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The city around the clock: space-time patterns of urban ecological structure

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Abstract. The space-time diaries for more than 1500 respondents in Halifax, Canada are used to generate census-like data for spatial units at six different times during the day. A space-time factorial ecology reveals distinctive diurnal patterns in the city's social geography. Aside from illustrating temporal variations in traditional factors, such as status and family orientation, additional factors relating to activity patterns and their social settings are identified.

1 Introduction

The ecological composition of cities is as much a product of the timing of events as it is of the spacing of people, activities, and structures. This theme was recognised in several influential essays in the first half of this century (Wirth, 1938; Whittlesey, 1945; Engel-Frisch, 1948; Hawley, 1950). Nonetheless, with notable exceptions, research on urban sociodemographic patterns continues to focus dominantly on land use, social-group territories, and long-term processes of change. Investigations based on the classical models of urban social ecology (Burgess, 1925; Hoyt, 1939), and recent extensions based on the factor analysis of multivariate census data (Berry, 1971), have considered population movements and demographic shifts over years and decades. And interest in functional transactions at the daily level have been confined largely to more segmented views of urban structure and to particular types of activities.

After World War II, the escalation of urban growth, traffic problems, concerns for allocating public and private services, and even concerns for the evacuation and sheltering of people during civil emergencies, prompted some planners (Foley, 1954; Schmitt, 1956; Chapin and Stewart, 1959) to suggest that urban population distributions be monitored throughout the day. In spite of their initial and imaginative experiments, most enquiries into social patterns in cities continued in their reliance on census data. Task-specific surveys (traffic counts, origin-destination studies, shopping surveys, and census aggregations by place of work) allow for piece-meal reconstructions of some aspects of daily human movements. But, useful as they are, they offer only limited insights for discerning the general patterns of routine which underlie the minute-by-minute synchronisation of diverse activities and which impart a decided rhythm to individual life.

In an ecological sense, the mixing of people with different backgrounds, predominantly during the daytime hours, is in sharp contrast to the homogeneity associated with the nighttime mix in residential areas. In general, it is the functional specialisations and role needs of people that bring them together at different times. Control over the timing of these movements is exercised by societal rules (for example, the eight-hour day, honouring the Sabbath, etc) and by dominant institutions that set the opening and closing hours of work, service availability, schools, public transportation, and other critical events and facilities. Although the schedules and programmes of individuals may differ, each pursuing a variant of a routine peculiar to her or his specialisation, role, life-style, or stage in the life cycle, the end product is a routine that is carefully interwoven with the programmes of other individuals and with

the timing of activities at particular sites. In the process of their movements, people encounter those whom they would not find in their own neighbourhoods, people with different incomes, religions, ethnicity, family circumstances, and so forth. Possibilities exist for the exchange of information and for the sharing of values and concerns.

As a result of the temporal coordination of individual movements, the human content of urban subregions is in continual flux. However, as a rule, there occurs a distinct pattern of temporal specialisation of areas based on systematic variations in the characteristics of the populations that occupy them at different times of the day.

It is not possible to document all the daily transactions that lead to the particular characteristics of a given region at a specific time. However, the ability to trace the daily movements and activities of individuals and to identify their socioeconomic characteristics would permit the creation of a 'census-like' accounting for any time of the day at any level of spatial aggregation. Such an accounting would provide the evidence needed to relate Lynch's (1972; 1976) ideas on the temporal imageability of places, or Melbin's (1978) focus on the greater use of nighttime, with contextual frameworks concerning the dominant rhythms and activity patterns affecting the city as a whole or particular segments of the population. An integrated space–time framework for gathering and analysing such information would be of advantage to many professions and disciplines concerned with the description, explanation, and control of urban processes. However, the principal impediment to incorporating these considerations in practical analyses, and also ultimately in inductive theory building and deductive hypothesis testing, has been lack of data.

In an important breakthrough, Taylor and Parkes (1975) illustrated how such data, if available, could be used to enhance our understanding of urban ecological structure. They used artificial data for a hypothetical British city of 200000 people to explore an experimental design based on the use of factor analysis. Values were assigned to twenty-four variables for each of ten geographical areas at eight separate times for a typical workday. Each geographical unit was treated as eight separate observations, yielding a total of eighty space–time units (STUs). The variables included social and demographic characteristics of the population in each STU, and information on their dominant activities and travels. Common factor analysis reduced this 22 x 80 matrix into a set of eight factors, each represented by maps of factor scores for STUs. Distinct temporal variations in the spatial patterns of class segregation, bright-lights entertainment, journey to work, age-group segregation, and workday cycles were recognised. Although the use of artificial data precluded any substantive conclusions, Taylor and Parkes drew attention to the limitations of conventional ecological studies and underscored the importance of being able to match such a methodological approach with actual data. Indeed, their seminal contribution was a strong motivating force behind the study design and empirical documentation that follow.

2 Objectives

Our objective in this paper is to replicate and extend the Taylor and Parkes's (1975) experiment using actual data for the city of Halifax, Canada. Along with other recent contributions (Chapin, 1974; Hanson and Hanson, 1981; Dangschat et al, 1982) this study exploits the advantages of space–time budgets (Anderson, 1971) for reconstructing the activities and whereabouts of respondents at different times of the day and for compiling census-like data for STUs. As far as possible, the investigation retains close correspondence with Taylor and Parkes's study design.

