U.S. Department of Housing and Urban Development
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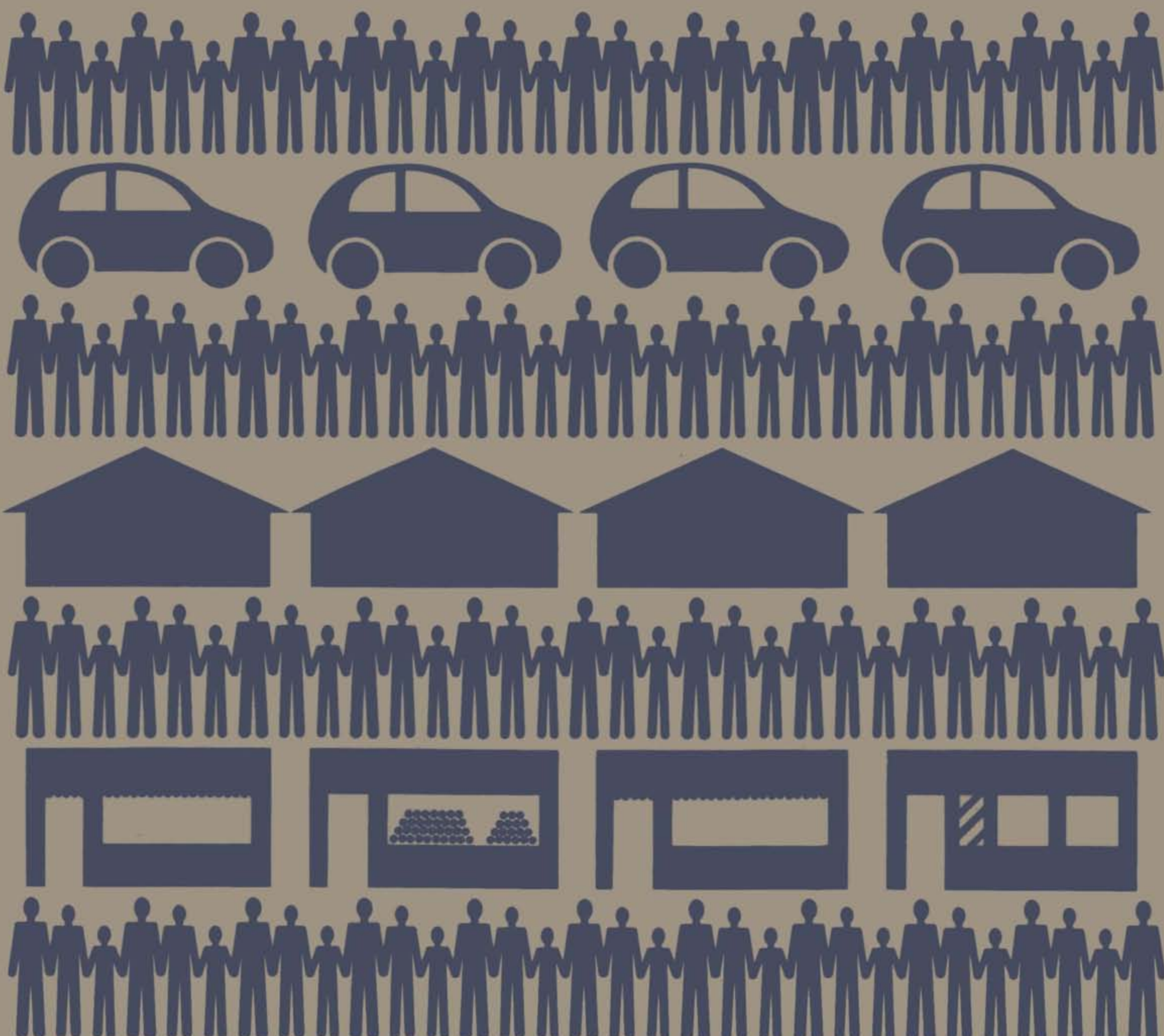
# A Critical Evaluation of "The Community Analysis Model"



# A CRITICAL EVALUATION OF "THE COMMUNITY ANALYSIS MODEL"

by

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for the

Department of Housing and Urban Development

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# FOREWORD

The process of neighborhood change is a complex and multifaceted subject which has engaged the attention of scholars from a number of diverse disciplines. Much has been written and a variety of approaches to the subject have been tried. One approach has taken the form of large-scale computer-based mathematical models which attempt to explain the behavior of the various actors who make up urban neighborhoods. The most recent effort in urban spatial model building is the Community Analysis Model, the product of an ambitious effort by a team of scholars at the Massachusetts Institute of Technology.

This report is an independent technical evaluation of the Community Analysis Model. The model is described concisely and in non-technical terms in this report, and the differences between this model and other existing urban models are also discussed. This report is a valuable introduction to the Community Analysis Model and a useful document for anyone interested in the subject of urban spatial models.

Professor Edwin S. Mills of Princeton University has done an incisive and thorough job in preparing this report. Earlier drafts received extensive comment from the Government Technical Representative, Howard J. Sumka, of the Division of Community Conservation Research and from Raymond J. Struyk, Deputy Assistant Secretary for Research.

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Assistant Secretary
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## PREFACE

This report is an independent technical evaluation of the Community Analysis Model (CAM), an ambitious and wide-ranging urban spatial model which was developed by a research team at the Massachusetts Institute of Technology. A detailed presentation of CAM is contained in two separate documents published by the Office of Policy Development and Research: The Community Analysis Model, and The Behavioral Foundations of Neighborhood Change, both by David Birch, et. al. These documents constitute the basis for this technical evaluation.

The objectives of this report are twofold: description and criticism. An impressive amount of work in a range of academic disciplines has gone into the CAM project, and a massive amount of technical material and reportage has been produced in the process. This evaluation concisely summarizes this research and provides a coherent, non-technical description of the structure and use of the model, and the data base underlying the model. In this sense, this report serves as a lucid introduction to the Community Analysis Model.

There have been a number of efforts in the field of urban modelling in recent years, each effort differing from the others in theory as well as methodology. Two such efforts which have been supported by HUD are the models developed by the Urban Institute and by the National Bureau of Economic Research. This report carefully details the strengths and weaknesses of the Community Analysis Model and discusses the manner in which it differs from other extant urban models. The characteristics of the model structure as well as the potential uses of the model are critically evaluated, and recommendations for future development are made.

CONTENTS

## 1. Summary

This report is a critical evaluation of the Community Analysis Model, a large computer-based mathematical model of growth and change in urban neighborhoods, prepared by a team of M.I.T. scholars headed by David Birch. The computer model has been estimated and solved for six metropolitan areas and has been used to analyze developments, to forecast growth and change, and to plan development in the six places.

The Community Analysis Model is the latest and most ambitious research effort in a history of urban spatial model building that covers nearly two decades. Economists, city planners, geographers and other specialists have contributed to the subject. The Community Analysis Model is the work, primarily, of non-economists. Each large urban model has advantages and disadvantages compared with others. The Community Analysis model has the advantage of freshness of approach to a subject increasingly dominated by economists in recent years. It has the disadvantage that it is not grounded in techniques and findings of economists on the subjects studied.

