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A Simulation Model for Boom Town Housing

University of California

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CONTENTS

FIGURES

LIST OF TABLES

A SIMULATION MODEL FOR BOOM TOWN HOUSING

by

Raymond Rink and Andrew Ford

ABSTRACT

This report provides the technical documentation for a computer simulation model that can be used to test the effectiveness of various boom town housing proposals. The housing model builds upon an earlier boom town simulation model developed at the Los Alamos Scientific Laboratory in the summer of 1976. The housing model uses Systems Dynamics, conventions and techniques to represent the interplay between the supply and demand for boom town housing.

This report is written in a technical style designed to provide analysts with a full knowledge of the structure, parameter values, and behavioral tendencies of the housing simulation model. It concludes with a series of policy tests that show the effectiveness of six different housing proposals in reducing the severity of the boom town housing problem. These tests show that the only effective way to eliminate the housing problem under adverse boom town conditions may be direct intervention in the housing market by the energy company or by the state or federal governments.

I. INTRODUCTION

A. The Boom Town Problem

One consequence of the energy crisis in North America is the emergence of a new wave of boom towns in those western states and provinces that have untapped energy resources. These resources are needed urgently, and their extraction and use require the rapid construction of large-scale industrial plants in areas remote from any large population center. However, in most cases there are smaller towns in the vicinity of the large projects. Company-sponsored new towns are sometimes established when there are no pre-existing towns.

At the outset of the construction project, the nearby town typically has neither the needed pool of construction workers nor the facilities to accommodate such a labor force. The contractor must bring in hundreds or thousands of workers from elsewhere, and the presence of these workers and their families leads to severe shortages of housing, retail and professional services, and public facilities. Boom town life has become stressful for both newcomers and original residents under such conditions, and the social malaise accompanying this stress has come to be termed the "adverse impact" of the new-found prosperity.

Among the many examples of impacted towns are Rock Springs/Green River, Wyoming (coal mining, chemicals, power production), Gillette, Wyoming (coal mining, oil, gas), Colstrip, Montana (coal mining, power production) and Fort McMurray, Alberta, Canada (synthetic crude oil from tarsands). Numerous case studies have been made of these and other boom towns (Gilmore 1975a, Blevins 1974, Gold 1974, Oklahoma 1976).

The following quote from one observer of the Gillette, Wyoming, scene may serve to portray the housing facet of the adverse impacts.

> Row upon row of new trailers already reach out across the bleak, treeless grassland and red dirt hills surrounding this city. The ragged trailer camps have been thrown up so fast that local officials complain raw sewage lies frozen on the ground in some encampments. But the vacancy rate is just about zero and most people here believe the real population rush has not yet begun. A study done this year for Gillette by the Washington, DC, firm of Gladstone Associates says Gillette has 15,000 people, with surrounding Campbell County adding another 5,000. By 1990, the study predicts, Gillette's population will be as much as 43,500 while the county as a whole will have 64,700: Several county officials complained privately that the consulting firms predictions are far too low.
>
> Currently, there is one strip mine in operation here. But Gladstone notes that four more are preparing to open and, by 1985, there could be fifteen giant mines. Other studies have predicted that Gillette and Campbell county will be the center of a vast energy-producing center of coal gasification and liquification plants and huge coal-fired electrical generating facilities. "If only half of what the energy companies want goes on line, this part of the state will look like Pittsburgh by 1990," said a county official. Right now, most newcomers are construction workers and life for them is often as raw as the land they are living on...
>
> (Richards 1976)

Another dramatic description of the boom town housing problem appears in a document entitled *Resource City, Rocky Mountains* prepared by the Federation of Rocky Mountain States. In this document, Federation staffers describe the kinds of conditions that they felt would be present in some degree in most boom areas. We quote from this document at length.

> The city was unprepared for the resource boom. Tents have been erected and many well-paid workers find shelter wherever they can. One newcomer called a Resource City realtor and begged him to sell or rent a cave for shelter. Mobile homes now house more than thirty-five percent of Resource's population. Trailer camps were established quickly, crammed into canyons, ravines or open fields and packaged onto odd-shaped lots. For children's play areas they barely offer more than a mud paddy between units—without grass, trees, or sidewalks. But the trailers rent for as high as $85 a week. Most native home-owners converted spare space into apartments and sleeping rooms soon after the boom began in 1970. The newcomer now faces dim prospects. Every "nook and cranny" is occupied and trailer courts are filled almost before they are built. Motel rooms are being rented on eight-hour shifts. Land now available for development is scarce and prices are inflated. Land currently costs $6,000 an acre—compared to $800 an acre only three years ago. Many wide open areas surrounding the city, which could ease growth pains by allowing the construction of quick, inexpensive housing, are tightly held by the federal government, a railroad and a grazing association.
>
> Major industries in and near the city are taking steps to deal with housing problems, since the situation affects their operations. One company developing resource outside the city has proposed a quick start on a partial "company town" — with convertible mobile home sites, prefabricated temporary schools and public services...
>
> (Federation 1974)

Denver Research Institute investigators argue that the various boom town problems are not random but are interrelated and self-sustaining. A particularly exasperating chain of interrelationships has been described as follows.

> The Rock Springs case study describes how the boom degraded quality of life in the community. The effect a degraded quality of life may have on productivity and turnover was experienced by Bechtel Corporation in their construction of the

> Jim Bridger plant in Rock Springs. During the spring of 1974, productivity of construction workers at the plant dropped well below expectations. Since the contractor was on a tight schedule, the loss in productivity had to be made up by hiring more construction workers. The additional population created an even greater strain on provision of local services, and caused further decline in the quality of life. Productivity then dropped even more.
>
> (DRI 1975, p. 102)

The time-course of interrelated phenomena such as these can be traced by using computer simulation with dynamic models. One such model is BOOM1, a generic boom town model developed at the Los Alamos Scientific Laboratory (LASL). Since BOOM1 provides the overall basic framework for the housing-sector model described in this report, a brief discussion of BOOM1 follows.

B. The BOOM1 Model

Particular sectors modeled in BOOM1 are

1. electric power plant construction and operation,
2. housing (replaced by the model described in this report),
3. retail and services,
4. public construction and municipal financing, and
5. migration.

These sectors are shown in Fig. 1. Also indicated is the aforementioned "vicious circle" chain of interrelationships involving shortage of facilities, reduced productivity of construction workers, increased work force, and exacerbated shortages.

BOOM1 traces out the time-course of its variables, given specified conditions at the outset of the simulation run and given assumed policies that might be implemented by town officials, energy company planners, or higher levels of government. Figure 2 shows selected results from one such simulation, the "business as usual" run with no special adverse-impact-mitigating policies being implemented. Evident is the large population bulge, beginning in 1975, when power plant construction was initiated, with corresponding increases in mobile homes and property tax rate and decrease in

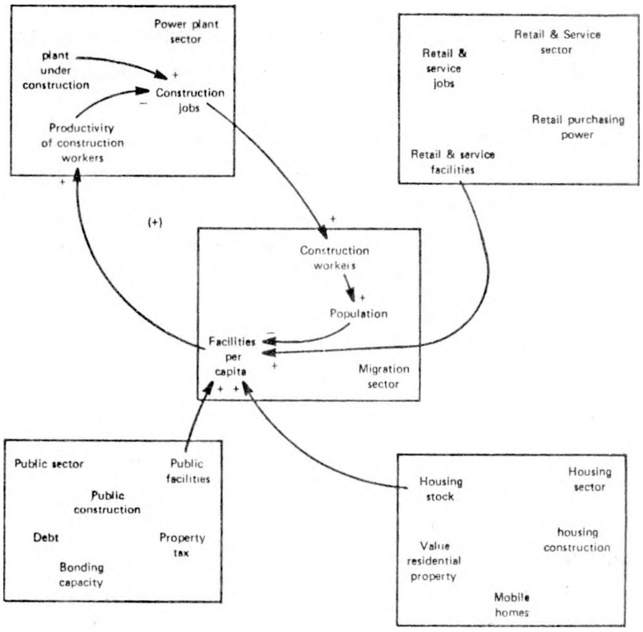

Fig. 1.
The five sectors of BOOM1 and an example of a feedback loop.

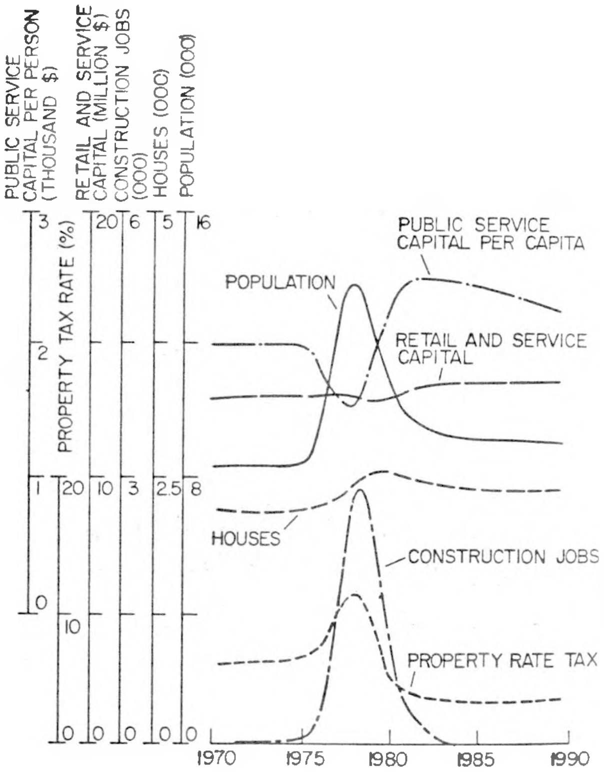

Fig. 2.
Business-as-usual simulation results of the BOOM1 model.

public facilities per person. These changes are reversed when the construction project nears completion in 1980.

In this simulation, power company managers expected a peak work force of about 1,500, but as Fig. 2 shows, the work force numbers 3,000 at the peak of construction in 1978. This surprising increase is caused by the actions of the "vicious circle" shown previously in Fig. 1—the community falls behind in providing adequate public and private services; construction worker productivity declines because of high turnover and poor morale; and the construction contractor must hire many more workers to complete construction on schedule. The net result of this exasperating sequence of events: large cost overruns on the power plant and increased stress on the local community.

Quantification of the strength of the vicious circle (Fig. 1) is, however, extremely difficult given the shortage of time series and cross-sectional data. Thus, we have taken care to test the sensitivity of the model's behavior to the strength of this particular set of relationships. Such tests have shown that the vicious circle is, indeed, a key determinant of model behavior (Ford 1976a, p. 35). These tests show that the causes of construction worker turnover and absenteeism is one area where further research and data could be used to advantage.*

For further information on the structure and behavior of the original BOOM1 model, we refer the reader to the summary and technical documentation available from the Los Alamos Scientific Laboratory (Ford 1976a, b). Moreover, the reader is referred to the critical comments on BOOM1 and other local impact models provided in two model reviews (Stinson 1977 and Markusen 1978).

C. The Boom Town Housing Problem

Insufficient and inadequate housing is one of the most acutely and widely felt negative effects of the rapid population growth accompanying energy development. In summarizing surveys of Sweetwater County and six other booming areas, investigators from the Denver Research Institute (DRI) noted that the lack of adequate housing was the single most common problem encountered (DRI 1975, p. A-152). A survey of Sweetwater County, Wyoming, showed that residents ranked housing as the second most critical problem in impacted communities, after health services (Gilmore 1975b, p. 84). In a separate survey of 188 communities, the Regional Office of the Federal Energy Administration concluded that "available housing was one of the most serious problems. ... The lack of adequate housing is a major factor in individual productivity, in worker turnover rates and in an acceptable living environment in the energy impacted communities." (FEA 1977, p. 22) And according to the Wyoming Department of Economic Planning and Development (DEPD), "housing is often the most immediate and critical area associated with [boom town] impact because of the complex process involved in satisfying housing requirements." (DEPD, Wyoming 1977, p. 1.)

Direct effects of inadequate housing stem from stress within families and may include discontent, alcoholism, and family disintegration. An indirect effect of inadequate housing is to increase the difficulty of attracting badly needed doctors, teachers, and public employees to these communities; with consequent shortages in these other components of the quality of life.

On the national level, developers and buyers alike are concerned over the rapid increases in the cost and price of housing. According to a study by the National Association of Home Builders (NAHB), housing costs have increased by about 100% between 1969 and 1976. The most rapidly increasing cost component appears to be land. According to the NAHB study, land costs rose by over 200% during the eight-year interval, whereas the cost of the structure rose by around 45% (McGraw-Hill 1977b, p. 11). With such inflation in costs, it is reasonable to expect a considerable amount of price inflation. According to an MIT-Harvard study, the median sales price of new houses rose to $44,200 in 1976, while the fraction of U.S. families able to afford such a house, by conventional rules-of-thumb, fell to 27% (*Time* 1977, p. 42). So, although need is great for more houses, there is relatively little effective economic demand for them.

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*Relevant studies in this area include the Old West Regional Commission's Construction Worker Profile (Mountain West 1975), a Battelle Pacific Northwest study of construction worker productivity (Schulte 1977), and current research under way at the Electric Power Research Institute.

On the local level of the isolated boom town, the housing problem is amplified by the following factors (DRI 1977):

1. unavailability and/or high cost of skilled construction labor,
2. difficulties in assembling suitable land,
3. lack of infrastructure such as water/sewer facilities,
4. resistance of developers to the assumption of the abnormal risks present in boom town involvement,
5. limitations on housing entrepreneurial skills in immediate locale, and the
6. absence of local financial institutions specializing in mortgages.

It should be noted that the first five factors are *supply* constraints, and as such have not usually been dealt with in current impact assessments, most of which have limited themselves to estimates of the numbers of different types of housing units that need to be provided. Although current impact assessments may provide quantitative projections of the timing and location of housing demand, their treatment of housing supply is usually little more than a qualitative discussion of the five factors that amplify the housing problem under boom town circumstances.

In the BOOM1 model, the effects of the supply-inhibiting factors are represented in a very simplified form through the action of the housing construction multiplier from boom town conditions (HCMB)* (Ford 1976a, p. 52). This multiplier simulates the effects of developers who are reluctant to construct housing under adverse boom town conditions by reducing the number of housing starts whenever conditions in the town begin to deteriorate. A second simplifying assumption of the BOOM1 model is that any shortages of permanent housing will automatically (and instantaneously) lead to an increase in the number of mobile homes. The need to improve upon these simplified representations of boom town housing supplies is one of the primary motivations for developing the detailed housing sector described in this report.

D. The New Housing Sector

The model described in this report was constructed by replacing the original housing sector of the BOOM1 model with a new housing sector designed to allow a more detailed representation of the obstacles that limit the growth in housing under adverse boom town conditions. The position of the new housing sector within the original BOOM1 model is described in the DYNAMO flow diagram shown in the "fold-out" in Appendix A.

The expanded housing sector noted in Appendix A will allow investigators to test a wide range of proposals designed to improve the availability of housing under boom town conditions. Specific proposals examined in this technical report include

- Promotion of factory-built modular housing to reduce the amount of on-site labor.
- Public land assembly and zoning for orderly development.
- "Front-end" financing for infrastructure, backed by higher levels of government or the energy company.
- Risk insurance for developers, by higher level of government or the energy company.
- Special mortgage financing programs, such as provided for in the Wyoming Community Development and Coal Conservation Bill (Lindauer, 1975, p. 89).

E. Related Research

Additional efforts are currently under way to extend other sectors of the basic BOOM1 model. Among these are an effort at LASL to adapt the model to the specific settings of Northwestern New Mexico, at the United States Department of Commerce to expand the energy sector to include coastal energy facilities that fall under the jurisdiction of the 1976 Coastal Zone Management Act Amendments, and at the Texas Energy Advisory Council to expand the public sector to distinguish between different types of public facilities and expenses (Ford 1977a).

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*When a specific variable in the BOOM1 or BOOMH models is mentioned in this report, the computer name given to this variable is noted in parentheses.

Each of these "second-generation" simulation models is designed to focus more carefully on a particular set of policies. Each is constructed by replacing the particular sector of BOOM1 (housing, public, energy, etc.) with a more sophisticated representation that will allow explicit representation of specific policy parameters.

A second area of closely related research is quite different from the simulation modeling efforts described in this and other reports. In the new area, investigators have attempted to measure the values and preferences of individuals who are to choose the "best" of several simulated outcomes (like the outcome shown in Fig. 2). The technique used to measure these values is called Multi-Attribute Utility Measurement (MAUM), and the use of MAUM to evaluate boom town policies is described elsewhere (Gardiner 1976, 1977, and Ford 1977b).

II. STRUCTURE OF THE BOOMH MODEL

A. Permanent Housing

The model keeps track of two major quantities, called "levels" in the System Dynamics conventions of Forrester (Forrester 1961), namely, the stock of permanent-type housing units and the market price per unit. The rate at which each level increases or decreases at each time step depends on several factors; the key assumptions about these factors are listed in Table I.

The assumptions of Table I are represented in the form of DYNAMO flow diagrams in Figs. 3 and 4. The particular notation used in these diagrams is explained in Appendix A.

Figures 3 and 4 show that the representation of the supply and demand for permanent housing involves many interconnections. The key to understanding the likely behavior of this complex system is an understanding of the two feedback loops shown in Fig. 5.

In the notation of Fig. 5, model variables are interconnected by arrows that represent explicit relationships programmed into the housing sector. A positive sign (+) at the head of an arrow indicates that the two linked variables tend to change in the same direction. A negative sign (-) is used for relationships that cause the variables to change in opposite directions. An increase in the stock of housing, for example, tends to cause the vacancy rate to increase (+ relationship). An increase in the vacancy rate, however, causes the market price of housing to decline (− relationship).

The interplay of the supply and demand loops in Fig. 5 works as follows.

> The *supply loop* reacts to a housing shortage whenever the housing price rises to a sufficient level that a favorable price/cost ratio is achieved. Suppose, for example, that the influx of new families leads to a worsening of the housing shortage. The more severe shortage would lead to a lower vacancy rate, increased market prices, a more favorable price/cost ratio, an increase in housing starts, and an increase in the housing stock. This increase in the housing stock tends to counteract the original worsening of the housing shortage.
>
> The *demand loop* reacts to a worsening housing shortage through changes in the vacancy rate and market price as well. A more severe shortage is reflected in lower vacancy rates that lead to an increase in the market price. Higher prices tend to reduce the fraction of families that can qualify for mortgage money, thus reducing the qualified demand for housing. The reduction in demand tends to restore the vacancy rate toward its nominal value.

Thus, it is apparent that both these loops react to a change by setting into motion further changes that tend to nullify the original disturbance. An increase in the market price, for example, leads eventually to an increase in the housing stock (by the supply loop) and a decrease in the income-qualified demand (by the demand loop)—both of which tend to counteract the original increase in price. Loops that behave in this manner are called "negative" feedback loops to contrast their behavior with "positive" feedback loops like the one shown earlier in Fig. 1. Notice in the positive feedback loop from Fig. 1 that an initial change in the loop leads to subsequent changes that amplify or exasperate the original disturbance. A decline in worker productivity, for example, leads to further population growth, more severe shortages of public and private services, and still further declines in construction worker productivity. Examples of positive feedback loops in the housing sector are described later.

TABLE I

ASSUMPTIONS FOR PERMANENT HOUSING

Demand Factors

1. Economic demand depends on the fraction of all families whose income exceeds the current qualifying income, the latter based on the 4:1 rule for income/shelter payments ratio.
2. Shelter payments depend on market price of housing, property tax rates, and mortgage interest rates.
3. Market price of housing rises or falls in response to variations in the vacancy rate.

Supply Factors

1. Builders plan projects on the basis of a shortfall of housing stock as compared with the number of permanent-type families.
2. Planned rate of starts will be reduced or nullified if unit costs rise to approach or exceed market price of finished unit.
3. Building cost depends on productivity of labor that may decline under adverse boom conditions.
4. Cost of an unserviced lot depends on the alternate-use value of the land, which is the value for mobile home lots unless prevented by zoning policy.
5. Cost of lot servicing is paid by developer unless either a special assessment district is established or houses are displacing mobile homes on serviced land.
6. Town may levy an extra fee on building lots to cover cost of water and sewer.
7. Delays between initiation and completion of a project include a planning and approval delay (which depends on regulatory agency policy) and a construction delay (which depends on whether or not modular-type housing is allowed).
8. Depreciation of permanent housing depends on the size and average lifetime of the initial stock of permanent housing.

B. Temporary Housing

In the original BOOM1 model, temporary housing was assumed to instantaneously make up the difference between the number of families preferring permanent housing and the stock of permanent housing available. A shortage of 100 permanent homes, for example, would lead automatically (and without delay) to an additional 100 mobile homes in the town.

In the new housing model, we replace this highly simplified treatment of the supply of mobile homes with a new representation. As the list of key assumptions in Table II shows, the assumptions governing the supply and demand for temporary housing are generally similar to those for permanent housing.

One important difference between the permanent and temporary housing sectors involves the assumption about the number of families that generate the "effective economic demand" for housing. As the first assumption in Table I indicates, *all* the families would generate demand for permanent housing if the price of housing were low enough. The first assumption listed in Table II notes, however, that *only* those families that fail to qualify for permanent housing generate effective demand for temporary housing.

The set of assumptions in Table II are portrayed in the form of a DYNAMO flow diagram in Figs. 6 and 7. A comparison of Figs. 6 and 7 with the diagrams for permanent housing (Figs. 3 and 4) indicates, again, the general similarity between the permanent and temporary housing sectors. A close

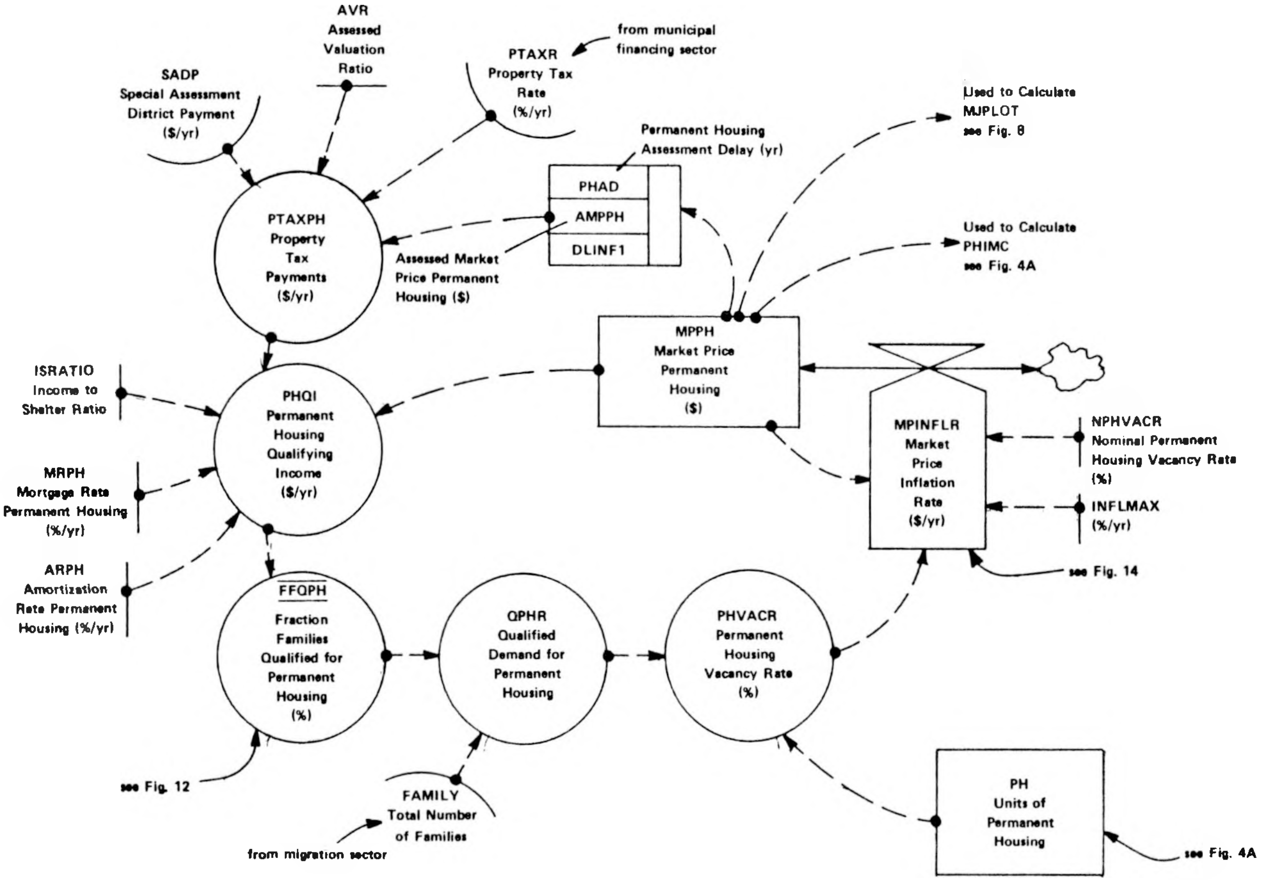

Fig. 3.
Permanent housing demand calculations.

examination of the supply factors in Fig. 6 will show, for example, that the supply for temporary housing is controlled by a negative feedback loop similar to the supply loop shown previously in Fig. 5. Moreover, a careful look at the demand factors in Fig. 7 will reveal a negative feedback loop similar to the demand loop in Fig. 5. As with the permanent housing sector, both of these loops react to changes in the vacancy rate and the market price so as to counteract any disturbance that would push the vacancy rate away from the nominal level.

