SOCIAL AND SPATIAL MOBILITY AND URBAN DYNAMICS

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ABSTRACT

While the results generated by Urban Dynamics are problematic these results are less important than the fact that Forrester posed a challenge to social scientists and urban modelers alike by including phenomena that are generally omitted in urban simulations. This paper focuses on one such phenomena, social mobility, and addresses the questions of whether social mobility is sufficiently important to be included in urban simulations and whether Forrester's modeling of this phenomena is adequate.

A consideration of the role of social mobility in determining the population structure in urban areas indicates that social mobility is relevant to a wide class of dynamic simulations in which the socio-economic structure of the simulated population is important. An analysis of the migration patterns generated by the Urban Dynamics model and experimentation with a modified model indicates that Forrester's formulation of the industrial and job sector of the model is incompatible with social mobility. This result is not only relevant to those seeking to refine or apply Urban Dynamics but also suggests that in general the simulation of social mobility must be complemented by simulating a changing labor market structure.

INTRODUCTION

Despite the avalanche of criticism directed at it, Urban Dynamics (Forrester, 1969) is likely to have a continuing impact. The most direct impact is possible from efforts to use the model to simulate specific cities, which include a version calibrated for Harris County, Texas (Porter, et al, 1970), and the models for Lowell, Massachusetts (Strongman, 1973) and Providence, Rhode Island (Kadanoff, 1973).

However, the indirect influence of Urban Dynamics may be even greater. It is significant that several economists (Oates, et al, 1971), after characterizing the forces that affect urban life as a number of "feedback relationships which reinforce one another and are likely to generate cumulative movement over time" suggest that the extensive literature dealing with dynamic processes "may prove useful in the analyses of urban economic problems." Further, the authors identified the studies contained in this literature as demonstrating "that it is one of the properties of these (dynamic) processes that what appears on the surface well suited to resolving a particular problem may in fact increase the severity of the problem or at least provide only a temporary improvement", which is virtually a paraphrase of Forrester's famous assertion of the counter-intuitive behavior of complex dynamic systems. While the authors do not cite Forrester, it seems fairly obvious that this paper represents an acknowledgement by economists that the Forrester methodology may be helpful in dealing with the kinds of policy problems that have long been primarily the province of urban economists.

Perhaps the greatest potential influence of Urban Dynamics will be realized if urban modelers and social scientists jointly meet the challenge that Forrester posed when he incorporated a number of phenomena that are generally not included in urban simulations. This challenge can be met by an examination of the importance of such phenomena and if necessary by improving Forrester's modeling of them. This paper is concerned primarily with one such phenomenon, social mobility, the effects of Forrester's method of modeling social mobility on the patterns of spatial mobility generated by the Urban Dynamics model, and the demands that the modeling of social mobility make on other facets of an urban simulation.

SOCIAL MOBILITY IN URBAN SIMULATIONS

In Urban Dynamics the population is divided into three groups; manager-professional (MP), labor (L) and underemployed (U). Forrester's description of the population sector in the Urban Dynamics model is shown in Figure 1, and as indicated, there are two types of population flows; spatial movement into and out of the simulated area by each population class, and social mobility from the labor to manager-professional class and between the labor and the underemployed classes. To my knowledge, Forrester's Urban Dynamics is the only urban simulation which includes social as well as spatial

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mobility. This fact raises two questions:

1. Is social mobility sufficiently important to include in urban simulations, and
2. What lessons can be learned from Forrester's modeling of this phenomena.