The remainder of this report is in eight sections. Section 2 refers briefly to the documents on which the report is based. Section 3 contains a non-mathematical summary of the model. Section 4 contains a brief summary of the major background document for the model. Section 5 presents a critical evaluation of the Community Analysis Model, emphasizing its underlying theoretical structure. Section 6 presents a discussion of the collection of data for the Community Analysis Model, the estimation of its parameters, and its testing by

forecasting neighborhood changes. Section 7 discusses the potential uses of the Community Analysis Model for practical urban planning. Section 8 discusses possible directions for future developments of the model. Section 9 presents conclusions of the paper.

A summary evaluation of the model follows:

First, it is a large and ambitious model. It attempts to analyze and forecast more characteristics of urban development, and in greater spatial detail, than other extant urban models.

Second, the numerical implementation of the model has proceeded much further than with competing models. All the important published data sources have been exploited. More important, Birch and his team have collected large amounts of relevant data from field surveys in the six metropolitan areas studied. The result is an impressively large data collection and storage effort that has been used to estimate the model, forecast developments and analyze local government planning alternatives.

Third, the method of solving the model on the computer is much more modern and efficient than are numerical methods used with competing models.

Fourth, the model suffers in some respects from lack of contact with recent economic literature. The most important examples are that behavioral patterns are attributed to mechanical characteristics of actors -- such as age, sex, race, etc. -- instead of to underlying economic conditions and constraints.

Fifth, estimation of the model appears to be uninfluenced by modern econometric and statistical estimating techniques. Estimation techniques appear to be restricted to computation of average behavior and "multipliers" from the data.

Sixth, there is no adequate discussion of the model's policy uses. It was formulated to analyze and forecast urban growth and change. Yet it is used, apparently advantageously, by local planners. However, the model contains few planning parameters and no procedures by which to evaluate the social desirability of alternative local government actions.

Formulation, estimation and analysis of a large urban model is an enormous job, entailing many years of work. Many compromises must be made with ideal techniques to get the job done within limitations of time, data and money. The Community Analysis Model is an original and important scientific contribution to a growing field. Criticisms at least as serious as those made in this report could be made about every existing urban spatial model. Future urban model builders should not begin their work without taking account of the contributions made by the Community Analysis Model.

## 2. Sources

This report is based on four documents: The Community Analysis Model, by David Birch, et.al. (March 1977); The Behavioral Foundations of Neighborhood Change, by David Birch, et.al. (March 1977); Using and Evaluating the Community Analysis Model, no author listed, (September 1977); and Models of Neighborhood Evolution, by David Birch, et.al. (November 1974). In what follows, the first two reports will be referred to as CAM and BFNC.

CAM contains the literary background, the mathematical model of urban change, and some numerical forecasts made with the model. BFNC presents data, largely collected from surveys conducted from the project and used to estimate parameters of the model. Using and Evaluating the Community Analysis Model presents information on uses that have been made of the model in six cities. Models of Neighborhood Evolution is an annotated bibliography of urban models. Most of what follows will be concerned with CAM. Less will be said about BFNC, and no comments will be made on the final two documents.

The only existing models that are comparable with CAM are the Urban Institute Model, The Web of Urban Housing, by Frank deLeeuw and Raymond Struyk (Urban Institute, 1975), and the NBER model, The Detroit Prototype of the NBER Urban Simulation Model, by Gregory Ingram, John Kain and J. Royce Ginn (NBER, 1972). In what follows, these studies will be referred to as the UI and NBER models. Many other urban models have been formulated and estimated, but they are either dated, much smaller or have much more restricted purposes than CAM. Forrester's Urban Dynamics, for example, has no spatial detail and almost no empirical content.

## 3. A Critical Summary of CAM

### a. General Characteristics

CAM is an extremely ambitious model. Its goal is a remarkably comprehensive account of urban growth and change. Its mechanism is a large mathematical model, designed for computer solution and employing thousands of equations and variables.

The subject of the model is a generic urban area. The model has been implemented for six urban areas, each of which is the urbanized part of a Standrad Metropolitan Statistical Area. It could presumably be implemented for any urban area, including those too small to qualify as SMSA's. All variables in the model refer to a given urban area (referred to in CAM as a "region," an unfortunate choice of terminology).

The basic exogenous variables in the model are the annual total migrations of people (classified by age, education and ethnicity) and jobs (classified by job type) into and out of the urban area.[1] Each year, some people and jobs already in the urban area change locations. Sections of the model analyze the choices made among neighborhoods by people who move (each neighborhood defined as one or more contiguous census tracts) and the choices made among district employers who move production sites (each district consisting of several contiguous neighborhoods). Sectors of the model allocate workers to jobs and workers and their families to available housing. Sectors of the model analyze the construction, maintenance, deterioration, demolition and abandonment of housing. Two activities of local governments are analyzed in the model: zoning and resource allocation to public schools.

[1]Total inter-urban area movements of jobs and people are said to be determined by an aggregative model, reference [2], p. 60, CAM; but the totals are exogenous to the model under review.

All the behavioral equations in the model are estimated, mainly from census data and from data collected by surveys conducted for the project. In fact, given behavioral equations are the same in all six urban areas; only the exogenous variables and initial conditions vary from one urban area to another. In principle, the procedure is appropriate. If behavior is related to fundamental socio-economic and demographic variables, responses to such variables should be independent of community. But shortcuts are taken in all urban models, including CAM, and behavior is related to proxies for underlying variables. Such behavior may in fact be community specific; it is difficult to know without reestimating the model separately for each urban area. The entire numerical model is programmed into a large computer. Starting with initial conditions for a given year (say 1960) and urban area (say Houston), and using values of the exogenous variables for the same city and next year, the computer solves the model for the next year (say 1961). Using the solution of the model for year T as initial conditions, and using values of exogenous variables for year T+1, the computer solves the model for year T+1. Proceeding in this fashion, the computer can solve the model for forecasts of all endogenous variables for any future year. In particular, solution of the model for a subsequent year (say Houston in 1970) can be compared with actual data for the urban area in the subsequent year. This constitutes the basic test of the model.

CAM is much more ambitious than the UI or NBER models. They concentrate almost exclusively on supply and demand of housing by neighborhood and socio-economic characteristics of families. CAM analyzes, in addition, employment location and the two local government activities (zoning and public school provision). CAM is not less detailed than the UI and NBER models in its classification of neighborhoods, personal characteristics and employment locations and characteristics. If anything it is more detailed, especially than the UI model. CAM requires a computer with a large memory because many variables and parameters must be stored. Yet it is not expensive to solve. One reason for the cheapness of its computation may be that it is more efficiently programmed than other urban models. But another important reason, related to the substance of the model, is its relative lack of simultaneity. The NBER model, for example, allocates large numbers of movers to large numbers of dwellings in such a way that the housing market is cleared each solution period. In CAM, people tend to make decisions based on data from earlier periods. This permits each equation to be solved separately. In a simultaneous model, all simultaneous equations must be solved together. There is in fact some simultaneity in CAM. It appears to be less than in the UI and NBER models, but it is difficult to be sure because endogenous variables are not designated clearly in CAM. The substantive issue is whether it is more realistic to assume that markets clear within a solution period or to assume that markets may be left uncleared at the end of the period. For example, housing vacancies may be above or below equilibrium in a solution of

CAM. Of course, high or low vacancies affect behavior of residents, landlords and builders in the next period. The example makes clear that there should be no presumption of superiority for a model that clears markets each period. (Of course market clearing is only partial in the UI and NBER models.) But it is more important to study whether solutions converge to market clearing values in a model that lacks simultaneity and, therefore, market clearing properties in each period. More will be said on this subject below.

