SOME DYNAMIC INDICATORS OF NEIGHBORHOOD CHANGE*

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Several recent studies of social and residential mobility have argued that the descriptive properties of discrete space stochastic matrix models provide extremely useful constructs on which to base explanatory inferences concerning both the distribution and transformation of local population characteristics. Furthermore, when these models are time homogeneous (even if only in the short run), it can be shown that they may also be used as a basis for projections of future distributions. Unfortunately, owing to limitations in the availability of data and very weak conceptualizations of most city and regional planning situations, there have been few attempts to employ these models in development of such indicators for use in social planning and decision-making. This has been especially true in those cases when time homogeneity is not demonstrably present and sensitive indicators of change are required. In this paper, we will outline an approach using stochastic matrix models to generate indicators of social and residential changes in small areas. More specifically, we show that by using the types of detailed longitudinal data files currently being developed in several cities in the United States and Europe, selected parameters can be used to present summary descriptions of associated short-range shifts in social structure and neighborhood composition as well as a formal framework for developing indices of structural change.

1. *Social Indicators*

As they are usually conceived of, social indicators are sets of measures which summarize certain (functionally specified) observable properties of a complex system and which may be compared with identical measures for the same properties of other (perhaps ideal) systems. Where the relevant properties of the system are known to be homogeneous in their behavior, there is clearly no need for other than descriptive indicators. Where the system is heterogeneous, alternative measures of observable characteristics must serve to indicate the state of the system and its pattern of change or deviance.[1]

The problem in developing social indicators is to find those measures which accurately and intercomparably describe the states of the social system, their patterns of change, and those instrumental factors which can potentially be used to regulate these changes. This problem, itself, can be regarded as made up of four related subproblems: (a) issues concerned with the relationship between the types of indicators and their uses (i.e., functional questions); (b) the formulation of conceptual models; (c) data availability; and (d) the difficulties encountered in devising uniformly meaningful (and interpretable) measures or scales. The first and last of these problems (a and d) require much deeper philosophical and mathematical analysis than can be provided here and thus neither of these issues will be treated in this paper. We will concern ourselves primarily with the development of a particular functional class of dynamic indicators (i.e., for local area population changes) and, more specifically, with the kinds of conceptual models and data required for their development.

1.1 A Conceptual Model

The proposed indicators of local population change require a conceptual model combining both neighborhood status and change components; this model should include not only measures of current conditions but also parameters which reflect the size, direction, and relationships among the variables which affect shifts in these conditions. Of the several formal models which have been employed in studying local area mobility, perhaps the most significant development has been the use of discrete space stochastic process models based on individual-level (disaggregated) data. Originally, these models seemed appealing mainly because it appeared that the characteristics of the residential location and relocation process bore striking similarities to the processes of social mobility and age-specific population change, both of which have been examined using stochastic models (e.g., Bartholomew (1967), White (1970)). More recently, additional epistemological and methodological justification has been provided for the use of this class of models through an examination of the criteria for explanation and explanatory evidence (Fisher (1960), Gale (1971), Gale (1973)). These models will thus be employed as the formal basis of our subsequent development of social indicators.

Since many of the analytical consequences of using discrete space stochastic matrices as models of residential location behavior are predicated on a close correspondence between the desired theory and the definitions and classification schemes employed, it is particularly important that these aspects of the model be fully comprehensible. In this regard, it is useful to have a notation which both illuminates the definitional and classificatory issues and provides an explicit means for comparing results obtained from several alternatives. Such a notation has been described previously in terms of a general finite-dimensional cross-classification table K^N where $N=\{n_1,\dots,n_N\}$ is the set of properties or conditional predicates and $K^{n_i}=\{k_1^{n_i},\dots,k_{K_i}^{n_i}\}$ is the set of classifications associated with each of the properties, n_i $(i=1,\dots,N)$ (Gale (1972)).[2]

