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THEORETICAL ISSUES AND PRACTICAL ALTERNATIVES IN MODEL DESIGN

THE ECONOMIC THEORY underlying the design of the model is based on several simplifying assumptions about the characteristics of the housing market. The need to simplify does not stop with the development of the theoretical model, however. Programming, technological, and budgetary considerations imposed further compromises between what would have been desirable and what was feasible. In this chapter, we discuss several of these compromises.

Some Problems of Implementation and Theory

Numerous problems were encountered in transposing the model design sketched in Chapter 3 to a workable computer model. Some of these problems were theoretical in nature and stemmed from the representation of market processes in the model. Others were caused by a lack of data or budget constraints. For example, small sample size is an obstacle when studying housing choices of minority groups, and zonal attributes such as school quality or neighborhood amenity levels are difficult to measure. A more serious constraint on the final model was computer technology, or more precisely, model-running costs. To be useful the model had to have the capability of running for several market periods at a reasonable cost. This self-imposed requirement was the primary limitation on the size and complexity of the model, rather than computer technology in any simple sense. Because of these considerations some housing market detail had to be truncated or eliminated entirely. As is discussed in the final chapter, we have been successful in building a large and complex model with modest running costs and with potential for growth. In this section of the chapter we describe how several theoretical and practical problems were resolved when the operational version of the model was developed.

Market Clearing, Excess Demand, and Disappointed Expectations

The interaction of the supply and demand sectors in this model does not guarantee that supply will be precisely equal to demand in each submarket during each market period. Therefore, in a strict sense the housing market is not cleared each period. The housing market is viewed in the model as dynamically adjusting toward, but not necessarily reaching, a new equilibrium during each market period; and short-term disequilibria in housing submarkets are accepted as consequences of this view. A disequilibrium representation of the housing market may be a better representation of reality than one which requires that all markets adjust fully, since at any point in time there are vacancies outstanding in some unit types and an excess of demand for other types.

The manner in which excess demand or supply is handled in a housing submarket of the model derives from the use of linear programming in the demand and price formation sectors. After households are assigned to housing types by submarket demand equations, they are assigned locations within their submarket by a linear programming algorithm which minimizes the travel cost within the submarket. The dual variables from the programming solution are then used by the price formation sector to adjust expected prices for the next time period. It is a requirement of the linear programming problem, which is a transportation or Hitchcock problem, that the total number of households to be located must equal the total number of dwelling units available.[1]

In a submarket with excess supply during a market period, the number of households choosing the housing type is increased by adding pseudo-households until demand is exactly equal to supply. These pseudo-households have zero travel costs to all residence zones and thus are assigned to the locations which would be most

1. Sasieni, Yaspan, and Friedman, *Operations Research*, pp. 194–220.

expensive for the households with nonzero travel costs. When a pseudo-household is located in a housing unit, the shadow price on the unit is zero, and it is noted as vacant. The price formation sector of the model then forms location rents and market prices, setting the location rent in a marginally vacant zone to zero. If a submarket has a large excess supply of units, this procedure causes prices in the submarket to fall over time.

When a submarket has an excess demand in a given period, that is, more households to be assigned than dwelling units available, the number of available dwelling units is increased by adding pseudo-units. The travel costs required to locate in these pseudo-units are quite high for each household. In the Detroit Prototype they are 5 per cent greater than a household's highest travel cost to an actual zone.

Several interpretations can be applied to these pseudo-units. For example, they may be considered locations outside the metropolitan area because of the high travel outlays required to reside in them. Alternatively, pseudo-units may be thought of as representing fairly expensive temporary quarters, such as hotels occupied by the household while it searches for a dwelling unit. The pseudo-units have an affiliated travel cost and therefore a spatial dimension in the model, but they are treated as temporary shelter. All households assigned to a pseudo-unit during a market period become movers again the following period.

In the price formation sector of the model, pseudo-units have a zero location rent. Because of the high travel costs assigned to pseudo-units, setting their location rents to zero will increase the location rents and housing prices in submarkets which have excess demand. This procedure augments the location rents of units in excess demand to reflect the upward pressures such demand exerts on expected prices.

The foregoing treatment of possible excess demand in housing submarkets is a manifestation of the over-all market model's tentative and incomplete treatment of short-term market dynamics. Although both the demand and supply sectors of the model are keyed to expected prices, it is clear that significant exogenous changes in levels of demand could easily result in disappointment of price expectations.