The replication requires the designation of STUs and the ability to trace the locations and activities of individuals throughout the day. Furthermore, the sample of respondents must be representative of the general population in regard to socio-demographic mix and location of residence. The data base for Halifax meets all of

these requirements. In addition, with a population of approximately 200000 and with a nearly full-employment economy at the time of the survey, the study area matches closely the hypothetical city used in Taylor and Parkes's experiment.

3 The Halifax space-time budget survey

The data for this analysis were gathered between October 1971 and May 1972 by the Institute of Public Affairs at Dalhousie University (Harvey and Clark, 1973; Elliott et al, 1976). Included was a random sample of single-day diaries for more than 2100 respondents in the twin cities of Halifax and Dartmouth and in the surrounding parts of the metropolitan region. Aside from following the methodology of the International Time-Budget Study (Szalai, 1972), the Institute also geocoded the activity sites to the nearest 0.10 km and compiled a sociodemographic profile on each respondent. People under nineteen years of age and over sixty-four years of age, and those from households lacking at least one full-time nonagricultural employee, were excluded from the survey. Otherwise, Harvey and Clark (1973) have been able to document the sample's close correspondence with results from the 1971 Census of Canada.

4 Designating space-time units

Taylor and Parkes (1975, page 673) viewed STUs as an integration of the "taxonomy of the city's social geographic space with a taxonomy of diurnal 'social' time". Operationally, this requires the division of the day into time periods that are representative of dominant types of activities, and the division of the city's area into spatial units akin to census tracts. In this study, Dartmouth and Halifax, excluding areas beyond their political boundaries, were divided into thirty-two 'pseudo' census tracts (PCTs), and six time slices were designated. Thus there are six observations for each tract, creating a total of 192 STUs. The 1561 sampled respondents, whose residences are located within this region, represent the basis for describing each tract's sociodemographic composition. As sampled individuals move from one tract to another, or in and out of the study region, the numbers and average characteristics of the tracts' populations are altered. However, since these values are, in part, products of how time and space are divided and combined into STUs, it is essential to isolate the rationale for each.

The selected study times were based on empirical evidence of when the participation rate was highest for each of six dominant types of activities. These include sleeping—2.00 am, morning worktime—9.10 am, lunchtime—12.15 pm, afternoon worktime—3.00 pm, early-evening discretionary time—7.00 pm, and late-evening activities—10.30 pm. Except for the exclusion of morning and afternoon commuter periods, these are the same as the 'activity bundles' used in the Taylor and Parkes's (1975) study. Although the six time slices may be insufficient for capturing activity patterns that follow other periodicities, they are satisfactory for demonstrating the technical procedures used in this study and they should permit substantive observations of patterns that would be completely camouflaged in studies where time of day is ignored entirely.

The division of the study area into spatial units is less direct than the sector-ring combinations used in Taylor and Parkes's hypothetical city. Moreover, census tracts were unacceptable because of the random sampling procedure used in gathering the Halifax data. Within the study region, sixty-eight census enumeration areas (EAs) were randomly selected from the 380 Census of Canada EAs for 1971. Then, households were randomly selected in proportion to the chosen EAs' total share of the city's households. Finally, within households, individuals were selected such that, in aggregate, they would match the metropolitan area's population characteristics.

To overcome the problem of incomplete spatial coverage, an algorithm was developed to combine the 380 EAs according to a least increase in the sums-of-squares criterion, such that each new spatial unit—PCT—contained at least one of the sampled EAs as a core and such that there was contiguity among the EAs of any resulting PCT. The forty variables used in this procedure were derived from the 1971 Census of Canada. Included were fourteen sociodemographic variables: five age-related variables, two concerning educational status, four related to housing (age, ownership, housetype, and rent), two to familial status (marriage and number of children), and one to language spoken.

Since the PCTs were established to maximise the internal homogeneity of social and demographic content, they are, in general, more suitable for urban ecological analyses than are traditional census tracts. In principle, census tracts are supposed to be homogeneous, but, in practice, no objective standards of homogeneity are used and other constraints impinge on this goal. Among these are population limits, and the necessity that tract boundaries follow easily identifiable natural and man-made features and that they be either the same as or composites of tracts used in previous census years.

5 Sociodemographic and activity measures

Having established a suitable set of STUs, it is possible to sort the 1561 respondents according to the geocoding of events listed in their diaries for the six study times. Then, for each STU, average or percentage values may be calculated for the variables listed in table 1. The variables were selected to provide a range of measures relating to the individual traits and activity patterns of respondents. Whereas the fourteen

Table 1. Sociodemographic and time-budget variables.

