMOD(KP,9).EQ.0.0) GO TO 240
      TT=T4T-(15.-ACTMOD(IP,9))
      IF (TT-15.) 220,220,240
220   ACTMOD(IP,7)=K
      ACTMOD(IP,8)=AL
      ACTMOD(IP,9)=15.
      ACTMOD(KP,9)=(DACT(K,1,2)+DACT(K,2,2)+DACT(K,3,2))/3.
      ACTMOD(KP,8)=AL
```

```
      ACTMOD(KP,7)=K                                                    TIM
230   OK=.TRUE.                                                         TIM
      RETURN                                                            TIM
240   OK=.FALSE.                                                        TIM
      RETURN                                                            TIM
      END                                                               TIM
      SUBROUTINE TRAN (IP,FLAG,IT,Q)                                    TRN
C                                                                       TRN
C        USING TRANSITION PROBABILITIES, TRAN DERIVES ACTIVITY LINKAGES TRN
C        FOR BOTH FORWARD AND BACKWARD OPERATIONS                       TRN
C                                                                       TRN
      COMMON /B2/ FACT(72,65),ALINK(9,9),FIXT(65,16,4),ALOC(65,9,6)     TRN
      INTEGER TRAN1(9),TRAN2(9)                                         TRN
      LOGICAL FLAG                                                      TRN
      DATA (TRAN1(I),I=1,9)/1,10,15,18,24,33,43,46,53/                  TRN
      DATA (TRAN2(I),I=1,9)/9,14,17,23,32,42,45,52,65/                  TRN
      K=1                                                               TRN
20    IF (IP.GE.TRAN1(K).AND.IP.LE.TRAN2(K)) GO TO 30                   TRN
      K=K+1                                                             TRN
      GO TO 20                                                          TRN
30    I=K                                                               TRN
      J=1                                                               TRN
      CALL RNUM (R,VAL,OVL)                                             TRN
40    IF (FLAG) GO TO 50                                                TRN
      VAL=VAL+ALINK(J,I)                                                TRN
      GO TO 60                                                          TRN
50    VAL=VAL+ALINK(I,J)                                                TRN
60    IF (R.GT.OVL.AND.R.LE.VAL) GO TO 70                               TRN
      OVL=OVL+VAL                                                       TRN
      J=J+1                                                             TRN
      GO TO 40                                                          TRN
70    II=TRAN1(J)                                                       TRN
```

```
      ACTMOD(KP,7)=K                                                    TIM  890
230   OK=.TRUE.                                                         TIM  900
      RETURN                                                            TIM  910
240   OK=.FALSE.                                                        TIM  920
      RETURN                                                            TIM  930
      END                                                               TIM  940
      SUBROUTINE TRAN (IP,FLAG,IT,Q)                                    TRN   10
C                                                                       TRN   20
C        USING TRANSITION PROBABILITIES, TRAN DERIVES ACTIVITY LINKAGES TRN   30
C        FOR BOTH FORWARD AND BACKWARD OPERATIONS                       TRN   40
C                                                                       TRN   50
      COMMON /B2/ FACT(72,65),ALINK(9,9),FIXT(65,16,4),ALOC(65,9,6)     TRN   60
      INTEGER TRAN1(9),TRAN2(9)                                         TRN   70
      LOGICAL FLAG                                                      TRN   80
      DATA (TRAN1(I),I=1,9)/1,10,15,18,24,33,43,46,53/                  TRN   90
      DATA (TRAN2(I),I=1,9)/9,14,17,23,32,42,45,52,65/                  TRN  100
      K=1                                                               TRN  110
20    IF (IP.GE.TRAN1(K).AND.IP.LE.TRAN2(K)) GO TO 30                   TRN  120
      K=K+1                                                             TRN  130
      GO TO 20                                                          TRN  140
30    I=K                                                               TRN  150
      J=1                                                               TRN  160
      CALL RNUM (R,VAL,OVL)                                             TRN  170
40    IF (FLAG) GO TO 50                                                TRN  180
      VAL=VAL+ALINK(J,I)                                                TRN  190
      GO TO 60                                                          TRN  200
50    VAL=VAL+ALINK(I,J)                                                TRN  210
60    IF (R.GT.OVL.AND.R.LE.VAL) GO TO 70                               TRN  220
      OVL=OVL+VAL                                                       TRN  230
      J=J+1                                                             TRN  240
      GO TO 40                                                          TRN  250
70    II=TRAN1(J)                                                       TRN  260
```

```
      JJ=TRAN2(J)                                                         TRN  270
      Q=0.0                                                               TRN  280
      DO 80 KK=II,JJ                                                      TRN  290
      IF (FACT(IT,KK).GT.Q) Q=KK                                          TRN  300
80    CONTINUE                                                            TRN  310
      RETURN                                                              TRN  320
      END                                                                 TRN  330
      FUNCTION UNIFRM (IX)                                                UNF   10
C                                                                         UNF   20
C        UNIFRM GENERATES RANDOM NUMBERS UNIFORMLY DISTRIBUTED BETWEEN    UNF   30
C        0 AND 1.                                                         UNF   40
C                                                                         UNF   50
      LOGICAL FLAG                                                        UNF   60
      DATA FLAG/.FALSE./,N/35/,M/2/                                       UNF   70
      IOR(II,JJ)=(II.O.JJ).A.(.N.(II.A.JJ))                               UNF   80
      IF (FLAG) GO TO 40                                                  UNF   90
      FLAG=.TRUE.                                                         UNF  100
      M1=0                                                                UNF  110
      M2=0                                                                UNF  120
      J=1                                                                 UNF  130
      L=M-N                                                               UNF  140
      DO 20 I=1,N                                                         UNF  150
      M1=M1.O.J                                                           UNF  160
      IF (I.LE.M) M2=M2.O.J                                               UNF  170
20    J=SHIFT(J,1)                                                        UNF  180
      A=M1                                                                UNF  190
      IA=IX                                                               UNF  200
      IF (IX.NE.0) GO TO 30                                               UNF  210
      CALL TIME (IA)                                                      UNF  220
      IA=SHIFT(IA,-12)                                                    UNF  230
30    IA=IA.A.M1                                                          UNF  240
      M1=.N.M2.A.M1                                                       UNF  250
```