It is easy to get the impression that large computer models are extremely complex and can be understood only by specialists. The conclusion is incorrect for CAM. The model consists of many equations and variables. But they fall into a relatively small number of sets of equations and variables, with similar characteristics within each set. Each equation is written out clearly and all variables are defined in easily accessible places. (The mnemonic designations of variables leave something to be desired.) All equations in the volume can be understood by anyone with the patience to go through them carefully. Equally important, there is no mathematical analysis in the volume. All the mathematics is done by the computer.

Unfortunately, understanding the model is easier than evaluating it. It is easy to conclude, after a careful reading of the volume, "I understand each equation and most look plausible, but is the model true?" That is a difficult question. Basically, the test of the model is whether its forecasts, conditional on correct values of exogenous variables and initial conditions, accord with the facts.

That is not easy to ascertain. One reason is that many variables needed for testing come only from decennial censuses. Thus, the model is forced to make 10-year forecasts and one must wait a decade for a test. Such tests have been done for 1970 forecasts. A second reason is that forecasts have been compared with facts for only relatively few variables in CAM (Section 12). A second way to test the model is to ask whether individual equations or sectors of the model accord with economic theory or with common sense. Much of the analysis in this report is of the second type.

Finally, being correct is not the same as being useful. A model that forecasts that the sun will rise 365 times each year may be correct, but it is not very useful. It is legitimate to ask exactly what the purpose of a model is. Most urban models are intended to shed light on the effects and desirability of actual and proposed government programs to solve urban problems such as poor housing. An important criticism of urban models intended for government policy evaluation is that they lack variables to represent government programs and criteria by which to judge them. CAM explicitly disclaims any goal of policy relevance (page 1). The two local government programs it contains are present in the model mainly to analyze their interaction with private decision making, not for the purpose of policy evaluation. It would not be easy to modify or extend the model to enable it to do government program evaluation. Many modifications would be required. In addition, for most program evaluation, the spatial detail in the model is unneeded. For example, evaluation of a housing allowance program depends, among other things, on its effect in improving poor housing, but not on the exact neighborhood location of the housing. But for detailed planning of roads, schools, sewers, etc., much more spatial detail is needed. Although few such public policy variables appear in the model, it is apparently for such detailed planning that the model has been mainly used. More will be said on this matter in Section 7.

If the goal of the model building effort is not normative, it must be positive, i.e. to gain new insights into the mechanisms of urban and neighborhood growth and change. The model should be judged a success to the extent that it increases understanding of this complex process. This is a difficult task with CAM. Each equation is comprehensible, but the number and detail of the equations make it difficult to get a good picture of how the model works, and what insights it provides. Economists have a strong sense of how variables should relate to each other in equilibrium models and what the structure of the model should be. But in a model like CAM, structural equations relate less to economic theory than they do in an equilibrium model. The best way to get a good picture of CAM would be to solve it repeatedly, for fixed values of exogenous variables, until it converged (if it converged) to a stationary solution. Then, change one or more exogenous variables, and solve again until a new stationary solution is reached. Finally, compare the two stationary solutions to test the "long run" effect of the changes in exogenous variables. But such analysis has not been done with CAM.

b. Detailed Characteristics

Section 3. Neighborhood Definition. Two topics are discussed in this section of CAM. First, given that the neighborhood is the basic unit of analysis in CAM, what neighborhood characteristics are of interest so that they should be explained by the model? Second, how should neighborhoods be defined?

Neighborhood characteristics to be used as variables in the model are discussed only briefly (pages 34-38). Characteristics were identified from previous literature, from interviews with urban residents and from data availability. The following are the neighborhood variables chosen for inclusion: neighborhood residents (age, race, ethnicity, education, occupation, industry, income); housing stock (tenure, market value or rent, demolition, construction, vacancies); land use (residential density, non-residential land uses, vacant land); nearby employment (driving time, industry, total employment, projected future job accessibility); adjacent neighborhoods (resident characteristics, racial and ethnic changes); public services (schools); history (neighborhood aging).

No clear rationale is given for selection of these variables. But the research group's interest was in variables that represent and determine the growth, shrinkage, prosperity, poverty and tensions in neighborhoods. In fact, the variables chosen are rather conventional in urban model building. The main distinction of CAM is that it has gone beyond the focus on housing and resident characteristics included in other models. But the additional variables are in the spirit of previous model building, and are natural candidates for inclusion.

Defining neighborhood units occupies most of the section (pages 38-43, 46-48). The goal is to define neighborhoods as units of analysis that are homogeneous in terms of variables about which people feel strongly. Neighborhoods were defined as sets of contiguous census tracts. The operational criterion for combining census tracts is presented on pages 46-48. Eight variables are chosen, having to do with race, age, education and housing characteristics. Starting with a given tract, all adjacent tracts are considered for combining into a neighborhood. Variability of all adjacent tracts is computed for each variable, and each adjacent tract is given a score of 3, 2 or 1 for each variable depending on whether it is similar to, different from or very different from the starting tract. Then the scores are added for all eight variables. The tract is combined with the first tract if the score is high, but not if it is low.

The aggregation procedure is odd and seems of doubtful value. The resulting neighborhoods are not independent of the choice of the initial tract. CAM does not say how high a score is required to amalgamate tracts. (The maximum score appears to be 3 x 8 = 24, not 30 as stated on page 47.) Finally, CAM does not say whether the procedure is repeated once the initial set of adjacent tracts is considered. Logically, it seems it should be, but the result could be some odd-looking neighborhoods. However, the matter is not of great importance to the model.

In correspondence, Birch has indicated that the mechanical procedure for aggregating census tracts into neighborhoods that is described in CAM is supplemented by subjective evaluation of results by people familiar with the communities in question. It is not possible to evaluate the unknown results of the supplementary procedure, but a reasonable judgment is that the results -- and probably those of several other procedures -- are adequate for the purpose at hand. The basic notion of neighborhood is subjective and no one knows exactly what neighborhood concept influences people's behavior, or indeed whether any neighborhood concept is an important determinant of behavior.

Aggregation of neighborhoods to districts is discussed on pages 43-44. Districts are sets of neighborhoods used in locating jobs. Aggregation takes place on the same criterion as tracts were aggregated into neighborhoods, but less homogeneity was required for aggregation to districts.

Section 4. Natural Increase and Migration. This section studies births, deaths, population aging and migration. In this section, people are classified by age (4 categories), race/ethnicity (3 categories) and education (3 categories), for 36 categories in all.

