Continued Development of the Vancouver Model

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This paper describes the refinements made during 1975 to models used in an urban simulation project. The refinements include the estimation and implementation of equations for regional housing and the development and implementation of an algorithm that is used for demolishing a portion of the standing housing stock that is in areas where actual densities are less than permitted (zoned) densities. Minor programming errors have been eliminated, and the running time of the models has been improved. Principal conclusions relate to the increased reliability and realism of the models. A comparison of output from models in different states of evolution was made, and the current version is superior to earlier versions. The simulated output was compared with actual events in the region to verify that the simulations are consistent with recent development trends. Since the refinements have been encouraging, continued development of the model is warranted. The model is being continued, and the data base is being expanded so that empirical estimations of a number of relations can be included as ad hoc intuition. These empirical estimations should further improve the models.

The work described in this paper began 5 years ago and is part of a large-scale urban simulation project. That project was an experiment in interinstitutional cooperation between the University of British Columbia and the city of Vancouver (departments of Engineering, Finance Planning, and Social Planning), the Greater Vancouver Regional District (a prototype regional government and its planning department), and the province of British Columbia (Department of Municipal Affairs). The federal Ministry of State for Urban Affairs (the federal department responsible for urban policy and research) also joined the effort. The project began in mid-1970, and the federal government became involved in late 1971. Federal involvement ($200 000/year) was terminated in December 1974, and, thus, the larger project that had been called Interinstitutional Policy Simulator (IIPS) was terminated.

This paper reports on several simulation models that were begun under the sponsorship of IIPS, but were developed independently after the IIPS program ended.

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Detailed information about the IIPS undertaking is given elsewhere (1), and additional material on the housing and land use models can be found in other reports (2, 3, 4).

Figure 1 shows the basic modeling system and its four principal components: employment forecasting, population forecasting, land use and housing, and transportation. Each component is a model that was developed to stand alone and to integrate with each other in the module. Since the transportation component has taken a separate path of development, it is not discussed in detail in this paper. Currently, the transportation component is a unimodal model that acts on 82 subareas with trip generation, distribution, and assignment algorithms. This model is being upgraded to include a modal-split component for at least two modes and to handle nearly 200 zones. The end product of the transportation model is the 82 by 82 matrix of travel times that are prime input to the land use and housing components.

Population forecasts are derived from a cohort-parity model that uses 100 male-female cohorts of similar age and five fertility states. Migration is a policy intervention that is currently set at the 1966 to 1971 average level. The forecasting model for employment has been carefully developed and is based on an input-output model (5) designed for the Vancouver region. However, data are missing from the data base; therefore, it has not been possible to calibrate the econometric portion of the model that is used for estimating the final future demands (6). Instead of using this theoretically sound and innovative forecasting structure, we have had to use a simple trend. This trend is clearly unsatisfactory and is a primary focus for future improvement.

The land use models are shown in Figure 2. The various elements for land use are on the left side of the figure, and the elements for land supply are on the right side of the figure. Resolution of supply and demand takes place in the simulated market that is shown in the center of the figure. The models are designed so that a variety of supply policies (such as rezoning, annexation, land fill, or land reserves) can be implemented by changing the supply variables. Demand can similarly be affected by the intervention of any of the land-consuming activities that are shown on the left side of

Figure 1. Interaction between module and regional transportation model.