Variable	Variable
Sociodemographic	*Percentage in travel*
1 Average age	21 Employment related
2 Female (%)	22 To or from nonemployment obligatory activities
3 Not married (%)	23 To or from discretionary activities
4 Widowed, divorced, or separated (%)	
5 Employed (%)	*Percentage occupying sites*
6 Employed as skilled, semiskilled, or unskilled worker (%)	24 In own residence
7 Average median household income (by income groups)	25 At workplace
8 Homeowners (%)	26 In yard, garden, or court of own home
9 Paying more than $200 rent per month (%)	27 At someone else's home
10 Living in same residence for more than two years	28 On streets or in public transportation
11 No car owned by household (%)	29 At indoor leisure establishment
12 Average number of years of schooling	30 At outdoor leisure establishment
13 At least one year of university education (%)	31 In eating and drinking locale
14 Protestant (%)	32 At public or private service establishment
Percentage in activity [a]	*Percentage in social contact with:*
15 Employment-related	33 Self only
16 Home-centred obligatory	34 Spouse or fiancé(e)
17 Nonhome-centred obligatory	35 Child of household
18 Home-centred discretionary	36 Adult member of household or other relative
19 Education and voluntary participation	37 Colleagues and students
20 Active and passive leisure	38 Organisation members
	39 Neighbours
	40 Officials or formal contacts

[a] Table 2 provides a description of the activity classification in relationship to the activity coding of the Multinational Time-Budget Study (Szalai, 1972).

sociodemographic variables are commonly included in other studies of urban factorial ecology, the activity, travel, site, and social-contact variables are associated with the kinds of data available in time-budget studies. Table 2 provides some explanatory notes on the activity codings and shows their relationships to those of the Multinational Comparative Time-Budget Study (Szalai, 1972). The distinction between obligatory and discretionary activities follows established practices (Chapin, 1974); however, such divisions must be regarded as arbitrary since, as Chapin notes, many activities exist along a continuum between these extremes. Although the activity categories are fairly general, the contextual information about site and social contacts helps to convey some of the complexity of activity patterns in urban environments. The site variables provide indicators of the functional and structural attributes of activity locations, and the social-contact variables offer distinctions based on whom the respondent is with.

Table 2. Description of activity categories and their correspondence with codes of the Multinational Time-Budget Study (note: a useful description and critique of activity classifications is provided by Clark and Harvey, 1977).

Activity	General description	Multinational codes [a]
Employment-related	Work for money	00-08
Home-centred obligatory	Domestic work and care of children	10-25, 27
Nonhome-centred obligatory	Purchase of goods and services, including personal and medical care	26, 30-37, 44
Home-centred discretionary	Active and passive leisure at home (including hobbies, crafts, music, TV, radio, reading, relaxing, etc)	83-86, 90-98
Nonhome-centred discretionary:		
(a) education and voluntary participation	Adult education, professional training, civic and collective participation, religion	50-56, 60-68
(b) active and passive leisure	Social events; attending spectacles, exhibitions, sporting and entertainment events; participating in exercise and sports	70-78, 80-82
Employment-related travel	Trips to and from employment site(s)	09
Travel to or from non-employment obligatory activities	Trips related to obtaining goods and services, and for care of children	29, 39, 49
Travel to or from discretionary activities	Trips related to active and passive leisure	59, 69, 79, 89, 99

[a] The multinational codes are based on the Multinational Comparative Time-Budget Project, described in Szalai (1972). Although they are available in the Halifax Time-Budget Survey, the following codes were not included in the data base for this study: 40-43 and 45-48 (home-centred activities relating to private needs, sleep, and meals).

6 Related analyses

Studies by Procos and Harvey (1977), Hanham (1976), and Langlois (1983) warrant specific comment because of their relationship to the study design by Taylor and Parkes (1975) and to that used in this analysis. Procos and Harvey based their analysis on subsets of the Halifax data. However, instead of integrating the population and activity variables with times and locations, as proposed here, they performed three separate factor analyses on three segmented sets of this data. First, a factorial ecology of sociodemographic variables produced traditional constructs relating to family structure, socioeconomic status, age, and employment. Second, using descriptive

measures of the locational settings of households, another factor analytic solution gave three factors labelled suburbanism (areas high on single-family homes and long-term residents), diversity (areas with high variations in rooms per unit, length of residence, and rental rates), and areas of high house values and rental rates. Finally, using the same methodology on measures of activity duration, aggregated to averages at the daily level, they identified three principal groupings of respondents: 'ants'—low on employment but having high involvement in home-centred maintenance activities; 'out-of-home crickets'—high on nonhome discretionary activities and related travels; and 'home crickets'—high on discretionary activities at home. Given the similarity of variables and the differences in the analytic frameworks, it is reasonable to expect that the analysis proposed in this study will yield factors similar to those identified by Procos and Harvey, in addition to dimensions that are unique to an integrated space-time framework.

Since the analytic procedure used in this study follows that suggested by Taylor and Parkes (1975), it is subject to the criticisms expressed by Hanham (1976). Hanham used the hypothetical data from Taylor and Parkes's experiment to demonstrate the superior theoretical reasons for using a psychometric technique known as INDSCAL (Individual Difference Scaling). The advantage of this technique is its ability to measure, for separate time slices, the variance explained by each factor. However, as Hanham's experiment indicates, and as shown by our experiments based on the PARAFAC technique (see Harshman et al, 1977), these three-way or multiway factor models tend to yield highly complex factors that are difficult to interpret. Although Langlois (1983) has demonstrated a more successful interpretation of Taylor and Parkes's data by using a three-mode factor analysis developed by Walsh and Walsh (1976), we have chosen to follow the approach used in the prototype study by Taylor and Parkes.