Using this framework, the specific conceptual model of neighborhood change is defined as a K^6 time-dependent contingency table which, in order to satisfy both planning needs and the desire to be consistent with existing theory, includes information on geographic area, the attributes of households, and dwelling-unit type. The model is thus defined by $N=\{n_1,n_2,n_3,n_4,n_5,n_6\}$ and $K^{n_i}=\{k_1^{n_i},\dots,k_{K_i}^{n_i}\}$ $(i=1,\dots,6)$. n_1 is geographic area at time t, n_2 is geographic area at t+1, n_3 is type of dwelling unit at t, n_4 is type of dwelling unit at t+1, n_5 is household-type at t, and n_6 is household-type at t+1; K^{n_1} and K^{n_2} represent the classification of $K_1=K_2=n$ mutually exclusive and exhaustive subareas, K^{n_3} and K^{n_4} represent the classification of the $K_3=K_4=s$ mutually exclusive and exhaustive dwelling-unit types; and K^{n_5} and K^{n_6} represent the classification of $K_5=K_6=m$ mutually exclusive and exhaustive household-type subgroups. If we now define the allocation of household types to dwelling-unit types as the *occupancy pattern* at time t (e.g., the set of n x s x m submatrices, A(t), corresponding to the dimensions n_1,n_3, and n_5), we may then designate the focus of our attention as being on both the nature of the occupancy patterns, A(t), and the matrices which transform A(t) to A(t+1).

1.2 Data

The choice of a generalized cross-classification model as the conceptual framework for the development of dynamic social indicators does more than specify the form of the model with which we will work; it also strongly influences the kinds of data required to estimate the parameters on which the indices are based. For example, by a judicious selection of class boundaries so as to coincide with the units on which federal and state agencies collect information, the n x s x m matrix representing the overall occupancy pattern can be obtained directly from published records. However, where alternative classifications and definitions are desired and where the matrix which transforms one state description to another is of interest, more finely disaggregated (i.e., individual level) data are generally required.[3]

For the present purposes, the combination of model-specific and functional requirements strongly implies that data be collected on the level of individual units. For geographic areas this requires a specific spatial referencing system (e.g., coordinate designations); for dwelling-unit types, detailed information on the size and condition of each unit; and for household-type, detailed information on characteristics such as family structure, age, race, and economic condition. Moreover, since the conceptual model with which we will be working involves time dependencies, the data collected must also include information which allows inferences on changes in status at intervals which are appropriate to the problem in hand.

Clearly, the type of data we require is not generally available in the United States (although it is available in some European countries). However, under funding from federal, state, and local sources, one city has recently developed a set of data on which to base the types of dynamic indicators in which we are interested; these data are currently available for both 1971 and 1972. Locational information is given by the address of the dwelling as well as a household identification number. By using address matching procedures it is thus possible to extract information concerning dwelling-specific occupancy changes as well as removals (e.g., demolitions) and additions (e.g., new construction).[4]

2. *A Representational Model of Neighborhood Change and Some Classes of Dynamic Indicators*

We now consider a specific form of the conceptual model described in section 1.1. In particular, we examine the form of the 6-way matrix which transforms A(t) into A(t+1). To this simple model we also wish to add "birth" (e.g., new construction) and "death" (e.g., demolition) components. Moreover, since the size of this 6-way matrix would render direct analysis impracticable in most cases and since our main interest is on the shifts in occupancy patterns for given sub-areas, we will also modify the model such that we consider only area-specific occupancy patterns--i.e., the transformation from ${}_iA(t)$ to ${}_iA(t+1)$ (i=1, ...,n).[5] More specifically, we define the area-specific occupancy matrices as the set ${}_iA(t)=\{{}_ia_{jk}(t)\}$ with marginals ${}_ia_H(t)=\{{}_ia_{.k}(t)\}$ (the vector of household composition of area i at t) and ${}_ia_D(t)=\{{}_ia_{j.}(t)\}$ (the vector of dwelling unit composition in area i at t).