Within the present model framework there are two ways of improving the short-term dynamic behavior of the model, but both are expensive. First, the model time period could be shortened considerably. This would require an explicit treatment of seasonality and would incur the cost of having the model run more times per calendar year, although a shorter time period would presumably make price changes between periods smaller and disappointed expectations easier to overlook. The second approach would require iterating between the demand sector and price formation sector of the model in order to revise price expectations until they matched market prices. This technique would also substantially increase computer running time per calendar year. Because their costs in computer time are very great and the gains seem rather small, neither of these modifications has been incorporated into the NBER model. If experience with the NBER model suggests these are serious problems, the decision can be reconsidered in future model development. However, period-to-period changes in expected prices of dwelling units have not been large in trial runs of the model, rarely exceeding 10 per cent for specific units.

Travel Costs, Work Trips, and Work Places

In the demand sector of the market model, relocating households are assigned to locations within each submarket in a manner which minimizes their travel costs. Theoretically all travel costs incurred by a household should be included in this minimization procedure. Such a total would include the time and out-of-pocket costs of at least three types of travel: work trips, shopping trips, and social and recreational trips. However, the travel costs of a household's shopping and recreational trips have been excluded from its total travel costs because the costs of these trips are difficult to calculate in the model, and omitting them may not affect the locational assignment of households.

Since households are classified in the model by workplace zone and household class, it is a simple matter to formulate a household's hypothetical work-trip travel cost to each residence zone. On the other hand, formulating the cost of a household's shopping and recreational trips cannot be done with such precision because the destinations and frequencies of nonwork trips are unknown in the model.

Omitting nonwork trips is not important if the costs of such trips do not vary much by residence zone. There are at least two reasons for expecting the costs of these trips to have relatively little spatial variability. First, the possible destinations for shopping and recreational trips are distributed throughout the metropolitan area; so most residence locations will be near suitable destinations for these trips. Second, there is evidence that households faced with longer nonwork trips become more efficient in their trip-making behavior—for instance, by making more multipurpose trips—so their travel costs for nonwork trips probably do not vary a great deal by residence zone.[2] It is generally not possible, however, for a household to increase the efficiency of work trips, e.g., by going less often and working longer hours; so the travel cost of the fixed destination work trip has a wide spatial variation.

If the costs of nonwork trips have no variation by residence zone, excluding them will not affect the outcome of the assignments because the solution as well as the values of the dual variables of the Hitchcock problem are invariant if a constant is added to each element of the transport cost array. Thus the travel costs used in assigning households to residence zones consist entirely of the cost of the work trip.

The use of only the work trip in models of residence location and the housing market is a common simplification. For example, the monocentric models described in Chapter 2 above typically treat all trips as work trips. This simplification is usually justified by the observation that work trips are the single most important component of total trips, accounting for between 40 and 50 per cent of a household's total trips.[3] Because work trips are usually the longest trips made by households, the work-trip share of the total travel costs of a household undoubtedly exceeds the work-trip share of total trips.[4] And some authors have suggested that the regularity of work trips makes them more dominant as a determinant of a household's residence choice than the size of their share of travel costs would suggest.[5]

2. Ginn, "Transportation Considerations," pp. 55–69.
3. Kain, "Journey-to-Work," p. 139.
4. Meyer, Kain, and Wohl, *Urban Transportation Problem*, p. 188.
5. Hoover and Vernon, *Anatomy of a Metropolis*, p. 206.

Using the work trip as the sole component of travel costs in a multiworkplace setting raises a problem if multiworker households have more than one workplace. Households with several workplaces may locate in a manner which minimizes their total work-trip cost, or they may continue to base their choice of residence location solely on the workplace location of the household head or major worker. In this latter case workers other than the household head would have a secondary status, choosing their workplace location only after their new residence location is given. The multiworkplace possibility has been handled in the model by assuming that a household's residential location is dependent only upon the workplace location of the household head; other workers in the household are assumed to adjust their workplace location to the household's residence location. In Detroit, approximately one-quarter of the sampled households contained more than one worker.

In addition, significant fractions of households have no workplace and, therefore, no work-trip travel cost. In Detroit, 12 per cent of sampled households were headed by a retired person, and in 6 per cent the occupation listed was housewife (Table 4.1). To be included in the model, the household had to have an employed head. Therefore only slightly more than 79 per cent of Detroit households are represented in the Detroit Prototype.