In the analysis that follows, a principal-axis factor analysis is used to identify the underlying dimensions of the 192 STU x 40 variable matrix. The mapping of factor scores by STUs provides the basis for presenting and discussing the results.

7 Space-time patterns of urban sociodemographic structure

Table 3 presents the variable loadings on the eight most significant factors. The factors, accounting for 91% of the explained variance, have been given general labels as follows: 1 employment related activities; 2 family associations; 3 household incomes; 4 educational status; 5 unemployment obligatory activities; 6 nonhome social and leisure activities; 7 age and transcience (life cycle); 8 discretionary education and participation. A ninth factor, not listed because of its low explained variance, nonetheless represented a distinct dimension. With high positive loadings on percentage of females, home-based obligatory activities, and visits with neighbours, it was designated as the housewife factor, and is similar to what Procos and Harvey (1977) referred to as 'ants'.

In figure 1, bar graphs of factor scores are mapped to provide a basis for interpreting the space-time patterns for each factor. The length of a bar is related to the number of standard deviation units that a given tract is above or below the mean value for all tracts at a given time. The advantage of this portrayal is the ease with which diurnal changes in a tract's composition can be detected. Also, it is possible to discern systematic spatial variations in the temporal trends among the thirty-two PCTs. But, for several reasons, these cross-tract trends must be interpreted with caution. Since the raw data were in percentage and average form, the heights of bars bear no relationship to numerical presence. And, whereas the factors are operative simultaneously, each is interpreted in isolation from the others—a standard shortcoming of many studies that rely on the varimax solution from factor analysis.

In the interpretations that follow, the authors' familiarity with the Halifax–Dartmouth area is put to the test. Where specific interpretations are possible, they are presented. However, general themes suggested by Parkes and Thrift (1979) and by Lynch (1976) are emphasised. Parkes and Thrift have documented the ability of dominant institutions and functions to entrain the activities and schedules of individuals and nearby areas. Related to this idea is Lynch's description of the evening evacuations and nighttime invasions that lead to the displacement of dominant population and activity combinations in given parts of the city. Evidence of these diurnal patterns is present in the Halifax study.

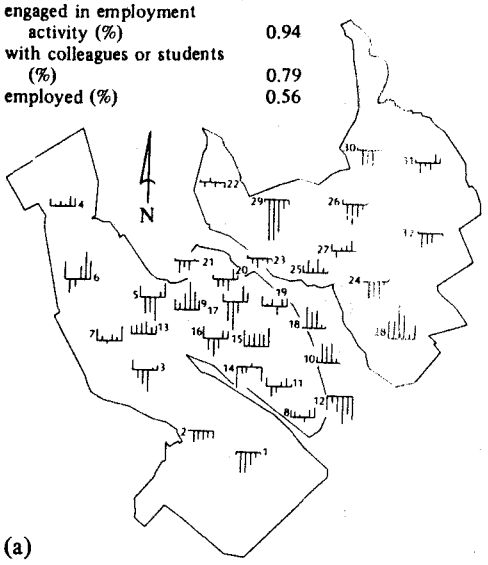
Table 3. Factorial ecology of population and activity characteristics for Halifax-Dartmouth space-time units [based on principal-axis factor analysis (SPSS, 1982) with varimax rotation after Kaiser normalisation. Data (forty variables) were derived from the 1971-1972 Halifax Time-Budget Study (see Elliott et al, 1976)].

Factors and variables[a]	Loading	Factors and variables[a]	Loading
1 Employment related activities		*2 Family associations*	
At workplace (%)	0.95	With adult member of household or relative (%)	0.93
In employment-related travel (%)	0.94	With child of household (%)	0.82
In employment-related activity (%)	0.94	Not married (%)	−0.62
With colleagues and students (%)	0.79	Homeowners (%)	0.55
Employed (%)	0.56	With spouse or fiancé(e)	0.49
At indoor leisure establishment (%)	−0.41	Eigenvalue 4.8	
Eigenvalue 8.3		Explained variance (%) 16.8	
Explained variance (%) 29.2			
3 Household incomes		*4 Educational status*	
Average median household income (%)	0.83	Average number of years of schooling	0.70
Rent more than $200 per month (%)	0.77	At least one year of university education	0.69
No car owned by household (%)	−0.75	Employed as skilled, semiskilled, or unskilled worker (%)	−0.64
With spouse or fiancé(e) (%)	0.53	With spouse or fiancé(e) (%)	−0.52
Widowed, divorced, or separated (%)	−0.51	Not married (%)	0.43
Average number of years of schooling	0.49	Eigenvalue 2.4	
Homeowners (%)	0.47	Explained variance (%) 8.5	
Eigenvalue 3.7			
Explained variance (%) 13.1			
5 Nonemployment obligatory activities		*6 Nonhome social and leisure activities*	
In obligatory nonemployment travel (%)	0.93	In someone else's home (%)	0.79
In nonhome obligatory activities (%)	0.78	In nonhome active and passive recreation (%)	0.68
At eating and drinking locales (%)	0.48	In travel for discretionary purposes (%)	0.66
On streets or on public transport (%)	0.46	In outdoor leisure establishment (%)	0.52
Eigenvalue 2.2		Eigenvalue 1.9	
Explained variance (%) 7.8		Explained variance (%) 6.6	
7 Age and transience		*8 Discretionary education and participation*	
Average age	0.84	In education and organisational activities (%)	0.74
In same residence for more than two years (%)	0.84	At public and private service establishments (%)	0.61
Homeowners (%)	0.52	Eigenvalue 1.0	
Eigenvalue 1.6		Explained variance (%) 3.7	
Explained variance (%) 5.7			

[a] That load onto a particular factor. The authors' subjective label for the factor is shown in italics.