C. Land Speculation

Some elements of land speculation and its interaction with the boom town housing market are modeled in BOOMH. The major assumptions on which this part of the model is based are listed in Table III.

The DYNAMO flow diagram of the land speculation sector is shown in Fig. 8. Principal input variables to this sector include the rates of construction of retail facilities, permanent housing, and temporary housing. Each of these activities consumes land available for development and leads to increases in the "Speculative Value of Outer Land for Permanent Conversion" (SPECP2), which is the principal output variable of the speculation sector. [This output variable is used in the Temporary Housing Sector as one of the components of the cost of land (Fig. 6)].

To calculate the speculative value of outer land, the speculation sector computes a so-called, rational "discount" factor based on the rate at which land development activity appears to be consuming the

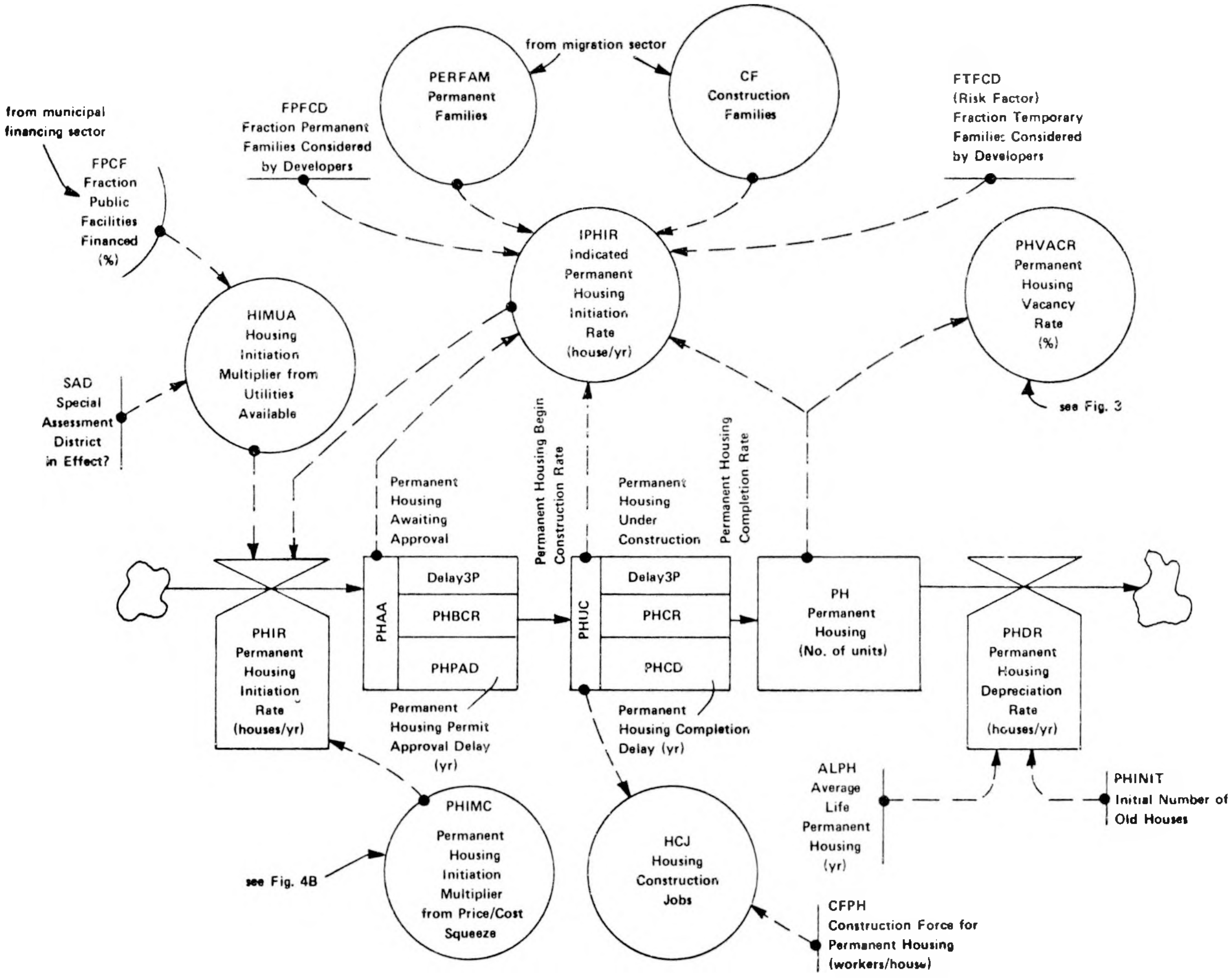

Fig. 4a.
Permanent housing supply calculations.

reserve of land available. This factor is then used to relate the current, permanent-use value of land (called SPECP1) to a speculative value on land at the outer edge of development (called SPECP2).

In our judgement, the representation of the behavior of individuals or groups interested in capturing speculative gains from land is the most difficult portion of the new housing sector. Therefore, we wish to reiterate the following points.

(1) The speculative behavior represented in the housing sector captures only one aspect of a complex phenomenon. Related patterns of speculative behavior such as acquisition of monopoly control, wild surges of investment funds completely divorced from actual prospects for eventual permanent development,* and acquisition of key parcels of property are not represented in the model.

(2) The speculative sector generates one, *and only one*, output variable that is used elsewhere in the BOOMH model. This variable, named SPECP2, represents the speculative value of "raw" land not immediately ready for conversion to permanent use. SPECP2 is used as part of the cost

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*A notable example of wild investment in land with little prospect for conversion to permanent use was the Florida land boom of 1927-1928 (Galbraith 1961).

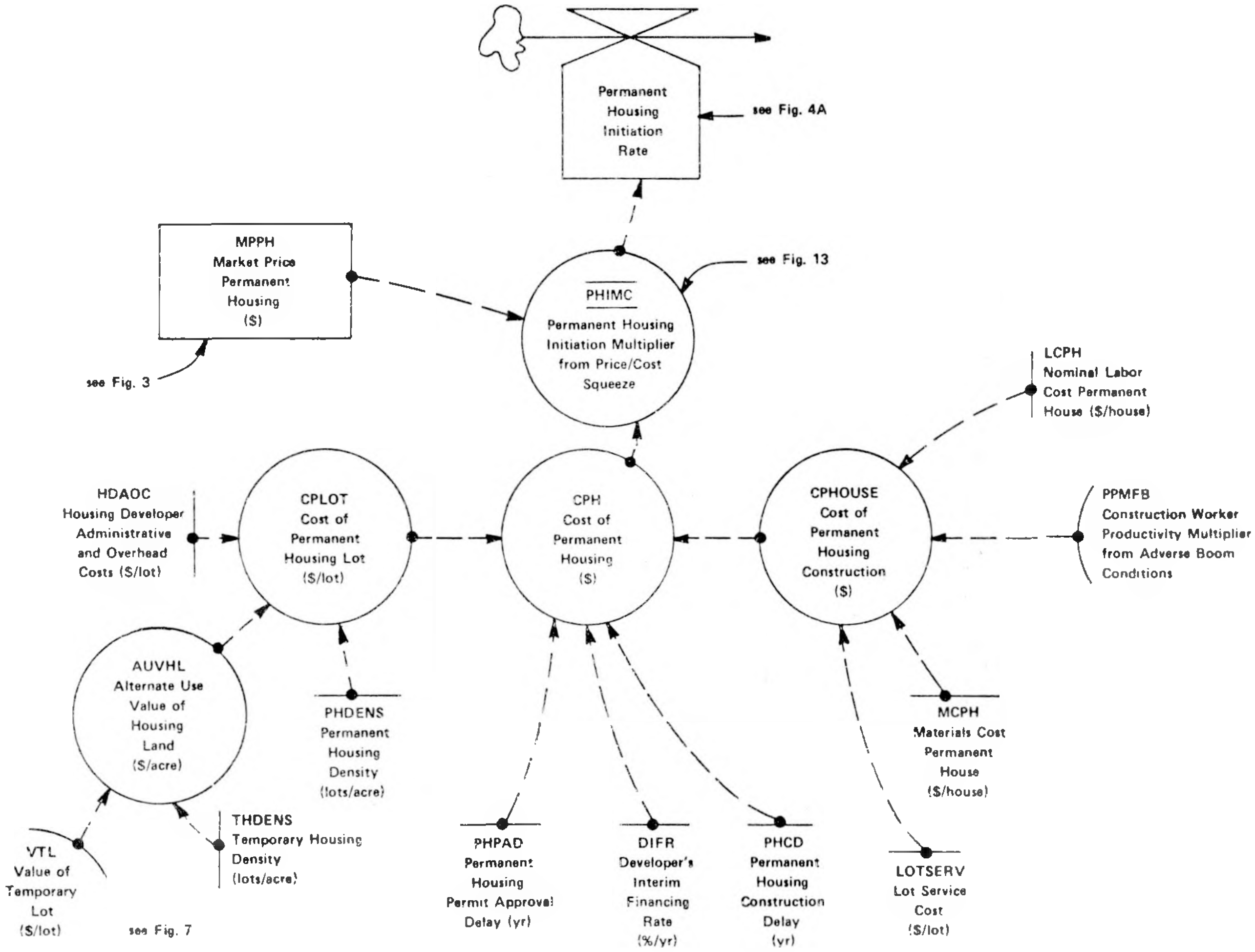

Fig. 4b.
Effect of price/cost ratio on the permanent housing starts.

calculations used in the temporary housing sector as shown in Fig. 6. Should SPECP2 increase dramatically, for example, some temporary housing developers are assumed to forego the development of temporary housing parks with the hope of securing speculative gains when their land becomes ready for conversion to permanent use.

Although the land speculation sector plays a limited role in the BOOMH model, the phenomenon deserves considerable study, especially when specific towns with severe land constraints are under investigation. For further information on the details of the land sector of BOOMH, we refer the reader to Appendix D. For a general description of the concepts used to develop the speculation sector, we refer the reader to the land use modeling work by Calligan (Calligan 1975).

D. Vicious Circles in BOOMH

Because sensitivity analysis of the original BOOM1 model has revealed the key role played by vicious circles (or positive feedback loops) like the one shown in Fig. 1, we have taken care to identify any additional vicious circles that are introduced into the model from the new assumptions about boom town housing. Three examples of new positive feedback loops arising from the new housing sector are shown in Figs. 9-11.

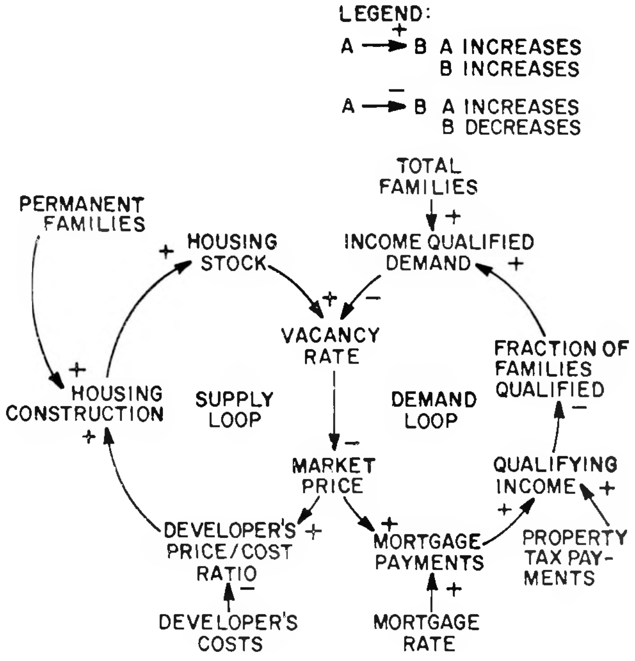

Fig. 5.
Supply and demand for permanent housing.

TABLE II

ASSUMPTIONS FOR TEMPORARY HOUSING

Demand Factors

1. Economic demand depends on the fraction of all families without permanent-type housing, and whose income exceeds the current qualifying income for temporary housing. The latter is based on the 4:1 ratio for income/shelter payments.
2. Shelter payments depend on market rent for mobile home lots, property tax rates, and mobile home financing rates.
3. Market rent on mobile home lots rises or falls in response to below or above normal vacancy rate, respectively.

Supply Factors

1. Mobile-lot developers plan projects on the basis of a shortfall of existing lots as compared with the current number of all families without permanent-type housing.
2. Planned rate of development will be reduced or nullified if unit costs rise to approach or exceed the value for which current market rent represents an acceptable rate of return.
3. Cost of an unserviced lot depends on the speculative value of the land, looking toward ultimate use for permanent-type development.
4. Cost of lot servicing is paid by the developer, and may rise if speculation or zoning force the development onto less suitable terrain.
5. Town may levy extra fees on new mobile lots to cover cost of "people-serving" public construction (e.g., public safety, public health, parks, and recreation).
6. Delay between initiation and completion of a project depends on regulatory agency policy.

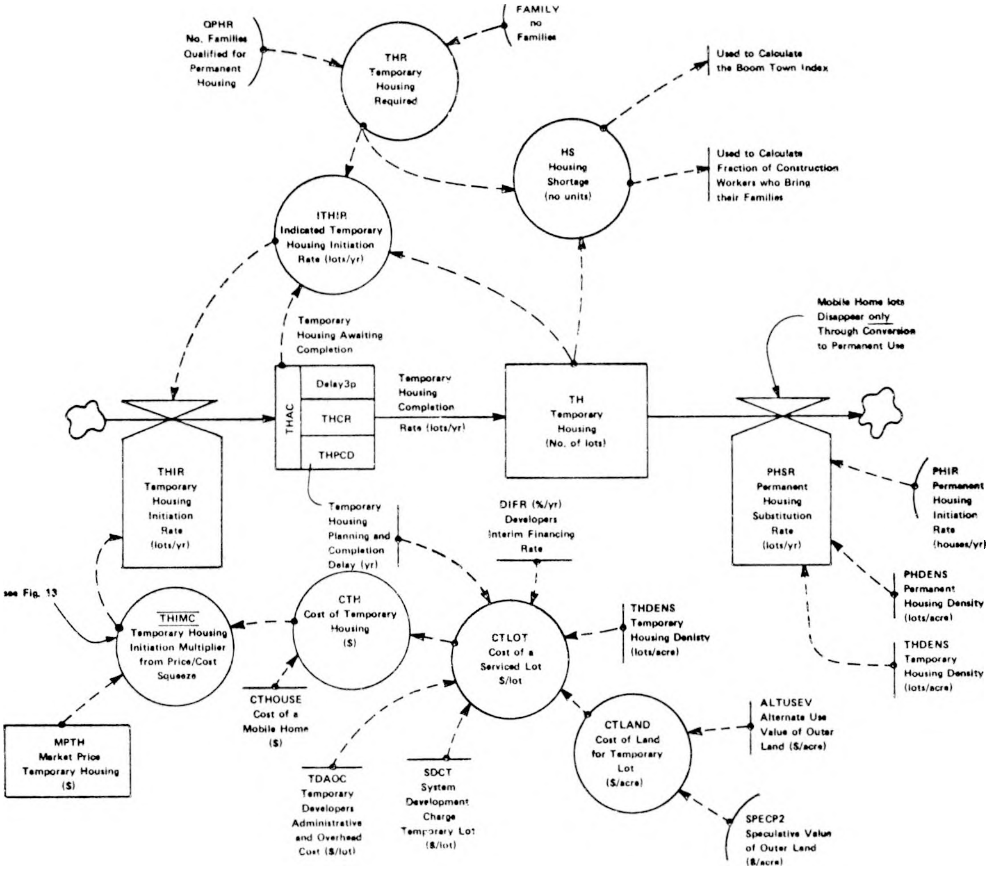

Fig. 6.
Temporary housing supply calculations.

The first loop (Fig. 9) involves the demand for housing from the housing construction workers. It operates only if builders consider some fraction of construction workers in their projection of the potential market for houses. This can occur if a series of projects is expected, requiring a rather permanent construction work force.

The loop shown in Fig. 10 is related to the vicious circle shown previously in Fig. 1 since both involve a decline in construction work productivity. Notice that the loops in Fig. 1 and Fig. 10 both act to widen the gap between housing supply and demand. In Fig. 1 declining construction worker productivity leads to a larger population and a growing demand for housing; in Fig. 10, declining construction worker productivity leads to cutbacks in the housing starts whenever local labor costs reduce the developer's price/cost ratio to unfavorable values.

The two loops shown in Fig. 11 are more complex, involving interactions between the markets for the two types of housing. The interaction represented by the left-hand side of Fig. 11 is competition for land, in which the cost of development land for one housing type is driven up by high values (and profits) for the other housing type. This competition can be eliminated by policies requiring that the two types of housing be developed in widely separated areas. The second interaction between the two markets is the competition for demand represented by the right-hand loop in Fig. 11. This interaction cannot be eliminated by policy action.

E. Changes in Other Sectors of BOOM1

The BOOMH model includes not just the major changes in the housing sector of the original BOOM1 model but some changes in the other sectors as well. These changes were made to allow the nonhousing sectors to take advantage of the increased level of detail in the new housing sector. These changes are noted in the program listing in

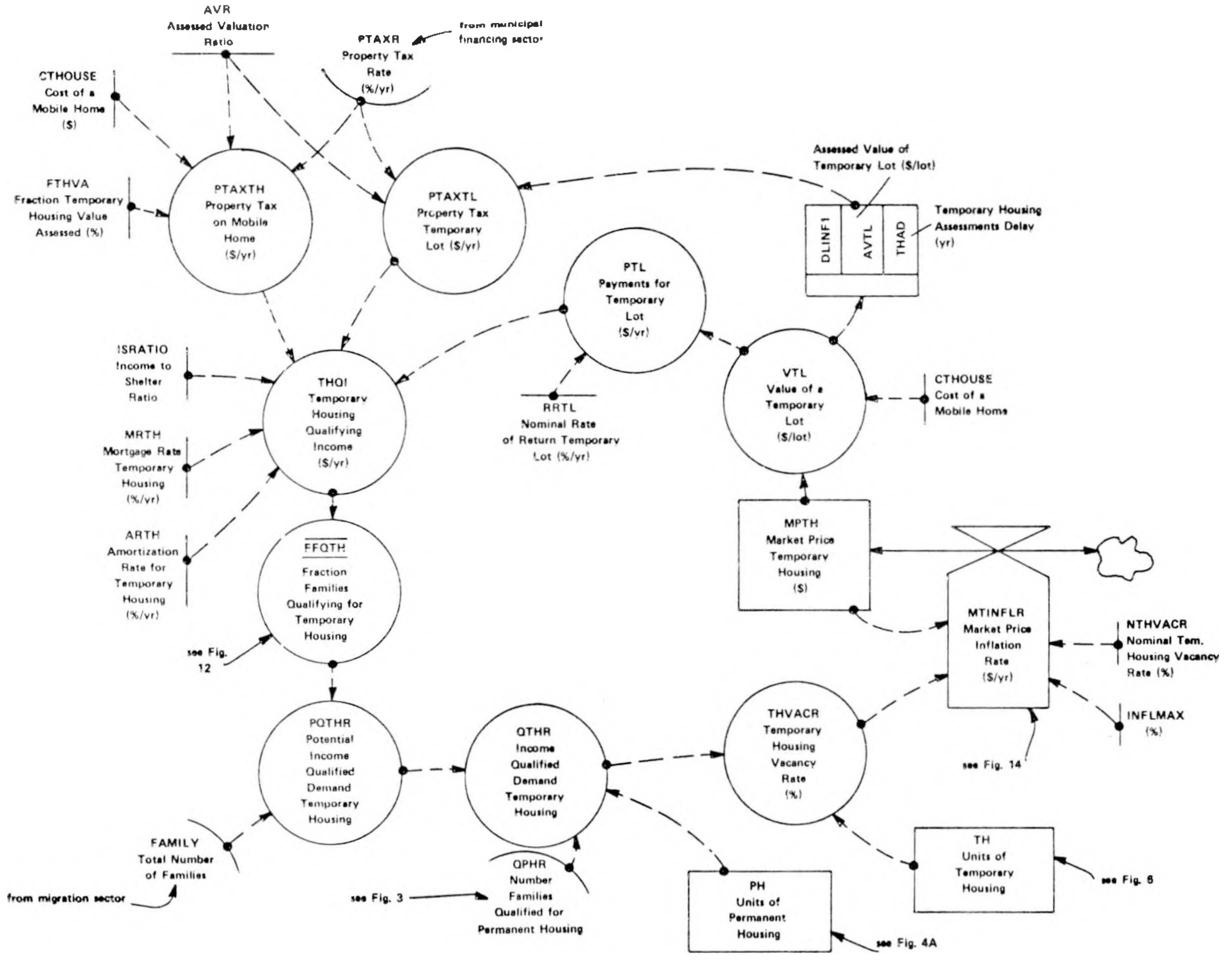

Fig. 7.
Temporary housing demand calculations.

Appendix B (Appendix C is a guide to the listing) and are also apparent from a comparison of the BOOMH flow diagram in Appendix A with the flow diagram of the original BOOM1 model (Ford and Lorber 1977, p. 27). These changes involve the public sector, the migration sector, and the "reaction to boom town conditions" sector of the original BOOM1 model.

In the public sector, the BOOMH model distinguishes between two types of public facilities according to whether their demand is more directly related to the growth in the housing stock or to the growth in population. The housing-related public facilities include water, sewage, and streets; the population-related facilities include schools, libraries, health, safety, and recreational facilities.

The municipal financing sector of BOOMH can choose one of two modes of financing for the housing-related facilities. One mode involves direct charges to the housing developer on the basis of housing starts. Under this mode, the special charge (multiplied by the rate of housing starts) creates an additional source of municipal revenue. The developer's charge is, of course, counted as one of the developer's costs in computing the developer's price/cost ratio. Under this mode of financing, the capacity of the town to issue new bonds for population-related construction projects is not impaired by heavy expenditures for the housing-related facilities.

The other mode of financing requires the municipal financing sector to issue new debt which is repaid by special assessments that add to the home owner's tax bill. If the town chooses this mode of financing, its ability to issue new debt for other facilities may be impaired. Another difference between the two modes involves the way in which they

TABLE III

ASSUMPTIONS FOR LAND SPECULATION

1. Current (smoothed) value of a lot for permanent-type housing is the basis for speculative valuation of land not yet ready for permanent development (e.g., not proximal to services, not zoned R, or not best location currently available).

2. Speculative valuation involves estimation of holding time until conversion, found by calculating the total acres to be developed before the land in question is converted to permanent use and dividing this by the current (smoothed) conversion rate.

3. Speculative valuation further involves discounting of the expected ultimate value according to the estimated holding time, with discount rate based on interest rate, and return (if any) on interim use of land for other (e.g., agricultural) purposes.

4. Other types of land speculation are not modeled as explicitly. In some boom towns, there are topographic constraints on easily serviced land which might allow a speculator to acquire a monopoly position. He could then control the current price of building lots, rather than merely discounting from a market-controlled current price. The effect can be examined with the model by setting an "easily serviced land" parameter to a low value or zero, and setting the servicing cost parameters on other land to a high value.

5. Preboom public land assembly and zoning for orderly development can minimize the effects of "monopolistic" and "free market" land speculation, respectively.

affect the interplay between supply and demand for housing. When developers are charged a direct fee, the cost of housing-related public facilities has a direct effect on the *supply* loop shown in Fig. 5. Depending on the developer's price/cost ratio, the direct charge may have a strong influence on the rate of housing starts. When the special assessment district is used to finance housing-related public construction, the *demand loop* in Fig. 5 is directly affected. By adding to the home owner's tax burden, the cost of new public facilities tends to reduce the fraction of families that can qualify for permanent housing. This, in turn, leads to an increased vacancy rate, a reduced market price, and a reduction in the developer's price/cost ratio. Depending on the length of various delays in the model, the eventual reduction in the developer's price/cost ratio may be quite different under the second mode of financing.

In the runs shown in this report, we assume the direct mode of financing that requires the developer to pay the bill for the housing-related public construction. By a simple parameter change, however, the model can be run under the alternative mode of special assessment district financing.

A second change appears in the migration sector, where the Fraction of Single Workers or workers without Families (FSWOF) is calculated on the basis of housing availability rather than on the basis of the Average Boom Town Index (ABTI) as is done in the BOOM1 model (Ford 1976a, p. 52). This change takes advantage of the calculation of absolute shortages of housing in the new housing sector, and is based on the assumption that housing availability will be the dominant factor influencing the construction worker's decision about whether to bring his family to the boom town.