A plausible assumption about the locational decisions of retired households, particularly homeowners, would be that they do not typically move upon retirement, but await some change in status, such as failing health or the death of one member before changing

Table 4.1
Status of Household Heads in Detroit

Status of Household Head	Percentage of Households
Employed	79.1
Retired	12.1
Housewife	6.3
Unemployed	1.3
Student	0.6
Disabled, etc.	0.6

Source: 1965 Detroit Transportation and Land-Use Study (TALUS) home interview survey.

location. Research on household mobility by Kain and Quigley for St. Louis households and by Brown and Kain for San Francisco provides some support for this view. Both studies find that retired households have very low rates of mobility.[6]

It should be noted, therefore, that the data presented in Table 4.1 are somewhat misleading because it is a classification of all households in the sample. In any time period, only those households that seek housing during the year must be located. Although approximately 12 per cent of household heads referred to in Table 4.1 are retired, the moving rate of household heads over 60 years of age is far less than the average moving rate of the whole population. This implies that in any market period much less than 12 per cent of the locating households would fall in the retired category.

Some Problems of Causality

In the NBER Urban Simulation Model it is assumed that each household knows its workplace when it makes its residence choice. A number of important theoretical questions are raised by this assumption. Specifically, it is obvious that households are not indifferent about their choice of employment and that elements of utility maximization are involved in the selection of a particular job location. In addition, it is apparent that many persons develop strong attachments to particular neighborhoods. As a result, they may first choose a residence and then choose a workplace from among a large number of equally good jobs accessible to their preferred residence area. This practice would be particularly feasible for workers whose job opportunities are distributed throughout a metropolitan area. Others may make truly simultaneous choices of workplace and residence. The theoretically correct way to model these choices would be as simultaneous utility maximization decisions.

It is obvious that this approach is hopelessly impractical for a large-scale model of the kind represented by the NBER Urban Simulation Model. Therefore, the relevant questions are: (1) How correct is the workplace dominance assumption? (2) Does a model using this assumption provide useful conclusions about the behavior of urban housing markets and the processes of urban growth and

6. Kain and Quigley, "Discrimination and a Heterogeneous Housing Stock"; Brown and Kain, "Moving Behavior."

development? Moreover, the conclusions need to be significantly more correct than those provided by simpler economic theories of location and urban structure. A corollary question is whether a model in which the opposite assumption is made, i.e., that households first choose their residence and then pick a workplace, would produce better results.

We believe there are substantial theoretical advantages to the structure of the NBER Urban Simulation Model. Furthermore, there is a good deal of empirical support for the approach used in the model. Support for the assumption of workplace dominance is of two general kinds: (1) evidence on the effect of changes in workplace location on household decisions to move; and (2) evidence on the effect of workplace-specific housing costs on the type and location of housing chosen by spending units.

Evidence of the first kind can be inferred from studies of household moving behavior. In several such studies attempts were made to examine the effect of job changes on household decisions to relocate. Earlier studies are virtually unanimous in the conclusion that intrametropolitan changes in workplace locations have little or no effect on household moving decisions. For example, Goldstein and Mayer conclude: ". . . that intra-urban residential moves are not associated with changes in job location."[7] Rossi is more cautious but emphasizes the life-cycle aspects of moving behavior to the virtual exclusion of employment location or job changes.[8] The near universality of agreement on the question is illustrated by a 1968 review article by J. W. Simmons who, after reviewing studies of mover behavior, states, "all studies reject job location as an important reason for moving."[9]

The unanimity of these views is disturbing since if correct they undermine, if not disprove, the workplace-dominance assumption. Of course, it is possible for households to employ the calculus outlined above when their house hunting is first begun, even if they do not move in response to job changes. Still, unless households adjust their residence choices to significant changes in job location, the empirical and theoretical bases for the NBER model would be weakened

7. Goldstein and Mayer, "Migration," p. 479.

8. Rossi, *Why Families Move.*

9. Simmons, "Changing Residences," p. 637.

Table 4.2
Moving Rates by Job-Change Characteristics and Kind of Move

Characteristics of Job Change	Characteristics of Household Move		
	All Moves	Moves Within Tract	Moves Outside Tract
No job change	.111	.015	.096
Job change within zone	.170	.037	.133
Job change outside zone	.281	.027	.253

Source: Brown and Kain, "Moving Behavior"; compiled from tables 7, 8, and 9 derived from BATSC survey.

considerably. Households change jobs frequently, and any initial explanatory power provided by the model would be reduced over time if they then failed to respond to significant changes in job location by choosing a more suitable residence location.