High loadings on factor 1

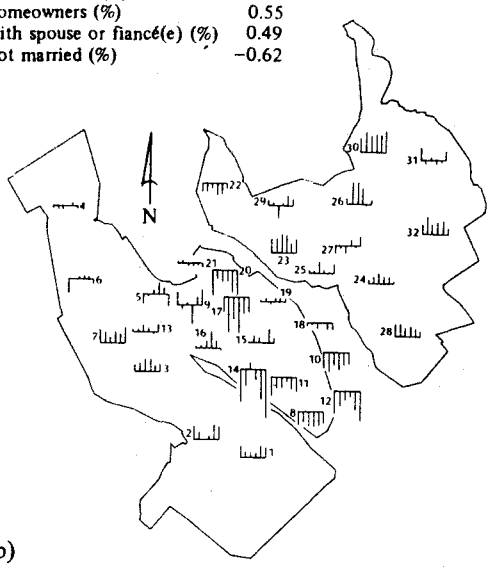
at workplace (%)	0.95
traveling to or from work (%)	0.94
engaged in employment activity (%)	0.94
with colleagues or students (%)	0.79
employed (%)	0.56



(a)

High loadings on factor 2

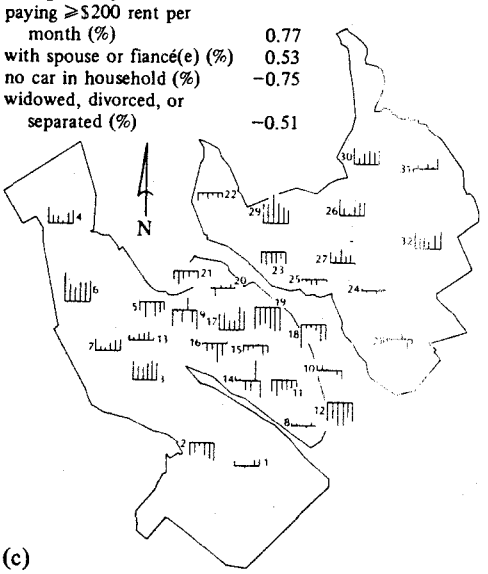
with relatives (%)	0.93
with children (%)	0.82
homeowners (%)	0.55
with spouse or fiancé(e) (%)	0.49
not married (%)	−0.62



(b)

High loadings on factor 3

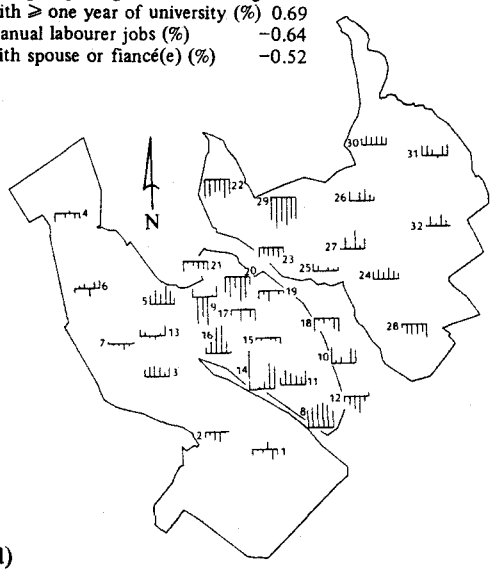
average family income	0.83
paying ≥$200 rent per month (%)	0.77
with spouse or fiancé(e) (%)	0.53
no car in household (%)	−0.75
widowed, divorced, or separated (%)	−0.51



(c)

High loadings on factor 4

average highest grade of schooling	0.70
with ≥ one year of university (%)	0.69
manual labourer jobs (%)	−0.64
with spouse or fiancé(e) (%)	−0.52

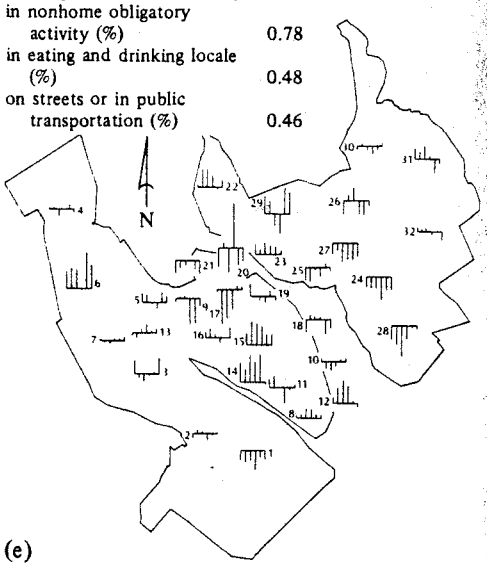


(d)

Figure 1. Diurnal variations in (a) employment-related activities (factor 1), (b) family associations (factor 2), (c) household incomes (factor 3), (d) educational status (factor 4), (e) nonemployment obligatory activities (factor 5), (f) nonhome social and leisure activities (factor 6), (g) age and transience (factor 7), and (h) discretionary education and participation (factor 8), of respondents within tracts for Halifax-Dartmouth, Canada [calculated by the authors (using a principal-axis factor analysis of forty sociodemographic and activity variables) from space-time diaries collected by the Institute of Public Affairs at Dalhousie University, 1971-1972].