The third change in the nonhousing sectors of the BOOM1 model involves the nonlinear relationship between the decline in construction worker productivity and the deterioration of local conditions as represented by an increase in the Average Boom Town Index (ABTI). After many discussions with boom town experts, and in light of recent interviews with construction foremen (Schulte 1977), we

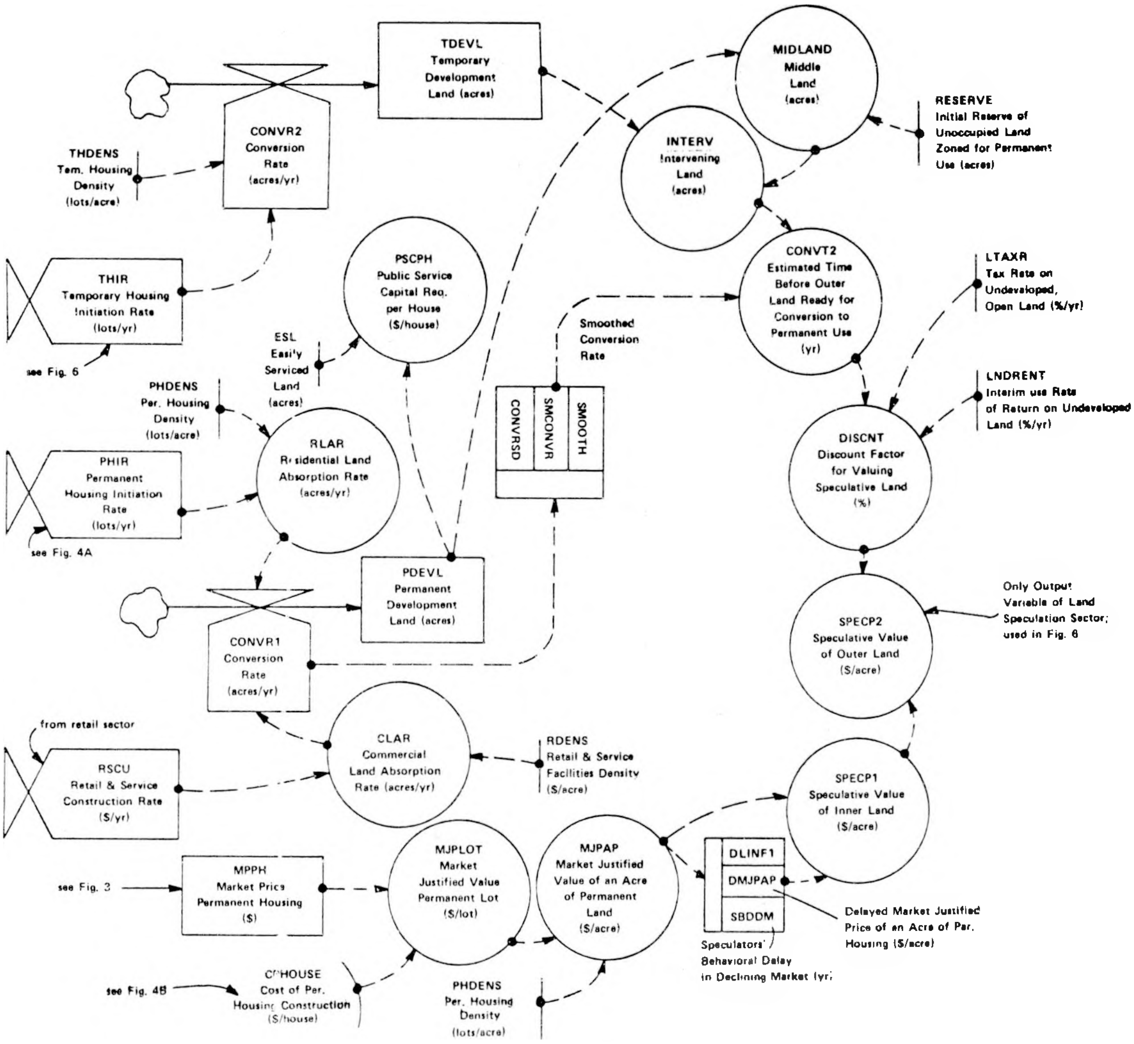

Fig. 8.
Land speculation calculations.

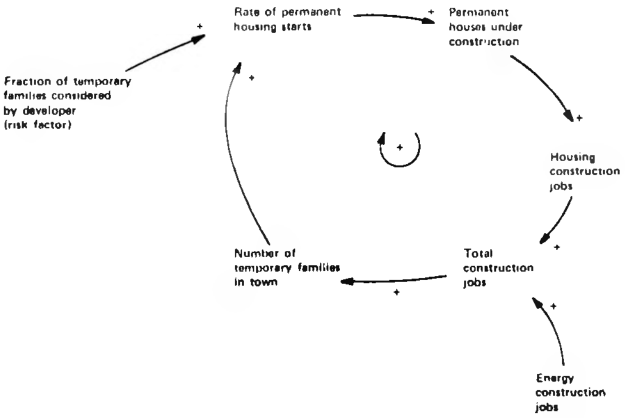

Fig. 9.
Building houses for construction workers is a self-reinforcing activity.

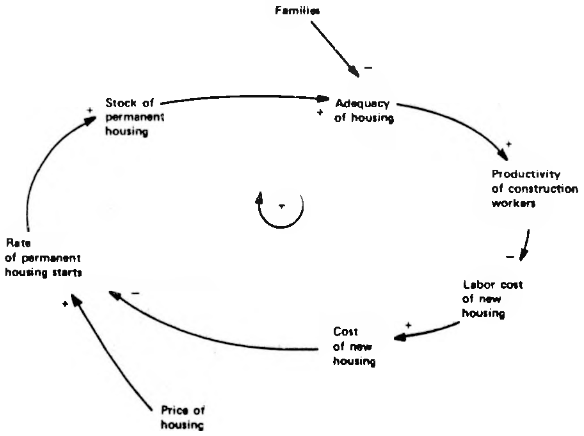

Fig. 10.
Shortage of permanent housing reinforces itself through a decline in construction worker productivity.

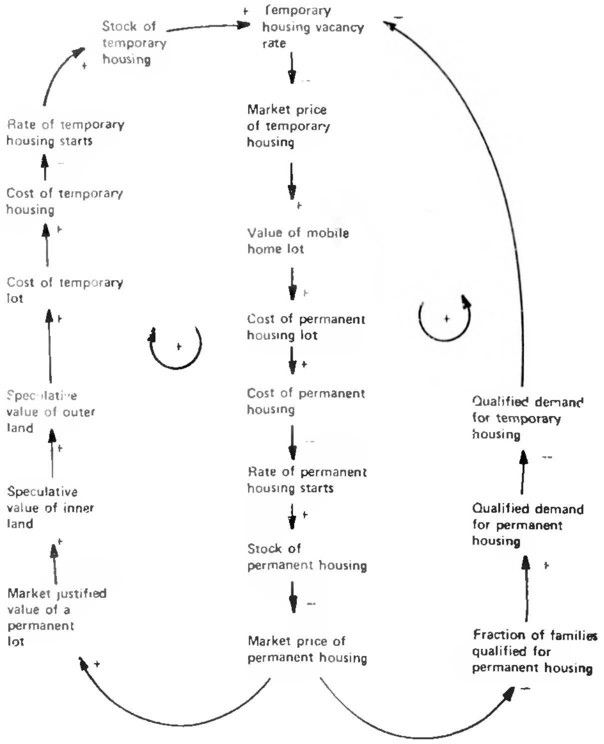

Fig. 11.

Two ways in which a rising price of one type of housing reinforces itself by causing a rising price in the other type of housing.

believe that this particular relationship may exaggerate the size of the decline in construction worker productivity. Thus, we have reduced the severity of the decline in productivity to be expected from a given value of the Average Boom Town Index (ABTI). However, we have maintained the same general shape of the nonlinear relationship, so the vicious circle shown in Fig. 1 is still likely to play an important role in the model.

III. HOUSING SECTOR CONCEPTS

By now the reader may have questions about some of the usual housing concepts and their treatment in this model. We attempt to anticipate and answer some of the conceptual questions.

A. Housing Types

Only two kinds of housing are defined: permanent and temporary. The permanent type is thus an aggregate of physical types ranging from single-family detached to apartment units, whereas the temporary type is exclusively identifiable with mobile homes. A residual kind of housing, not explicitly treated in the model, is the job-site portable dormitory provided by a company for construction workers when no housing is available. The existence and amount of such housing may influence worker morale and productivity, but is not thought to have major socioeconomic influence on the town.

This simple level of aggregation contrasts markedly with the highly detailed description of housing categories that appear in some other modeling efforts. In one proposal, investigators from the DRI suggested the use of five boom town housing categories: (1) single family, site constructed, owner-occupied; (2) single family, modular, owner-occupied; (3) multifamily rentals; (4) mobile homes; and (5) other types ranging from bachelor quarters to recreational vehicles (DRI 1977, p. 18). In an urban housing model built in the 1960s, system analysts defined literally hundreds of housing categories; so numerous were the categories, that extraordinarily clever (and expensive) programming efforts were required to submit the model to the computer (Brewer 1973).

Two pragmatic reasons led to the choice of a simple, two-category representation of boom town housing. First, we felt that the key to understanding the problems of boom town housing lay in the interplay of various feedback loops and not especially in a description of 5, 10, or 20 different types of housing. Second, we wanted to construct and document a simple version of the housing model before considering a more sophisticated representation.

B. Substandard Housing

In any community, some of the resident families have incomes too low to qualify for any type of standard housing. From the income distribution assumed by the model, 15% of all families have incomes below $8,000, which means that they are not qualified to purchase even a mobile home with typical preboom payments of $2500 per year for financing, lot rental, and taxes (WGREPO 1977, p. 528-34). These families are assumed to occupy 400 units of substandard housing at the beginning of the simulation time period, and these units are assumed to remain in place during the boom and to meet part of the demand that would otherwise have to be met by temporary housing.

C. Owning vs Renting

In the model, mobile homes are assumed to be occupied by their owners and to be placed on rented lots. In the case of permanent-type housing, however, no distinction is made between occupant-owned and rented housing. Net annual cost to the occupant is the same either way, when equity savings and opportunity costs are taken into account; so the qualifying income level is independent of the type of occupancy. Purchasing vs renting is thus assumed to be a matter of individual preference, without major socioeconomic implications, and this is the reason for making no distinction in the model.

As a general rule for interpreting the simulation results of the model, the reader should view an increase in the market price for housing as an indicator of increases in the monthly rental for housing. Similarly, periods in which the model exhibits a decline in the market price would be characterized by declining rental rates.

D. Preboom Residents and Newcomers

The basic boom town model (BOOM1) distinguishes between "permanent" families and construction worker families; this distinction is used in the housing sector. No distinction is made, however, between preboom residents and newcomers. The rationale here is that, although newcomers tend to have higher wage incomes and thus might be supposed to be better qualified for available housing, preboom residents tend to own housing and remain qualified to occupy despite rising housing prices. The rising cost is to them only an opportunity cost and doesn't need to be met by wage income. Therefore, a "newcomer" income distribution of families is used in the model for calculating qualified housing demand regardless of the relative numbers of preboom and newcomer families; the assumption being that preboom families have the equivalent of nonwage income from preownership of real assets.

E. Location and Topography

No locational distinctions are explicit in the model. The hypothetical boom town is considered to be too small for differences in travel time to work or service facilities to be significant in real estate valuation. There is, however, an implicit spatial ordering in the way land is assumed to be developed for housing. Sewer and water services are assumed to be extended contiguously, so that the land area converted to permanent use expands outward without "leapfrog" discontinuities. The land used for temporary-type housing may be at some distance, however, with the intervening land being "reserved" by zoning or other statutory device for permanent-type use. These categories of land are described in more detail in Appendix D. The shape of the land-use pattern depends on the particular town topography, highways, railroad, etc., and is not treated in the model. Only the amount of land, in acres, reserved at the outset for permanent-type development needs to be determined to run the model.

F. Housing Preference

In the migration component of BOOM1, the total number of families is projected for each time period in the simulation. This number also is taken to be the number of permanent-type housing units nominally required. The assumption being that any family would prefer to occupy one unit of permanent-type housing if all other factors were fixed. The fact that many boom town construction worker families occupy mobile homes and seem satisfied to do so is interpreted as resignation to the realities of the housing market, in particular to the nonavailability of permanent-type rental units and of mortgages. All families who can qualify to occupy permanent-type housing are assumed to do so.

IV. PARAMETER VALUES OF THE BOOMH MODEL

A. Constants

The values of constants used in the housing sector of BOOMH are given in Table IV. The constants used in other sectors are the same as described in the User's Guide to the BOOM1 Model (Ford 1970a, p. 27).

B. Table Functions

Three table functions are used in the housing sector to represent nonlinear relationships between variables. One of these represents the distribution of family incomes and is shown in Fig. 12. In this figure, the ordinate gives the fraction of families whose annual income is *more* than the number of dollars shown on the horizontal scale. Figure 12 shows, for example, that 80% of the families are assumed to earn $10,000 per year or more in combined, family income. Only 10% of the families are assumed to bring home more than $40,000 per year in combined income. This table function is used to calculate the number of families who can qualify for housing (see Figs. 3 and 7).

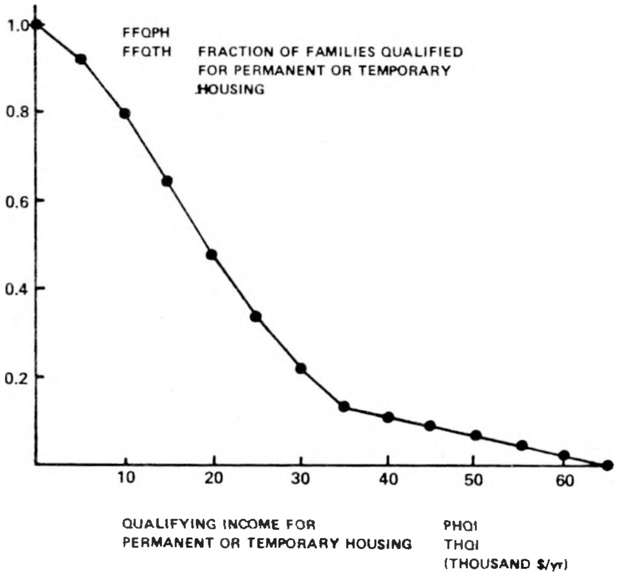

Fig. 12.
Family income distribution.

The graph shown in Fig. 12 was obtained by taking the income distribution for Montana families in 1969 (Commerce Dept. 1969) and scaling it up to 1976 dollars. The scaling was accomplished by taking the 1976 average income for Montana mining and construction worker families, reported to be $19,250 (WGREPO 1977, p. 472), and dividing this by the median income of $8,500 from the 1969 data to obtain a scaling factor of 2.265. This factor, applied to the 1969 income scale, resulted in Fig. 12.

The second table function used in housing calculations represents the assumed behavior of developers when faced with a cost/price "squeeze." According to the graph shown in Fig. 13, developers don't build *any* houses or develop any mobile-home lots if their expected profit from such operations, based on current prices and costs, is zero or negative, regardless of how great is the need for housing. However, they develop *all* the houses or mobile lots that are needed if there is a profit margin of 20% or greater. Between these two limiting cases, it is assumed that some developers will go ahead with their construction schedules, accepting a reduced profit, whereas others will not. We assume, for example, that 20% of needed development will proceed with a profit margin of 5%, 50% will proceed with a profit margin of 10%, and 80% will proceed if the profit margin is 15%.

Although our discussions with experts on boom town housing lead us to have confidence in the general shape of the nonlinear relationship in Fig. 13, we do not claim that each entry in the table function is an accurate representation of developer's behavior. Further interviews could lead to an improved specification of the table function in Fig. 13,

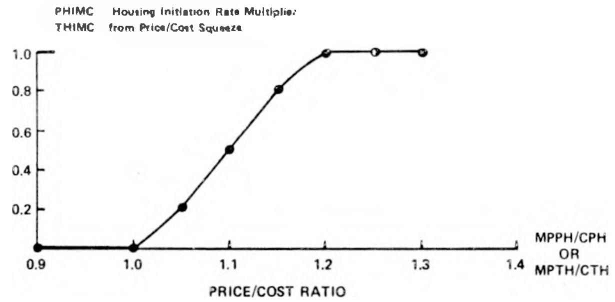

Fig. 13.
Housing initiation multiplier from price/cost ratio.

TABLE IV

ESTIMATES OF THE CONSTANTS IN BOOMH

Constant	Name	Source
ALTUSEV=$250/acre.	Alternate-use value of land.	Assumed, non-irrigated rangeland, net return $25 per acre, per year, at 10% expected return date.
ISRATIO=4.0.	Income/shelter payments ratio.	(Willis 1976).
LCPHO=$14,000. (assumed total cost of house $35,000, excluding lot and servicing.	Labor cost component per unit of permanent housing.	40% for on-site labor (*Time* 1977), Manager, Home Planning & Development Co., Los Alamos, New Mexico.
MCPHO=$21,000.	Cost of materials and fixtures per unit of permanent housing.	(see above).
LCSMH=$10,000.	Labor cost saving with modular housing, per house.	(McGraw-Hill 1977a, p. 64).
MCIMH=$4,000.	Material cost increase with modular housing per house.	Net saving of $6,000/unit with modular housing, (McGraw-Hill 1977a, p. 64).
NPHVACR=0.05.	Normal permanent housing vacancy rate.	(Willis 1976).
ALPH=50 years.	Average life of permanent housing.	Assumed.
ARPH=0.02/year (av of 0.015 for purchased house, 20-yr 1st mortgage on 80%, 10-yr 2nd mortgage on 15%, and 0.03 for rented housing).	Amortization rate, permanent housing.	Manager, Canadian Imperial Bank of Commerce, Edmonton, Canada.
ARTH-0.05/year (10-yr max financing).	Amortization rate, temporary housing.	Manager, Canadian Imperial Bank of Commerce, Edmonton, Canada.
RRTL=0.15.	Expected return rate on mobile home lots.	Assumed.

TABLE IV (cont)

Constant	Name	Source
LCPHS=$4,000/lot ($4,000/gross acre for water and sewer dist'n and collection lines, 3.0 houses/acre; also $1300/house for water supply and water/sewage treatment and $1400 assumed for street and sidewalk).	Permanent housing lot services cost, easily serviced land.	(DRI 1975, p. 240).
LCTHS=$2000/lot (see above, 6.0 mobiles per gross acre, no street).	Temporary housing lot services, easily serviced land (low cost).	
HPCHS=$6000/lot ($10,000/gross acre for water/sewer lines).	Permanent housing lot services cost (high).	Assumed.
HCTHS=$3000/lot (6.0 mobiles per gross acre).	Temporary housing lot services cost (high).	
NTHVACR=0.07.	Normal temporary housing vacancy rate.	(Willis 1976).
CTHOUSE=$12,500.	Cost of mobile home.	(WGREPO 1977, p. 528-34).
PHDENS=3.0 houses/gross acre.	Density of permanent housing.	(DRI 1975, p. 240).
THDENS=6.0 mobile homes/gross acre.	Density of temporary housing.	Assumed.
THVA=0.5.	Fraction of mobile home value assessed for tax.	(Prestgaard 1974, p. 59, 71).
LNDRENT=$25/acre.	Land rent, annual, alternate use.	Assumed (see ALTUSEV).
INTR=0.08.	Interest rate used to discount in speculation.	Assumed.
LTAXR=0.01.	Annual property tax rate on unimproved land.	Assumed.
CFPH=1.0 worker per house under construction.	Construction force per unit of permanent housing under construction.	Manager, Home Planning and Development Company, Los Alamos, New Mexico (also consistent with LCPH, PHCD, and $19k av income for construction workers).

TABLE IV (cont)

Constant	Name	Source
HDAOC=$1000/lot (5% of total $20k cost of building lot).	Housing developers administrative overhead costs.	N. Runka, Land Development Division, Weber Bros. Realty, Edmonton, Canada.
TDAOC=$500/lot.	Temporary housing developers admin overhead cost.	Assumed.
SBDDM=2.0 years.	Speculator behavioral delay in a declining market.	Assumed.
FTFCD=0.0.	Fraction of temporary families considered by permanent housing developers.	Assumed in order to represent "risk adverse" behavior (see Fig. 30 for an example of "bold" behavior).
FPFCD=0.85.	Fraction of permanent families considered by permanent housing developers.	Assumed.
INFLMAX=0.25.	Inflation rate on housing when vacancy rate is zero.	Assumed.
PHCD=0.75 years.	Permanent housing delay construction.	Assumed.
PHPAD=1.0 year.	Permanent housing planning and approval delay.	Assumed.
THPCD=1.0 year.	Temporary housing planning and completion delay.	Assumed.
MRPH=0.09.	Mortgage rate on permanent housing.	(WGREPO 1977, p. 528-34).
DIFR=0.12.	Developers interim financing rate.	Assumed.
PHAD=3.0 years.	Permanent housing assessment delay (normal).	Assumed.
MRTH=0.12.	Financing interest rate on mobile homes.	(WGREPO 1977, p. 528-34).
THAD=1.0 years.	Temporary housing assessment delay (normal).	Assumed.
RDENS=100,000 $/acre.	Density of retail and service capital.	Assumed.

but the behavior of the housing model is not likely to be substantially affected as long as the new table function conforms to the same general shape as shown in Fig. 13.

A third table function is used to represent the relationship between the vacancy rate for permanent or temporary housing and the rate of inflation in the market price of permanent or temporary housing. This relationship, as shown in Fig. 14 for temporary housing, indicates that there is some nominal vacancy rate due to the "normal" turnover of ownership and/or occupants that doesn't indicate either a "buyer's market" (deflation) or a "seller's market" (inflation). For permanent housing, we assume a nominal vacancy rate of 5% of the permanent housing stock (Willis 1976). At lower vacancy rates, however, it is possible for sellers and landlords to raise their prices without risking long delays in selling or renting. In fact, the model can obtain *negative* vacancy rates at some period during the boom, and this indicates that there are more buyers or renters who need and are able to afford housing than there are units of housing. Clearly, prices must be rising rapidly during such periods, just as they do at an auction sale. We assume, for example, that the market price of housing would rise at the rate of 50% per year should the vacancy rate fall as low as −5%. At this rate of inflation, the price of housing would double in less than 18 months.

Although we are satisfied with the general shape of the relationship shown in Fig. 14, this table function is another example of where precise estimation of the relationship is not possible.*

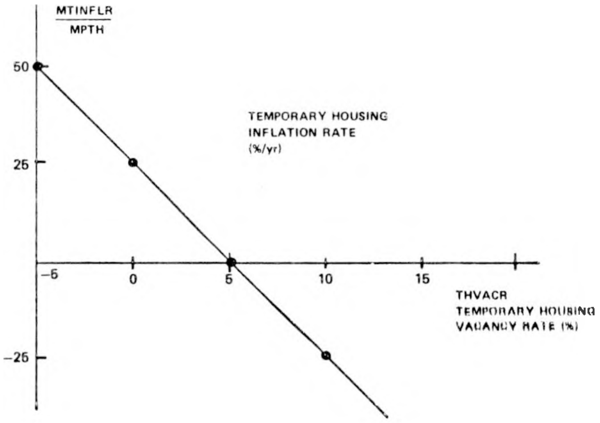

Fig. 14.
Market price inflation rate from vacancy rate.

C. Initial Values

In addition to setting the shapes of the nonlinear relationships and specifying the values of the constants, the model user must specify the initial value of each of the levels (see Appendix A) or "state variables" in the model. In the simulations shown in this report, the nonhousing levels are initialized as shown in the *User's Guide to the BOOM1 Model.* That is, the levels of Public Service Capital (PSC), outstanding Municipal Debt (MD), and Retail and Services Capital (RSC) are all initialized so that the different sectors of the town are in balance with one another before the simulated boom (Ford 1976a, p. 6).

Additional levels in the housing sector that must be initialized are Permanent Housing (PH), Temporary Housing (TH), Substandard Housing (SSH), amount of Easily Serviced vacant land (ESL), and the Market Price of Permanent and Temporary Housing (MPPH and MPTH). These levels in the housing sector are not initialized to obtain a "static equilibrium" mode of preboom behavior. Rather, the levels are set initially to capture the current "transitional phase" of the national housing markets (*Time* 1977, p. 42). Additional comments on the transitional phase are discussed later.

D. Exogenous, Time-Dependent Inputs

The final category of variables to be specified by the model user is the group of input variables whose values may change during the simulation. Three

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*Because the housing markets in most towns operate near or at the nominal vacancy rate, it is difficult to obtain information on the rate of price inflation when vacancy rates move far to the left or right in Fig. 14. In the past few years, however, some houses have been sold at auction indicating an extreme seller's market. At a house lottery in Southern California, for example, 12,000 people showed up for the sale of 221 houses. All the houses, priced from $50,000 to $90,000 were sold in an hour (McGraw-Hill 1976, p. 16, and McGraw-Hill 1977b, p. 26). Unfortunately, even these episodes may not provide a dependable indication of the maximum rate of inflation because developers often extract "non-price" concessions from the buyers. Such concessions may include requirements to join tenants' organizations, to obtain mortgage money from a specific bank, and so on.

such inputs are used in the nonhousing portion of the model: the power plant initiation rate, the number of jobs in the town's original basic sector, and the taxable value of the property in the town's original basic sector. In the simulations shown in this report, we assume that the town's original basic sector is agricultural and that the status of the agricultural economy (jobs, wages, and taxable property) is constant during the simulation. Furthermore, we assume that no additional basic industry locates in the town during the simulation.