Careful examination of these studies of intrametropolitan mobility reveals, however, that in most of them job changes were considered almost as an afterthought. As a result, the effects of job changes on residence location are difficult, if not impossible, to observe. In contrast, recent NBER research by Brown and Kain, using data and methodology designed directly to test moving behavior in response to employment location changes, strongly supports the workplace-dominance assumption.[10] The employment and residence histories analyzed by Brown and Kain are far more suitable for an examination of the interrelationship between workplace and residence choice than the data used in most earlier studies, and their results indicate that significant intrametropolitan workplace changes do cause households to change their residence locations.

The data in Table 4.2 provide considerable support for the workplace-dominance view of residence location. The moving rates shown are the proportions of each household category that moved during the year. San Francisco households are divided into three categories in each year: (1) those in which there was no job change within an 18-month period (12 months prior to and 6 months after the midpoint of each year); (2) those in which the head changed jobs within this period, but continued to be employed within the same

10. Brown and Kain, "Moving Behavior"; and Brown, "Changes in Workplace."

workplace zone (these zones are quite small; there are 290 in the San Francisco region); and (3) those in which the head changed jobs during the period and took a job in another workplace zone. The data further distinguish between short (within the same Census tract) and long (outside of Census tract) residence moves.

The results indicate that job changes have little association with short residence moves. The rates are uniformly low, ranging from a moving probability of 0.02 for households with no job change to 0.04 for households which changed jobs within the same workplace zone. The association between job change and the rate of long-distance intrametropolitan moving, by comparison, is striking. The probability of a household's moving from its Census tract of residence is about 0.10 for households with no job change, about 0.13 for households in which there is a change to a nearby job, and 0.25 for households in which the head takes a job in another workplace zone.

Further evidence of the effect of job changes on household moving behavior was provided by Table 3.1, above, which showed moving rates for households by age of head and tenure before the move, the two most important determinants of moving identified by earlier studies, as well as by job-change status (job changes include both long- and short-distance changes). From Table 3.1 it appears that job changes have a substantial effect on moving rates even when tenure and age of head are held constant. For example, the probability of a young (less than thirty years of age) homeowner's moving in a particular year is nearly twice as large if he changes his job within the region than if he does not—0.140 versus 0.076.

Statistics on changes in travel time between home and work for households with job changes provide further support for the hypothesis that households do change their residence in response to job changes that significantly alter their gross housing prices. Again, two groups can be identified from the San Francisco sample: (1) households that changed both their job and their residence within the region, and (2) households that changed their job, but not their residence. For the first category, a comparison of mean travel times between the old workplace and old residence and new workplace and old residence indicates that on average changes in job location would have increased both the distance and travel time between work and home if the households had not moved. For those who changed both their workplace and their residence, mean travel time between the old workplace and old residence was 17.2 minutes; but between the new workplace and old residence the travel time was nearly seven minutes longer. After a change in residence location, however, the difference is less than two minutes. Households that did not change their residence in response to a workplace change on average lived closer to their residence after the job change than before.

Evidence on the effect of workplace-specific housing expense in housing choices also must depend primarily on NBER studies. The first systematic evidence that we are aware of, however, was provided by Kain in a series of papers based on analysis of origin-and-destination data from Detroit and Chicago.[11] More rigorous tests of the hypothesis have been provided by a series of NBER studies which are summarized in Chapter 8. All of these studies contain compelling evidence that the location of the household's workplace systematically affects its choice of residence site and housing type.

Finally it should be noted that it is not essential for the assumed causal relationship between workplace and residence to be literally true. It will suffice for households to choose their workplace and residence in ways consistent with the assumption. It may be enough that households recognize the time and money cost of commuting as well as spatial variations in housing costs in choosing jobs and residences, and that they attempt to minimize these costs in a manner that is consistent with their preferences for both different kinds of housing and higher-paying employment. U.S. families change residences and jobs frequently and for a variety of motives. The model will have some validity even if households attempt only in a general sort of way to maximize their real incomes in making these residence and job changes. The question of how well the model represents reality cannot be determined a priori. The answer to this question can be determined only by subjecting the model to rigorous testing.