```
      GO TO 50                                                          UNF   260
40    IB=INOR(IA,SHIFT(IA,M))                                           UNF   270
      IA=IB.A.M1.O.INOR(IA,SHIFT(IB,L)).A.M2                            UNF   280
50    UNIFRM=FLOAT(IA)/A                                                UNF   290
      RETURN                                                            UNF   300
      END                                                               UNF   310
```

APPENDIX G.

SUMMARY OF SIGNIFICANCE TESTS.

TABLE G-1.

RESULTS OF SIGNIFICANCE TESTS FOR GROUP I

Member No.	Activity Sequences		Locational Sequences	
	D	X^2	D	X^2
1	.113	17.438	.126	20.047
2	.236	81.938	.142	33.835
3	.211	60.126	.160	42.391
4	.262	97.474	.188	48.761
5	.227	57.506	.204	88.786
6	.314	124.586	.217	107.634
7	.280	109.423	.196	61.803
8	.214	71.562	.151	33.867
9	.080	9.267 *	.092	12.933
10	.199	50.433	.143	37.867
11	.253	84.364	.216	98.440
12	.343	107.766	.289	110.434
13	.137	26.497	.141	28.117
14	.295	89.733	.198	54.218
15	.142	24.442	.132	22.584
16	.188	50.449	.138	35.542
17	.248	82.907	.363	148.977
18	.297	100.919	.337	124.206
19	.402	229.413	.290	139.270
20	.190	46.633	.173	46.279

TABLE G-1 -- CONTINUED

21	.323	97.686	.249	88.360
22	.345	127.298	.217	102.265
23	.298	93.556	.213	94.667
24	.207	64.448	.185	46.525
25	.193	48.772	.128	23.641
26	.212	57.529	.194	58.223
27	.139	20.263	.145	26.003
28	.335	101.284	.267	75.618
29	.084	9.280 *	.090	8.993 *
30	.258	86.538	.197	62.288
31	.354	131.472	.206	93.505
32	.211	51.497	.132	19.664
33	.273	121.560	.170	26.642
34	.284	117.643	.139	60.010
35	.188	60.242	.116	17.670
36	.326	106.599	.271	97.412
37	.280	89.750	.184	53.292
38	.187	34.704	.168	18.993
39	.145	30.763	.125	26.034
40	.133	32.704	.114	13.396
41	.315	105.945	.217	68.584
42	.151	17.727	.146	27.423
43	.136	19.851	.130	26.527
44	.195	58.635	.086	7.885 *
45	.259	77.948	.144	36.768

TABLE G-1 -- CONTINUED

46	.148	31.645	.113	15.284
47	.362	112.905	.217	71.433
48	.136	28.851	.102	17.667
49	.257	63.875	.119	22.741
50	.237	78.659	.124	35.831
51	.315	87.542	.188	51.219
52	.143	27.668	.087	9.305 *
53	.412	183.552	.231	76.197
54	.304	146.001	.177	40.235
55	.248	83.919	.137	24.534
56	.323	97.686	.190	25.893
57	.174	36.057	.136	25.993
58	.198	52.389	.124	16.576
59	.283	84.956	.234	57.668
60	.182	48.933	.121	21.737
61	.093	10.064	.067	6.880 *
62	.273	86.549	.127	28.482
63	.139	26.562	.145	33.835
64	.227	57.406	.204	86.008
65	.298	94.919	.135	21.475
66	.348	123.162	.202	89.591
67	.191	45.433	.173	47.922
68	.243	68.250	.167	38.445

*Significant at the 0.01 level.

TABLE G-2.

SUMMARY OF SIGNIFICANCE TESTS FOR GROUP II

Member No.	ACTIVITY SEQUENCES		LOCATIONAL SEQUENCES	
	D	X^2	D	X^2
1	.217	59.297	.142	23.490
2	.138	27.612	.117	20.257
3	.257	56.857	.118	22.471
4	.124	18.976	.086	8.667 *
5	.180	30.691	.102	15.558
6	.083	9.006 *	.078	9.017 *
7	.220	47.663	.090	21.301
8	.155	34.337	.130	16.702
9	.218	71.003	.134	27.751
10	.164	21.331	.090	12.985
11	.110	11.954	.107	13.514
12	.144	30.733	.125	25.034
13	.196	52.538	.089	17.891
14	.236	56.230	.164	37.956
15	.132	29.704	.141	34.360
16	.141	25.869	.088	10.443
17	.183	33.799	.126	26.732
18	.311	94.945	.192	44.489
19	.151	17.724	.119	26.085
20	.164	61.962	.148	25.524
21	.192	43.357	.130	30.033
22	.136	18.951	.097	15.044
23	.216	44.327	.190	59.584

TABLE G-2 -- CONTINUED

24	.091	6.423 *	.111	19.635
25	.251	80.036	.142	30.980

*Significant at the 0.01 level.

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