Births and deaths are accounted for by applying estimated birth and death rates to the neighborhood's population for each of the 36 categories. Aging is handled by moving a certain percentage of people in one age category in one year into the next age category the next year. Educational attainment is handled by applying coefficients peculiar to each racial/ethnic group to the neighborhood's population in the appropriate age group. Migrants to and from the urban area are exogenous to the model. Migrants to the urban area are located by neighborhood in Section 5. Migrants leaving the urban area are assigned to neighborhoods by applying coefficients to owner and renter households in each neighborhood.

The relationships used in this section are simple and uncontroversial. The only real issue is whether the numerical coefficients are correct.

Section 5. Residential Location. This is a key section of the model.

The decision to move applies a set of mobility coefficients to households in each neighborhood. Households are classified by tenure, age, education and race/ethnicity. Mobility rates are estimated for each of the resulting 54 categories for each urban area from census data on mobility. Then each mobility coefficient is multiplied by the neighborhood population in that category and the total is adjusted for racial transition nearby (calculated in an unspecified way). A term is added for those forced to move because of demolitions. This equation set is typical of behavior equations in CAM. Neighborhood population in a certain category is multiplied by a coefficient calculated from data to obtain a predicted behavior type. Population characteristics are classified finely so that more fundamental determinants of the behavior are at least partly captured by the classification.

Choice of a new location by a mover is determined by a probability function generator. The PFG calculates the probability that a mover household of a particular type will seek a new residence in a particular neighborhood. There are 27 household types defined by socio-economic characteristics. The probability that a given household type will seek a residence in a particular neighborhood depends on: vacancies of house types sought in the neighborhood, racial transition in contiguous neighborhoods, percent minority, percent foreign, number of jobs within 35 minutes one way travel time, and a measure of neighborhood social class.

The PFG, described in detail in Appendix C, pages 91-111, is a model of probabilistic choice comparable with the logit model. It assumes that movers narrow the focus of residential choice sequentially, first eliminating neighborhoods that are too far away from places of work, then sequentially introducing other choice criteria.

The choice procedure generated by the mover model and the PFG model does not ensure neighborhood housing equilibrium. There may be more people seeking houses in a neighborhood than vacant houses or vice versa. Markets are cleared in a two-step procedure. First, the overall urban market is cleared, then neighborhood markets. In both cases, markets are cleared by adjusting preferences by the minimum amount that will clear markets. The measure of preference adjustment is based on a technique developed by Mosteller.

The preference adjustment technique is unsavory to economists.

They believe that disequilibrium results in price movements or in frustrated behavior, not in shifts in preferences. But the use made of the technique in CAM is less objectionable than it sounds. Mover behavior is determined by certain multipliers, as indicated above. For example, renters are more likely to move than are owner occupants and movers are likely to "move up" in the price range. If initial demand and supply calculations do not match, these multipliers are adjusted by the Mosteller technique. But an economist would be loathe to identify the multipliers with preferences. They are more nearly observed regularities, observed mainly in conditions at or near equilibrium. Therefore, if the propensity to "move up" in the price range is less when houses in the higher price range are scarce, economists need not be disturbed.

Economists have little experience estimating behavior when that based on preferences and expectations of prices is frustrated. Evidently, some aspects of planned behavior must then give. The particular modification of behavior indicated by the Mosteller technique appeals to common sense, but has not been widely tested with economic data. But neither has any other technique.

Section 6. Dynamics of Local Real Estate Markets. This section investigates several somewhat subsidiary aspects of real estate markets.

The first subject is rent and sales price setting for rented and owner-occupied dwellings. Rents and sales prices are assumed to rise when vacancies are low and to fall when vacancies are high.

Prices are grouped into three categories: high, medium and low. Price changes are constrained so that no more than certain percentages of dwellings can move to higher or lower categories in one year. A larger percentage of dwellings is permitted to move to a higher than to a lower price category each year, allowing for inflation. However, it is unclear how the model deals with the more rapid inflation rate experienced after about 1973.

Conversions are handled in similar fashion. Houses are converted between rented and owner-occupied categories as a function of relative vacancy rates in the categories.

Finally, the process of denying mortgages and home insurance in neighborhoods is considered (redlining). The pressure to redline is a multiplicative function of variables that depend on racial mixture and housing stock conditions in the neighborhood. However, the only effect of redlining is partially to inhibit housing price increases and construction in the neighborhood. Neither housing mortgages nor insurance appear explicitly in the model. The result is that the role of what is referred to as redlining in CAM is merely to introduce the effect of neighborhood racial composition and housing stock conditions on price increases and on construction. Presumably, the effect is important, but use of the term "redlining" is unfortunate. "Redlining" is merely a term introduced to motivate inclusion of the effect of racial composition and housing stock conditions on price increases. There are apparently no data on red-lining that lie behind the analysis. The treatment of redlining in CAM therefore has no implications for government desires to combat the phenomenon.

Section 7. Construction and Demolition of Housing Units. Housing construction in a given year, neighborhood, tenure class and price range equals housing construction last year in the same categories multiplied by several variables. One depends on the difference between actual and normal vacancy rates in the neighborhood, one on neighborhood prestige (a function of educational attainment of residents), one on land availability, one on land prices (not measured), one on zoning restrictions (on rental units), one on redlining, one on employment access, one on overall urban area vacancy rates, and one on exogenous forces.

An innovative equation in the model describes the numbers of units constructed in areas opened up for new development in the year. Units constructed in areas opened for development depend on land availability, the presence of manufacturing activity in the area opened, a prestige variable, the current construction level in the neighborhood, exogenous factors, the distance to developed neighborhoods, the extent of development in adjacent neighborhoods, and construction rates in adjacent neighborhoods.

Certain events and variables that influence housing are assumed exogenous. Among them are demolitions, construction of public and government-assisted housing, and local government growth controls.

Section 8. Investment in Maintenance of the Housing Stock. This section analyzes deterioration, maintenance and abandonment.

Housing condition is measured by a scale running from zero to 100. Newly constructed units are assigned a value of 100. Each unit deteriorates 6.5 percent per year, but deterioration can be offset by maintenance expenditures. Each age, education and ethnicity group of residents has a propensity to maintain coefficient. Then maintenance activities are modified to take account of housing demand, redlining and the condition of the housing stock. Based on these factors a new value of the housing condition index is calculated each year.

No information is provided as to how the 6.5 percent deterioration per year was estimated. CAM claims the exact figure is not important since its purpose is to determine relative housing conditions. That may be correct in practice, in that the solution of CAM may be insensitive to the assumed deterioration rate. But, in principle, relative conditions are affected by choice of assumed deterioration rate. In contrast, much attention is paid (in BFNC) to data sources on maintenance expenditures. Treating maintenance propensities as characteristics of groups defined by age, ethnicity and education is in principle unsatisfactory. It would be better to treat maintenance as an investment decision, assuming it to be made on the basis of return to the owner. But such a model would be difficult to formulate and estimate. The procedure used is probably best in the circumstances.

Abandonment depends on the housing stock condition index, in a nonlinear fashion. The basic nonlinear relations between abandonment and housing conditions are constrained in ad hoc ways to keep abandonment within certain bounds. Finally, abandonment is distributed among the housing price categories. There is no land use succession in the model in that abandoned units do not free land for new construction.