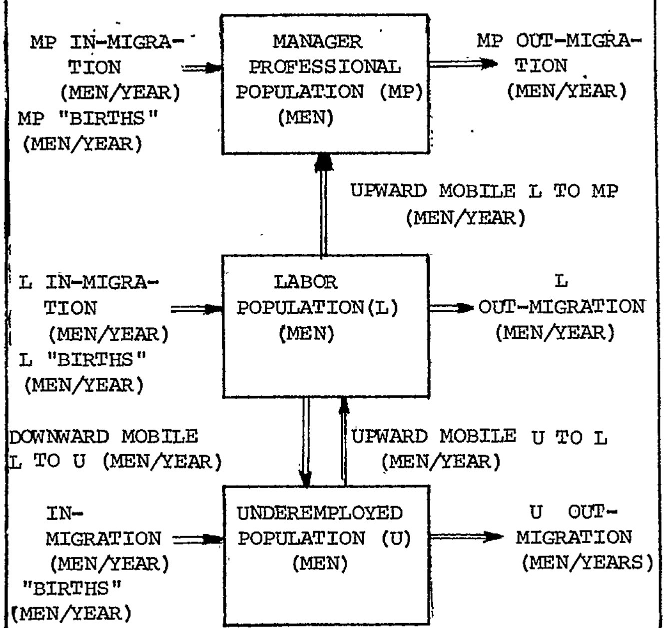


FIGURE 1

POPULATION SECTOR IN URBAN DYNAMICS

IS THE SIMULATION DYNAMIC?

There is no agreed upon definition of social mobility. Within the structure of the Urban Dynamics model, social mobility reflects changes in occupation as well as changes in life style, e.g., different family size, different housing requirements, different housing densities, different value systems for assessing the attractiveness of the simulated areas. However, the most easily obtainable data generally used in empiric studies of this phenomena refer to occupational mobility. In any case, social mobility, like spatial mobility, identifies a flow. In a static model (e.g., Lowry (1964), no flows are considered and thus social mobility is not relevant.

IS THE SOCIO-ECONOMIC STRUCTURE OF THE POPULATION IMPORTANT?

In Urban Dynamics, the level of each of the three population classes in the model determine the pattern of demand for housing, influence the growth of industry, determine the tax requirements of the simulated area, and influence the migration rates. While the influence of population mix is probably more extensive in Urban Dynamics than in most simulations, the demand for housing is often related to socio-economic characteristics.

For example, in the NBER (National Bureau of Economic Sresearch) Urban Simulation Model (Ingram, et al, 1972), which focuses principally on the urban housing market, the households are divided into 72 groups defined by age and educational level of the household head, the household income, and the family size. These demographic considerations influence housing demand and ultimately housing price and supply. Anticipated extensions to the model include characterizing housing sub-markets in terms of the average socio-economic status of the residents in a neighborhood (Ingram et al, 1972, p. 168). In such a model, the effects of social mobility on the changes in socio-economic status and the resulting patterns of housing vacancies and housing demand may warrant consideration.

IS THE TIME PERIOD COVERED BY THE SIMULATION SUFFICIENTLY LONG?

The Urban Dynamics model considers what Forrester calls "an entire life cycle of an urban area" (Forrester, 1969, p. 10). An overall population flow generated by both social and spatial mobility over a simulated 250 year span can be seen from the data in Table 1 which show the make-up of the in- and out-migration streams in terms of the three population classes identified in the model.

TABLE 1

TIME, YEARS	POPULATION CLASS, % IN-MIGRANT STREAM MP	L	U	OUT-MIGRANT STREAM MP	L	U
25	3	39	58	11	36	53
50	4	40	56	19	42	39
75	3	41	56	20	41	39
100	3	42	53	20	41	39
125	2	35	62	14	35	51
150	3	32	65	14	35	51
175	3	31	66	13	38	49
200	2	30	68	14	37	49
225	2	30	68	14	37	49
250	2	30	68	14	37	49

Composition of Migrant Streams in the Urban Dynamics Model

As these data show, throughout its history Forrester's "city" acts as a social converter, absorbing higher proportions of the lowest economic class than it emits. Historic studies show that urban areas, at least during period of growth, do in fact act as social converters providing opportunities for upward mobility for individuals migrating into the city at the lower rungs of the social ladder.

For example, studies of Philadelphia in the period 1820-1840 (Warner, 1967) and Omaha in the period 1880-1920 (Chudacoff, 1972) indicate that the growth of these cities was due in large part to an influx of foreign born who generally were in manual occupations. Further, in Omaha a full 20% of the labor force engaged in manual occupations in 1880 moved to non-manual occupations in the period 1880-1890 when Omaha's population grew from approximately

13,000 to just over 100,000.

The mobility rates observed in Omaha are, as Chudacoff points out, consistent with a study of Boston at the beginning of the 20th century (Thernstrom, 1969) while a study of Atlanta (Hopkins, 1968) after the Civil War shows an even higher rate of upward mobility. The fact that the upward mobility observed in Omaha was higher for the native born and that the higher rates observed in Atlanta seem to be related to the availability of the black population for the unskilled occupations further substantiates the general concept of the city as a social converter with immigrants providing the basis for upward mobility within the city. Thus social mobility is relevant to considerations of historic patterns of growth in urban areas.