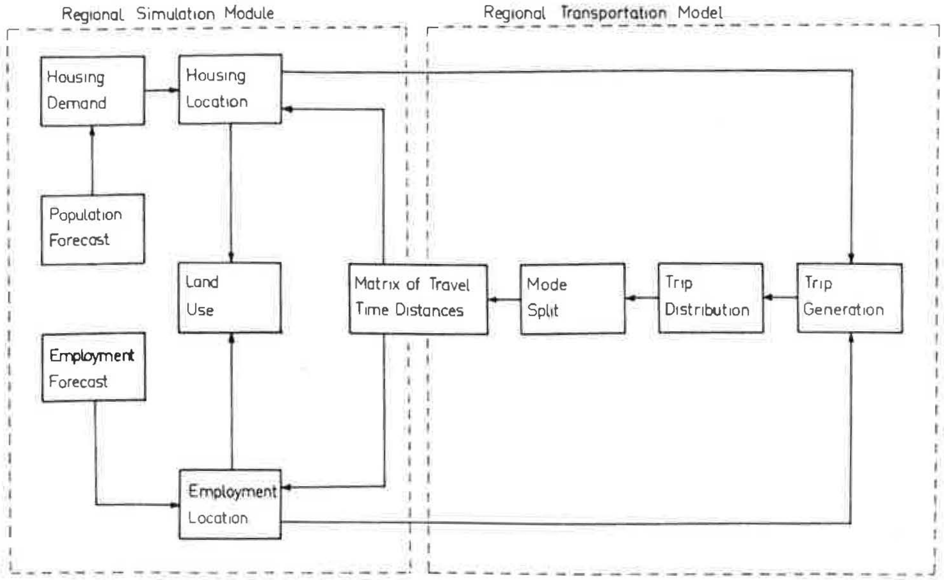
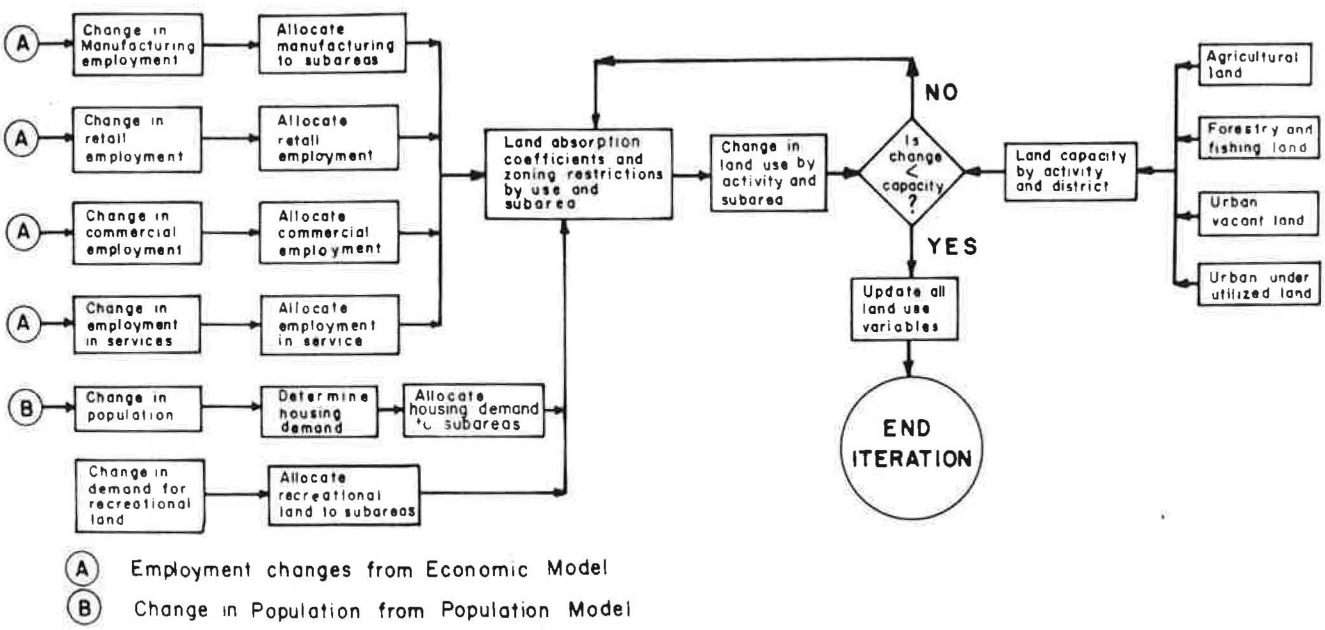


Figure 2. Flow chart for land use models.



the figure. Thus, a wide variety of policies for impact analysis are available to the model user.

We can now examine a number of refinements that have been made to the housing component of the land use model during 1975. Similar refinements are currently under way for the employment component of the land use models. Each set of improvements began with the development of an improved data base on which empirical estimates of allocation and forecasting relations could be based.

RECENT REFINEMENTS TO THE MODEL

Two major refinements have been implemented during 1975, and these are the focus of this paper. The first refinement deals with replacing the equation that determined the regional supply of new housing in each period. The second refinement deals with modeling the demolition process so that actual densities in the long-run approach will permit densities in growing areas.

Determination of total starts for the region has been one of the weakest areas since the inception of the model. Originally, total starts were estimated by using the following equation:

$$NS_t = TNHH_t - TH_t + VACRAT_t \cdot TNHH_t \quad (1)$$

New supply (NS_t) was assumed equal to the change in the number of households ($TNHH_t$) plus a demand for vacancies (DV) to allow for equilibration of short-term disturbances (i.e., some inventories for short-run adjustments) minus the housing supply (TH_t). The demand for vacancies was assumed to be a function of vacancy rates ($VACRAT_t$) for the succeeding 3 years since there is a 3-year planning horizon for developers in our region (7). If NS_t is negative, then a small number of units are still built, reflecting the fact that construction does not cease even though there is a high excess in housing stocks.