Planning interest is usually focused on the behavior of either ${}_ia_H(t)$ or ${}_ia_D(t)$. For present purposes we will focus on ${}_ia_H(t)$. The basic argument to be pursued is twofold:

i) that the transformation from ${}_ia_H(t)$ to ${}_ia_H(t+1)$ is dependent on the specific occupancy pattern ${}_iA(t)$ and therefore we need to develop measures of the *differential* contribution of different dwelling-unit types to changes in the household composition; and

ii) that the transformation from ${}_ia_H(t)$ to ${}_ia_H(t+1)$ possesses three components and therefore we need to develop measures of the differential contribution of each of these sources to changes in household composition. The set of computed measures for each of these decompositions would then provide the basic set of descriptive indicators of the process of change which can be used as input to planning and policy decisions. (Note that each set of such measures is definition and classification specific.)

2.1 A Representational Model of Neighborhood Change

Three classes of events may be regarded as leading to changes in ${}_iA(t)$:

i) decrements to the stock due to demolition, abandonment, dwelling unit combination and division; ii) additions to the stock due to new construction, dwelling unit combination and division; iii) changes in the household and dwelling unit characteristics of dwelling units whose physical identity remains the same during the interval (t+1-t). This class of events is further split into two components. We first define an *occupancy transfer* as the replacement of one household by another during the interval (t+1-t) and then define the two events as a) changes in household and dwelling characteristics for those dwelling units experiencing an occupancy transfer; and b) changes in household and dwelling characteristics for dwelling units *not* experiencing an occupancy transfer.

The following notation will be used to describe the above conditions:

${}_iD(t)=\{{}_id_{jk}(t):j=1,\ldots,s,k=1,\ldots,m\}$, the matrix of decrements to the occupancy classes jk

${}_iV(t)={}_iA(t)-{}_iD(t)=\{{}_iv_{jk}(t):j,\ldots,s;k=1,\ldots,m\}$

${}_iM(t)=\{{}_im_{jk}(t):j=1,\ldots,s;k=1,\ldots,m\}$, the occupancy pattern at time t of dwelling units experiencing occupancy transfers in the interval (t+1-t)

${}_iM^*(t)=\{{}_im^*_{jk}(t)\}$, the occupancy pattern at time t+1 of those dwelling units experiencing occupancy transfers in the interval (t+1-t)

${}_iS(t)=\{{}_is_{jk}(t)\}$, the occupancy pattern at time t of those dwelling units *not* experiencing occupancy transfers in the interval (t+1-t)

${}_iS^*(t)=\{{}_is^*_{jk}(t)\}$, the occupancy pattern at time t+1 of those dwelling units *not* experiencing occupancy transfers in the interval t+1-t)

${}_ib(t)=\{{}_ib_j(t)\}$, the vector of additions by dwelling type during (t+1-t)

${}_iB^*(t)=\{{}_ib^*_{jk}(t)\}$, the occupancy pattern of additions at the end of the interval (t+1-t)

Relations between these patterns are illustrated in Figure 1.

For the present we will assume that the characteristics of ${}_iD(t)$ and ${}_iB^*(t)$ are known and we will therefore focus our attention on the transitions from ${}_iM(t)$ to ${}_iM^*(t)$ and from ${}_iS(t)$ to ${}_iS^*(t)$.

2.1.1 ${}_iM(t) \rightarrow {}_iM^*(t)$

Given the availability of disaggregated data on occupancy patterns at t and t+1 which includes household name and address identification (as discussed in section 1.2), we are able to represent this transfer system as a 4-way contingency table ${}_iF(t)$ whose individual elements ${}_if_{jkh\ell}(t)$ represent the number of dwelling units in occupancy class jk at time t (the occupancy of a type of dwelling unit by a type k household which, in experiencing an occupancy transfer, changed to occupancy class $h\ell$ at time t+1. In many practical situations we may make a useful modification by assuming that dwelling characteristics remain stable in the short run. We then define the modified 3-way table ${}_iF^+(t)$ with elements ${}_if^+_{jh\ell}(t)$. Expression (4) gives a model of this class of occupancy changes:

$$ {}_im^*_j(t)={}_im_j(t)\,{}_{ij}P(t) \tag{4} $$

where ${}_im_j(t)$ is the j^{th} row of ${}_iM(t)$, ${}_im^*_j(t)$ is the j^{th} row of ${}_iM^*(t)$, and ${}_{ij}P(t)$ is the household transfer matrix for the j^{th} dwelling type in area i; its elements are given by

$$ {}_{ij}P_{h\ell}(t)=\frac{{}_if^+_{jh\ell}(t)}{{}_if^+_{jh\cdot}(t)}\,. $$

2.1.2 ${}_iS(t) \rightarrow {}_iS^*(t)$

We may also define corresponding representations for those dwelling units *not* experiencing occupancy transfers. The notations corresponding to ${}_iF(t)$ and ${}_iF^+(t)$ and ${}_iG(t)$ and ${}_iG^+(t)$, and corresponding to expression (4) we have

$$ {}_is^*_j(t)={}_is_j(t)\,{}_{ij}Q(t) \tag{5} $$

An important rationale for formulating the process in this way is that it is now possible to test a wide variety of hypotheses concerning the structure and components of changes in the system as well as for interactions between household and dwelling classifications. Furthermore, in the short run it is also possible to examine the degree to which ${}_{ij}P(t)$ and ${}_{ij}Q(t)$ are spatially and temporally homogeneous, thus casting greater light on small area forecasting problems. However, in the present context we are concerned mainly with developing sets of measures from this basic structure which will yield more sensitive statements regarding change than those currently available; it is to this problem that we now turn our attention.

2.2 Some Classes of Dynamic Social Indicators

The detailed representational model of neighborhood change outlined above (section 2.1) can be used to generate a wide range of measures relating both to the persistence of particular occupancy classes and to the rates of change in population composition attributable to different sources. For illustrative purposes we will consider two such classes: (i) those relating to gross mobility associated with given occupancy classes; and (ii) component rates of change for occupancy classes.

2.2.1 Gross Mobility by Occupancy Class

The activity rate associated with a given occupancy class provides an indication of the degree of involvement of that class in neighborhood mobility and, indirectly, of the potential for regulation of change in that occupancy class. To obtain such an index from the model of occupancy patterns we define a measure akin to the usual gross movement rate which is used in migration studies (e.g., Gittus (1961)). Let the total activity rate of an occupancy class jk be given by ${}_iW_{jk}$, where

$$ {}_iW_{jk}=\frac{({}_if_{jk\cdot\cdot}+{}_if_{\cdot\cdot jk})+({}_ig_{jk\cdot\cdot}+{}_ig_{\cdot\cdot jk}-2{}_ig_{jkjk})}{0.5({}_if_{jk\cdot\cdot}+{}_if_{\cdot\cdot jk}+{}_ig_{jk\cdot\cdot}+{}_ig_{\cdot\cdot jk})}. $$

The overall activity rate of the dwelling type j (${}_iW_{j\cdot}$) can also be obtained as a weighted average of the ${}_iW_{jk}$.

A measure which is complementary to the total activity rate is the degree of persistence of an occupancy class over time. Although this could be computed by taking the proportion of $v_{jk}(t)$ which is still in occupancy class jk at t+1, such a measure would be misleading in that it is composed of two distinct elements:

i) persistence deriving from the propensity to move; and
ii) persistence deriving from the probability of an out-migrant household being replaced by another household with the same characteristics.

However, if we define the persistence due to the first element as

$$ {}_{ijk}U_S=\frac{{}_ig_{jkjk}}{{}_is_{jk}} $$

and, for the second element as

$$ {}_{ijk}U_M=\frac{{}_if_{jkjk}}{{}_im_{jk}} $$

we can obtain the following identity for the overall persistence of occupancy class jk

$$ {}_{ijk}U_T={}_i\theta_{jk}\cdot{}_{ijk}U_M+(1-{}_i\theta_{jk})\cdot{}_{ijk}U_S \tag{6} $$

where ${}_i\theta_{jk}$ is the proportion of dwelling units in v_{jk} which experience an occupancy transfer in (t+1-t). The advantage of this type of index is that we can now link the concepts of stability and change with the mobility rate of different subgroups. As has been shown elsewhere (Moore (1972)) there is no *necessary* relation between mobility and change, and one function of developing these classes of indicators is to spell out the range of relations in specific urban relocation situations.