High loadings on factor 5

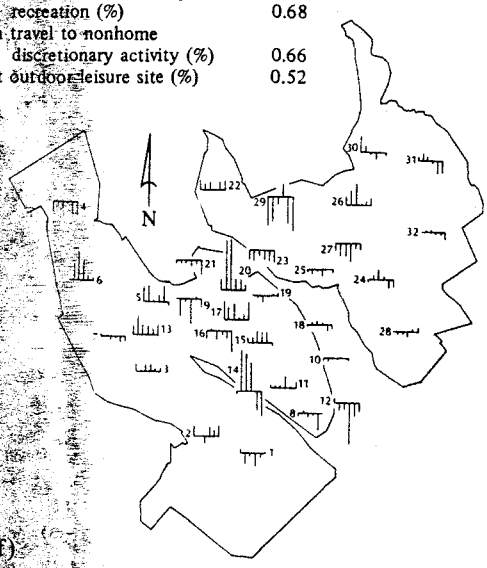
in travel to nonemployment obligatory activity site (%)	0.93
in nonhome obligatory activity (%)	0.78
in eating and drinking locale (%)	0.48
on streets or in public transportation (%)	0.46



(e)

High loadings on factor 6

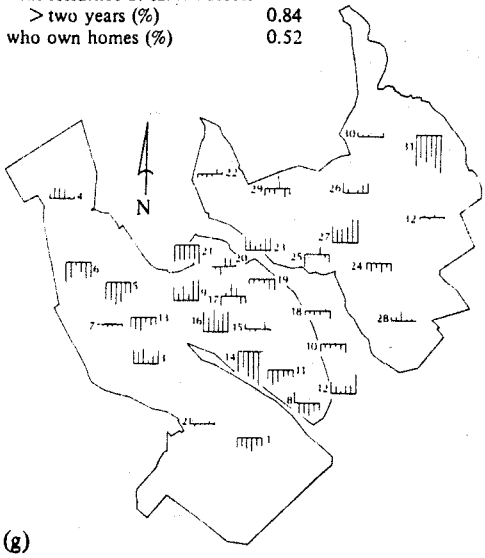
in someone else's residence (%)	0.79
in nonhome active and passive recreation (%)	0.68
in travel to nonhome discretionary activity (%)	0.66
at outdoor leisure site (%)	0.52



(f)

High loadings on factor 7

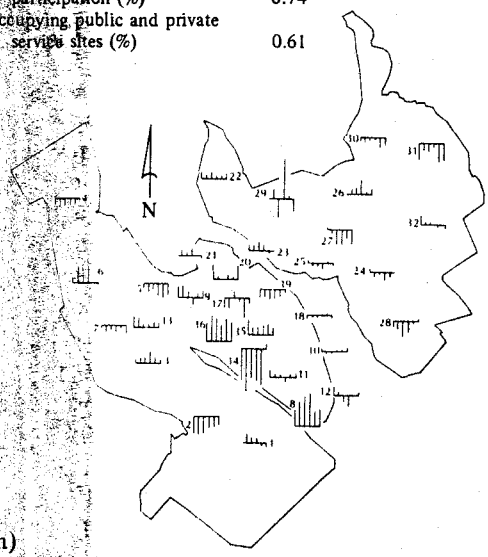
average age	0.84
with residence at same address > two years (%)	0.84
who own homes (%)	0.52



(g)

High loadings on factor 8

in discretionary education and participation (%)	0.74
occupying public and private service sites (%)	0.61



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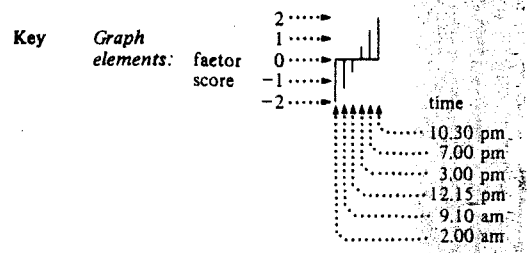

Figure 1 (continued)

Factor 1 [figure 1(a)] accounts for 29.2% of the variance in the data. It is not surprising that the most significant factor relates to employment activities. Aside from sleep, probably more than any other activity, work, and its implied authority constraints, set the dominant rhythm of the weekday routine. The highest loadings on this factor include variables from all of the major categories identified in table 1—sociodemographic, activity, travel, site, and social relationships.

In figure 1(a), the areas with above-average scores include the central business districts (CBDs) of Halifax (tracts 10 and 18) and Dartmouth (25), industrial and defence-related establishments (9, 19, and 28), shopping centres and commercial areas (in the eastern portions of tracts 7 and 13), universities (6 and 8), and hospitals (15). The operations and schedules of these institutions and functions appear to have strong regulatory control over the timing of movements and the availability of time for other activities.