Of course, most urban simulations are not intended to represent a time period as long as is represented in Urban Dynamics. For example, a simulation developed at the Center for Urban Policy Research (James, et al, 1972) was designed as a predictor of the effects of growth in the pharmaceutical industry by the year 1980 on suburban and urban areas in New Jersey. The change in employment projected by the authors over this time period is shown below. These projections show an increase in the proportion of workers in the high white collar categories (professional and managers) of 28% in 1969 to 31% in 1980 and a drop in the low blue collar categories (operatives, service and laborers) from 27% to 21%.

TABLE 2

	1969	1980
Professional, Technical and Kindred	6,220	10,100
Managers, Officials, Proprietors	2,410	3,120
Clerical and Kindred	6,080	7,490
Sales Workers	4,200	8,390
Craftsman, Foreman, and Kindred	3,070	4,530
Operatives and Kindred Workers	6,570	7,760
Service Workers	710	940
Laborers, Excluding Farmers and Miners	540	470
Farmers and Farm Workers	0	0
TOTAL	29,800	42,800

Changing Occupational Distribution
Pharmaceutical Industry*

*James, F.I., J.W. Hughes, Economic Growth and Residential Patterns - A Methodological Investigation, Center for Urban Policy Research, Rutgers University 1972 (Exhibit V-9, p. 71).

A study of six major labor markets (Palmer, 1954) provides data on the relative importance of social and spatial mobility in meeting the needs of labor markets exhibiting similar patterns of growth and shifts in occupational make-up over a similar time period. Palmer's data (1954; Table 43) for the six labor markets showed growth of employed persons over the period 1940-1950 of 122%, while the growth in professional workers was 129%, managerial workers 127%, labor 111%, and for service workers only 102%. Palmer (1954; Table 46) presents a retrospective view of the origin of the 1950 labor force in the six areas. A summary for the occupations classified as professional and managerial is given in Table 3.

TABLE 3

	PROFESSIONAL WORKERS	MANAGERIAL WORKERS	PROFESSIONAL AND MANAGERIAL WORKERS
Accessions*	16%	8%	10%
Upward Mobile	10%	31%	22%
Immigrants	29%	21%	25%
Same Occupation, Same Area	45%	40%	43%

*Not in the labor force in 1940

1950 Workforce

These data indicate that the proportion of professional and managerial workers in the 1950 workforce that had moved upward from other occupations in the same labor markets (upward mobile) was about equal to the proportion of workers who migrated into the labor markets (immigrants). Thus, in a decade social mobility and spatial mobility were of about equal importance in the structuring of the upper strata of the labor force.

Because the CUPR model is static, questions of social and spatial mobility are not directly relevant. However, this comparison between the projected changes in employment in a major industry in New Jersey with the Palmer data does suggest that social mobility may well be relevant to a dynamic simulation concerned with a planning horizon of even 10 years.

FORRESTER'S MODELING OF SOCIAL MOBILITY

On the basis of the issues raised above, it seems clear that Forrester was correct in including social mobility in the Urban Dynamics model. Further, it would appear that social mobility may be appropriate to a variety of urban simulations. Moreover, because Forrester did extend the issues normally considered in urban simulations he also provided an opportunity to other modelers to determine whether his modeling of social mobility is adequate.

Forrester ignored inter-generational social mobility. Thus, all of the net births (presumably new household formations minus household dissolutions) attributed to each population class was added to the level of only that class. Social mobility then was modeled entirely as an intra-generational phenomena in which the flows between classes were calculated by multiplying the population levels by a set of transition rates. The transition rates defined by Forrester as "normal rates" are shown in Table 4. These normal rates are influenced by such local conditions as job opportunities, population mix, and taxes collected per capita.

TABLE 4

	MANAGER PROFESSIONAL	LABOR	UNDER-EMPLOYED
Manager-Professional	1.0	0	0
Labor	.02	.95	.03
Underemployed	0	.10	.90

Normal Transition Rates
Between Social Classes in Urban Dynamics
%/year

Table 5 shows the social and spatial mobility flows generated by the Urban Dynamics model at various points in the "history"of the simulated city.