2.2.2 Component Rates of Change

An important set of measures from the standpoint of the local area planner are the rates of change in each occupancy class attributable to the classes of event defined above (section 2.1). At an early stage of inquiry, knowledge of such rates provides perhaps the strongest basis on which to evaluate the consequences of different planning and policy decisions affecting a particular local area. For each of these classes of events we may thus define the following rates of change for a given occupancy class, jk:

i) due to decrements $= \dfrac{{}_i\mathrm{d}_{jk}}{{}_i\mathrm{a}_{jk}} = {}_i\gamma_{jk}$

ii) due to additions $= \dfrac{{}_i\mathrm{b}^*_{jk}}{{}_i\mathrm{a}_{jk}} = {}_i\delta_{jk}$

iii.a) for dwellings experiencing occupancy transfers

$$= \frac{{}_i\mathrm{m}^*_{jk} - {}_i\mathrm{m}_{jk}}{{}_i\mathrm{m}_{jk}} = {}_i\alpha_{jk}$$

iii.b) for dwellings not experiencing occupancy transfers

$$= \frac{{}_i\mathrm{s}^*_{jk} - {}_i\mathrm{s}_{jk}}{{}_i\mathrm{s}_{jk}} = {}_i\beta_{jk}$$

and the composite measure for events (iii.a) and (iii.b)

$$ {}_i\lambda_{jk} = {}_i\theta_{jk} \cdot {}_i\alpha_{jk} + (1 - {}_i\theta_{jk}) \cdot {}_i\beta_{jk} \qquad (7)$$

Equation (7) has particular import for understanding the processes underlying neighborhood change. It is quite possible that ${}_i\alpha_{jk}$ and ${}_i\beta_{jk}$ have different signs and change in composition will thus depend critically on the mobility rate ${}_i\theta_{jk}$. For example, in some cases (e.g., inner city apartment areas) it is only a high mobility rate which can maintain the population composition in stable form and it is crucial for a planner to be able to distinguish between this and stability which results from very low overall mobility rates.

2.3 Indicators: A Prospectus

The set of indicators outlined above are for highly disaggregate sub-groups. One of the tasks for subsequent analyses is to identify sub-groups of areas, household, and housing types over which the indicators are homogeneous. We expect to be able to use the definitional properties expressed by the notation of the K^N model in combination with existing theory relating to residential mobility, filtering of house values, condition aging and residential location to provide bases for formulating hypotheses regarding the specification of definitional and classificational procedures which lead to homogeneity. At present, this theory is not sufficiently strong to enable us to forego the use of the kind of disaggregate analysis we have outlined. However, by employing such an analysis in a wide variety of cases, it is hoped that a basis will be provided for modifying and refining existing theory in such a way as to make detailed monitoring necessary in only a few representative cases.

Footnotes

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1. It is possible to treat this problem formally by using time inhomogeneous Markov processes or semi-Markov processes (e.g., Ginsberg (1972), Gilbert (1972), rather than by developing indices but, given our weak understanding of neighborhood change, the assumptions contained in these models are still unnecessarily restrictive.
2. Note that this is especially crucial when sensitivity tests are to be employed to assess the stability of the computed parameters and indices under alternative theoretical conceptualizations.
3. The transformation matrix can be uniquely computed from marginal distributions only under the condition in which there are no higher-order (i.e., third or fourth order) interactions (Goodman (1970)). Since most of the literature on residential relocation indicates that this is not the case, and since there is no *a priori* reason to believe that it should be true for any particular sub-population, we will not treat this aspect in any further detail.
4. Note that this implicitly restricts us to considering those changes that take place at intervals of at least one year. However, for most types of neighborhood changes this appears to be quite adequate.
5. Note that other kinds of mobility models could also be defined using this same framework--e.g., residential mobility, condition aging, occupational mobility, etc.