No exogenous, time-dependent inputs are used in the new housing sector. All the input variables required by the housing sector (such as the local property tax rate or the total number of families) are provided by the other sectors of the original BOOM1 model as illustrated in Appendix A.

E. Generic vs Town-Specific Parameter Values

The constants, table functions, initial values, and time-varying inputs chosen for the simulations in this report represent conditions in a hypothetical town. The values are chosen to be representative of boom town conditions in North America. Whenever a model is designed to represent conditions for a whole class of objects, the model is said to be "generic."

Building a generic boom town model is quite a challenge when the conditions that characterize boom towns in North America vary so widely from region to region, from state to state, and from province to province. Thus, the model user must realize that a generic model that is broadly representative of the whole class of boom towns will not be applicable to any individual town.* If this is true, one may well ask "What's the use of a generic model?"

Generic models are only useful if they provide insight and understanding to decision makers who must make generic decisions. Decisions about federal and state assistance to boom towns fall into this category. The boom town legislation enacted at the state and federal level must be broadly applicable to a wide range of boom towns (legislators can't enact a different bill for each and every boom town!). In the next section, we exercise the boom town housing model to learn if there are particular insights of use to state and federal decision makers debating alternative proposals to deal with the boom town housing problem.

V. MODEL BEHAVIOR

A. Quasi-Equilibrium Behavior

Figure 15 shows the projections of prices and costs for permanent and mobile housing in the absence of any energy facility development. Note that the variables whose behavior is shown in Fig. 15 are not in static equilibrium. No new houses are built between 1970 and 1990 because the cost of building a new house is about $45,000 (1976 dollars) and the market price of a house reaches this level only at the end of the simulation. Meanwhile, the stock of

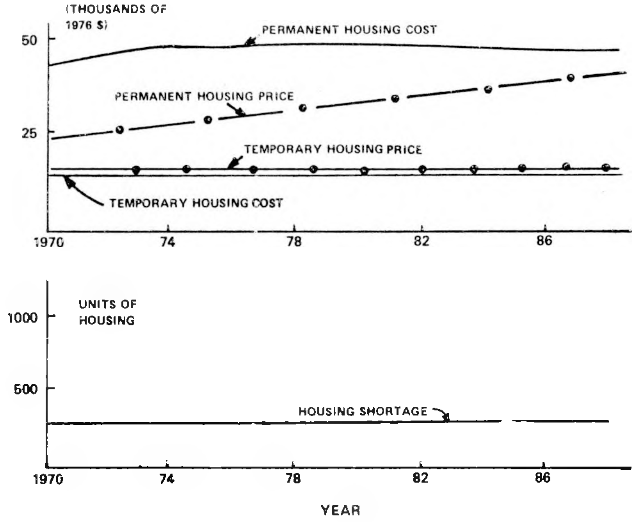

Fig. 15.

Quasi-equilibrium behavior without energy development.

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*The model described in this report can be adapted to represent conditions in a specific town by making appropriate changes in parameter values and by introducing additional interrelationships where needed. These changes would be needed if the model is to be useful to officials asking specific (not generic) questions such as: "How many school-age children will live in school district 2 at the peak of the construction boom?" A variety of boom town models exist that propose to answer such town-specific questions. Perhaps the most elaborate of these town-specific models is the Economic-Demographic model developed in the Regional Environmental Assessment Program in North Dakota (Johnson 1976).

permanent-type housing declines steadily. The declining stock of housing leads to a declining vacancy rate that forces the price of permanent housing to increase. As the market price increases, the fraction of the town's families qualified to occupy permanent housing declines.

This quasi-equilibrium behavior reflects the current transitional phase of the national housing sector (*Time* 1977, p. 42). Until this decade, many North American families traditionally owned and occupied permanent-type detached houses. Now, however, most families could not afford to purchase the houses they presently occupy. This means that effective economic demand is weak and new construction rates are low, which will force housing prices to keep on rising. Eventually, of course, a price level will be reached where economic demand and supply are again in equilibrium. An obvious cause for concern is that the equilibrium state is characterized by such high market prices that only a small fraction of families will occupy the traditional type of housing.

In the projections of Fig. 15, the growing gap between permanent housing supply and demand leads to larger numbers of temporary housing with prices remaining stable at a level just about the cost of temporary housing.

With prices at this level, the developer's price/cost ratio is in a more favorable position, and the supply of temporary housing can respond to the increased demand.

Because the variables are changing very slowly in Fig. 15, we characterize this mode of behavior as "quasi-equilibrium." In the next section we examine the reaction of the town's housing markets when the quasi-equilibrium is disturbed by the construction of a large energy facility.

B. Base Case (Worst Case) Behavior

Figure 16 shows the projected behavior of prices and costs if a 1500-MW coal-fired power plant is built near the town. Construction of the plant is initiated in 1975 and almost completed in 1981. Contractors expect the construction work force to peak at 1500 workers in the third year of construction; an operating work force of 150 is required once the plant is completed. Evident here are the dramatic increases in market prices of both housing types, peaking in 1977, and the enormous increase in the cost of permanent-type housing. The cost increase is caused partly by the greatly reduced productivity of construction workers under the adverse boom town conditions* and partly by the high cost of a building lot due to the extreme profitability of the competitive land use for parking mobile homes.** Both of these cost factors disappear during the "bust" phase of the cycle (1978-1981), and the price/cost ratio actually is attractive for housebuilders during 1980-1981. Approximately 450 new houses are constructed during the bust phase, replacing 900 mobile homes that were placed on serviced lots, during the boom. The final stock of permanent-type housing is thus higher than in the quasi-equilibrium situation of Fig. 15.

Figures 17-24 show the behavior of other variables for this base case (worst case) simulation. Notable are the *negative* vacancy rates shown in Fig. 17 for 1976, indicating an extreme "seller's market" for housing, and the large number of unhoused families during 1976-1979 shown in Fig. 18.

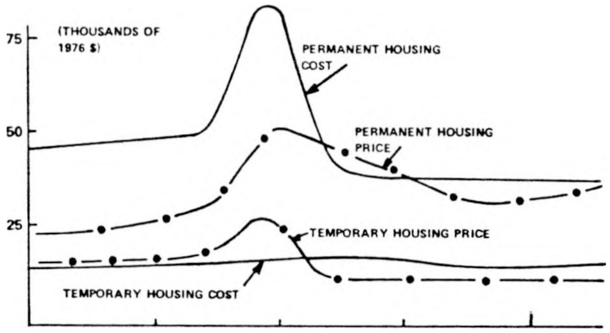

Fig. 16.
Base case simulation results, cost and price of housing.

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*Under the worst case conditions shown here, construction worker productivity drops to 50% of nominal levels causing the labor component of permanent housing costs to rise from $14,000 to $28,000.

**The value of a mobile home lot, based on market rent and expected return rate, rises to $14,000 under the worst case conditions of Fig. 16.

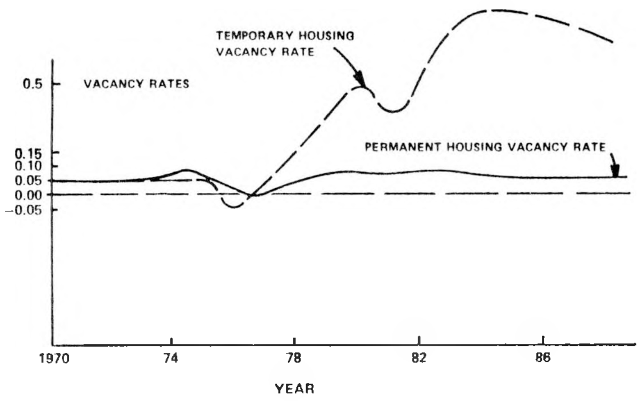

Fig. 17.
Base case simulation results, vacancy rates.

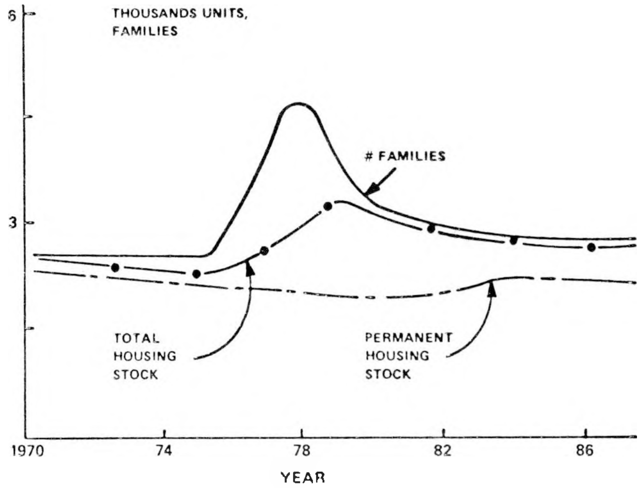

Fig. 18.
Base case simulation results, housing stocks.

Figure 19 shows the sharp rise in the income families must earn to qualify for permanent housing under these worst case conditions. At the peak of the boom, for example, a family must earn almost $25,000 per year to qualify for mortgage money. This high figure is due mostly to the high market price shown in Fig. 16, but it is also caused by the higher property tax burden arising from the town's attempt to finance needed services for the large population. Figure 19 shows that barely 35% of the families can qualify for permanent housing during the peak of the construction boom. Figure 20 shows a similar pattern for temporary housing.

Figure 21 shows the changes in the cost of servicing a mobile home lot during the construction boom. The rapid cost increase in 1977 arises from the exhaustion of the easily serviceable land. Figure 22 shows the behavior of the speculative prices of land with potential for conversion to permanent lots. Notice that the increase in the speculative price of outer land does not occur until after power plant construction is completed. This delayed increase arises from the developer's unfavorable price/cost ratio that eliminates the economic demand for land to be converted to use for permanent housing during the early part of the boom.

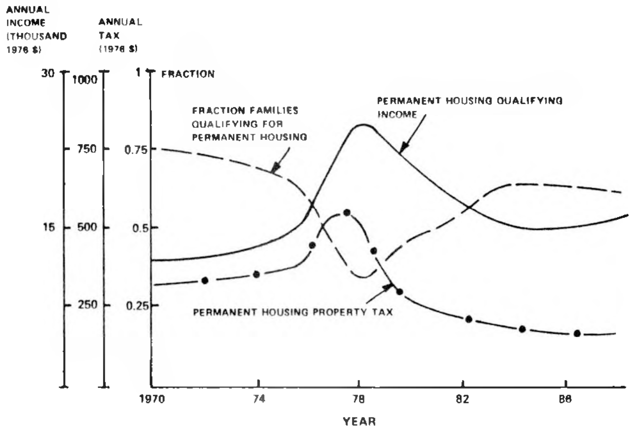

Fig. 19.
Base case simulation results, permanent housing qualifying income.

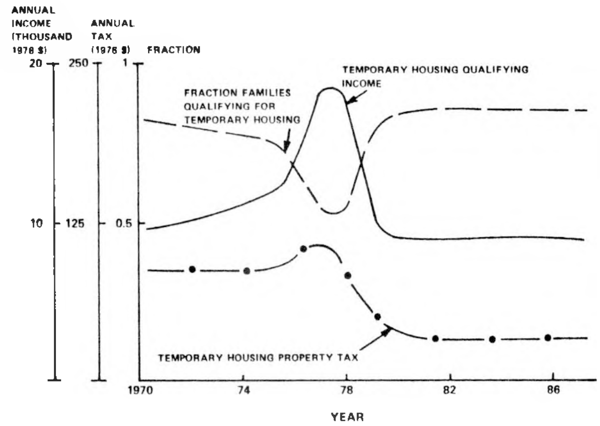

Fig. 20.
Base case simulation results, temporary housing qualifying income.

Figures 23 and 24 show the behavior of some nonhousing variables in the model. The change in the town's population and the number of construction

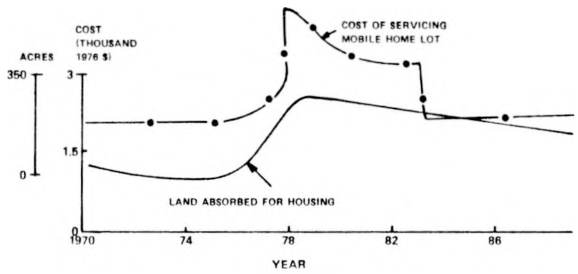

Fig. 21.
Base case simulation results, exhaustion of easily serviceable land.

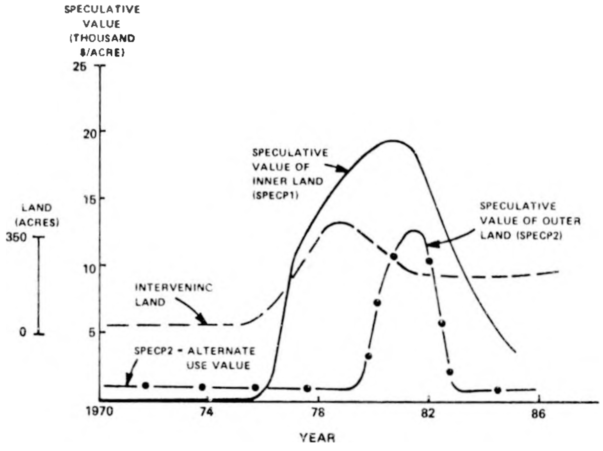

Fig. 22.
Base case simulation results, land speculation.

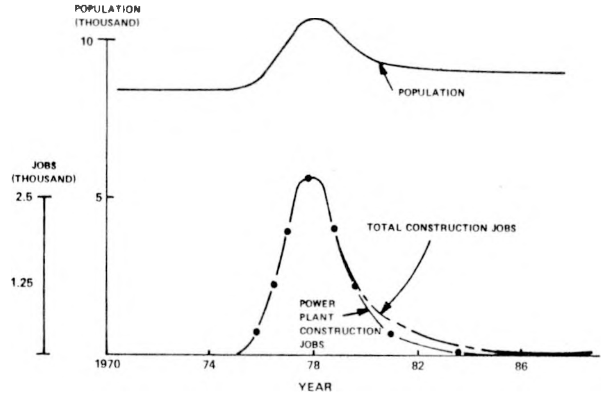

Fig. 23.
Base case simulation results, population growth.

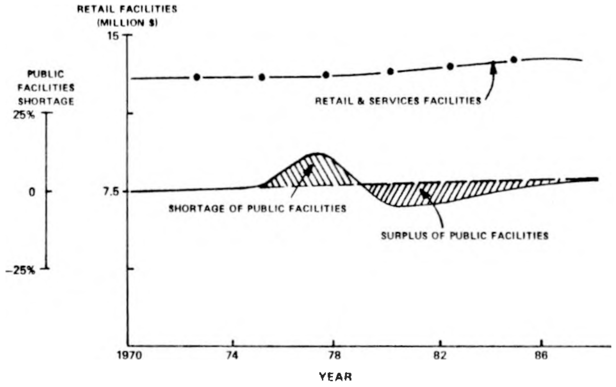

Fig. 24.
Base case simulation results, retail and public sectors.

jobs are shown in Fig. 23. Notice that about 3,000 construction workers are required if the contractor is to get the power plant constructed on schedule despite the large decline in worker productivity. Figure 23 also shows that housing construction jobs make absolutely no contribution to the total construction jobs until the 1980s when developers perceive a favorable price/cost ratio.* Also apparent from Fig. 23 is the rather small overall increase in population despite the large increase in construction employment. The rather small increase in population arises from the reluctance of construction workers to bring their families when there is no place to house them and the reluctance of retail investors to construct new retail facilities to cater to the "temporary" business of the construction boom.

The reluctance of retail investors to locate in the simulated boom town is also evident from Fig. 24, which shows the total stock of retail capital. Also evident from Fig. 24 is a shortage of public facilities during the construction phase followed by an oversupply of public facilities during the operation phase of the plant. The initial shortage is caused by the reluctance of public officials to build expensive new facilities before the arrival of new families. The subsequent surplus of public facilities occurs when large numbers of construction workers leave town when work on the power plant is completed.

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*This projection of employment in the housing construction industry contrasts sharply with the "accelerator effect" used in other studies that relate housing construction jobs directly to changes in employment (Auger 1976, p. II-133).

C. Discussion of Worst Case Behavior

The plots shown in Figs. 16-24 show an extremely severe shortage of housing with concomitant increases in market prices. This shortage arises from a combination of supply-inhibiting factors that prevent developers from initiating sufficient construction to meet the rapidly growing demand. Several of these supply factors were described in the introductory section. The way in which each of the supply factors is represented in the model is described below.

1. *Inflated cost of skilled construction labor*: As the flow diagram in Fig. 4b shows, this factor is represented by dividing the Nominal Labor Cost of a Permanent House (LCPH = $14,000) by the Productivity Multiplier from adverse Boom Town Conditions (PPMFB). The effect of inflated labor costs is readily apparent from the skyrocketing cost of permanent housing shown in the model output in Fig. 16.
2. *Difficulties in assembling suitable land*: As Fig. 4b shows, this factor is represented by assuming that the cost of providing utilities may increase once the Easily Serviced Land (ESL) is exhausted.

   The exhaustion of prime land also inhibits the supply of housing through the action of land speculators. Land speculation that drives up the price of developed lots leads to increased costs of housing development to the outside developer (see Fig. 4b).
3. *Lack of infrastructure such as water and sewer facilities*: Figure 24 shows that the public sector of the model is experiencing difficulties in providing the full complement of public facilities needed for the rapidly growing population.

   Shortage of public facilities in general does not necessarily imply a shortage of the water and sewer hookups, however. In the simulation shown in Figs. 16-24, the model operates on the assumption that the initiation of housing construction is *not* inhibited by lack of water and sewer facilities. Specifically, we have decoupled the Housing Initiation Multiplier from Utilities Availability (HIMUA) shown in Fig. 4a from the Fraction of Public Facilities Financed (FPCF). Our assumption is that housing developers pay a System Development Charge (SDCH) that guarantees availability of utilities in spite of the financing difficulties experienced by the town.
4. *Resistance of developers to assume the abnormal risks present in boom towns*: The developer's attitude toward risk is represented by the Fraction of Temporary Families Considered by Developers (FTFCD), which is shown in the DYNAMO diagram of Fig. 4a. This fraction is used to help calculate the Indicated Permanent Housing Initiation Rate (IPHIR). When the fraction is set to zero, developers ignore the construction families who may only be in town for three or four years; a value of one indicates that developers treat the construction families as if they were going to be in town permanently. Thus, a value of zero reflects "risk adverse" behavior by the developer; a value of one indicates "bold" investment behavior in face of the boom town risks. In the simulations shown in Figs. 16-24, this fraction is set to zero to represent risk adverse behavior by the developers. In a simulation shown later in this report, we test the effect of a change in this risk factor.
5. *Limitations on housing entrepreneurial skills in the town*: Small towns with no active construction industry may experience inordinate delays before outside developers decide to "set up shop" in the town. We represent this supply factor in an implicit fashion by calculating the Indicated Permanent Housing Initiation Rate (IPHIR) on the basis of the *current* (not the forecast) number of families in town (see Fig. 4a). In effect, we are representing the "wait until the bodies are in town" attitude of developers who are reluctant to prebuild in a town where they have no local office or representative. This reluctance to initiate housing before the beginning of the boom can be quite important due to the effects of the housing approval and construction delays shown in Fig. 4a.
6. *Absence of local financial institutions specializing in mortgages*: As we mentioned in the introductory section, this last factor is related more directly to housing demand than

to housing supply. When local banks are forced to call on correspondent banks to obtain sufficient mortgage money, prospective buyers may face higher costs, longer delays, or outright refusal to grant the loan (LANB & NMBA 1977). This demand-limiting factor is ignored in the housing model described in this report. Notice from the diagram in Fig. 3a, for example, that the Mortgage Rate for Permanent Housing (MRPH) is constant during the simulation. Thus, the model assumes that a sufficient supply of mortgage money is available at the constant rate regardless of the total value of loans issued.

To summarize, we assume that the demand for housing grows unfettered by limitations on mortgage money as the number of families increases sharply during the construction boom. The dominant portion of that demand is viewed as "temporary" and is ignored by the risk-adverse developer regardless of his price/cost ratio. But as Fig. 16 shows, the developer's price/cost ratio is hardly in a favorable position. Due to the several supply-inhibiting factors (inflated labor, inflated costs of lots, and exhaustion of easily serviced land), the housing costs are driven up much faster than the increase in housing prices. In short, developers choose to cater to neither the "risky" nor the permanent demand for permanent housing. Thus, the potentially aggravating effects of the housing permit approval delay and the housing construction delay are never felt to any substantial degree (because little housing is initiated).

With the supply loop rendered inoperative, the only mechanism left to the model to balance supply and demand is to activate the demand loop (see Fig. 5). That is, the market mechanism simulated in the model leads to a price increase that is sufficiently large to allocate the fixed stock of permanent houses among the many families that prefer to live in them. As Fig. 16 shows, price doubling of permanent housing is required to clear the market. Put differently, the price of permanent housing doubles in order to disqualify 70% of the families (see Fig. 19) and return the vacancy rate to the equal level.

Although some residents would profit greatly from a pattern of behavior like the base case results of Figs. 16-24, most observers would describe the base case conditions as undesirable. Shortages of housing not only lead to bad morale and high turnover among the power plant construction work force, but they pose a health and safety problem as well. Shortages as severe as those portrayed in Fig. 18 are usually accompanied by overcrowding in existing housing and illegal placement of mobile homes and recreational vehicles in unserviced "nooks and corners" about town.

In the next section, we examine the effectiveness of various boom town housing policies in improving upon the worst case behavior shown in Figs. 16-24.

VI. HOUSING POLICY ANALYSIS

The policies tested with the model can be classified roughly into the following three groups, which are differentiated according to the degree of interference with the "free market" assumptions made for the base case run.

1. Minimal intervention policies, single energy facility.
   - Organize financial institution to raise mortgage and builder's interim financing funds at minimum possible rates.
   - Permit modular-type permanent housing and minimize approval delays.
2. Planning for orderly development, multiple energy facilities.
   - Sequence of energy facilities to be constructed; planned spacing.
   - Orderly land development by zoning, public land assembly, and servicing.
3. Direct market participation by energy company or government agencies.
   - Building of housing before initiating energy facility construction.
   - Backing of risk investment in housing and retail facilities.

The results of simulations that test these particular policies are described below. In these simulations, policies are "stacked" so that each run assumes one new policy *in addition* to the previously tested policies.

Because repeating the nine plots of Figs. 16-24 for each and every policy run would be quite laborious, we have singled out four principal variables for examination in the policy simulations. The behavior of these four variables in the base case, worst case situation is shown in Fig. 25. These variables summarize in one plot the severity of the housing problem; they show the inflation in permanent and

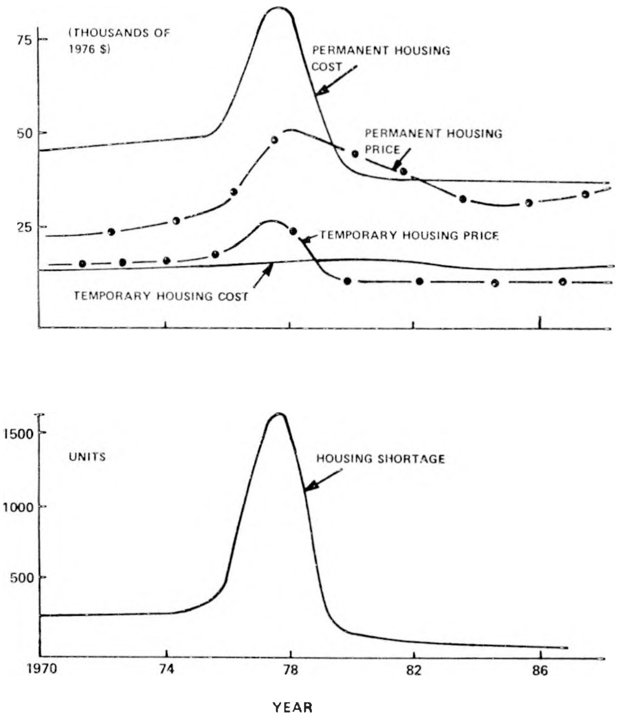

Fig. 25.
Base case simulation results, principal output variables.

temporary housing prices and the price/cost ratio used by the developer in making his investment decision. Also, they show the housing shortage as measured by the number of families that cannot qualify for permanent or temporary housing and are unable to live in one of the 400 units of substandard housing. According to the lower plot in Fig. 25, the town experiences a housing shortage of around 1800 units at the peak of the construction boom.