An attempt to compare Forrester's formulation of social mobility with empirical studies is difficult because, as indicated earlier, social mobility in Forrester's model implies changes in lifestyle as well as changes in occupation, while the data generally used in studies of this phenomenon refer to occupational mobility only. Second, data collected by the generally accepted occupation classification system is not totally reliable*, and further, there is no clear mapping of these standard occupation classes into Forrester's three population classes. Finally, studies that focus on social mobility flows generally deal with national data, while the Forrester model presumably focuses on a city (or section of a city) in which mobility rates are formulated to be functions of local conditions.

However, the data on spatial mobility shown in Table 5 does suggest a problem. As these data show, the Urban Dynamics model generates a net out-migration of the manager-professional class throughout the history of the simulated "city". If, as Forrester (1969; p. 43) suggests, one views Urban Dynamics as a simulation of "a section of one of our older cities, not as the entire area within the political boundaries." this result may be reasonable. For example, Chudacoff (1972; Tables 1,2) points out that of the sample living in the census tract that included what was considered Omaha's finest residential district in 1880, 62% had moved out by 1885 and two-thirds of this group had left the city. Similarly, a study of one ward in Pittsburgh (Soens, 1969) showed that virtually all of the 73 families living in the ward in 1889 who were listed in the Blue Book, a register of the socially elite, had left the ward by 1909, most of them moving to other less developed areas within the city.

However, if one views Urban Dynamics as applicable to an entire city, as Forrester apparently does when he applies the model to Lowell, Massachusetts, then a net out-migration of manager-professionals from urban areas at every stage in their development implies the obviously absurd result that there is an ever-growing accumulation of such people not only living outside urban areas, but working outside urban areas. This result could conceivably arise from an overstatement of the upward mobile flow to the manager-professional class which might be corrected by an adjustment of the "normal" transition rates. However, further analyses indicate that the problem lies with the formulation of the job and industry sectors of Urban Dynamics.

*On the basis of a Census Bureau study of the reliability of its decennial occupation data, it has been estimated that 18 per cent of all persons classified in the 1960 population census in a given major occupation group really belonged in another one. (Lebergott, S., 1968)

TABLE 5

	FLOWS BETWEEN CLASSES, MEN/YEAR (SOCIAL MOBILITY)			FLOWS ACROSS SYSTEM BOUNDARIES, MEN/YEAR (SPATIAL MOBILITY)					
				MANAGER-PROFESSIONAL		LABOR		UNDEREMPLOYED	
YEAR	LABOR TO MANAGER	LABOR TO UNDEREMPLOYED	UNDEREMPLOYED TO LABOR	IN	OUT	IN	OUT	IN	OUT
25	312	851	1286	100	222	1188	761	1761	1126
50	654	1167	2803	183	585	1979	1250	2747	1174
75	1607	3641	6681	412	1171	4872	2405	6660	2301
100	4613	10908	18134	1158	3413	15211	6833	19018	6590
125	3901	16855	16821	814	6832	11600	17450	20248	24952
150	3207	11304	14915	611	4319	7579	12692	15265	17472
175	3636	11540	16767	709	4797	7832	13150	17084	16987
200	3616	11544	16737	670	4984	7547	13373	17208	17681
225	3620	11380	16772	658	4821	7401	13190	17166	17417
250	3639	11349	16839	656	4832	7369	13174	17241	17395

Annual Flow Rates (Men/Year) Between Classes (Social Mobility) and Across System Boundaries (Spatial Mobility) Generated by the Urban Dynamics Model

INDUSTRY AND JOB SECTORS OF URBAN DYNAMICS

Forrester models the industrial sector as a filtering process in which industrial units originate as new enterprises but decline inexorably through the stages of mature business and declining industry. With each successive stage providing fewer manager-professional jobs, there is a continuing loss of such jobs that can be offset only by the creation of new enterprise units. The net rate of change of manager-professional jobs, computed as 10 year averages centered at several points in the 250 year Urban Dynamics-generated history, are shown in column 1, Table 6.