Section 9. Land Use and Zoning. Zoning is determined by a political process which can be interpretted as voting for land uses or as voting for zoning officials who will vote for the land uses.

Maximum residential density is determined by changing present residential density according to coefficients, or votes, that represent densities groups of people are willing to tolerate. Most household groups vote for the status quo. Certain groups, classified by age, education and ethnicity, vote for moderate increases and a few groups vote for large increases. Voting apparently affects density of only undeveloped land. High density is tolerated if at least 10 percent of the land is devoted to trade and services. Once again, density preferences are introduced by simple, mechanical coefficients, each specific to a group defined by race, age and ethnicity. No attempt is made to introduce explicitly the fiscal considerations raised in the literature on the Tiebout hypothesis.

Seven land uses are simulated: residential; light manufacturing; heavy manufacturing; trade and service; vacant, easy to build; vacant, hard to build; and unavailable (because of public use).

Residential construction was determined in Section 7. Residential density is gradually adjusted toward the average for the urban area.

But residential construction is adjusted according to the availability of suitable land.

Land use per employee coefficients are determined for land uses for employment. Employment location is determined in Section 10. Equations in Section 9 add up land used by the various employment categories to obtain totals for land use by neighborhood.

Section 10. Employment Location. The first task of the section is to classify firms and other employers. Three categories of employers are used: plants, offices and stores (POS). Plants include manufacturing, construction, transportation and wholesale trade. Offices include communications and utilities and finance, insurance and real estate. Stores include retail trade, services and government. The criterion of classification is similarity of locational characteristic. Jobs are assigned to the three categories, and the modelling proceeds in terms of job location, not firm location.

The second task is to define appropriate geographical areas. The areas chosen are groups of neighborhoods, called regional job areas (RJA's). RJA's need to consist of several neighborhoods because so few jobs are located in many neighborhoods. RJA's do not consist only of contiguous areas. For example, part of RJA 8 in New Haven is on the east side, part on the north and part on the west. Presumably, commuting time to a given RJA is calculated from its nearest part.

The third task is analysis of employment change. Changes are classified by births, expansions, in-moves, deaths, contractions and out-moves. Each urban area is assumed to have the same loss rate (the sum of deaths, contractions and out-moves) of jobs in each POS category. Job gains (the sum of births, expansions and in-moves) vary by urban area for each POS category, but are exogenous to the model. Then, urban area-wide gains and losses are assigned to RJA's. Gains in a given POS category in a given RJA are assigned to neighborhoods according to inertia and attractiveness characteristics. Inertia characteristics are availability of floor space and existing industry mix. Attractiveness depends on availability of suitable sites and on proximity to good residential neighborhoods.

Section 11. Schools. The task of this section is to determine school characteristics by neighborhood. Residents' preferences for school characteristics are assumed to depend on residents' ages, social class, education and race/ethnicity. According to these characteristics, residents are placed in one of three attitude categories: A, education should be functional, with rigid structure; B, education has innate value, with rigid structure; and C, education has innate value, with open structure. The variation of attitude toward schools by age, social class, education and race/ethnicity is estimated from a sample survey on the subject, reported in BFNC. Although the attitude categories are different from those used in studies of education, they may be appropriate for the purpose at hand. The purpose is to help determine neighborhood characteristics that are attractive to certain classes of potential residents. A study intended to help in planning improved education would have to proceed quite differently.

Different resident groups have different tendencies to participate in political activities that affect education. Based on their preferences and on their propensities to participate, residents "vote" for school characteristics. The characteristics voted on are class size and the proportion of students remaining in school after high school.

Finally, school characteristics respond to votes according to a reaction function in which the characteristic changes more the stronger the vote for the change.

This completes the description of the model.

Section 12. Validation. The purpose of this section is to present tests of the model's predictive accuracy. The test statistic employed is the sum of the absolute values of prediction errors divided by the sum of the actual values.

Most tests are computed by predicting 1970 values of variables taking 1960 actual values as initial conditions. Tests are presented for all six urban areas (New Haven, Worcester, Dayton, Rochester, Charlotte and Houston).

Tests are presented at the urban area, county and neighborhood levels. Predictions at the urban area level are exogenous to the model. Those at the county level are aggregations of those at the neighborhood level. The neighborhood is the basic unit of analysis.

Tests are presented for predictions of population, households, housing stock and employment. Tests are also presented for the two school characteristics (class size and percent going to college) for cities and towns in the New Haven area.

In most cases, prediction errors are smallest for urban areas, next smallest for counties and largest for neighborhoods. Urban area error statistics are mostly less than five percent, whereas many error statistics at the neighborhood level are about 15 percent and a few are much larger. Houston, which was the most rapidly growing urban area, mostly had the largest error statistics. No comparisons are made between forecast errors of CAM and those of a "naive" forecasting model, as is done routinely in macroeconomic forecasting. The easiest such naive forecasts would be to assume percent changes from 1960 to 1970 would be the same as those from 1950 to 1960. Such forecast errors would be easy to compute with data available to CAM and to compare with CAM's forecast errors.

Error statistics for the New Haven school characteristics are absolute values of percent errors for individual characteristics and jurisdictions. All are less than 10 percent and most cluster around 3 percent.

A limited amount of prediction is reported for 1975, using 1970 as the base year. The problem, of course, is data for a noncensus year. Using Census Bureau population estimates, 1975 error statistics are calculated for population by county for four of the urban areas. Average errors range from 5 to 9 percent.

For three cities, local data provided 1975 population estimates at the neighborhood level. Average errors ranged from 6 to 12 percent.

The section concludes with a discussion of the possibility of comparing model forecasts with population and other estimates from satellite photographs.

4. A Brief Summary of BFNC

In the course of the model-building effort, much fieldwork was undertaken. Sample surveys were conducted among residents in the six urban areas, and discussions were held with realtors, construction industry officials, officials in local government and others. In addition, large amounts of data were used from census and other official sources. Altogether, the project represents a massive data accumulation effort. More data has been used in implementing the model than has been used to implement any other urban model.

BFNC mainly reports on information collected in fieldwork. Much of the data is attitudinal. The presentation in BFNC is mostly literary, with only moderate amounts of tabular material included. BFNC is well written and readable, and is an interesting presentation of the authors' views about urbanites' attitudes toward housing, employment and schools.

Section 2. Residential Mobility. The topics discussed include sample design, reasons for moving, rationale for choosing a new neighborhood and search mechanisms. The samples were carefully designed, and interviews were composed and carried out by professionals. Emphasis in Section 2 is on tabular presentation. Findings support the view that racial considerations are still of pervasive importance in American urban life.

Section 3. Attitudes toward Neighborhoods. This section discusses respondents' attitudes toward many characteristics of neighborhoods, including the varying senses in which people use the term. Responses are classified by class of respondent. Most of the data discussed are attitudinal, and the presentation is literary for the most part. Most of the attitudes are extremely subjective and it is difficult to compare results with other surveys without knowing exactly how questions were asked. The presentation is, however, fascinating.