A. Financial Organization

One financial organization proposed to make housing more affordable in boom towns is the "loans to lenders" program of the Wyoming Community Development Authority. If successfully implemented,* the program would make mortgage money available to local banks and savings and loan associations at rates lower than those offered by the federal home loan bank. It has been calculated, for example, that a reduction in mortgage rates by 2.5% would reduce the qualifying income by about 20% (Lindauer 1975, p. 89).

To test the effect of such a program, we reran the boom town housing model under the assumption that mortgage rates were reduced by 2-1/2% from their base values in 1976. Implicit in this change is the assumption that local banks will be able to satisfy the demand for low interest mortgage money without having to change the interest rate during the remainder of the simulation. In addition to the financial assistance to home buyers, we also provide assistance to the home builder. Specifically, we have lowered the developer's interim financing rate shown in Figs. 4b and 6 by 2.5%.**

The new behavior of the four principal output variables is shown in Fig. 26. The major change from the base run results is that the market price for

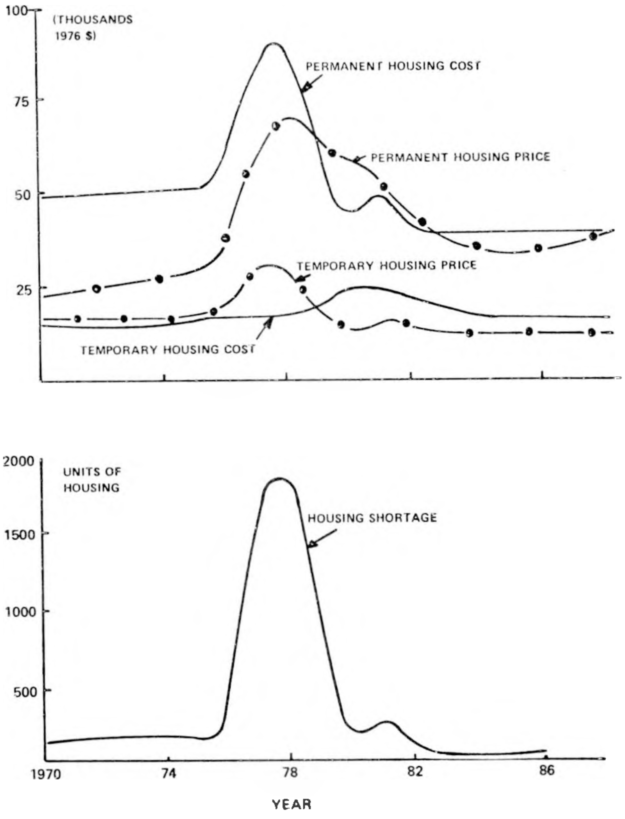

Fig. 26.
Policy result No. 1, reduced mortgage rate in 1976.

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*The Wyoming Community Development Authority was declared unconstitutional on February 13, 1978, by the Wyoming Supreme Court.

**An example of a program to provide low interest funds to housing investors is the Mitchell-Lama program used in New York City (Sternlieb 1976, p. 9).

permanent-type housing rises more quickly after 1976. By 1978, the price of permanent housing is about 20% higher than the peak value of the base case run. The fact that the 20% increase in market price is just sufficient to nullify the expected 20% reduction in qualifying income is no coincidence; it is a direct result of the failure of the supply loop to respond to higher housing prices. Notice, for example, that the cost of permanent housing is still much higher than the price despite the reduction in the developer's interim financing rate. With such an unfavorable price/cost ratio, developers do not begin construction of any new housing. Thus, the same stock of housing must now be allocated among thousands of families who are able to borrow about 20% more money from the local banks. The net result—prices rise by an additional 20% to clear the market.

Although the reduced mortgage rate does nothing to change the severity of the housing shortage, it does lead to benefits for some people in the town. Landlords reap greater profits during the boom, and the builders who initiate housing construction in the postboom period earn a higher return on their investment. Moreover, the speculative value for development land (not shown in Fig. 26) increases as well. By 1981 for example, the price of land with immediate potential for permanent development is about $44,500 per acre.

B. Relaxed Regulations

Figure 27 shows the behavior of the four principal output variables when modular-type permanent housing is permitted and used, and approval delays are reduced.

The use of modular housing and the relaxation of regulations are simulated by the following parameter changes in the model.

- The Labor Cost component for Permanent House (LCPHO) is reduced from $14,000 to $4,000. This $4,000 worth of labor is subject to inflation should the productivity of construction workers decline during the boom;
- the Material Cost component for a Permanent House (MCPHO) is increased from $21,000 to $26,000;

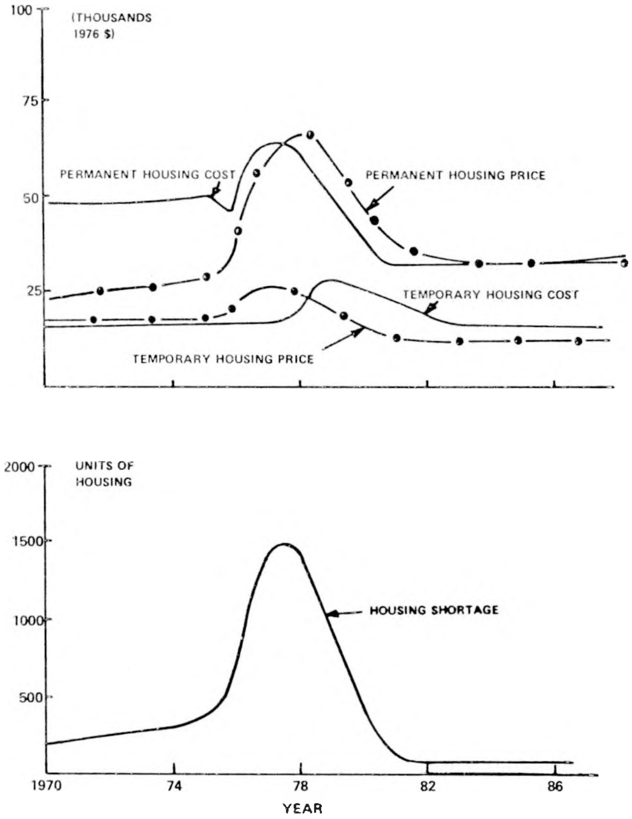

Fig. 27.
Policy result No. 2, relaxed regulations and modular housing in 1976.

- the Permanent Housing Approval Delay (PHPAD) shown in Fig. 4a is reduced from twelve months to six months;
- the Temporary Housing Approval Delay (THPCD) shown in Fig. 6 is reduced from nine months to three months;
- and the Permanent Housing Construction Delay (PHCD) shown in Fig. 4a is reduced from 0.75 year to 0.25 year.

Notice that we make no assumptions about the quality of workmanship in the modular housing. Neither do we make any assumptions about the preferences of families for modular or on-site housing. The factors that lead to a high use of modular housing in some communities* and minimal use in others are not of interest in this analysis. Our focus

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*Approximately 75% of all new single family dwellings in the Southeastern Utah area, for example, are factory built and trucked to the building site (Gore 1977, p. 31).

is on the extent of which two attributes of modular housing (less dependence on on-site labor and a shorter construction delay), can lead to less severe shortages of housing under adverse boom town conditions.

A comparison of Figs. 25 and 27 shows several changes resulting from the use of modular housing and the reduction in the housing permit delays. First, the peak shortage of housing units is reduced slightly from 1800 units to about 1500 units. Second, the cost of permanent housing is substantially reduced because modular housing requires much less on-site labor subject to rapid inflation during the boom. Nevertheless, the price/cost ratio is still unfavorable during the initial three years of the boom. It is not until 1978 that the developers perceive a favorable ratio, and approximately 800 houses are built in the "postboom" phase from 1978 to 1982. These houses are earmarked for the "safe" market of families with permanent-type jobs.

C. Sequence of Energy Facilities

Figure 28 shows the projection of the same four variables when the energy facility initiated in 1976 is followed by two identical facilities, initiated in 1980 and 1984. Here the first boom follows the same course as in the previous run.

The town enters the second and third boom with the prices of permanent and temporary housing at a much inflated level that makes the price/cost ratios more favorable from the developer's point of view. Despite the inflated prices, much of the market for permanent housing is viewed as "risky" by the permanent developer, and the housing shortages in the second and third booms are as large, if not larger, than the shortage created in the first boom.

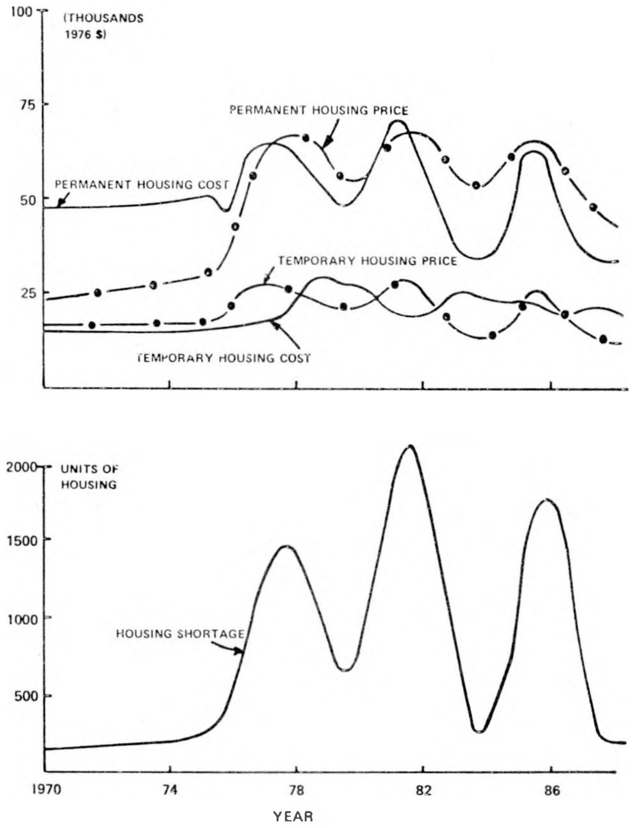

Fig. 28.
Policy result No. 3, sequence of energy facilities.

D. Orderly Land Development

This run includes policies that separate the two housing types spatially, so that they don't compete for the same land, and that provide for adequate supplies of easily serviced land for each housing type. The reserve of land with potential for permanent development (RESERVE) is set to 1,000 acres, which may be interpreted as a block of land zoned at the outset for permanent-type development, whereas services for mobile homes are extended to other land. The Easily Serviced Land (ESL) is set to 2,000 acres. In many cases, energy resources are located in areas with rough terrain, limiting the amount of land that can be serviced easily for development. Implementing the policy to guarantee an adequate stock of easily serviced land could involve preboom public acquisition of this land before speculation can effectively remove it from the market. In other cases, implementation might involve government or energy company subsidies to offset a part of the servicing cost when this would otherwise be excessively high. Senate Bill 977, for example, would transfer funds to the Farmers Home Administration to

> ...acquire land and develop and transfer acquired land to any State or to a political subdivision thereof, or to any qualified housing contractor if

> he determines that such transfer is an integral and necessary element of an economically feasible plan for the development of housing in the energy impacted region...after completion of the housing project, the recipient of the transferred land shall pay to the Administrator the fair-market value of the land prior to development...no part of the funds provided under this section may be used to pay the actual construction costs of housing.
>
> (Senate Bill 977, pp. 125-26)

Figure 29 shows the behavior of the principal variables for the "Orderly Land Development" run. The cost of building permanent houses is *not* a supply-constraining factor in this simulation because (1) lot costs remain low throughout the run, (2) labor costs remain low with modular housing that needs little local labor, and (3) developers qualify for lower cost interim financing. Notice that only the first six months of inflation in housing prices is sufficient to turn the price/cost ratio to a favorable value. Thus, developers are not confronted with the unfavorable economic prospects characteristic of all the previous runs. Nevertheless, the supply of housing is not significantly greater in Fig. 29 because the housing developer is assumed to avoid the "risky" market of the temporary, construction worker families.

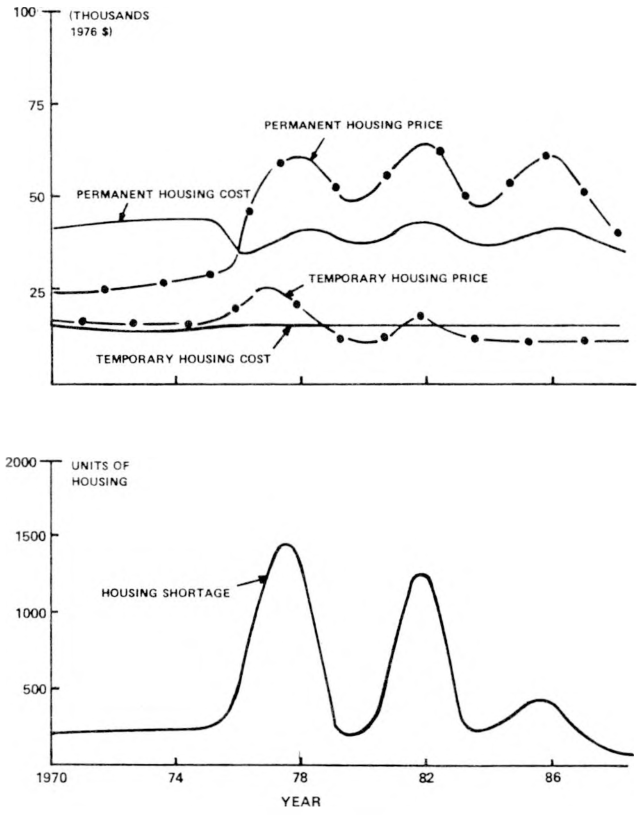

Fig. 29.
Policy result No. 4, orderly land development.

As compared with the previous run, the supply of mobile home lots in Fig. 29 is much improved after 1978 because the permanent housing doesn't displace mobile homes or occupy lots previously used for mobile homes. All such lots remain (many vacant) after each boom, and are available if needed. As a result, the peak housing shortages in the second and third booms are significantly smaller than the shortage in the first boom.

E. Risk Removal

As the previous sequence of simulation runs has indicated, eliminating the factors that inflate the costs of housing development is not sufficient to eliminate the shortage of housing units during the boom. Somehow, the risk of building for the temporary, uncertain market of the construction workers must be eliminated as well. One mechanism to remove the risk is to ensure that housing developers receive *dependable* information about the potential for subsequent industrial development in the area. If, for example, the housing developer knew in advance that the second and third booms shown in Fig. 29 were a "sure thing," he would begin to consider the presence of large numbers of construction worker families as a more permanent phenomenon.

The uncertain duration of the construction work force creates problems for all the sectors of the town. Thus, to test the effect of removing this uncertainty, we must consider each of the three sectors where large investment decisions are made.

1. *In the public sector*, the attitude of local officials toward risk is characterized by the extent to which they decide to invest in new public facilities for the peak population. The question of whether a town should provide public facilities for the peak population (if such facilities would not be used fully after the construction-related families leave town) is treated in considerable detail in a separate

LASL report. The separate report concludes that "local viewpoints could arrive at a consensus to provide the full complement of public facilities needed at the peak of the boom as long as specific boom town policies are implemented." (Ford 1977b, p. 28). On this basis, we have assumed in all the simulations shown in this report that public officials make no distinction between the temporary and permanent families as far as public facilities are concerned.

2. *In the retail sector*, the attitude of investors toward risk is characterized by the Fraction of Temporary Income Considered by the Retail Investor (FTCR) (Ford 1976a, p. 12). In the simulations shown previously, we assume that this fraction is set to zero to represent the behavior of a cautious, risk-adverse retail investor. In the simulation shown in Fig. 30, we assume that the uncertainty and risk have been removed partially; we reset the Fraction of Temporary Income Considered by the Retail investor (FTCR) to 0.5.

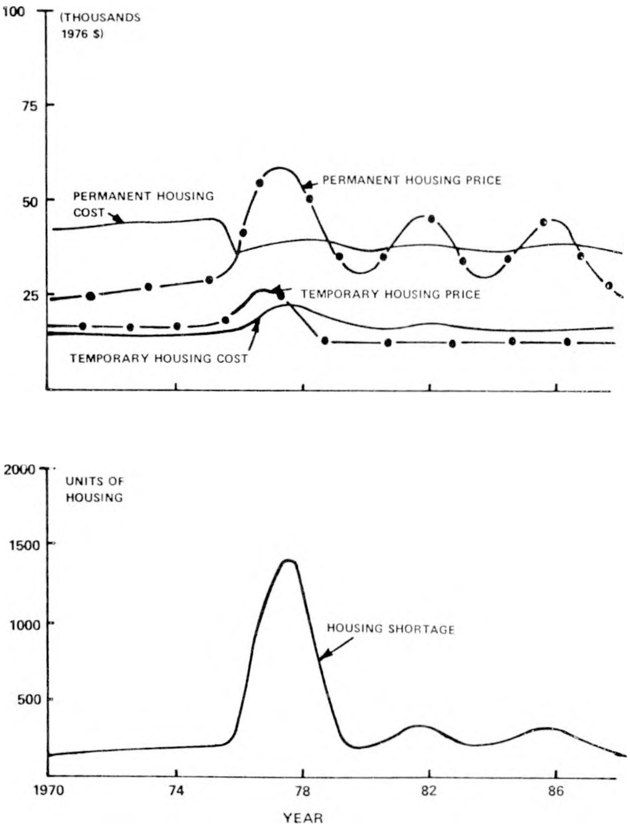

Fig. 30.
Policy result No. 5, risk removal.

3. *In the new housing sector*, the attitude of housing developers toward risk is characterized by the Fraction of Temporary Families Considered by the Developer (FTFCD) shown in Fig. 4a. In previous simulations, this fraction is set to zero to represent the behavior of a cautious, risk-adverse developer. In the simulation shown in Fig. 30, we reset this fraction to 0.5.

A comparison of Figs. 30 and 29 shows the effect of the risk removal. More permanent houses are not constructed during the first boom, and the market price of permanent housing drops more quickly after 1977. In fact, the price drops so low by 1980, that the price/cost ratio for permanent housing becomes unfavorable. As the second and third booms occur, the market price of permanent housing peaks at values well below the peak value of the first boom.

The housing shortage is practically nonexistent for the second and third booms, but still peaks at about 1400 units during the first boom. This shortage is due to the lack of predevelopment of housing before residents arrive, coupled with the delays for approval and construction. It is also due to the increased demand for housing that is caused by the influx of new workers to take jobs in the growing retail sector. Also, for the same reasons, an excessive number of mobile lots are developed during the first boom and vacancy rates for such lots remain very high thereafter.

F. Prebuilding Permanent Housing

The package of policies simulated in Fig. 30 does many things to eliminate the supply constraints that lead to a housing shortage during the boom:

- the provision of lower cost developers' financing reduces the overall cost of housing;
- the use of modular housing reduces the need for high cost, on-site labor;
- assistance with orderly land development reduces the speculative cost of land and the cost of bringing water and sewer services to the lots, and

- the provision of dependable information about subsequent industrial development removes part of the risk of building housing for the temporary families.

Moreover, the assistance given to local banks to make mortgage money available at lower interest rates leads to a more rapid increase in housing prices and an earlier improvement in the developer's price/cost ratio.

Despite all these improvements, however, a shortage of about 1400 units is shown to persist in Fig. 30. Since the base case results of Fig. 25 show an initial shortage of 1850 units, the package of policies has been only partly successful in eliminating the shortage during the first two years of the initial boom.

The reason for the persistent shortage is the assumed hesitancy of housing developers to build housing "before the bodies are in town." This hesitancy is characteristic of developers who have grown cautious from watching large-scale plans for industrial development be announced and then later postponed or abandoned.

If, on the other hand, the energy company were to provide a dependable signal about the date of initiation and completion of the power plant and a reliable estimate as to the size of the construction work force,* housing developers could go ahead with the planning and construction of new housing *before* the new families arrive in town. If dependable information is not available to housing developers, prebuilding would probably only take place through extraordinary intervention in the housing market by the energy company or by the state or federal governments.

To simulate the effect of the prebuilding of permanent housing, we initiate exogenously the construction of 1500 permanent houses in the year 1975. This group of houses is built before the arrival of new families and is built regardless of the risk and price/cost ratio of the permanent housing market. We have used the figure of 1500 prebuilt units with the intention of eliminating the shortage of 1400 units which occurred in the first boom of Fig. 30. Additional housing may also be constructed by ordinary developers if market conditions are favorable.

The effect of the 1500 prebuilt houses is evident from a comparison of Figs. 30 and 31. Notice, for example, that the shortage in the initial boom begins earlier but peaks at a substantially lower value in Fig. 31. The early increase in the housing shortage is caused by the influx of construction workers needed to install the 1500 modular houses. Because these houses are in place before the influx of large numbers of construction workers, the shortage of housing at the peak of the first boom is now around 800 units. The price of permanent housing is considerably lower in Fig. 31 due to the availability of the prebuilt housing. In fact, the price remains below the level of $50,000 for the first time in the many simulations shown in this report.

Although the provision of the 1500 prebuilt houses leads to lower prices and a substantial reduction in

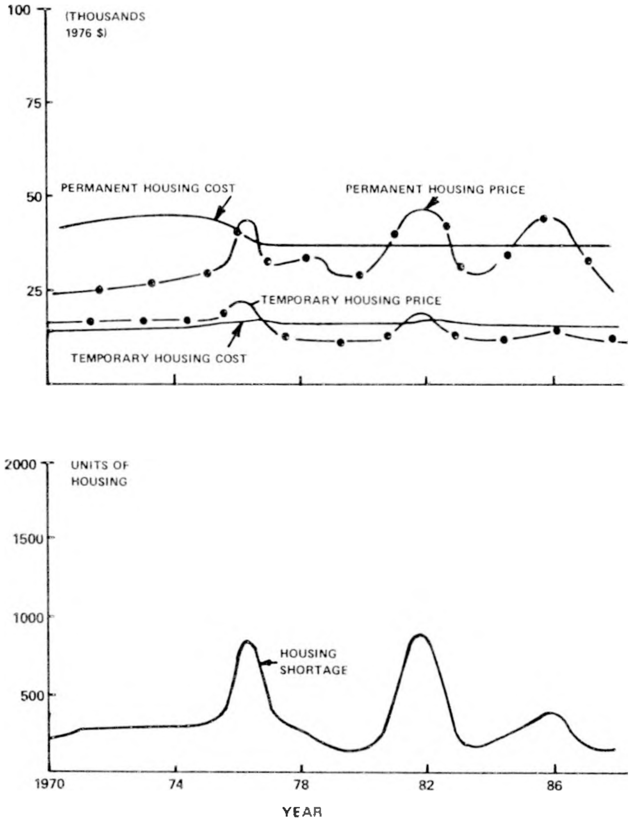

Fig. 31.
Policy result No. 6, prebuilding of permanent housing.

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*An example of such a signal from the energy company is the provision by Missouri Basin Electric Co-operative to the town of Wheatland, Wyoming, which limits the number of construction workers on the Laramie River plant to within a certain margin of the announced employment forecasts (Ellis 1976).

the peak housing shortage (from 1400 units to 800 units), this policy did not totally eliminate the housing shortage as intended. Two factors are responsible for this somewhat disappointing result:

1. The arrival of housing construction workers to install the 1500 prebuilt houses contributes to the housing shortage during the short interval before the houses are ready for occupancy.
2. The intervention in the permanent housing market by the prebuilder tends to reduce the activity of the "ordinary" developers who are competing for the same market. The ordinary developers were responsible for around 1260 permanent housing starts in 1977-78 in Fig. 30; they generated *no* housing starts in Fig. 31.

Another disappointing aspect of the simulation results shown in Fig. 31 is that the intervention in the housing market by the prebuilder causes the shortage during the second boom to become more severe. Notice, for example, that Fig. 30 exhibits a housing shortage of around 300 units in 1982, whereas Fig. 31 shows a shortage of around 900 units in the same year. The worsening of the shortage in the second boom is caused by the reaction of the temporary housing developer to the intervention of the prebuilder. In Fig. 30 (with no intervention) the number of temporary houses grows to about 1550 by the year 1979 and stays at that level for the duration of the simulation. Thus, these mobile homes are in position for the second and third surges in population that accompany the construction of the second and third power plants. In Fig. 31, on the other hand, the intervention of the prebuilder cuts into the market of the temporary housing developer, and the number of temporary houses is only around 830 in 1981 just before the peak of the second boom. Although temporary housing developers react to the second boom by adding another 484 units, the additional units do not arrive in time to prevent the overall shortage shown in Fig. 31.

Since a housing shortage of 800 units still exists in Fig. 31, one might be tempted to try a larger prebuilding program. To test the effect of an expanded prebuilding policy, we have repeated the simulation shown in Fig. 31 with the number of the prebuilt houses increased from 1500 to 2300. The results of the new simulation (not shown here) indicate that an expanded prebuilding program would actually increase the size of the housing shortage during the year 1976. The increased shortage is caused by the larger influx of housing construction workers needed to install the 2300 houses.

Clearly, larger prebuilding programs will not eliminate the housing shortage unless the developer can find some way to provide separate housing for his own employees. To test the effect of a prebuilding program in which the developer provides off-site housing for the housing construction workers, we have repeated the simulation shown in Fig. 31 with the added assumption that the number of construction workers in town per houses under construction (CWPHO) is reduced to zero. The results of this new simulation are shown in Fig. 32.