TABLE 6

TIME	CHANGE IN MGR.-PROF. JOBS JOBS/YEAR	LABOR TO MGR.-PROF. MEN/YEAR	DIFFERENCE (2) - (1) % of MGR.-PROF. POP.
25	179	312	-2
50	277	654	-3
75	831	1607	-3
100	1727	4613	-4
125	-895	3901	-5
150	23	3207	-5
175	43	3636	-5
200	-43	3616	-5
225	-8	3620	-5
250	-3	3639	-5

Social Mobility Flows and Changes in Jobs For Manager-Professional Class in Urban Dynamics

The rate of flow of labor to the manager-professional class at corresponding points is shown in column 2. The difference between these rates, (after multiplying column 1 by the conversion factor, one man/job), expressed as a percentage of the level of the manager-professional class (column 4, Table 5), gives the rate of change of the manager-professional class required just to maintain a constant population/job ratio for this class. This change can be achieved only by a net out-migration. Even with continuous net out-migration, the manager-professional population is always greater than the job level for that class (Figure 2) and thus this class shows the highest unemployment, 27.5% in steady-state, of any population class in the model.

Experimentation with a portion of the model being developed as a foundation for an urban game (Belkin, 1972) substantiates the conclusion that a more realistic pattern of migration cannot be achieved by merely manipulating parameters in the Urban Dynamics model.

ALTERNATIVE MODEL FOR SOCIAL MOBILITY IN URBAN DYNAMICS

For reasons discussed elsewhere (Belkin, 1972) our own work has been directed at the extension of Urban Dynamics to a multi-neighborhood model. In this context, it is necessary to explicitly recognize both inter- and intra-urban moves. Thus it becomes desirable to be explicit about the process of new household formations because this element of the population is significantly more mobile than other elements. A natural extension of modeling household formations is the modeling of social mobility as an inter-generational phenomena. A schematic of the population sector of the revised model is shown in Figure 3.

"Births", represented by UBR, LBR, and MPBR for the three population classes now refer to gross rates of new household formations and a common "death" rate was established for all classes. The normal portion of new households that move to higher population classes are defined by UMN (underemployed to labor), UTMN (under-employed-to-manager) and LMN (labor to manager). As in Urban Dynamics, these rates are influenced by such long-term factors as public expenditures, i.e., education, and population mix, but are <u>not</u> influenced by job conditions which are here considered as <u>local</u> conditions in contrast to the more widespread influences that give rise to generational upward mobility.

Because the geographic mobility of newly-formed households is greater than for the population as a whole, the normal rates of departure for new households, defined by UNEWDN, LNEWDN, and MNEWDN, are respectively much higher than the normal rates of departures, UDN, LDN, MDN defined for the rest of the population. However, the actual rates of departures of new households may be higher or lower than the normal, depending on the same factors that Forrester defines as influencing out-migration.