The early-morning invasions and late-afternoon evacuations of the employment regions are most obvious in the Halifax CBD tracts (10 and 18) and in tract 9 (a Department of National Defence installation). However, other patterns are in evidence. For example, two hospitals impose a continuous high level of employment activity in tract 15. The same is true for the operations of industries and of the Shearwater Air Base in tract 28; however, there is a lull in the early evening. Tracts 16 and 17 are moderately high-density residential areas in close proximity to the Halifax Forum, the Exhibition Grounds, and the Bus Terminal. Their patterns tend towards higher levels of employment in the evening than during the midday period, possibly in association with the dominantly evening orientation of the nearby facilities on weekdays. This pattern is also present in tract 6, where Mount Saint Vincent University offers evening courses. A possible interpretation for tracts with daytime scores far below average is the dominance of residential land uses and the significance of a large residual of unemployed adults—particularly housewives.

Factor 2 [figure 1(b)], representing 16.8% of the explained variance, focuses on the importance of family life as a stabilising influence on the daily routine for many respondents. The polarisation of low family orientation over much of the central peninsula, with high family orientation in the suburban areas (particularly in Dartmouth) is the dominant pattern in figure 1(b). Within tracts, diurnal changes in scores reflect temporal patterns in family 'closeness'. Because of the high relative significance of unmarried residents in some tracts (for example, 12 and 14), family orientation is greater during the day than at night. In contrast, tract 9, with many unmarried employed military personnel during the day, shows higher levels of family orientation at night. Thus, the relative levels of family orientation shift in response to movements in and out of tracts at various times of the day.

Factors 3 and 4 [figures 1(c) and 1(d)] illustrate the space-time patterns for two status-related dimensions—household income and education/occupation. Although one might expect correspondence between these, there are significant divergences in some areas, possibly because of their distinct associations with marital status and the way that the income variable is defined. Since income is measured at the household level, unmarried respondents, who tend to live by themselves, are linked with lower incomes. This accounts for the negative loadings of 'with spouse or fiancé' on the two factors. On factor 4, areas with high resident populations of single people (5, 8, 11, and 12) tend to have higher-than-average levels of education status.

In general, figure 1(c) illustrates the polarisation of income levels between the central and peripheral areas. Exceptions include the lower-than-average incomes along the harbour and bay in Dartmouth, and the low-income Spryfield area (12) in south-west Halifax. Figure 1(d) shows generally lower-than-average education status in association with the commercial and industrial zones on the east side of the peninsula.

In contrast, tracts on the west side, that enjoy the amenities of the northwest arm and the presence of universities in tract 8, have higher-than-average educational status.

In a comparison of figures 1(c) and 1(d), certain tracts warrant special mention. Tracts 2 and 19, two of the lowest-income areas, are below average on both measures, whereas tracts 17 and 29 have high household incomes and low educational status—typical of some blue-collar residential areas where both spouses work. Tract 5, however, being an apartment area with high residential turnover of young married couples and singles, has the opposite pattern—high on education, but low on income.

In comparison with other factors, these status dimensions tend to show less diurnal variations within tracts—this is particularly the case for the suburban areas. But on the peninsula, the exodus of residents and the invasion of workers result in notable changes in CBD tract 18, where status levels are much higher during the day than in the evening. And tracts 9 and 16 illustrate interesting reciprocal trends. As military personnel leave their residences in tract 16 for work at the Department of National Defence installations in tract 9, the daytime declines of educational status in tract 9 are matched by increased average educational status for the remaining occupants in tract 16. For tract 12, the combined departure of white-collar workers and students, and the arrival of workers at the marshalling yards and container pier, result in declining daytime levels of educational status. No interpretation is offered for tract 14. It is on all counts a high-status area, but the sharp fluctuations are difficult to assess.

Factor 5 [figure 1(e)] refers to activities and travels of an obligatory nature that, in general, are not job-related and do not occur at home. These include shopping, medical care, personal business, eating out, transportation of children, and so forth. High loadings on transportation variables mean that high scores may reflect travel between sites that are not included in the tract itself. Thus it is exceedingly difficult to offer anything more than general comments on the temporal patterns within tracts.

The more exclusively residential tracts (2, 24, 27, and 32), and several of those previously identified as employment areas (business districts—10, 18, and 25; military—9; industrial—28), tend to have average to very low scores on this dimension. In contrast, high scores are associated, in part, with tracts that act as gateways to the peninsula or passageways through it. Thus high scores in tracts 22 and 23 (the Dartmouth entrances to bridges across the harbour) are related to functional linkages between the two cities. And, sitting astride two major access roads into the heart of the peninsula (Quinpool and Chebucto roads) from Halifax's famous 'Rotary'—a traffic circle or roundabout at the head of the Northwest Arm—tracts 14 and 15 have steady high scores throughout the entire day.