Figure 32 shows that a prebuilding program in which the developer finds off-site housing for his employees,* would eliminate the housing shortage

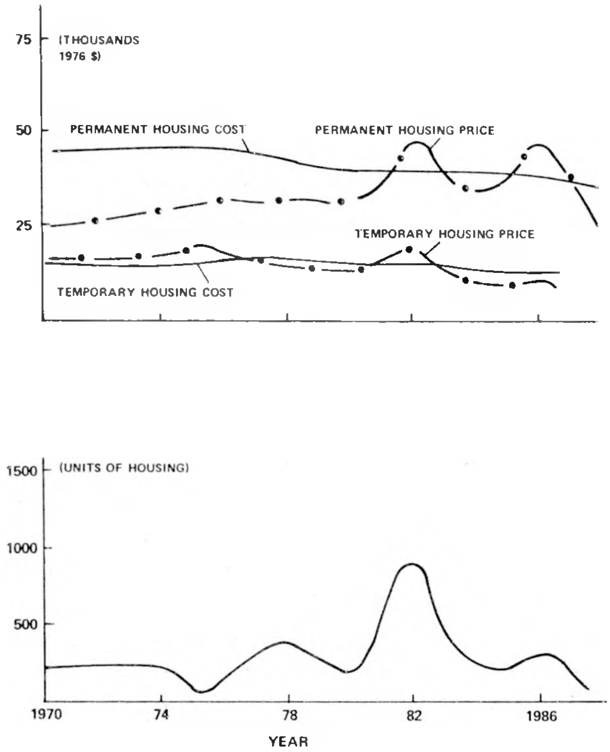

Fig. 32.
Policy result No. 7, prebuilding with off-site housing for housing construction workers.

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*It might be reasonable to expect the energy developer to provide off-site housing for the power plant construction workers if one expects the housing developer to find off-site housing for the housing construction workers.

associated with the initial boom. As in the previous simulation, however, the intervention of the prebuilder would cut into the temporary developer's market and leave the housing sector without sufficient housing for the second boom. Although we will not show a policy test here, we suggest that the shortage in the second boom could be eliminated in the same fashion as in the first boom—by a prebuilding program with off-site housing for the prebuilder's construction workers.

Figure 32 concludes the illustrative set of housing policy tests to be reported here. Before turning to the conclusions to be drawn from this analysis, we pause to make some observations about the interrelatedness of the housing and public sectors of a generic boom town.

VII. HOUSING SECTOR PROBLEMS VS PUBLIC SECTOR PROBLEMS

The output variables plotted in Figs. 26-32 show only the immediate effect of the various housing policies on variables in the new housing sector. This focus on housing problems has been maintained until we could demonstrate one package of policies with the potential to eliminate the housing shortages and rapid price inflation characteristic of the base case run. Now, however, we turn to investigate the indirect effect that this package of policies has had on other sectors of the model. Specifically, we show the effect of the final package of housing policies (simulated in Fig. 32) on the town's population and adequacy of public facilities in Fig. 33.

A comparison of the population curve in Fig. 33 with the base case population in Fig. 23 shows the indirect effect of the package of housing policies on the town's population. The most obvious difference between the two population curves is the second and third surges in population in Fig. 33 that are caused by the construction of the second and third power plants. Another noticeable difference is the general upward trend in the population curve in Fig. 33 that results from the increased investment in retail facilities by the "bolder" retail investors. Also evident from Fig. 33 is the more rapid growth in population during the initial boom. Notice, for example, that the population peaks at around 12,500 in 1978 in Fig. 33, whereas a peak population of slightly over 10,000 occurred in Fig. 23. The more rapid initial increase is due not just to the increased number of retail jobs created in Fig. 33 but also to the reaction of the construction workers who enter a town that enjoys a substantially improved housing supply in Fig. 33. With 1500 houses prebuilt and ready for occupancy, and with permanent housing selling for under $35,000, the workers arriving in 1976 are much more inclined to bring along their families than the workers simulated in Fig. 23 (where a severe housing shortage exists and permanent houses sell for around $50,000).

Because of the more rapid population growth shown in Fig. 33, the public sector is less able to provide the nominal per capita stocks of public facilities.* A comparison of the Public Facilities Shortage in Fig. 33 (with housing policies) with the shortage shown in Fig. 24 (without housing policies) shows that the public sector shortage has become more severe during the initial boom. Thus, the reduction of the severity of the housing sector problem has exasperated the problems faced by public sector officials.

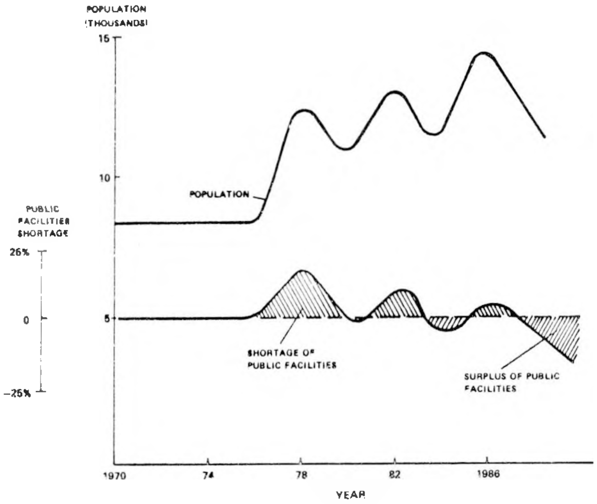


Fig. 33.
Behavior of population and public facilities shortages under Policy No. 7 conditions.

---

*Housing policies that tend to keep the price of permanent housing from skyrocketing also have some adverse effect on the public sector since the assessed valuation of residential property is reduced in those simulations with lower market prices for permanent housing.

Public sector shortages of the type shown in Fig. 33 have been analyzed in detail in previous reports on the use of the BOOM1 model (Ford 1976a and Ford 1977b). These analyses have shown that the most important policy required if public officials are to avoid shortages of public facilities is a dependable signal from the energy company about the size and timing of the construction work force (Ford 1977b, p. 28). Such a signal would allow local officials to invest in expensive new public facilities before the arrival of the construction worker families. Since such a signal is assumed to have been provided to housing developers to permit the prebuilding of 1500 permanent houses, it is reasonable to assume that prebuilding in the public sector would also occur. To simulate the effect of prebuilding in the public sector, we assume that the public sector of BOOMH makes the investment decisions somewhat differently during the time interval from 1974 to 1978. Specifically, we assume that the public sector invests in sufficient public facilities to serve an expected peak population of 12,500. At the conclusion of this four-year interval, the public sector reverts to the practice of "waiting until the bodies are in town" before investing in further public projects. Just in case the town encounters any limitations on its ability to issue new debt during this four-year planning interval, we have also made a change in the municipal financing sector of BOOMH. By setting the Fraction of New Debt Obtained (FNDO) to one (regardless of the ratio of the town's outstanding debt to its bonding capacity), we simulate the effect of the town's receiving a loan guarantee. The behavior of the model with these two additional changes is shown in Fig. 34.

The result of the prebuilding of public facilities is evident from the large surplus of public facilities created during the interval from 1974 to 1978. This investment by local officials before the first boom allows the town to experience the three booms with only modest shortages during the peak years of 1982 to 1986.

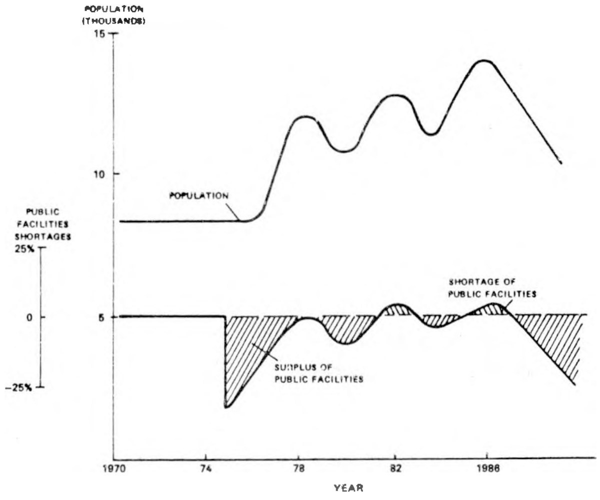


Fig. 34.
Removal of the public sector shortages through prebuilding of public facilities.

One obvious consequence of this commitment to providing the full complement of public facilities needed at the peak of the booms is that the town must deal with surplus public facilities after 1986. This dilemma is characteristic of towns that host the construction and operation of facilities whose construction work force is several times larger than the operation work force. A careful analysis of the tradeoffs between shortages and surplus and public facilities under these difficult conditions is provided elsewhere (Ford 1977b).

The comparison of the public sector shortages shown in Figs. 33 and 24 has revealed just one of the ways in which the housing and public sectors of a generic boom town are intimately interrelated. To the extent that the interrelatedness of the two sectors is represented in the BOOMH model, several public sector policies may be tested for their indirect effects on the housing sector (and for the effects on the public sector). Further policy testing, for example, could focus on the following issues.

1. To what extent would a higher system development charge on housing developers help the municipal financing sector meet its rapidly increasing expenses during the boom? To what extent might such an added charge inhibit the development of permanent housing and reduce the amount of assessed valuation from permanent housing?
2. To what extent would a reduction in the residential property assessment delay (see Fig. 3) allow the municipal financing sector to capture an increased valuation from the skyrocketing price of permanent housing? To what extent would higher property tax burdens on local families simply allow the permanent

housing market to clear at a lower cost, thus nullifying the potential increase in assessed valuation.

3. To what extent would partial exemptions from local property taxes encourage the construction of more permanent housing. Would the increased housing construction, when taxed at the reduced rate, make up for the loss of revenues from the tax exemption? This sort of analysis has been performed in an urban setting and is described elsewhere (Sternlieb 1976).

VIII. SUMMARY AND CONCLUSIONS

A. Summary

This report documents in detail the structure, parameters, and behavioral tendencies of a boom town housing simulation model. The model, entitled BOOMH, is the only computer model that represents explicitly the interplay between the supply and demand for housing under boom town conditions. Because of the detailed representation of the impediments to a responsive housing supply, the model can be used to test a variety of housing policies. Specific supply-oriented policies that have been tested with the model include

(1) financial assistance to housing developers,
(2) cutting red tape to reduce the delays and costs of obtaining approval of developments,
(3) use of modular housing to avoid inflated on-site labor costs,
(4) land assembly to prevent speculative price increases from making land costs prohibitive to the developer,
(5) land assembly to help local officials maintain a low cost of housing-related public facilities, and
(6) prebuilding of permanent housing by either the energy company or by the state or federal governments.

The principal demand-oriented policy tested with the model is the reduced mortgage rate policy proposed in Wyoming under the "Loans to Lenders" program.

The model builds upon an earlier boom town simulation model, entitled BOOM1, which was constructed at LASL in the summer of 1976. BOOMH is designed to be broadly representative of boom town conditions in towns scattered across the states and provinces of North America, that is, a "generic" boom town model. As such, it is to be used to test a variety of policies under consideration by state, provincial, and national leaders who must design "generic" boom town policies (policies that have the potential to be effective across a wide range of boom towns). Before turning to the specific conclusions to be drawn from the policy tests performed with the model, we offer several comments on the difficult question of model validity.

B. Validity of the BOOMH Model

The question most frequently asked about models of social systems is "Has the validity of this model been proved?" It is quite unsettling to learn that the answer to this question is always a "no." An objective, scientific proof of model validity is simply not possible. This view of model validity is aptly described by Greenberger as follows.

> There is no uniform procedure for validation. No model has ever been or ever will be thoroughly validated. Since, by design, models are all simplifications of the reference system, they are never entirely valid in the sense of being fully supported by objective truth. "Useful," "illuminating," "convincing," or "inspiring confidence" are more apt descriptors applying to models than "valid." One can bolster one's confidence in a model by having it reproduce past behavior of the reference system, exploring its response to perturbations, critically examining the premises and theories on which it is based, and finally, putting it to use. In fact, such tests are aimed more at invalidating than validating the model. They can only reveal the presence (not the total absence) of errors. However convincing a model, there is always a chance that its next test or use will turn up a serious shortcoming.
>
> (Greenberger 1976, p. 70)

We share Greenberger's preference for an emphasis on specific tests that can be performed to "inspire confidence in a model." Generally speaking, at least four tests can be used to help a decision maker decide whether or not to place confidence in a model.

1. The model should be implemented on an independent computer system and the published results of the model developers should be reproduced by other researchers. This process is sometimes called model "verification" (House 1977, p. 66).
2. The model should be exercised to determine whether it reproduces the general historical trends of interest.
3. The individual parameters of the model should be examined for plausibility.
4. The model should be rerun with various changes in parameters. Such "sensitivity testing" can reveal if the model's behavior remains reasonable throughout the range of plausibility of the input parameters.

All of these tests should be performed with the BOOMH model before a decision maker can accurately gauge the degree of confidence to have in the model. Application of these four tests to the BOOMH model leads us to the following observations.

1. *Model Verification*. As of this writing, the BOOMH model has only been implemented on the computer systems at the University of Alberta and at LASL. It has not been verified by someone other than those responsible for its development. Indeed, the principal purpose of this report is to provide sufficient documentation that other analysts can implement and verify the BOOMH model on their own computer systems.
2. *Historical Behavior*. The simulations shown in Figs. 15-25 indicate that the model is capable of reproducing the broad range of housing problems characteristic of boom towns in North America. The behavior reported here not only reflects the problems of dealing with rapid variations in population, but also the housing problems that characterize stagnant, rural towns that are not host to major industrial projects.
3. *Parameter Plausibility*. The value of each parameter in the model is shown in Table IV (table of constants) or in Figs. 12-14 (graphs of nonlinear relationships). Each potential user should examine these estimates to make sure that they are reasonable. From our discussions with experts in the area of boom towns and housing development, and from our reading of the many studies in this area, the parameter estimates reported in Table IV and Figs. 12-14 are both plausible and reasonable.
4. *Sensitivity Testing*. The behavior of the BOOMH model has been examined under a variety of changes in parameter values. These tests have revealed no anomalous behavior that would cause one to lose confidence in the model.

C. Policy Conclusions

The second most frequently asked question about models of social systems is "What can this model tell me that I didn't already know?" We answer this question for the BOOMH model by noting the following conclusions drawn from the policy simulations performed with the model.

Severity of the Problem

(1) Isolated, small towns may experience shortages of housing and increasing prices for permanent housing even if energy development were not to occur (Fig. 15).

(2) Isolated, small towns may enter the boom period with the economics of the permanent housing market predisposed against development (Fig. 16, 1970-1974).

(3) Development of permanent housing during the rapid growth phase of an energy boom is unlikely due to numerous factors that drive up the cost of housing (Fig. 16, 1974-1978).

(4) The crest of the boom from a single energy project will probably already be over before the economics of the permanent housing market turn favorable to the developer (Fig. 16, 1980-1982).

(5) The influx of thousands of new families combined with the lack of growth in permanent housing stock can cause the price of permanent housing to double in less than three years (Fig. 16, 1976-1978).

(6) Skyrocketing housing prices combined with increasing property taxes can make housing so expensive that only the more affluent third of

the families could afford to occupy permanent housing at the peak of a boom (Fig. 19, 1978).

(7) Development of temporary housing during the rapid growth phase of an energy boom may come too late to avoid substantial shortages of housing (Fig. 16, 1974-1978).

(8) If sufficient land is not set aside to accommodate growth, the depletion of land with potential for conversion to permanent use could cause the speculative value of "raw" outer land to increase by two orders of magnitude (Fig. 22, 1980-1982).

(9) The so-called "accelerator effect" (housing construction jobs adding significantly to the total number of construction jobs) will be unimportant in a town characterized by a risky, uneconomic housing market (Fig. 23).

Effectiveness of Mitigation Policies

(1) The implementation of a loans-to-lenders program to provide reduced rates for home mortgages could simply drive the price of permanent housing up even faster if the program were not coupled with a package of supply-oriented policies (Fig. 26).

(2) It is possible to eliminate the boom-induced inflation in housing costs through the implementation of a variety of supply-oriented policies such as financial aid to developers, use of modular housing, relaxed regulations, and land assembly (Fig. 29).

(3) The riskiness of the permanent housing market could block development of permanent housing in spite of successful efforts to eliminate the boom-induced inflation in housing costs (Fig. 29).

(4) Delays in receiving approval and in actual construction, when coupled with the rapid population growth of the boom, could cause substantial shortages of housing despite the removal of risk and the elimination of boom-induced cost inflation (Fig. 30).

(5) Intervention in the permanent housing market by either the energy company or by the state or federal governments may be the only way to eliminate the housing shortage characteristic of the construction phase (Fig. 32).

(6) The improvement of conditions in the housing sector may lead to a deterioration of conditions in the public sector due to the many interconnections in a typical boom town (Fig. 32).

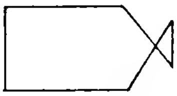
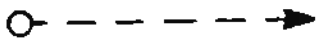
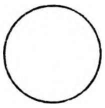
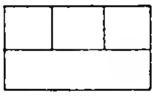
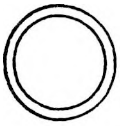
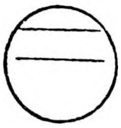
APPENDIX A

DYNAMO FLOW DIAGRAM OF THE BOOMH MODEL

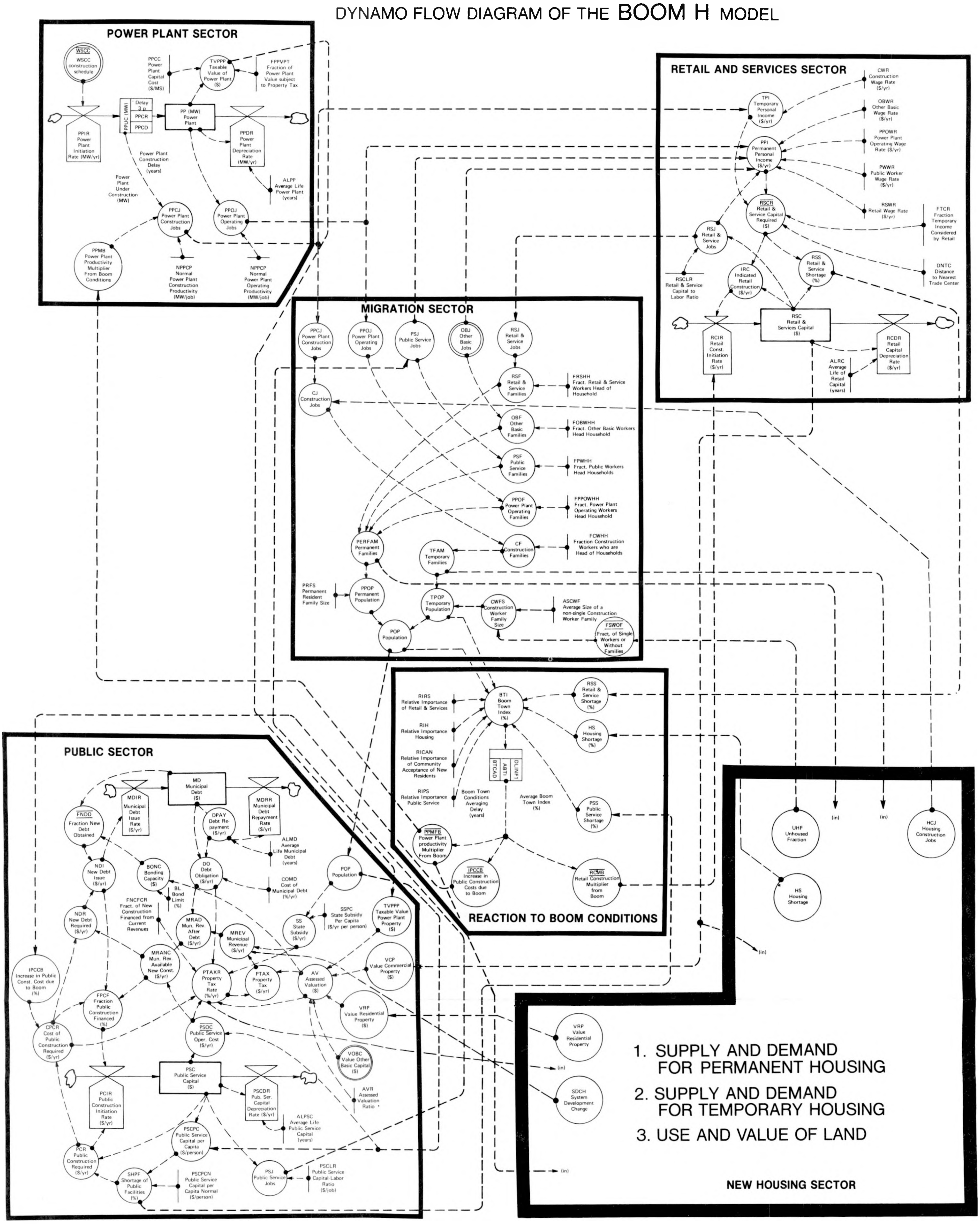
This appendix explains the symbols used in DYNAMO flow diagrams. These diagrams are used in Figs. 3, 4, 6, 7, and 8 to portray each variable and each interconnection between variables in the new housing sector. A diagram of the overall model which highlights the position of the new housing sector is given in the foldout at the end of this appendix.

These diagrams provide a second layer of description that is richer in detail than the "word and arrow" diagrams shown in Figs. 5, 9, 10, and 11. The final, most detailed description of the model is the actual listing of the DYNAMO computer code presented in Appendix B.

EXPLANATION OF SYMBOLS USED IN DYNAMO FLOW DIAGRAMS

	Level	- a result of accumulation or depletion; a stock. A level can vary only through the action of flows into it and out. In the public sector of BOOM1, for example, the level of Municipal Debt (MD) can vary only as new debt is issued (a flow in) or existing debt is retired (a flow out).
	Cloud	- a source or a sink; a level that is not of interest and is therefore outside the modeled system. In BOOM1, for example, power plant capacity enters the system by initiation and leaves by depreciation.
	Real Flow	- a flow of some quantity that is conserved (i.e., is neither created nor destroyed within the system). An example of a real flow in BOOM1 is the flow of capacity in the power-plant sector.
	Rate	- the magnitude of a real flow into or out from a level.
	Information Flow	- a flow of information, which is not necessarily conserved. An information flow indicates one variable's value being used to calculate another's, elsewhere in the model. In the power plant sector of BOOM1, for example, an information flow indicates that the amount of Power Plant capacity in operation (PP) is used to calculate the Power Plant Depreciation Rate (PPDR).
	Auxiliary	- an extra variable, included in the model to aid understanding. Auxiliaries are almost always used to calculate other auxiliaries and, ultimately, rates. In the housing sector of BOOM1, information flows show that the number of Houses already built (H), a level, is used to calculate the Indicated pace at which Housing Construction should proceed (IHC), an auxiliary, which in turn is used to calculate the Housing Initiation Rate (HIR).
	Constant	- a model element or an exogenous input that does not vary over the time horizon of the model.
	Delay	- a "macro" (similar to a subroutine in Fortran), a standardized submodel that simulates a delay in a real or an information flow; one or more tandem exponential lags. An example of a real delay in BOOM1 is the Power Plant Construction Delay (PPCD) in the power plant sector. An example of an information delay is the Boom Town Conditions Averaging Delay (BTCAD) in the reaction to boom conditions sector. Names inserted in the boxes in a delay symbol designate the particular type of delay, the name of the output quantity, the delay time, and sometimes, in the case of a real flow delay, the amount in transit.
	Exogenous Variable	- an exogenous input whose value may vary over time. An example in BOOM1 is the number of Other Basic Jobs (OBJ) in the migration sector.
	Nonlinear Functional Value	- an auxiliary whose value is that of a nonlinear function of a single input variable. In the public sector of BOOM1, for example, the Fraction of New Debt Obtained (FNDO) depends nonlinearly on the ratio of Municipal Debt outstanding (MD) to the Bonding Capacity (BONC).

DYNAMO FLOW DIAGRAM OF THE BOOM H MODEL



APPENDIX B

LISTING OF THE BOOMH MODEL

Printed below is the list of equations for the BOOMH model. BOOMH is programmed in the DYNAMO computer language and requires roughly 50 ARUs to compile and execute on the National CSS computer system. At current rates, 50 ARUs cost around $10. The high cost per run is caused by the small step size (DT = 0.01), which leads to 2000 iterations to complete one 20-year simulation. The small step size is necessitated by the rapid adjustment of the temporary housing demand loop (similar to the demand loop shown in Fig. 5). For users with a more limited computer budget, this loop could be replaced with a set of simultaneous algebraic equations that would allow a larger step size and a substantial reduction in the cost of $10 per run.