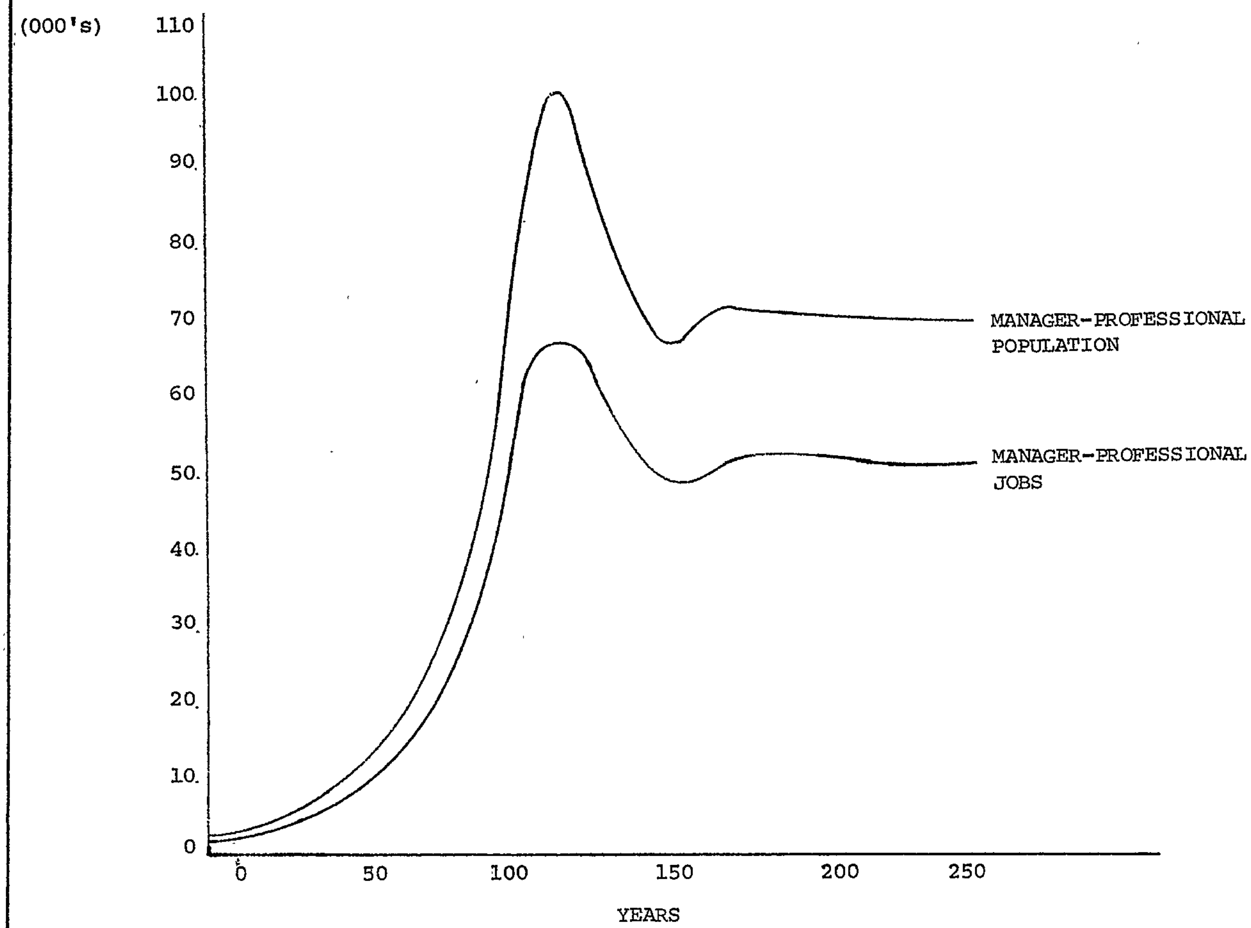
While this model was developed as part of a multi-neighborhood simulation, these changes were incorporated into the Urban Dynamics model to determine whether a plausible set of values could be found that would give rise to a net in-migration of manager-professionals, at least during the periods of most rapid growth of the simulated urban area. In addition, the values of jobs per business unit were set equal to 2 for the manager-professional class and 13 for the labor class for all business units, regardless of age, to offset the impact of Forrester's modeling of the industrial sector on the job market. In this way, the number of jobs for all classes is proportional only to the number of business units.

High and low values were established for each set of 3 variables (1 for each population class) defining household formation rates, social mobility rates, and departure rates for new households (Table 7).

The modified Urban Dynamics model was run for each of the eight combinations of the two levels of each set of variables. For all of these values, the normal upward flow to the manager-professional professional class is lower than the normal rate in the original model.* However, despite this fact and