The exact manner in which households make these choices does matter, however, and as a result, we are continuing our research on the interrelationships between workplace and residence choices. This

11. Kain, "Contribution to Urban Transportation Debate"; idem, "Journey-to-Work." Some findings from these papers are summarized above; see Chapter 3, "The Demand Sector."

research may either support the approach currently used or suggest modifications for subsequent and more advanced versions of the model. The most likely alteration would be to modify the location-choosing behavior of specific subgroups of the population.

Workplace-Residence Causation and Race

In the NBER Urban Simulation Model households are classified by their workplace zone and household class. Since the work trip is the sole component of travel costs, households are assigned to locations which minimize their work-trip costs within housing submarkets. In this approach it is implicitly assumed that households participating in the housing market follow a specified sequence of decisions. A household first participates in the labor market in order to find a suitable job and workplace location. The household then surveys the housing market from the vantage point of its workplace and picks a housing type and residence location.

Although this representation of a household's decision-making process may be an adequate summary of the way a large proportion of the population actually behaves, the process may run in the reverse order for some groups. For example, residential segregation not only limits the housing choices of nonwhite households but also affects the choice of workplaces by black workers. As a result the latter are significantly underrepresented in the labor forces of workplaces distant from the ghetto.[12] It may be more realistic to assume that nonwhite households are so constrained by their residence opportunities that they find a residence location first and then obtain a job and workplace. This alternative sequence of decisions may also be more satisfactory for households attracted to residence locations which have certain ethnic identities or for households that may have strong preferences for particular residence zones for other reasons.

Despite the possibility that a sequence of decisions running from residence choice to workplace location may be more appropriate for some groups, it has been excluded from the model described in this volume. The Detroit Prototype does not incorporate a racial dimension in the household classification system, and nonwhites have

12. Kain, "Housing Segregation."

been dropped from the set of households used to estimate the submarket demand equations for Detroit. The sample of nonwhites was somewhat small for separate estimation, and the inclusion of racial effects in a housing market model is a difficult task. Although such an enlargement of the model's framework is a high-priority item for future versions, the Detroit Prototype embodies racial effects only to the extent that the residential patterns of nonwhite households have influenced the housing choices of white households.

Model Specifications and Calibration

Theoretical considerations produce a general outline of the model and its relationships. When implementing the model design in a simulation framework, however, a general outline is not sufficient because each relationship suggested by theory must be precisely specified. One must turn from theory to empirical evidence to realize the precise specification required by the model.

For example, theoretical considerations may suggest that the value of time used in making trips is a function of income.[13] However, the form of this function, e.g., linear or nonlinear, and the value of its parameters are not specified by the theory. In this case several empirical investigations have been carried out to measure the value that commuters appear to place on their travel time. Examples of the results obtained are presented in Table 4.3, where it is shown that there is a choice in the specification of the relationship as well as in the magnitude of the coefficients. One can agonize over alternatives such as these and suffer the fate of Buridan's ass, who, caught equidistant between two similar piles of hay, starved to death out of indecision. In this case the simplest specification was included in the model, and the valuation of travel time on the work trip was assumed to be four-tenths of the wage rate. One virtue of simulation models is that sensitivity analysis can be carried out on functions such as the relation between income and the value of time. If model results are extremely sensitive to the results, further consideration of the specification can be made, or additional empirical research on the problem may be carried out.

13. Becker, "Allocation of Time"; and Gronau, *Value of Time*, pp. 7–11.

Table 4.3
Value of Commuters' Travel Time

Salary and Study	Value of Time as Proportion of Implicit Hourly Wage
Beesley[a]	
£ 650	.31
850	.37
2,200	.42–.50
Lisco[b]	
$ 4,000	.20
6,000	.29
8,000	.41
10,500	.51
13,500	.47
17,000	.38
Becker,[c]	
salary unspecified	.40

a. Beesley, "Time Spent in Traveling."
b. Lisco, "Commuters' Travel Time"; derived from Table 3, assuming 2,000 hours to constitute a working year.
c. Becker, "Allocation of Time," p. 510.

Time and Space in the Detroit Prototype

The Detroit Prototype simulates the behavior of households and firms located in urban regions that are the size of large metropolitan areas in the United States. Such areas typically consist of a high-density urban core, perhaps a few smaller outlying subcenters, and a low-density, lightly developed surrounding area.