Printed at the end of the listing are the rerun changes needed to reproduce each of the simulation runs presented in the technical documentation.

```
*           BOOMH, MARCH 1978
NOTE
NOTE          THIS IS THE VERSION OF THE BOOM TOWN HOUSING MODEL
NOTE          USED IN THE TECHNICAL DOCUMENTATION ENTITLED:
NOTE          A SIMULATION MODEL FOR BOOM TOWN HOUSING.
NOTE
NOTE          THIS LISTING APPEARS IN APPENDIX B OF THE TECH-
NOTE          NICAL DOCUMENTATION.
NOTE
NOTE          A GUIDE TO THE LISTING IS PRESENTED IN APPENDIX C.
NOTE
NOTE          THE FIRST PORTION OF THE LISTING IS VERY SIMILAR
NOTE          TO THE LISTING OF THE ORIGINAL BOOM1 MODEL SHOWN
NOTE          ON PAGES 41-45 OF THE USER'S GUIDE TO THE BOOM1
NOTE          MODEL.  SOME DIFFERENCES APPEAR IN THE EQUATIONS
NOTE          FOR TWO REASONS:
NOTE
NOTE          (1) THE BOOM1 MODEL LISTED IN THE USER'S GUIDE IS
NOTE              PROGRAMMED IN GASP IV AND NOT IN DYNAMO; AND
NOTE
NOTE          (2) SOME CHANGES APPEAR IN THE NON-HOUSING SECTORS
NOTE              OF BOOMH AS DESRIBED IN SECTION IIE OF THE
NOTE              TECHNICAL DOCUMENTATION.  EQUATIONS WITH SUCH
NOTE              CHANGES ARE NOTED BY THREE ASTERISKS (***) TO
NOTE              THE RIGHT OF THE EQUATION.
```

```
NOTE
T       WSCCT=0/0/0/0/0/0/0/0/0/0/0/0    ***     NO POWER PLANT CONSTRUCTED
T       PPMFBT=1./.9/.7/.5/.4/.4    ***
T       RCMBT=1/.9/.6/.5/.5/.5    ***    RETAIL CONST. MULT. FROM BOOM
T       IPCTAB=0./.05/.15/.4/.5/.6      INCREASE IN PUBLIC CONS. COSTS TABLE
T       FSWOFT=.2/.6/1    ***        FRACTION OF SINGLE WORKERS W/O FAM.
T       FNDOT=1./.95/.5/.2/0.           FRACTION OF NEW DEBT OBTAINED TABLE
NOTE
NOTE     CONSTANTS IN POWER PLANT SECTOR
NOTE
C       PPCD=3.             POWER PLANT CONSTRUCTION DELAY (1/2 TOTAL INTERVAL)
C       NPPCP=1.            NORMAL POWER PLANT CONSTR. PRODUCTIVITY
C       PPCC=700.           POWER PLANT CAPITAL COST
C       NPPOP=10.
N       PPMFB=1.            INITIAL VALUE OF POWER PLANT MULT. OF BOOM
C       PPLANI=0.           POWER PLANT (ON LINE) INITIAL
N       PP=PPLANI           INITIAL VALUE - POWER PLANT ON LINE
N       SS1=0.
N       SS2=0.
N       SS3=0.
C       FPPVST=.15          FRACTION OF POWER PLANT PROPERTY SUBJECT TO TAX
NOTE
NOTE      CONSTANTS IN RETAIL AND SERVICE SECTOR
NOTE
N       RCMB=1    ***
C       ALRC=25.            AVERAGE LIFE OF RETAIL AND SERVICE CAPITAL
C       RSCIN=13000000.             RETAIL AND SERVICE CAP., INTIT.
N       RSC=RSCIN           INITIAL VALUE - RETAIL AND SERVICE CAP.
C       RSCLR=6000.        RETAIL AND SERVICE CAPITAL LABOR RATIO
C       RSCVR=.44           RETAIL AND SERVICE CAP. TO RETAIL VOL. RATIO
C       FRPL=.75            FRACTION OF RE TAIL PURCHASES MADE LOCALLY
C       FIR=.44             FRACT. OF INCOME TO RETAIL
C       FTCR=0.             FRACT. OF TEMPOR. BUSINESS BY RETAILERS
C       CWR=16000.          CONST. WORKER WAGE RATE
C       OBWR=12000.         OTHER BASIC WORKER WAGE RATE
C       PPOWR=12000.     POWER PLANT OPER. WORKER WAGE RATE
C       PWWR=9000.          PUBLIC WORKER WAGE RATE
C       RSWR=7000.          RETAIL AND SERVICE WORKER WAGE RATE
NOTE
NOTE      CONSTANTS IN PUBLIC CONSTRUCTION
NOTE
N       IPCCB=0.
C       PSCI=10200000    ***
N       PSC=PSCI
N       CPCR=500000.
C       ALPSC=50.
C       PSCLR=42000    ***
C       FSCPCN=1200    ***
```

```
NOTE
NOTE     CONSTANTS IN MUNICIPAL FINANCING SECTOR
NOTE
N       FNDO=1.
C       SSPC=200.
C       FNCFCR=.4
C       MDI=1300000.    ***
N       MD=MDI
N       AV=26000000.    ***
N       BONC=2600000.    ***
C       ALMD=20.
C       COMD=.07
C       AVR=.33
C       BL=.1
C       POCPC=377.
N       PSOC=3000000.
N       POCSP=3000000.
C       PSOCR=.18
NOTE
NOTE     CONSTANTS IN THE MIGRATION SECTOR
NOTE
C       FCWHH=.75    ***
N       POP=10000.
C       FPOWHH=.85
C       FPWHH=.85
C       FRSHH=.5
C       FOBWHH=.85
C       PRFS=3.25
C       ASCWF=3.25
C       RIH=.2
C       RIPS=.2
C       RIRS=.2
C       RICANR=.4
N       PERFAM=2600.
C       BTCAD=.5
N       ABTI=0.0
NOTE
NOTE     CONSTANTS IN OTHER BASIC SECTOR
NOTE
C       OBJ=1500
NOTE
NOTE     AUXILIARIES IN POWER PLANT SECTOR
NOTE
A       WSCC.K=TABHL(WSCCT,TIME.K,1975.1986,1.)
A       TVPPP.K=PP.K*PPCC*FPPVST*1000.
A       PPUC.K=SS1.K+SS2.K+SS3.K
A       PPCJ.K=PPUC.K*1.23/(NPPCP*PPMFB.K)
A       PPMFB.K=TABHL(PPMFBT,ABTI.K,0.,.5,.1)
A       PPOJ.K=PP.K/NPPOP
```

```
NOTE
NOTE     AUXILIARIES IN RETAIL SERVICES SECTOR
NOTE
A       RCMB.K=TABHL(RCMBT,ABTI.K,0,.5,.1)    ***
A       IRC.K=MAX(0.,RSCI.K-PSC.K+RSC.K/ALRC)
A       RSCR.K=RSCVR*(DRPBS.K+FRPL*FIR*(TPI.K+PPI.K))
A       RSS.K=(RSCR.K-RSC.K)/RSC.K
A       RSJ.K=RSC.K/RSCLR
A       RSCI.K=LRPP.K*RSCVR
A       LRPP.K=RPP.K*FRPL+DRPBS.K
A       RPP.K=PICP.K*FIR
A       PICP.K=TPI.K*FTCR+PPI.K
A       VCP.K=RSC.K
A       TPI.K=CJ.K*CWR
A       PPI.K=OBJ*OBWR+PPOJ.K*PPOWR+PSJ.K*PWWR+RSJ.K*RSWR
NOTE
NOTE     AUXILIARIES IN PUBLIC CONSTRUCTION
NOTE
A       PSJ.K=PSC.K/PSCLR
A       CPCRH.K=PHIR.JK*PSCPH.K+THIR.JK*PSCPT.K    ***
NOTE
NOTE    SPECIAL EQUATIONS TO PERMIT PREBUILDING IN
NOTE    THE PUBLIC SECTOR DURING A PLANNING INTERVAL
NOTE
C       EPAPB=12500  EXP POP AT PEAK OF BOOM
A       EPFRPB.K=EPAPB*PSCPCN   EXP PUB FAC REQ AT PEAK
A       PCNHRR.K=CLIP(PCRR2.K,PCRR1.K,PDI.K,.5)
A       PDI.K=(CLIP(1,0,TIME.K,1974)-CLIP(1,0,TIME.K,1978))*PREPUS
C       PREPUS=0           PRE PLANNING IN PUBLIC SECTOR (0 OR 1)
A       PCRR1.K=MAX(0,SHPF.K*PSC.K+PSC.K/ALPSC)   NORMAL CONSTRUCTION
A       PCRR2.K=MAX(0,EPFRPB.K-PSC.K+PSC.K/ALPSC)  PRE BUILDING
NOTE
NOTE
A       PSCPC.K=PSC.K/POP.K
A       PSS.K=.5*(SHPF.K+SHPOE.K)
A       SHPF.K=(PSCPCN-PSCPC.K)/PSCPCN
A       SHPOE.K=(POCSP.K-PSOC.K)/POCSP.K
A       CPCR.K=PCNHRR.K*(1.+IPCCB.K)+CPCRH.K    ***
A       IPCCB.K=TABHL(IPCTAB,ABTI.K,0.,.5,.1)
NOTE
```

```
NOTE     AUXILIARIES IN MUNICIPAL FINANCING SECTOR
NOTE
A       DPAY.K=MD.K/ALMD
A       DO.K=DPAY.K+MD.K*COMD
A       SSUB.K=PCP.K*SSPC
A       AV.K=AVR*(TVPPP.K+VRP.K+VCP.K+VOBC.K)
A       PTAX.K=AV.K*PTAXR.K
A       MREV.K=PTAX.K+NTREV.K   ***
A       NTREV.K=SSUB.K+SDCH.K*PHIR.JK+SDCT.K*THIR.JK   ***
A       MRAD.K=MAX(0.,MREV.K-DO.K)
A       MRANC.K=MAX(0.,MRAD.K-PSOC.K)
A       TAXNEED.K=(DO.K+PSOC.K+CNPD.K*FNCFCR-GBNTREV.K)   ***
A       PTAXR.K=MAX(0.,TAXNEED.K/AV.K)   ***
A       CNPD.K=CPCR.K-CPD.K   ***
A       GBNTREV.K=NTREV.K-CPD.K   ***
A       BONC.K=BL*AV.K
A       NDR.K=MAX(0.,CPCR.K-MRANC.K)
A       FNDO.K=TABHL(FNDOT,MD.K/BONC.K,.6,1.4,.2)
A       NDI.K=NDR.K*FNDO.K
A       FPCF.K=MIN(MAX(1.,FIN.K)/MAX(1.,CNPD.K),1.)   ***
A       FIN.K=MRANC.K+NDI.K-CPD.K   ***
A       CPD.K=CLIP(PSCPH.K,0,0.SAD)*PHIR.JK+PSCPT.K*THIR.JK   ***
A       PSOC.K=(POCSP.K+POCSF.K)/2.
A       POCSP.K=POP.K*POCPC
A       POCSF.K=PSC.K*PSOCR
NOTE
NOTE      AUXILIARIES IN THE MIGRATION SECTOR
NOTE
A       HCJ.K=PHUC.K*CWPHUC.K   ***
A       CWPHUC.K=CWPHO/PPMFB.K   ***
A       CJ.K=PPCJ.K+HCJ.K
A       CF.K=CJ.K*FCWHH
A       PPOF.K=PPOJ.K*FPOWHH
A       PSF.K=PSJ.K*FPWHH
A       RSF.K=RSJ.K*FRSHH
A       OBF.K=OBJ*FCBWHH   ***
A       PERFAM.K=OBF.K+PPOF.K+PSF.K+RSF.K
A       PPOP.K=PERFAM.K*PRFS
A       FAMILY.K=PERFAM.K+CF.K
A       TPOP.K=CF.K*CWFS.K
A       POP.K=TPOP.K+PPOP.K
A       CWFS.K=FSWOF.K+(1.-FSWOF.K)*ASCWF
A       UHF.K=THR.K-QTHR.K   ***
A       PFSWOF.K=TABHL(FSWOFT,UHF.K/MAX(1,CF.K),0,1.,.5)   ***
A       FSWOF.K=SMOOTH(PFSWOF.K,HSDELAY)   ***
N       PFSWOF=0.2   ***
C       HSDELAY=0.1   ***
A       BTI.K=RIH*HS.K+RIPS*PSS.K+RIRS*RSS.K+RICANR*TPOP.K/POP.K   ***
NOTE
NOTE     AUXILIARIES IN OTHER BASIC SECTOR
NOTE
A       VOBC.K=12000000.
A       DRPBS.K=OBWR*OBJ
```

```
                       NOTE
LINE                   NOTE     RATES IN POWER PLANT SECTOR
                       NOTE
                       R      PPIR.KL=WSCC.K
 150                   R      R1.KL=SS1.K/(PPCD/3.)
                       R      R2.KL=SS2.K/(PPCD/3.)
                       R      PPCR.KL=SS3.K/(PPCD/3.)
                       NOTE
                       NOTE     RATES IN RETAIL AND SERVICES SECTOR
                       NOTE
                       R      RCDR.KL=RSC.K/ALRC
                       R      RSCU.KL=IRC.K*RCMB.K
                       NOTE
                       NOTE     RATES IN PUBLIC CONSTRUCTION
                       NOTE
                       R      PSCDR.KL=PSC.K/ALPSC
                       R      PCR.KL=FPCF.K*PCNHRR.K    ***
                       NOTE
                       NOTE     RATES IN MUNICIPAL FINANCING
                       NOTE
                       R      MDRR.KL=DPAY.K
                       R      MDIR.KL=NDI.K
                       NOTE
                       NOTE     RATE IN THE MIGRATION SECTOR
                       NOTE
                       R      R3.KL=(BTI.K-ABTI.K)/BTCAD
                       NOTE
                       NOTE     LEVELS IN POWER PLANT SECTOR
                       NOTE

                       L      PP.K=PP.J+DT*PPCR.JK
                       L      SS1.K=SS1.J+DT*(PPIR.JK-R1.JK)
 160                   L      SS2.K=SS2.J+DT*(R1.JK-R2.JK)
                       L      SS3.K=SS3.J+DT*(R2.JK-PPCR.JK)
                       NOTE
                       NOTE     LEVEL OF RETAIL AND SERVICE CAPITAL
                       NOTE
                       L      RSC.K=RSC.J+DT*(RSCU.JK-RCDR.JK)
                       NOTE
                       NOTE     LEVEL OF PUBLIC SERVICE CAPITAL
                       NOTE
                       L      PSC.K=PSC.J+DT*(PCR.JK-PSCDR.JK)
                       NOTE
                       NOTE     LEVEL OF MUNICIPAL DEBT
                       NOTE
                       L      MD.K=MD.J+DT*(MDIR.JK-MDRR.JK)
                       NOTE
                       NOTE     AVERAGE VALUE OF THE BTI
                       NOTE
 166                   L      ABTI.K=ABTI.J+DT*R3.JK
                       NOTE
```

```
LINE  NOTE            ************************
      NOTE               NEW HOUSING SECTOR
      NOTE            ************************
      NOTE
      NOTE       EQUATIONS FOR PERMANANT HOUSING SECTOR
      NOTE
167   A       QPHR.K=FAMILY.K*FFQPH.K
168   A       FFQPH.K=TABHL(FFQPHT,PHQI.K,0.,65000.,5000.)
169   A       PTAXPH.K=SMOOTH(MPPH.K,PHAD.K)*AVR*PTAXR.K+SADP.K
170   A       SADP.K=MDRSA.K*(COMD+1/ALMD)/MAX(1,NH.K)
171   L       NH.K=NH.J+DT*PHIR.JK
172   N       NH=0
173   L       MDRSA.K=MDRSA.J+DT*(SADINR.JK-SADOUTR.JK)
174   R       SADINR.KL=CLIP(PSCPH.K*PHIR.JK,0,SAD,0)
175   R       SADOUTR.KL=MDRSA.K/ALMD
176   N       MDRSA=0
177   A       PHQI.K=ISRATIO*(MPPH.K*(MRPH.K+ARPH)+PTAXPH.K)
178   A       CPLOT.K=(AUVHL.K/PHDENS)+HDAOC
179   A       CPH.K=CPLOT.K*(1.+DIFR.K*PHTD.K)+CPHOUSE.K*(1.+DIFR.K*PHCD.K/2)
180   A       CPHOUSE.K=(LCPH.K/PPMFB.K)+MCPH.K+LOTSERV.K
181   A       LOTSERV.K=CLIP(SDCH.K,0,0.PPHS.K)
182   A       LCPH.K=LCPHO-STEP(LCSMH,YMHP)
183   A       MCPH.K=MCPHO+STEP(MCIMH,YMHP)
184   A       PHVACR.K=(PH.K-QPHR.K)/PH.K
185   R       IPHIR.KL=MAX(0.,PERFAM.K*FPFCD+CF.K*FTFCD+(PHINIT/ALPH)-PHP.K)
186   A       PHP.K=PH.K+PHUC.K+PHAA.K
187   A       PHIMC.K=TABHL(PHIMCT,MPPH.K/CPH.K,0.9,1.3,.05)
188   A       HIMUA.K=CLIP(FPCF.K,1.,SAD,0)
189   R       PHIR.KL=IPHIR.JK*HIMUA.K*PHIMC.K+PREPHIR.K
190   A       PREPHIR.K=PREPH*(STEP(1,1975)-STEP(1,1976))
191   R       PHBCR.KL=DELAY3P(PHIR.JK,PHPAD.K,PHAA.K)
192   R       PHCR.KL=DELAY3P(PHBCR.JK,PHCD.K,PHUC.K)
193   L       PH.K=PH.J+DT*(PHCR.JK-PHDR.JK)
194   R       PHDR.KL=PHINIT/ALPH
195   R       MPINFLR.KL=(NPHVACR-PHVACR.K)*INFLMAX/NPHVACR
196   L       MPPH.K=MPPH.J+DT*MPPH.J*MPINFLR.JK
197   A       VRP.K=VPH.K+VTH.K
198   A       VPH.K=SMOOTH(PH.K*MPPH.K,PHAD.K)
199   A       VTH.K=SMOOTH(TH.K*VTL.K,THAD.K)+SMOOTH(TH.K*FTHVA*CTHOUSE,THAD.K)
200   A       MJPLOT.K=MAX(0.,MPPH.K-CPHOUSE.K)
201   A       SDCH.K=CLIP(PSCPH.K,0,0,SAD)+STEP(PRFS*PSCPCN,YSDCP)
202   A       PSCPH.K=CLIP(HCPHS.LCPHS,PDEVL.K,ESL)*(1+IPCCB.K)
203   A       AUVHL.K=CLIP(ALTUSEV,VTL.K*THDENS,0,PPHS.K)
204   A       PHTD.K=PHCD.K+PHPAD.K
205   A       PHCD.K=0.75-STEP(0.5,YMHP)
206   A       PHPAD.K=1.0-STEP(0.5.YRTP)
207   A       MRPH.K=0.09-STEP(0.025,YMRP)
208   A       DIFR.K=0.12-STEP(0.025,YDIFRP)
209   A       PHAD.K=3.0-STEP(2.0,YADP)
      NOTE
```

```
LINE   NOTE    EQUATIONS FOR TEMPORARY HOUSING SECTOR
       NOTE
210    A      THR.K=FAMILY.K-MIN(QPHR.K,PH.K)
211    A      QTHR.K=PQTHR.K-MIN(QPHR.K,PH.K)
213    A      PQTHR.K=FAMILY.K*FFQTH.K
213    A      FFQTH.K=TABHL(FFQTHT,THQI.K,0.,65000.,5000.)
214    A      PTAXTL.K=SMOOTH(MPTH.K-CTHOUSE,THAD.K)*AVR*PTAXR.K
215    A      PTAXTH.K=CTHOUSE*AVR*FTHVA*PTAXR.K
216    A      THQI.K=ISRATIO*(PTL.K+CTHOUSE*(MRTH.K+ARTH)+PTAXTL.K+PTAXTH.K)
217    A      PTL.K=MAX(0,(MPTH.K-CTHOUSE)*RRTL)
218    A      CTLOT.K=((CTLAND.K/THDENS)+SDCT.K+TDAOC)*(1.+DIFR.K*THPCD.K)
219    R      ITHIR.KL=MAX(0.,THR.K-TH.K-THAC.K-SSH)
220    R      THCR.KL=DELAY3P(THIR.JK,THPCD.K,THAC.K)
221    R      THIR.KL=ITHIR.JK*THIMC.K+PRETHIR.K
222    A      PRETHIR.K=PRETH*(STEP(1,1975)-STEP(1,1976))
223    A      THIMC.K=TABHL(THIMCT,MPTH.K/CTH.K,0.9,1.3,.05)
224    L      TH.K=TH.J+DT*(THCR.JK-PHSR.JK)
225    A      PPHS.K=CLIP(0,1,RESERVE,PDEVL.K)*CLIP(0,1,0,TH.K)
226    R      PHSR.KL=PPHS.K*PHIR.JK*THDENS/PHDENS
227    R      MTINFLR.KL=(NTHVACR-THVACR.K)*INFLMAX/NTHVACR
228    R      MTINFL.KL=MTINFLR.JK*MPTH.K
229    A      THVACR.K=MIN(1,(TH.K-QTHR.K)/TH.K)
230    L      MPTH.K=MPTH.J+DT*CLIP(MAX(0,MTINFL.JK),MTINFL.JK,CTHOUSE,MPTH.K)
231    A      CTLAND.K=MAX(ALTUSEV,SPECP2.K)
232    A      PSCPT.K=CLIP(HCTHS,LCTHS,LNDUSED.K,ESL)*(1+IPCCB.K)
233    A      LNDUSED.K=MAX(RESERVE,PDEVL.K)+TDEVL.K
234    A      SDCT.K=PSCPT.K+STEP(ASCWF*PSCPCN,YSDCP)
235    A      VTL.K=MPTH.K-CTHOUSE
236    A      CTH.K=CTLOT.K+CTHOUSE
237    A      THPCD.K=1.0-STEP(0.5,YRTP)
238    A      MRTH.K=0.12-STEP(0.025,YMRP)
239    A      THAD.K=1.0-STEP(0.5,YADP)
240    A      HS.K=(THR.K-MIN(QTHR.K,TH.K))/FAMILY.K
241    A      AHS.K=HS.K*FAMILY.K
       NOTE
       NOTE    EQUATIONS FOR SPECULATOR
       NOTE
242    R      CONVR1.KL=RLAR.K+CLAR.K
243    A      RLAR.K=(PHIR.JK-PHDR.JK)/PHDENS
244    A      CLAR.K=(RSCU.JK-RCDR.JK)/RDENS
245    L      PDEVL.K=PDEVL.J+DT*CONVR1.JK
246    R      CONVR2.KL=(THIR.JK/THDENS)-(PHSR.JK/THDENS)
247    L      TDEVL.K=TDEVL.J+DT*CONVR2.JK
248    A      SPECP1.K=MAX(SMOOTH(MJPAP.K,SBDDM),MJPAP.K)
249    A      MJPAP.K=MJPLOT.K*PHDENS
250    A      SMCONVR.K=SMOOTH(CONVR1.JK,1.0)
251    A      MIDLAND.K=MAX(0.,RESERVE-PDEVL.K)
252    A      INTERL.K=MIDLAND.K+TDEVL.K
253    A      CONVT2.K=INTERL.K/MAX(1.,SMCONVR.K)
254    A      F1.K=LNDRENT/(1.0+0.5*INTR)
255    A      F2.K=1.+1./(INTR+LTAXR)
256    A      F3.K=1.-DISCNT.K
257    A      SPECP2.K=SPECP1.K*DISCNT.K+F1.K*F2.K*F3.K
258    A      DISCNT.K=EXP(-CONVT2.K*LOGN(1.+INTR+LTAXR))
       NOTE
```

```
LINE       NOTE    TABLE FUNCTIONS FOR HOUSING SECTOR
           NOTE
259        T      PHIMCT=0/0/0/.2/.5/.8/1/1/1
260        T      THIMCT=0/0/0/.2/.5/.8/1/1/1
261        T      FFQPHT=1/.92/.8/.64/.48/.34/.22/.13/.11/.08/.06/.04/.02/0
262        T      FFQTHT=1/.92/.8/.64/.48/.34/.22/.13/.11/.08/.06/.04/.02/0
           NOTE
           NOTE    CONSTANTS IN HOUSING SECTOR
           NOTE
263        C      ALTUSEV=250.
264        C      ISRATIO=4.0
265        C      LCPHO=14000.
266        C      MCPHO=21000.
267        C      LCSMH=10000
268        C      MCIMH=5000
269        C      NPHVACR=0.05
270        C      ALPH=50.
271        C      ARPH=0.02
272        C      ARTH=0.05
273        C      FRTL=0.15
274        C      HCPHS=6000.
275        C      LCPHS=4000.
276        C      HCTHS=3000.
277        C      LCTHS=2000.
278        C      NTHVACR=0.07
279        C      CTHOUSE=12500.
280        C      PHDENS=3.0
281        C      THDENS=6.
282        C      RDENS=100000.
283        C      RESERVE=-500.
284        C      ESL=200.
           NOTE
           NOTE    POLICY YEAR CONSTANTS ARE SET TO
           NOTE    2000 IF POLICY NOT IMPLEMENTED.
           NOTE
285        C      YSDCP=2000
286        C      YMRP=2000
287        C      YADP=2000
288        C      YRTP=2000
289        C      YMHP=2000
290        C      YDIFRP=2000
           NOTE
           NOTE
291        C      FTHVA=0.5
292        C      LNDRENT=25.
293        C      INTR=0.08
294        C      LTAXR=0.01
295        N      CJ=0.
296        N      PH=2000.
297        N      PHINIT=PH
298        N      TH=65.
299        N      MPPH=24000.
300        N      MPTH=16000.
301        N      PDEVL=0
302        N      TDEVL=TH/THDENS
303        N      PHIR=0
304        N      PHBCR=0
305        N      THIR=0
306        C      CWPHO=1.0
307        C      HDAOC=1000.
```

```
LINE
 308     C      TDAOC=500.
 309     C      SBDDM=2.0
 310     C      FTFCD=0.
 311     C      FPFCD=0.85
 312     C      INFLMAX=0.25
 313     N      FPCF=1.0
 314     C      SAD=-1
 315     C      PREPH=0
 316     C      PRETH=0
 317     C      SSH=400
         NOTE
         NOTE     RUN CONTROL CARDS
         NOTE
 318     N      TIME=1970
 319     SPEC   DT=0.01/LENGTH=1990/PLTPER=.4/PRTPER=1.
```

Rerun Changes for Figures Shown in this Report

Fig. 15. Quasi-equilibrium without plant. No changes.