Section 4. Investment in Housing Maintenance by Owner -- Occupant Households. Maintenance is a complex notion. Large expenditures tend to be discreet and lumpy. An important finding is that maintenance expenditures, averaged over a three-year period, are substantial. They vary from 1.3 to 2.7 percent of dwelling value per year depending on the socio-economic group considered. Data in this section are objective and are especially valuable, given the paucity of data available on the subject.

Section 5. Employment Location. Three of the four topics discussed in this section are in the nature of background: classification of firms, grouping of neighborhoods, and classification of employment changes. The fourth topic is attitudinal, determination of neighborhood characteristics that are important to employers. The neighborhood characteristics considered regarding the fourth topic are tenure and value of housing, age and ethnicity of residents, distribution of neighborhood jobs by POS category, and land uses in the neighborhood. This section contains more statistical analysis, mainly correlations, than other sections.

Section 6. Schools. Attitudes toward many school characteristics were collected and analyzed in the interviews of residents. Of chief concern was what parents regard as important in public schools, and how evaluations may vary depending on age, class, education, etc. of respondents. A special section on busing is included.

5. CAM As a Theoretical Model

a. General Comments

Urban model building is a practical art. No urban model contains theoretical formulations of behavior that match the sophistication of papers in economics and other social science journals. The reasons are several. First, building an urban model is a massive job. It requires many man-years of work and the small teams that do the work have neither the time nor the background to become experts on every aspect of the background literature. Second, the estimation and computing are limited by the money, time and capacity available for computing. Third, data are limited, especially on a detailed geographical basis. Thus, it is important not to set excessively high standards for the theoretical foundations of urban models.

In addition there are styles of urban model building. There is only a small amount of experience with large urban models and it is therefore not possible to say that previous research clearly shows that one approach is wrong and another right. And the style of model building depends on the purpose of the model. A policy model might be quite different from a forecasting model. The authors of CAM are explicit that their goal is the positive one of gaining insight into how neighborhoods grow and change. At this stage of urban model building, there is value in diversity of approach.

The first preliminary comment is that CAM is extremely ambitious in its coverage. Other urban models focus on housing as the principle endogenous variable. CAM analyzes employment location and the two public sector activities (zoning and schools) in addition to housing. And the spatial detail is at least as great in CAM as in other urban models. Finally, CAM's forecast errors have been analyzed more extensively than have those for any other urban model.

The most striking characteristic of CAM to an economist is its repeated and pervasive use of numerical coefficients as "propensities" or "multipliers" in behavioral equations. In many places, such coefficients represent behavior of people classified by age, race/ ethnic status, education, social class, etc. Of course, economists also use similar coefficients, for example price and income elasticities of demand. But economists have an elaborate, well worked out, and frequently estimated and tested theory as to how and why prices and incomes affect quantities demanded. In CAM, multipliers sometimes seem to be introduced merely because the data suggest that certain groups behave in certain ways. Thus, many parameters in the behavioral equations have an ad hoc flavor to them.

Virtually all such parameters used in CAM have been estimated from data, mostly from sample survey data collected in the 6 cities to which the model has been applied. The criticism is not that they are not empirically based, but instead that they lack basic explanatory power. For example, why should housing maintenance expenditures vary by ethnic group? Is it a cultural characteristic? A better guess is that, instead, it is a matter of income level and housing condition. These are an economist's preconceptions. There is no guarantee that they are better than those of CAM's authors. And, on many subjects studied by CAM, there is little economic literature to which one can point to show that economists' preconceptions have been borne out by facts.

Closely related is the extensive use of interview data to estimate behavioral relations. Economists tend to be more distrustful of interview data as a foundation for behavioral equations than are sociologists and psychologists. Of course, data can be collected on many behavioral issues quite cheaply by sample survey interviews, but CAM would be a better model if more use were made of behavioral data in estimating behavioral relationships than is common in CAM. Most of the required data is in the project's computer.

Also closely related is the apparent slighting of prices, incomes and other economic variables in behavioral equations. This may be mainly a matter of exposition. Prices and incomes do appear in certain equations. But it is difficult to know whether they are as important as they should be in the model.

In many places, it is difficult to discover which variables in the model are exogenous. Variables on left sides of equations are endogenous. But variables on right sides may be exogenous or endogenous. Many right side endogenous variables are determined by equations presented in the same section of the model. But some right side variables are either exogenous or are endogenous but come from other parts of the model. Given the number of variables in the model, it is difficult to find out. A simple notational device could have been used to identify endogenous variables.

This is distinctly a model of non-economists. In fact, early in the volume, the authors explicitly reject economists' notion that people are rational. But when it comes to the analysis of behavior of actors in each sector, the analysis is distinctly rationalistic: people are assumed to do the best they can to further their interests, given their circumstances. For example, the fact that residents do not contemplate moves every week or month is hardly a refutation of rational behavior. As the authors point out, moving involves large psychological and monetary costs. It is therefore highly rational to move only when the present residence is quite far from equilibrium. This is exactly the way economists would think about the issue. Too often, rejection of "economic" behavior seems to be an excuse for ignoring what can be learned about the issue from the economics literature.

In some places the model is needlessly complex. In places, reading the model is like filling out a contemporary federal income tax form. If you are in a certain category, proceed to a certain operation. If the result lies within certain bounds, proceed to the next step. If not, go back and work out the answer by a different operation.

The probable reason for this complexity is that the model is strongly motivated by field observations. The collection and use of field data are valuable, and this is not intended to be overly critical. But the authors are strongly impressed that people behave in rather mechanical ways and that recent trends are the best guide to future trends. Thus, they constrain the model so that its solution does not stray far from trends they have observed in the field. They are thereby led to write that a certain behavior depends on a certain way on certain variables if a certain set of conditions hold. But if the solution lies outside "reasonable" bounds, then one goes back and calculates the variable in a different way.

There is nothing wrong in principle with the procedure just described. It is mathematically and intellectually unaesthetic, but computers can handle the procedures easily. The point is that the emphasis in CAM is on behavior rules that are based more on the authors' field observations than on economic and other theories of human behavior. The strength of the model is its ability to contend with massive detail more than the fundamental insights it yields about human behavior and neighborhood change. But that could be said about all recent, large urban models, except the Urban Institute model. It is based on rather fundamental theories of behavior, but lacks the scope and detail of CAM.

b. Specific Comments

This subsection contains specific comments on sections of CAM, some of which illustrate the comments in the previous subsection.

Section 5. Residential Location. The use of propensity-to-move multipliers (page 64) based on a classification of people by age, ethnic/racial status and education is unsatisfactory. A more satisfactory, and certainly more basic, analysis would have based the decision to move on reasons for moving. Among the important reasons are: changes in employment location; formation, dissolution and changes in size of families; changes in income or assets; and changes in neighborhood characteristics. The categories used are somewhat correlated with such causes. But correlation is presumably weak and, more important, the causal analysis is more fundamental and provides more basic explanations of behavior. Data availability is a problem in some cases. But compromises made because of data availability should be stated explicitly.