Factor 6 [figure 1(f)] identifies nonhome social and leisure activities. Tracts oriented to commercial (10, 18, and 25) or industrial (19, 22, and 28) land uses tend to have average scores throughout the day. However, many of the remaining tracts have sharp diurnal fluctuations. Morning and midday social visits amongst neighbours, and the attractions of local recreational amenities, may account for the sharp peaks in tracts 6, 13, 14, 16, 20, and 26. Specific recreational facilities include golf clubs in tracts 13 and 26, arenas in 16 and 20, and boating clubs in 14, 22, 23, and 26. In contrast, some residential tracts are conspicuous by their low scores. It is possible, for example, that residents in tracts 12, 17, and 29 spend more of their nonhome leisure time outside of their own residential tracts. For those on the peninsula, many nearby urban attractions are available in neighbouring tracts.

Factor 7 [figure 1(g)] relates to the age of respondents and their stability of residence. In a sense, it is a life-cycle factor. Although the patterns of positive and negative scores on figure 1(g) reveal sharp differentiation between tracts, the diurnal variations are not very pronounced. Negative scores identify younger respondents with histories of greater-than-average residential turnover, whereas positive scores

reflect above-average residential stability and older respondents. However, cycles of positive and negative scores distinguish tracts 17 and 20 from these general patterns. As prominent residential areas for military personnel, they appear to be highly entrained to the scheduling of activities at nearby installations.

Factor 8 [figure 1(h)] focuses on discretionary activities that concern education, voluntary work, and participation in organisations. Consistent with this is the positive loading on the percentage of respondents who occupy public and private service sites. From figure 1(h), it is apparent that the peak period for these activities is in mid-afternoon, possibly relating to activities with youth groups and to events sponsored by schools. Tract 29, with a large high school that serves much of Dartmouth, and an elementary school, has the most conspicuous mid-afternoon increase in scores on this dimension. However, the university areas (tracts 6 and 8) and tract 15 have the highest overall scores on this dimension. The presence of two hospitals and a large Catholic high school in tract 15 offer support for this interpretation. The business-district tracts of the two cities are conspicuous by their average showing on this kind of activity.

8 Discussion

In this study, we have demonstrated the use of space–time diary data to describe diurnal changes in urban ecological structure. The combination of social and demographic measures with indicators of activity patterns, site characteristics, and social relationships provided a broad contextual framework for the analysis. Aside from indicating how the conventional status and family factors change within subareas for different times of the day, dimensions relating to activity patterns and social settings were identified.

Although substantive descriptions and preliminary interpretations about diurnal changes in the human ecological structure of Halifax have been identified, this analysis is seen primarily as a technical statement. It illustrates how a standard technique, used in the novel way suggested by Taylor and Parkes (1975), can reduce the complexity of space–time activity patterns into more general constructs. However, the sensitivity of these results to the criteria used in defining space–time units, to the longitudinal extent of the diary period, and to the designation of variables requires additional investigation. But, irrespective of these technical issues, the findings of this research are suggestive of the need to reevaluate current theoretical views about urban structure and to consider how refinements in this type of analysis might be directly applicable in both private and public decisionmaking.

It is clear from this analysis that the traditional models of urban social structure, derived, for the most part, inductively from standard census data, have neglected significant elements of diurnal variation in the population compositions of urban subregions. Standard assumptions about the homogeneity of spatial units throughout the day offer only limited descriptions about the integration and spatial concentrations of different subpopulations. To the extent that diurnal temporal patterns in the spatial coincidence of activity types and subpopulations are identifiable, causal factors are suggested.

At the theoretical level, a useful extension of this research might incorporate explanatory statistical models such as stepwise regression or PARAFAC (Harshman et al, 1977). But both descriptive and explanatory research are needed to identify significant relationships between patterns of urban ecological structure and the behaviour of individuals. This might follow leads established by Burnett and Hanson (1979) in their investigations of the space–time movement behaviour of individuals in Uppsala, Sweden. Or, along the lines of the suggestions made by Parkes and Thrift (1979) and Pred (1981, page 16), documentation on the entrainment of individual

routines by dominant institutions may also contribute to our understanding of relationships between urban structure and individual behaviour.

At the applied level, the use of diary data to create 'census-like' information for designated times of the day has possible value for planning in many areas. The description of daytime as well as nighttime population patterns would enhance the potential for producing more informed decisionmaking by both public and private sectors. The locations of various commercial, social, educational, and emergency services should be responsive to diurnal variations in population distributions and to temporal changes in concentrations of the elderly, children, working mothers, and others. The ability of businesses to target their client populations more precisely was identified by McCaffrey (1981) as an important need. And it is reasonable to believe that the quality of public services could also be enhanced through greater awareness of temporal variations in public demands. Planning should not be constrained by the nighttime basis of social statistics.

Given the possible practical uses of space-time diary data and the potential they provide for expanding the theoretical understanding of urban environments, it would be ideal if related questions were incorporated as standard features of national censuses. However, because of the expense of gathering such information, the lack of experience in analysing it, and the limited examples of its direct application, it might be more prudent at this stage to encourage the collection of comprehensive geocoded diaries for only a few urban centres, differing in size, function, and cultural setting. This would allow for meaningful comparisons of research approaches and research findings, thereby enhancing opportunities for improving the techniques of analysis, for adding to the theoretical understanding of urban environments, and for demonstrating practical utility. From this, it may be possible to identify a minimum set of diagnostic questions for incorporation in standard census surveys. It is hoped that this preliminary description of the space-time patterns in Halifax, Canada will provide a base for expanded research efforts in these directions.

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