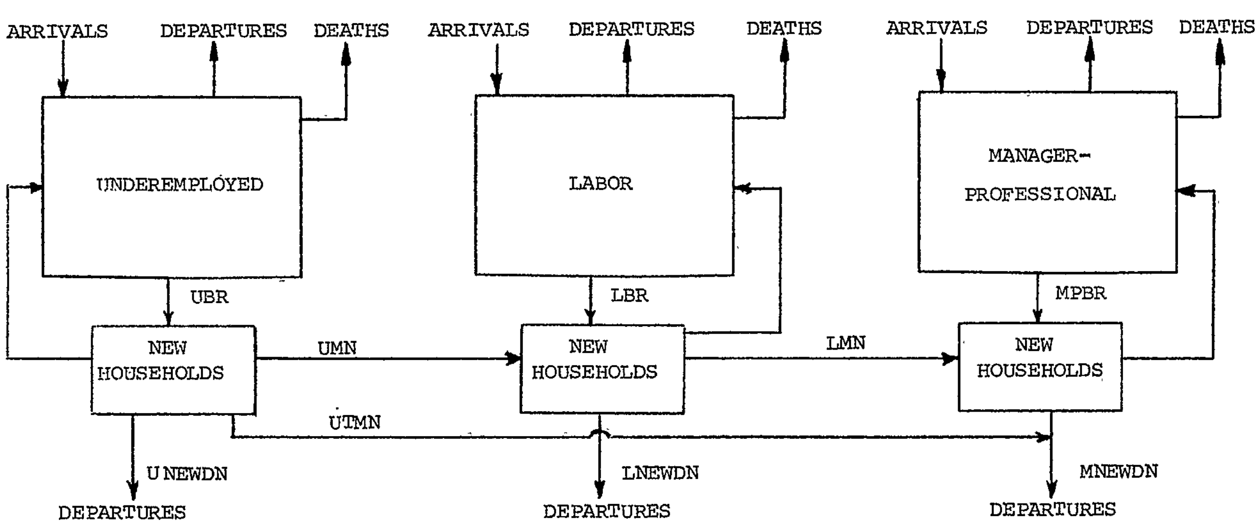
*The highest normal rate is achieved at high values of household formation and social mobility rates and at low values of new household departure rates. While the underemployed class is slightly smaller

FIGURE 1



MANAGER-PROFESSIONAL POPULATION AND JOBS: ORIGINAL URBAN DYNAMICS

FIGURE 2



SCHEMATIC OF INTER-GENERATIONAL MOBILITY MODEL despite the fact that jobs were not lost as industrial units aged, no combination of values tested generated a sufficient excess of manager-professional jobs to induce a net in-migration of this class during any period in the development of the simulated "city".**

What is not included, of course, is the fact that upward social mobility has been accomodated by an increase in skilled and white collar jobs required by changing technology. These results then would argue that any effort to extend, refine and apply Urban Dynamics must contend with the fact that the incorporation of social mobility in that model requires a compensating adjustment in the industrial sector to reflect the labor market's ability to absorb the upward mobile. More generally, urban modelers may continue to ignore social mobility or may follow Forrester's lead and incorporate it into their models; they can assume a static occupational mix in the labor market or they can recognize the changes that have occurred in the occupational mix; but as these results show, these choices are not independent.

SUMMARY AND CONCLUSIONS

By including phenomena that are generally ignored by urban modelers, Forrester posed a challenge to social scientists and urban modelers alike to determine whether such phenomena are important to urban simulations and if so whether Forrester's method of modeling is sufficient. This paper has focused primarily on one such phenomenon, social mobility.

A consideration of the role of social mobility in determining the population structure in urban areas indicates that social mobility is relevant to a wide class of dynamic simulations in which the socio-economic structure of the simulated population is important. However, an analysis of the migration patterns generated by the Urban Dynamics model and experimentation with a modified model indicates that Forrester's inclusion of social mobility is incompatible with his formulation of the industrial and job sectors of his model. This result is not only relevant to those seeking to extend, refine, and apply Urban Dynamics, but also suggests that in general if social mobility is included in a simulation it must be complemented by a changing labor market structure.

* (continued) than the labor class in the original Urban Dynamics model, assuming them to be equal, the highest normal flow [(1.0-.15)(.045*.40*L+.05*.05*U)] = .0174*L, as compared to .02*L in the original model.

** The model was less robust to changes in parameter values than we had anticipated. For runs with household formation rates, social mobility rates and departure rates at values of low, high, high; low, high, low; high, high, high and low, low, high respectively, the major levels of the model went to zero. To avoid this, we made the rate of creation of new enterprise units less sensitive to the ratio of man/jobs for the manager-professional and labor classes. The results reported here apply to runs before and after this additional change was made.

TABLE 7

	HIGH	LOW
HOUSEHOLD FORMATION RATES,%/YEAR		
UBR	5	3.65
LBR	4.5	3.45
MPBR	4.0	3.35
SOCIAL MOBILITY RATES,%/YEAR		
UMN	25	10
UTMN	5	2
LMN	40	15
NEW HOUSEHOLD DEPARTURE RATES,%/YEAR		
UNEWDN	15	5
LNEWDN	30	10
MNEWDN	45	15

Experimental Values Used in Modified Urban Dynamics Model

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