It is unsatisfactory to assume that commuters are indifferent to travel time up to 35 minutes, but refuse to travel longer. There is much evidence in the literature as to valuations of travel times, and it suggests strongly that there is no discontinuity. The data presented (page 68) do not suggest a discontinuity. In the urban areas considered, it is likely that only few commuters travel more than 35 minutes. But the conclusion would emerge from a model that lacked the discontinuity. There is evidence that commuters spend more time commuting (and cover more miles) the larger the urban area. Thus, Houston commuters are likely to have longer average trips than those in New Haven. The differences may not be great among the six urban areas studied. But the 35-minute discontinuity would be dangerous to apply in a comparison between New York or Tokyo and Charlotte.

The Mosteller technique of preference adjustment to clear the housing market (pages 75-76) is unsatisfactory. As was indicated in Section 3 above, inability to find the house you wanted changes your behavior, but not your preferences. More important, most urban models assume that prices or rents change to equilibrate demand and supply, not the behavioral coefficients, as assumed in CAM. If it is felt that the period used (one year) is too short to permit such equilibrating changes, the disequilibrium can be carried over to the next period, accompanied by partial price changes in the direction of equilibrium.

The probability function generator is hard to evaluate. It seems to do the same job (specifying probabilities of certain kinds of behavior) as the logit and tobit models. These models are easier to understand, probably easier to estimate, and have properties that have been widely studied. But work on the PFG probably started before much was known about logit and probit models.

On page 67, the statement appears " ... households pay very little attention to differences in levels of public services, with the exception of schools." Surely, this is false. People certainly care about police protection. In some suburban areas, public water and sewer provision are important issues. People also care about local tax rates. Again, data availability may be the issue.

On page 80, the vacancy variable may not be the important variable. A dwelling advertised for sale or rent may have the same effect on movers, although it is not vacant.

Section 6. Dynamics of Local Real Estate Markets. It is hard to understand why housing prices and rents have been classified into high, medium and low categories. No reason is given and there is no apparent advantage of the classification over using raw price data. The procedure merely throws away information. Also, there appears not to be a description of the way the categories are defined. If each category contains fixed absolute prices, inflation presumably moves most houses into the top category within a decade, thus removing all information about relative prices from the model. If the category intervals are adjusted as time passes, readers should be told how the adjustment is made.

On page 120, decisions of owners to convert tenure between rental and owner-occupied are discussed. What about the demand side of tenure? Some causal analysis of tenure choice would be valuable. It depends on location desired, family status and income and tax brackets.

On page 127, variables are defined poorly. XTOCC and TOCLOS have identical definitions. Likewise on page 128, XTOCC is defined inconsistently in two places. The same is true for XVAC.

Section 7. Construction and Demolition of Housing Units. There is confusion in the mathematics. (7.4) says (7.2) equals (7.3) in areas opened for development. But the appropriate set of right hand variables in (7.2) and (7.3) does not produce the result. Apparently, what is meant is that (7.2) does not hold in such areas, whereas (7.3) does. This is not clear.

The model of the determinants of construction activity is needlessly complex. Economists typically use stock adjustment models -- in which construction adjusts the stock in the direction of equilibrium -- for such purposes. Their properties are known and they work well.

The model of opening areas to new development (pages 112-171) illustrates the "income tax form" syndrome. There are too many categories, constraints, threshold values, etc. It is hard to learn from such a cumbersome model.

Section 8. Investment in Maintenance of the Housing Stock. This is a difficult topic. Recently two fine studies have appeared: one by Gregory Ingram in a book he edited, Residential Location and Urban Housing Markets, (NBER, 1977); and one by Ozanne and Struyk, Housing from the Existing Stock, (Urban Institute, 1976). That work should influence the next generation of CAM.

Why are dwellings abandoned instead of being demolished and replaced by new dwellings? Obviously, they are in some cases. CAM assumes demolitions to be exogenous, but abandonment to be endogenous.

Logically, abandonment is a breakdown of market processes of demolition and land use succession.

Section 9. Land Use and Zoning. On page 204, there is an especially questionable use of "multipliers." There, coefficients are assigned to 27 household types, classified by ethnicity/race, education and age, that represent their toleration of population density levels. It is hard to make sense of the coefficients assigned to various groups. Why, for example, is it assumed that minority high school drop outs aged 40-64 have much less tolerance of high density than foreign born residents of the same age and education? Surely, the density at which people live depends on land values, incomes, places of work, transportation costs and so on.

Section 10. Employment Location. It is unsatisfactory that RJA's are not contiguous pieces of real estate. It can be ascertained how many workers are within 35 minutes commuting time of a non-contiguous RJA. But use of non-contiguous RJA's provides little insight as to neighborhood locational choices for firms.

The assumption, made on page 236, that firms are attracted by the presence of similar firms is suspicious. That is certainly true of certain firms, especially if proximity to an input or comparison shopping are important. But it can hardly be typical in retailing.

Section 11. Schools. There are no budgeting considerations in the schools model. There is nothing in the model to prevent each school district from having the best schools imaginable, given their perceptions of what makes good schools. It would be more realistic and informative to introduce a cost of obtaining high quality schools.

## 6. Numerical Implementation of CAM

A tremendous data collection effort lies behind CAM. Undoubtedly, most effort has gone into field surveys, but large amounts of Census and other government data have been used. Data are used in several ways. First, data have clearly been examined in determining choices of variables to include and functions forms. Second, data have been used to estimate coefficients in the model. Third, data have been used to test the model's forecasting ability. Substantial amounts of data are presented and described in BFNC.

Nevertheless, evaluating the use of data in CAM is frustrating. After reading both CAM and BFNC, one can guess what data were used to estimate what coefficients. But in almost no instance are we told. For example, it is unclear how the coefficients representing tolerances for high residential density were estimated or from what data. The same is true for several other sets of behavioral coefficients in the model.

Furthermore, nothing is said about estimation techniques, except in the case of the PFG's. Many coefficients have apparently been estimated by taking simple averages of sample data. Have least squares or similar techniques been used? The reader is not told. The terms "least squares" or "regression" are not used in CAM or

BFNC.

Although the model apparently contains little simultaneity, the data certainly do. All of economics and econometrics teach us that if systems are anywhere near equilibrium, the data satisfy several simultaneous equations among similar sets of data. Relating price and quantity are both supply and demand equations. Such simultaneity must be taken into account in parameter estimation or estimates are inevitably biased. There is no recognition of the problem of simultaneity in CAM or BFNC and no indication that any simultaneous equation estimation techniques were used for any part of the model.

In Section 12, validation of CAM is discussed. There, predicted values of several variables in CAM are compared with actual values. There are of course many variables in CAM, only a few of which are compared with actual values in Section 12. Variables chosen mostly pertain to housing and population. In a way these are natural variables to compare in that they are important and easily available. But it would be nice to be told about reasons for selecting these variables to test the predictive accuracy of CAM. Probably, other variables have been tested, but results are not reported. It would be helpful to know what other variables have been tested and, at least in summary form, what the results are. What criteria were used in selecting variables for predictive tests?

## 7. CAM's Potential for Practical Use

This issue brings us back to the question "What is the purpose of CAM?" The authors say its purpose is not policy analysis, but rather gaining insight into processes of urban growth and change. Yet, government agencies in all six urban areas in which it has been implemented have shown interest in using CAM for policy, especially city planning, purposes.