Fig. 16-25. Base case with different plots.
TP WSCCT = 0/750/750/0/0/0/0/0/0/0/0/0

Fig. 26. Policy #1. Reduced mortgage rates.
CP YMRP = 1976
CP YDIFRP = 1976

Fig. 27. Policy #2. Previous policy plus relaxed regulations plus modular housing.
CP YMHP = 1976
CP YRTP = 1976

Fig. 28. Policy #3. Previous policies plus sequence of energy facilities.
TP WSCCT = 0/750/750/0/0/750/750/0/0/750/750/0

Fig. 29. Policy #4. Previous policies plus orderly land development.
CP ESL = 2000
CP RESERVE = 1000

Fig 30. Policy #5. Previous policies plus risk removal.
CP FTCR = .5
CP FTFCD = .5

Fig. 31. Policy #6. Previous policies plus prebuilding of permanent houses.
CP PREPH = 1500

Fig. 32. Policy #7. Previous policies plus off-site housing for housing construction workers.
CP CWPHO = 0

Fig. 33. Policy #7. Plot of public sector variables. No changes.

Fig. 34. Policy #8. Previous policies plus prebuilding of public facilities.
TP FNDOT = 1/1/1/1/1
CP PREPUS = 1.0

APPENDIX C

GUIDE TO THE PROGRAM LISTING

Lines 1-166 are generally similar to the listing shown in the *User's Guide to the BOOM1 Model.* Changes in these lines are described in Section II.E and noted at the end of Appendix C. The new Housing sector begins with Line 167.

Line No.	Variable	Name	Units	Figure or Table in Report
167	QPHR	Qualified Demand for Permanent Housing.	houses.	Fig. 3.
168	FFQPH	Fract. Families Qualified for Perm. Housing.	dimension-less.	Figs. 3 12, 19.
169	PTAXPH	Property Tax on Permanent Housing.	$/year.	Figs. 3, 19.
170	SADP	Special Assessment District Payments.	$/year.	Fig. 3.
171	NH	New Houses.	houses.	not used elsewhere in model.
173	MDRSA	Mun. Debt Related to Special Assessment District.	$.	Special assessment district.
174	SADINR	Special Assessment Debt Increase Rate.	$/year.	not used in this report.
175	SADOUTR	Special Assessment Debt Retirement Rate.	$/year.	not used in this report.
177	PHQI	Perm. Housing Qualifying Income.	$/year.	Figs. 3, 12, 19.
178	CPLOT	Total Cost of Perm. Housing Lot.	$/lot.	Fig. 4b.
179	CPH	Cost of Perm Housing.	$/house.	Figs. 4b, 15, 16.
180	CPHOUSE	Cost of Perm Housing Construction.	$/house.	Fig. 4b.
181	LOTSERV	Lot Service Cost.	$/lot.	Fig. 4b.
182	LCPH	Nominal Labor Cost of Perm. Housing.	$/house.	Fig. 4b, Table IV.
183	MCPH	Material Cost of Perm. Housing.	$/house.	Fig. 4b, Table IV.
184	PHVACR	Perm. Housing Vacancy Rate.	%.	Figs. 3, 17.

Line No.	Variable	Name	Units	Figure or Table in Report
185	IPHIR	Indicated Perm. Housing Initiation Rate.	houses/year.	Fig. 4a.
186	PHP	Perm. Housing Potential.	houses.	used to cal. IPHIR, see Fig. 4a.
187	PHIMC	Perm. Housing Initiation Multiplier from price Cost squeeze.	dimension-less.	Figs. 4a, 4b, 13.
188	HIMUA	Housing Initiation Multiplier from Utilities Availability.	dimension-less.	Fig. 4a, see Sec. V.C.
189	PHIR	Perm. Housing Initiation Rate.	houses/year.	Fig. 4a.
190	PREPHIR	Rate of Pre-building of Perm. Housing.	houses/year.	Fig. 31 (policy run No. 6).
191	PHBCR	Perm. Housing Begin Construction Rate.	houses/year.	Fig. 4a.
192	PHCR	Perm. Housing Completion Rate.	houses/year.	Fig. 4a.
193	PH	Stock of Permanent Housing.	houses.	Fig. 4a, 18.
194	PHDR	Perm. Housing Depreciation Rate.	houses/year.	Fig. 4a.
195	MPINFLR	Market Price Inflation Rate for Permanent Housing.	$/year.	Figs. 3, 14.
196	MPPH	Market Price for Permanent Housing.	$.	Figs. 3, 15, 16.
197	VRP	Value of Residential Property.	$.	Fig. B-5, *User's Guide to the BOOM1 Model.*
198	VPH	Value of Permanent Housing.	$.	used to cal. VRP in line 197.
199	VTH	Value of Temporary Housing.	$.	used to cal. VRP in line 197.
200	MJPLOT	Market Justified value of a Perm. Lot.	$/lot.	Fig. 8.

Line No.	Variable	Name	Units	Figure or Table in Report
201	SDCH	System Development Charge per House.	$/house.	see Sec. II.E, used to calculate extra source of municipal revenues in line 109.
202	PSCHP	Public Service Capital Required per House.	$/house.	Fig. 8.
203	AUVHL	Alternate Use Value.	$/acre.	Fig. 4b.
204	PHTD	Perm. Housing Total Delay.	years.	used in line 246.
205	PHCD	Perm. Housing Construction Delay.	years.	Fig. 4a, Table IV, (changed for policy run No. 2 in Fig. 27).
206	PHPAD	Perm. Housing Planning and Approval Delay.	years.	Fig. 4a, Table IV, (see changes for policy run No. 2 in Fig. 27).
207	MRPH	Mortgage Rate on Perm. Housing.	%/year.	Fig. 3, Table IV, (see policy run No. 1, Fig. 26).
208	DIFR	Developers' Interim Financing Rate.	%/year.	Fig. 4b, Table IV.
209	PHAD	Perm. Housing Assessment Delay.	years.	Fig. 3.
210	THR	Temporary Housing Required.	mobile homes.	Fig. 6.
211	QTHR	Income Qualified demand for Temporary Housing.	mobile homes.	Fig. 7.
212	PQTHR	Potential income Qualified demand for Temporary Housing.	mobile homes.	Fig. 7.
213	FFQTH	Fraction Families Qualified for Temporary Housing.	dimensionless.	Figs. 7, 12, 20.
214	PTAXTL	Property Tax on a Temporary Lot.	$/year.	Fig. 7.
215	PTAXTH	Property Tax on a Mobile Home.	$/year.	Fig. 7.

Line No.	Variable	Name	Units	Figure or Table in Report
216	THQI	Temporary Housing Qualifying Income.	$/year.	Fig. 7.
217	PTL	Payments for Temporary Lot.	$/year.	Fig. 7.
218	CTLOT	Cost of a Serviced, Temporary Lot.	$/year.	Fig. 6.
219	ITHIR	Indicated Temporary Housing Initiation Rate.	mobile home lots/year.	Fig. 6.
220	THCR	Temporary Housing Completion Rate.	mobile home lots/year.	Fig. 6.
221	THIR	Temporary Housing Initiation Rate.	mobile home lots/year.	Fig. 6.
222	PRETHIR	Prebuilding of Temp. Housing.	mobile home lots/year.	see policy run No. 6 in Fig. 31.
223	THIMC	Temp. Housing Initiation Multipler from price/cost squeeze.	dimensionless.	Figs. 6, 13.
224	TH	Stock of Temporary Housing.	mobile homes.	Fig. 6.
225	PPHS	Potential for Perm. Housing Substitution.	"yes" or "no" (binary variable).	used in line 226.
226	PHSR	Permanent Housing Substitution Rate.	mobile home lots/year.	Fig. 6.
227	MTINFLR	Market Price of Temporary Housing Inflation Rate.	%/year.	Figs. 7, 14.
228	MTINFLR	Market Price of Temporary Housing Inflation.	$/year.	Figs. 7, 14.
229	THVACR	Temporary Housing Lots Vacancy Rate.	%.	Figs. 7, 17.
230	MPTH	Market Price of Temporary Housing.	$.	Figs. 7, 15, 16.
231	CTLAND	Cost of Land for Temporary Development.	$/acre.	Fig. 6.
232	PSCPT	Public Service Capital required per Temp. Lot.	$/lot.	Fig. 21.
233	LNDUSED	Land Used.	acres.	used in Eq. 232, Fig. 21.

Line No.	Variable	Name	Units	Figure or Table in Report
234	SDCT	Service Development Charge per Temp. Lot.	$/lot.	see Sec. II.E, used to calculate extra source of municipal revenues in line 109.
235	VTL	Value of Temp. Lot.	$/lot.	Figs. 4b, 7.
236	CTH	Cost of Temporary Housing.	$.	Figs. 6, 15, 16.
237	THPCD	Temporary Housing Planning and Completion Delay.	years.	Fig. 6, Table IV, changes for policy run.
238	MRTH	Mortgage Rate for Temporary Housing.	%/year.	Fig. 7, Table IV, changes for policy run No. 1 in Fig. 26.
239	THAD	Temporary Housing Assessment Delay.	years.	Fig. 7, Table IV.
240	HS	Housing Shortage.	%.	Figs. 6, 15, 16.
241	AHS	Absolute Housing Shortage.	units of housing.	Not used elsewhere in the model, but plotted in Figs. 25-31.
242	CONVR1	Rate of Conversion of raw land for Permanent Use.	acres/year.	Fig. 8.
243	RLAR	Residential Land Absorption Rate.	acres/year.	Fig. 8.
244	CLAR	Commercial Land Absorption Rate.	acres/year.	Fig. 8.
245	PDEVL	Permanently Developed Land.	acres.	Fig. 8.
246	CONVR2	Rate of Conversion of raw land for Temporary use.	acres/year.	Fig. 8.
247	TDEVL	Land in use for Mobile Home Parks.	acres.	Fig. 8.
248	SPECP1	Speculative Value of innerland immediately available for permanent development.	$/acre.	Figs. 8, 22, Table D-1.

Line No.	Variable	Name	Units	Figure or Table in Report
249	MJPAP	Market Justified Value of an Acre Perm. Land.	$/acre.	Fig. 8.
250	SMCONVR	Exponentially Smoothed value of the permanent land Conversion Rate.	acres/ year.	Fig. 8.
251	MIDLAND	Middle Land.	acres.	Fig. 8, Table D-1.
252	INTERV	Intervening Land.	acres.	Fig. 8, Table D-1.
253	CONVT2	Estimated time before speculative land ready for conversion to perm. use.	years.	Fig. 8.
254-256	F1, F2, F3	Used to calculate SPECP2.		See Fig. D-2.
258	DISCNT	Discount factor for valuing speculative land.	dimension-less.	Fig. 8. D-2.
259	PHIMCT	Table for PHIMC (line 187).	dimension-less.	Fig. 13.
260	THIMCT	Table for THIMC (line 223).	dimension-less.	Fig. 13.
261	FFQPTH	Table for FFQPH (line 168).	dimension-less.	Fig. 13.
262	FFQTHT	Table for FFQTH (line 213).	dimension-less.	Fig. 12.
263	ALTUSEV	Alternate Use Value of outer land.	$/acre.	Fig. 6, Table IV.
264	ISRATIO	commonly used Income to Shelter costs Ratio for granting home loans.	dimension-less.	Figs. 3, 7, Table IV.
265	LCPHO	Nominal Labor Costs Permanent, On-Site Housing.	$/house.	Table IV.
266	MCPHO	Material Cost Permanent, On-Site Housing.	$/house.	Table IV.
267	LCSMH	Labor Cost Savings for Modular Housing.	$/house.	Table IV.
268	MCIMH	Material Cost Increase for Modular Housing.	$/house.	Figs. 3, 14, Table IV.
269	NPHVACR	Nominal Perm. Housing Vacancy Rate.	%.	Figs. 3, 14, Table IV.
270	ALPH	Average Life Perm. Housing.	years.	Fig. 4a, Table IV.

Line No.	Variable	Name	Units	Figure or Table in Report
271	ARPH	Amortization Rate Perm. Housing.	%/year.	Fig. 3, Table IV.
272	ARTH	Amortization Rate Temp. Housing.	%/year.	Fig. 7, Table IV.
273	RRTL	Rate of Return on Temp. Lot.	%/year.	Table IV. used in line 217.
274	HCPHS	High Value Cost Perm. Housing Services.	$/lot.	Table IV.
275	LCPHS	Low Value Cost Perm. Housing Services.	$/lot.	Table IV.
276	HCTHS	High value Temp. Housing Services.	$/lot.	Table IV.
277	LCTHS	Low Value Temp. Housing Services.	$/lot.	Table IV.
278	NTHVACR	Nominal Temp. Housing Vacancy Rate.	%.	Figs. 7, 14, Table IV.
279	CTHOUSE	Cost of Mobile Home.	$.	Fig. 6, Table IV.
280	PHDENS	Perm. Housing Density.	lots/acre.	Fig. 4b, 8, Table IV.
281	THDENS	Temp. Housing Density.	lots/acre.	Figs. 6, 8, Table IV.
282	RDENS	Density of Retail and Service Facilities.	$/acre.	Fig. 8, Table IV.
283	RESERVE	Initial Reserve of Land available for Permanent Use.	acres.	Fig. 8.
284	ESL	Easily Serviced Land.	acres.	Fig. 8.
285	YSDCP	Year of the System Dev. of Charge (set to 2000 for all runs in this report) Policy.		
286	YMRP	Year of Mortgage Rate Reduction (set to 1976 for policy runs 1-6).		
287	YADP	Year of Assessment Delay Reduction (as shown).		
288	YRTP	Year of Relaxed Regulations Policy (set to 1976 for policy runs 2-6).		
289	YMHP	Year of Modular Housing Policy (set to 1976 for policy runs 2-6).		
290	YDIFRP	Year of Developer Interim (set to 1976 for policy runs 1-6) Financing Rate Reduction.		

Line No.	Variable	Name	Units	Figure or Table in Report
291	FTHVA	Fraction of Temp. Housing Value subject to Assessment.	dimensionless.	Fig. 7, Table IV.
292	LNDRENT	Interim use Rate of Return on undeveloped land.	%/year.	Fig. 8, Table IV.
293	INTR	Interest Rate used in discount calculation for SPECP2.	%/year.	Fig. D-2, Table IV.
294	LTAXR	Tax Rate on undeveloped, open land.	%/year.	Fig. 8, Table IV.
295-305		Variables Initialized to reflect "transition phase" of housing market (see Sec. V.A).		
306	CWPHO	Construction Workers per Perm. House under construction.	jobs/house.	Fig. 4a, Table IV.
307	HDAOC	Perm. Housing Developers' Administrative and overhead cost.	$/lot.	Fig. 4b, Table IV.
308	TDAOC	Term. Developers' Administrative and overhead cost.	$/lot.	Fig. 6, Table IV.
309	SBDDM	Speculators' Behavioral Delay in Declining Market.	years.	Fig. 8, Table IV.
310	FTFCD	Fraction Temporary Families considered by Housing Developers.	dimensionless.	Fig. 4a, Table IV, changed for policy No. 5 in Fig. 30.
311	FPFCD	Fraction Permanent Families considered by Housing Developers.	dimensionless.	Fig. 4a, Table IV.
312	INFLMAX	Rate of Inflation should vacancy rate be zero.	%/year.	Figs. 3, 7, 14.
314	SAD	Special Assessment District in effect?	"yes" if SAD positive, or "no" if SAD negative.	used in line 174.
315	PREPH	Amount of Perm. Housing to be prebuilt in 1975-1976.	units.	used in policy run No. 6 in Fig. 31.
316	PRETH	Amount of Temp. Housing to be prebuilt in 1975-1976.	units.	used in policy run No. 6 in Fig. 31.
317	SSH	Substandard Housing		

Line No.	Variable	Name	Units	Figure or Table in Report
Changes in nonhousing sectors of BOOMH model to make new housing sector interface property with BOOM1 model:				
2	PPMFBT	Power Plant construction worker productivity multiplier from boom conditions (table).	dimensionless.	
38	PSCPCN	Public Service Capital Per Capita Normal.	$/person.	
92	PCNHRR	Public Capital (nonhousing) rate required.	$/year.	
89	CPCRH	Cost of Public Construction required for housing.	$/year.	
101	CPCR	Cost of Public Construction required.	$/year.	
108	MREV	Total Municipal Revenues.	$/year.	
109	NTREV	Nontax sources of Revenue.	$/year.	
112	TAXNEED	Estimate of Tax Revenues	$/year.	
114	CNPD	Cost of Public Const. not covered by Prepayment by Dev.	$/year.	
115	GBNTREV	Extra Funds for General Budget from Nontax Revenue.	$/year.	
120	FPCF	Fraction Public Construction Financed.	dimensionless.	
121	FIN	Financing Available for Const. of population related facilities.	$/year.	
122	CPD	Charges Prepaid by Dev.	$/year.	
126	HCJ	Housing Construction Jobs.	jobs.	
128	CJ	Total Construction jobs.	jobs.	
140	UHF	Unhoused Families.	families.	
142	FSWOF	Fraction Const. workers that are single or are without their families.	dimensionless.	
143	PFSWOF	Potential Const. Families single.	dimensionless.	
144	HSDELAY	Housing Shortage Delay.	years.	
145	BTI	Boom Town Index.	dimensionless.	
155	PCR	Public Construction Rate.	$/year.	

APPENDIX D

NOTES ON LAND SPECULATION

The purpose of this appendix is to illustrate the workings of the land valuation portion of the housing sector through an illustrative example. Basically, the land use portion of the model keeps track of eight categories of land as described in Table D-I and portrayed in Fig. D-1. An implicit assumption of the BOOMH model is that the permanently developed land grows outward without "leapfrog" discontinuities. Given this assumption, one can define an "inner ring" of land that surrounds the permanently developed land as shown in Fig. D-1. We ascribe to this inner ring a speculative value based on the market justified value of a lot that is already developed for permanent use. The purpose of the land valuation sector is to translate the speculative value of the inner ring of land into a

TABLE D-I

DESCRIPTION OF LAND CATEGORIES

Category	Model Variable	Line No.	Land Occupied by	Speculative Value ($/acre)
1. Permanently developed land.	PDEVL	---	Permanent housing, retail, and service facilities.	MJPAP (see Fig. 8).
2. Inner ring of land ready immediately for conversion to permanent use.	---	---	Unoccupied, zoned for permanent development.	SPECP1 (see Fig. 8).
3. Middle Land.	MIDLAND	---	Unoccupied, zoned for permanent development.	value is greater than SPECP2 but less than SPECP1.
4. Land available for mobile homes.	---	---	Unoccupied, zoned for mobile homes.	not calculated, but *cost* of this land driven up when SPECP2 increases.
5. Mobile Home land.	TDEVL	---	Mobile Homes	not calculated
6. Outer ring of land not ready for conversion until after INTERVENING LAND is consumed.	---	---	Unoccupied, zoned for permanent use.	SPECP2 (see Fig. 8).
7. Restricted land is the land that is not suitable for development due to rough terrain or unusual ownership.				
8. Intervening land (categories 3 and 5).	INTERV	---	Either unoccupied or occupied by mobile homes.	same as MIDLAND.

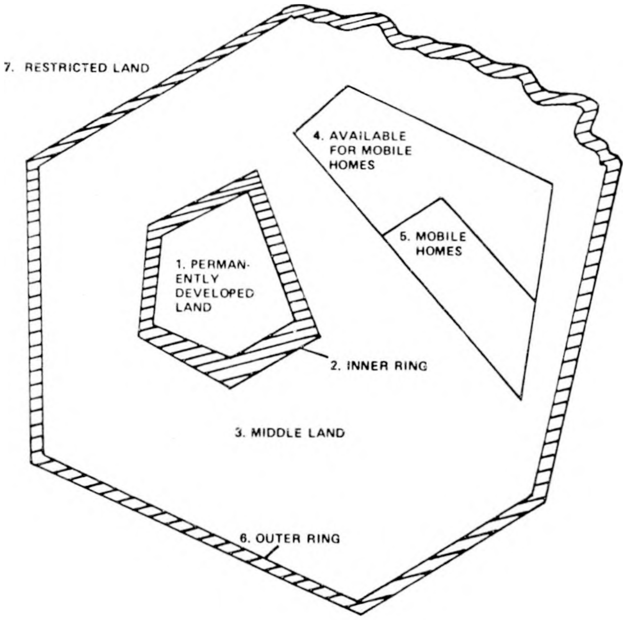


Fig. D-1.
Diagram of different land categories.

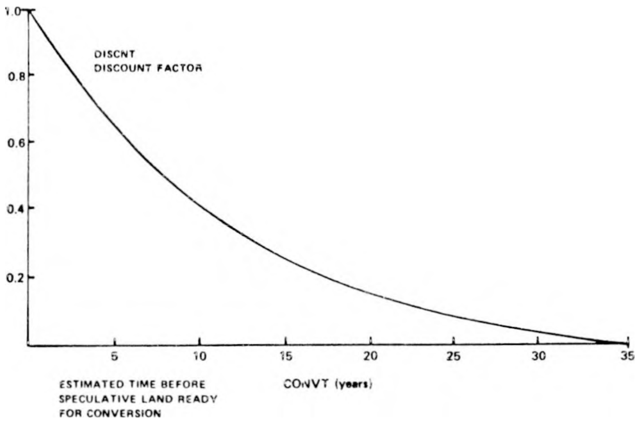


Fig. D-2.
Discount factor used to evaluate speculative value of outer land.

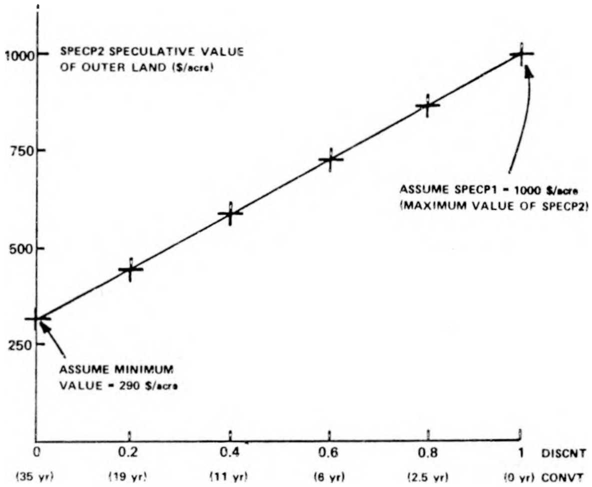


Fig. D-3.
Illustrative relationship between the speculative value of outer land and the discount factor.

speculative value that a "rational speculator" would associate with the outer ring of land estimated to be many years away from conversion to permanent use.

To achieve this translation, the model prepares an estimate (in each year of the simulation) of the number of years required before the growing inner core of permanently developed land would consume the intervening land available. If hundreds of years are required, the model ascribes no extra value to the outer land. If fewer than 5 years are required, the model ascribes a speculative value that is almost equal to the speculative value of the land that is immediately ready for conversion to permanent use. The specific discount factor used in the simulations shown in this report is graphed in Fig. D-2. The actual calculation of the speculative value of outer land (given the discount factor from Fig. D-2) is shown in Fig. D-3 for the hypothetical example where inner land has a speculative value of $1000 per acre and outer land has an alternate use value of $290 per acre. Notice that the speculative value of the outer land increases linearly from a minimum value associated with its alternate use to the maximum value of $1000 per acre as the discount factor grows from zero to one.

Should the model operate in a mode where a small inventory of intervening land is available and the inner core of permanent development is growing rapidly, the speculative value of outer land may increase substantially. Should this occur, the temporary developers may withhold their land from use for mobile home parks with the intention of securing larger profits from the eventual conversion to permanent use.

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