This large area is encompassed by the model so that relatively few interactions between the modeled area and the rest of the world need be represented. Since the modeled area includes the fringe of residential development, the interactions which must be represented at the boundary can be limited to a selected few. It is possible, for instance, for a household to live outside of the modeled area for a few time periods and have a place of employment within the area. However, a household cannot work outside of the area and live within it. Although both in-migration and out-migration of households take place between the modeled area and the rest of the world, the migration rates are dependent upon the growth of employment opportunities within the area. Conditions beyond the modeled area are not considered.

On the other hand, if the model represented a smaller area, such as a central city, it would have to simulate many of the interactions which occur between the city and surrounding suburbs. These interactions would have to include the impact of suburban commuters on the city's transport system and the effect of available housing outside of the central city upon the residence choices of central city workers.[14]

Locations within the modeled region are identified by a system of residence and workplace zones. The residence zones are contiguous and exhaust the simulated area, but in the Detroit Prototype only 19 of the 44 residence zones are workplace zones. Having fewer workplace zones than residence zones is not a requirement; it merely reduces computational costs.

The transportation system is described by an interzonal matrix of trip costs, travel times, and numbers of trips. Because it ignores variations in the distance between different points which are within pairs of zones, such a representation inherently oversimplifies the transport system. This problem becomes less serious, however, as the number of zones is increased and the size of each zone is reduced. The large size of the zones in the present model implies that it can only be used to investigate the impact of fairly large changes in transportation systems, such as the construction of a freeway or the establishment or improvement of mass transit service. Finally, the computational savings of an interzonal representation of transportation are significant as compared with a system of continuous coordinates or a transport network.

Within the simulation model, time is divided into discrete periods representing one year apiece. Although these time intervals could easily be altered to represent multiples of one year, shortening the model time period to less than one year would be difficult because there is a significant seasonal element in both household moving rates and construction activities.

Housing market activity which spans the entire time period is

14. For discussions of a model having a misspecified spatial representation, see Ingram, Review of *Urban Dynamics*, pp. 206–208; and Kain, "Computer Version of a City," pp. 241–42.

modeled as if it occurred at one point in time within each period. In effect, it is assumed that there is one relatively short period of time per modeled period during which all moving decisions are made by households and all vacant, transformed, and new housing units are made available by suppliers. One can think of the model as representing the market day on which all contracts are signed for the year. This does not mean that all houses are to be supplied the same day but rather that contracts calling for their construction or transformation are all signed on the same day. This assumption implies that the simulation model is not a good tool for studying the dynamics of short-term market adjustments, an application for which the model was never intended. Instead, its use must be limited to studying market behavior over more than one time period, a restriction of little importance in a wide variety of cases.

The ability of a simulation model to represent the real world adequately is a function of two fundamental model attributes: the behavioral structure of the model and its dimensionality. The model's structure incorporates behavioral assumptions which specify how the phenomena treated by the model interact with one another. It reflects both theory and certain empirical findings. Verification of the model's structure can be achieved either by carrying out empirical investigations or by calibrating the model and running it to produce a time path of an urban area. This trial path can then be compared to observed urban histories.

This latter approach immediately raises the question of model dimensionality. The results of a trial may not conform to real-world observations because the model lacks sufficient dimensional detail. Such dimensional shortcomings arise in two ways. First, the model may exclude variables which are in fact important. For example, the simulation model described here does not explicitly incorporate race. And second, the model may not allow sufficient degrees of freedom for those variables which are included. In the Detroit Prototype, for example, lot size is included as a dimension of the housing bundle, but perhaps four or six different sizes are required rather than the two allowed.

Once a variable is included, determination of its dimensions depends on the characteristics of available data; on the size, speed, and other capabilities of the computer; and on the extent and soundness of empirical evidence. The data used in the model calibration may limit the number of categories which can be used for some variables. For instance, if Census data are used, the number of structural types (units per building) cannot exceed eight, the number reported. Computer capacity limits dimensionality because there is an upper bound to the array size which can be handled in core at any time. Computer technology has improved at a rapid rate, however, and the capacity of present machines (the IBM 360/91 has 1.2 million bytes or more of core storage) is not as serious an obstacle for simulation models as it once was. Continuing progress in computers will make data limitations and model design more crucial than computer size. Computational considerations constrained the design of this model, not principally because of limited computer size, but because of the desire to have a model that could inexpensively produce large numbers of simulations for both model development and policy evaluation.