The first thing to say is that CAM has in it almost no variables that the government has to plan. It has no transportation system that is recognizable (variables such as distance to a highway appear in locational choice sections), it has no variables representing water supply, sewage, parks, police protection, health facilities, etc. Schools and land use controls appear as sets of variables to be decided by government agencies through a political process. But they do not appear in ways or forms that are likely to be particularly useful to planners. One reason is that there is no cost side to these government variables. There is no way to establish what it would cost to upgrade schools in ways the model tells us residents might want. There is no way to calculate benefits and costs of zoning changes that could be represented in the model.

Local planning officials are probably interested in the model as a "background" document to their activities. For example, the model might forecast a substantial growth of middle income housing in particular neighborhoods during coming years. Planners would be interested in those predictions because it would help them forecast where increased public services will be required. Of course, in fact, the predicted growth depends on public service provision. Predicted growth will not occur unless schools, roads and water are provided. But these causal relations are not in the model. Growth takes place for other reasons in the model, and planners would know without the aid of the model that growth will require public services.

Is this the right model to use for the purpose described in the last paragraph? One answer is that no other existing model will do it better. No detailed forecasting appears to have been done with any other existing model. Whether a model could be constructed that would better fill these needs is problematical. But it has been emphasized earlier that a strength of CAM is its forecasting ability. There are plenty of ways to improve CAM -- or any other large urban model. But for the purpose of detailed neighborhood forecasting of events that are important for planners, CAM is on the right track. A guess is that public officials only rarely need forecasts that have as much spatial detail as CAM, but there are certainly some purposes for which detail is important. In addition, many of the dependent variables in CAM are of no interest to planners, but the model is not expensive to solve and uninteresting variables can be ignored. Finally, it is unlikely that local planning officials really need 10-year forecasts. Probably, forecasts one, two or three years ahead would be much more valuable, and they would be much more accurate. CAM can, of course, make forecasts for any number of years ahead. Emphasis on 10-year forecasts results from availability of census data.

If the author were starting out to build an urban model that would be valuable to local planning officials, it would be quite different from CAM. It would contain as exogenous variables the things local governments plan -- schools, roads, etc. Equations would represent both the effect of public services on growth and the effect of growth on demand for public services. And the cost side of public service provision would be represented so that the model could be used for optimization of public sector activities. But that would be a planning model, and a planning model was not the goal of CAM's builders.

The conclusion is that CAM is quite useful to local planning officials as background for their planning activities. But CAM is not designed to test the effects of local public services on the growth or change of neighborhoods or on the welfare of residents.

## 8. Further Development of CAM

If CAM is to go through another generation, many suggestions made in Sections 3 and 4 can be included. They will not be repeated here.

In terms of gaining insight into urban processes, further numerical analysis with CAM is justified. CAM is a complex model with many equations and variables. Furthermore, the model specifies behavior as a function of data available to the actor at the time the decision is to be made. These characteristics make it difficult to know what the long term effects of certain variables are. For example, it might be interesting to know what the long term effects of a federal anti-poverty program would be in a particular urban area. For this purpose, one wants to hold most exogenous variables in the model constant, raise incomes as prescribed by the federal program, and solve the model repeatedly for many years to see to what values the variables converge. Effects on housing quality, neighborhood stability, schools, etc. would be of great interest.

In a model like CAM, the initial effects might be quite different from the long term effects. Calculating long term effects is called comparative static analysis. It would not be difficult to do with CAM, but apparently has not been done. It would be informative for policy analysis, and also for gaining basic insights from the model. It would tell us what effects or variables in the model are important and what variables have lasting effects on what other variables. For example, would an anti-poverty program affect housing quality? If not, it calls the model into question. Such comparative static analysis is more important with CAM than with many models because the structure of CAM makes it difficult to perceive long term effects. In a static model, long term effects may not differ from short term effects. But CAM is dynamic and behavior in each year depends on data easily available to actors at the time of decision. That formulation makes it especially difficult to perceive basic, underlying effects.

Comparative static analysis must be done with care with CAM. Endogenous variables in CAM do not converge to constants based on fixed values of exogenous variables. No matter how many times CAM is solved for fixed exogenous variables, old people and houses will continue to be replaced by young people and houses. Since the ages of people and houses affect behavior in the model, the process of constant replacement leads to constant changes in the model's solution. To do comparative static analysis with CAM, one wants to find stationary solutions based on a stationary age distribution of housing, people and other variables. Of course, given this broad definition of a stationary solution, there is no guarantee that CAM converges to a stationary solution. For fixed age distributions, endogenous variables may oscillate indefinitely or diverge steadily from a fixed solution. If so, it would call the validity of CAM into question. At least, that is so if, as is presumably true, real urban systems are basically stable. If real systems are stable, but CAM is not, then CAM cannot be an accurate representation of real systems. But CAM is probably highly stable. The 10-year projections provide some evidence in favor of the hypothesis of stability. If the system is stable, then comparative static analysis can be undertaken.

## 9. Conclusion

CAM is a highly professional, innovative and original piece of urban research. Its intellectual content is certainly on a par with that of other leading urban models. Its data base is more elaborate and probably more accurate than that of other urban models. Its estimation is something of a mystery, but techniques are probably not much worse than those used in estimating other urban models. Numerical analysis -- solution and forecasting -- is considerably better with CAM than with other models.

At least at the present stage of development, urban models cannot be uniquely ranked as to quality. The UI model has the most sophisticated programming submodel that allocates movers to the available housing stock. CAM has endogenous employment and local government service sectors. CAM is less sophisticated than the UI and NBER models in its underlying economic theory and statistical estimation techniques. But it is estimated in large part from data collected for the purpose of estimating the model. Furthermore, CAM is formulated, in substantial degree, so that it can be estimated from data that have been collected by the project.

A summary evaluation is that evaluation of proposed national policies would best be done with the UI or NBER model. Advising local planners on problems they will face from urban growth and change is best done with CAM. To gain basic insights into the processes of urban growth and change, all three models should be read carefully. A new model of urban growth and change should differ from all three models in important ways.

If more work is done on CAM, further thought should be given to just what its purpose is. Cities are complex systems and an all-purpose urban model is likely to be a no-purpose model. Is CAM's goal forecasting, policy analysis or gaining insight into urban processes? Future development of the model should probably be different depending on the answer to that question.

In any case, CAM can benefit from somewhat better attention to the economics literature. That is not so much a recommendation to study the NBER and Urban Institute models, with which CAM's authors are familiar, as it is a recommendation to study applied microeconomic papers on housing demand, urban travel demand, local public choice and so forth.

CAM is a non-economist's model. The disadvantage of that is that some of the understanding and techniques developed by economists have been missed. The advantage is diversity. CAM's authors are free of the preconceptions that economists bring to model building. Probably the most important evidence of this is CAM's authors' willingness to jump in fearlessly and include subjects in the model that would frighten economists. Attitudinal data about race, neighborhood prestige and so forth are the best examples. Another example is the analysis of the political process by which school characteristics are determined. This diversity is refreshing and important in a subject as underdeveloped and fraught with dangers as urban model building.

Diversity of approach is important, but it is no substitute for brains and hardwork. The evidence is that CAM has received a good portion of all three.

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