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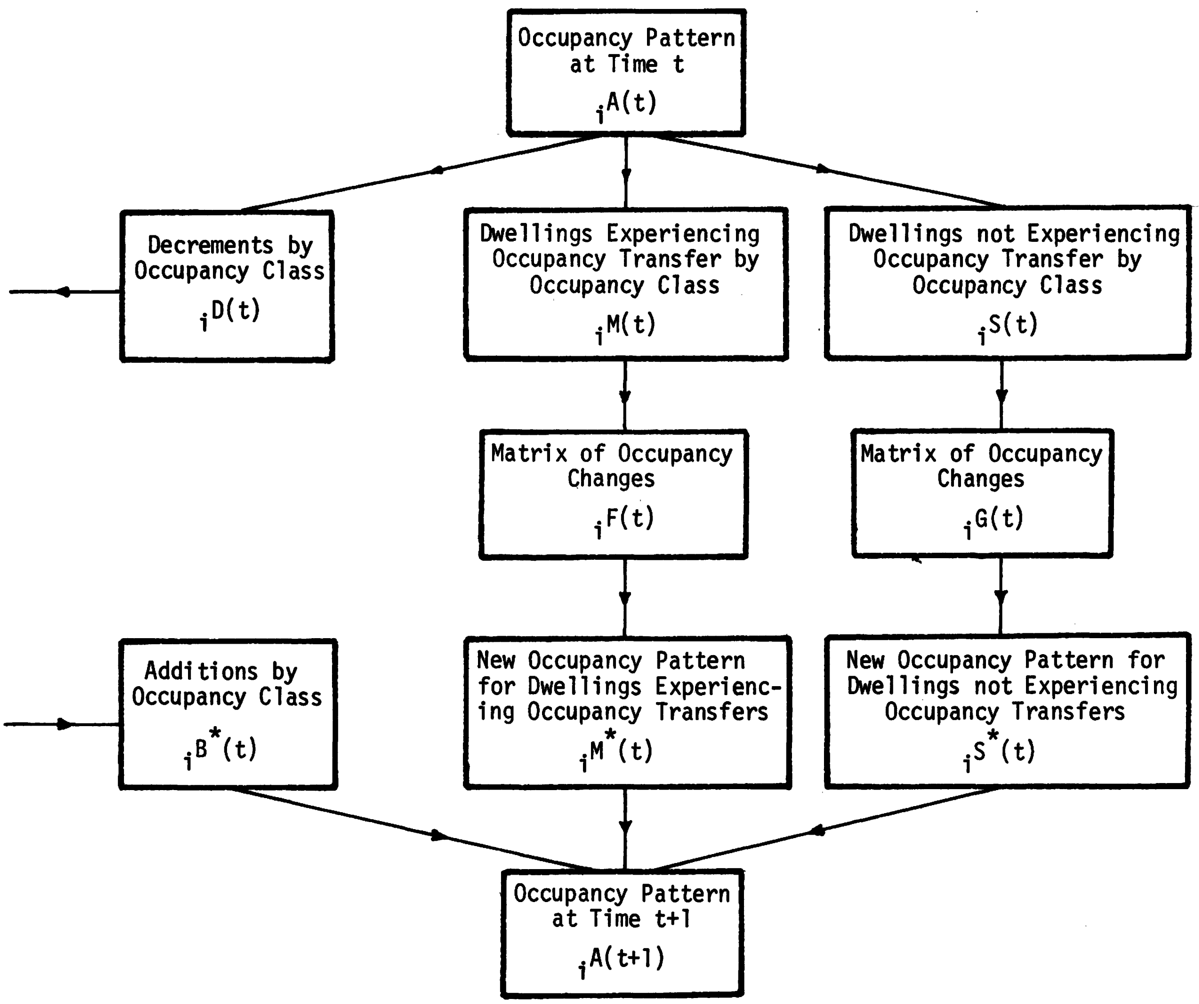

FIGURE 1: SOURCES OF CHANGE IN THE OCCUPANCY PATTERN IN THE i^{th} SUB-AREA