This initial approach for estimating the total housing starts in a region was largely an ad hoc procedure that also disaggregated housing into two structure types. The ad hoc technique has been improved by replacing equation 1 with two estimating equations. There is one for single starts, and one for multiple starts. These equations generate regional totals, and, as before, these totals are then allocated to the subareas. Refinement of the allocation algorithm depends on the development of additional data bases. This development is currently under way, but it is not expected to be completed for at least 6 months. Equations 2 and 3 are replacements for the single aggregate equation 1.

$$\underset{}{HS_t^m} = \underset{(0.132)}{0.139HS_{t-1}^m} + \underset{(0.087)}{0.397HS_{t-s}^m} + \underset{(0.039)}{0.095PoP_{t-1}} - \underset{(0.038)}{0.047PoP_{t-2}}$$
$$R^2 = 0.358 \text{ and F-statistic } (5107) = 100.443 \qquad (2)$$

$$HS_t^s = \left(-31.0 + \underset{(0.112)}{0.250HS_{t-1}^s}\right) - \underset{(0.117)}{0.129HS_{t-1}^s} + \underset{(0.023)}{0.051PoP_t}$$
$$+ \underset{(0.025)}{0.070PoP_{t-1}} + \underset{(0.023)}{0.045PoP_{t-2}} \qquad R^2 = 0.894 \text{ and}$$
$$\text{F-statistic } (6106) = 283.939 \qquad (3)$$

The second area of refinement relates to the newly developed algorithms for demolitions. Because of the lack of information on the age distribution of the stock of houses and other buildings, it was difficult, in the first stages of development, to derive an intuitively sensible yet operational algorithm to handle the demolition of existing structures. Therefore, a direct policy intervention was used. Thus, as areas were rezoned to allow for greater densities, the bulk of the existing structures was unaffected. This was a serious weakness. However, after studying a number of areas in the region that had been rezoned, we established that a demolition rate of 2 to 3 percent for the stock existing at the time of rezoning seemed to prevail over the last decade in such rezoned areas. Thus, our demolition algorithm was applied to the existing stock in areas where the actual density is less than the allowable density. Demolitions begin with the lowest value class of housing and continue to move up through the value classes and structure types. These demolitions continue until the stock has been rebuilt at the new densities and until there is no additional vacant land or underutilized land remaining. Another option we are also experimenting with is the application of a saturation variable that would affect the demolition rate. The reason is that the higher the level of saturation is (e.g., the smaller the percentage of developable or redevelopable land), then the higher might be the rate at which underutilized structures are demolished. Since this option is currently being programmed, it will not be discussed in this paper.

MODEL OUTPUT

This section illustrates the differences among the various stages of development for the housing component of the land use model. These differences are referred to by relevant output as follows:

1. Total construction is the total number of housing units of all types built during the year,
2. Total unzoned vacant land is the total amount of land that is currently unoccupied and is available for any use, and
3. Housing units by region is the aggregate of all types of housing for any specified region or subarea.

Most of the housing land was drawn from output 2. There are two fundamental types of changes that can be made to this model. The first type is a structural change in which the actual links between the subcomponents are modified or the equations that represent the subcomponents are changed. The second type of change is a policy or qualitative intervention in which data values are modified in the housing, zoning, or density files.

Figures 3 and 4 show the five different structural changes in the model. The original model produced what is referred to as the standard run. The construction gradually increased from about 10 000/year to about 16 000/year before the vacant land was exhausted in year 19 (year 0 corresponds to 1971). Steps 2 and 3 of development (vacancies and microspatial feedback) were incorporated into the run referred to as the micro-macro link. Goldberg and Stander (4) give the details of these steps. Basically, the model stops development as saturation is reached under the micro-macro link. Construction for this phase began to taper off at year 12 and slowly decreased until the vacant land was gone in year 24.

The refinements to the current model were tested independently and were labeled regression equation and automatic demolitions. A significantly higher rate of construction (maximum of 32 000/year) was projected by the regression equation than by the earlier runs. Since the equation was based on data collected during the housing boom of the late 1960s and early 1970s, it projected a very high rate of construction. Because of depletion of available vacant land, this rate declined quite sharply after year 14. The automatic demolitions and reconstruction provided some of the best output. The construction increased steadily from 10 000 to 20 000 units/year in years 0 and 25 respectively and still seemed to increase even though all of the vacant land was consumed by year 19.

Figures 5 through 8 show a modified base run. This run included the regression equation, housing vacancies, and the automatic demolitions and reconstruction with the standard run. The most advanced features of the model were all included in this option. The several policy options shown in Figures 5 through 8 are

1. The standard and modified bases that were used as reference lines for the three interventions,
2. The development of university endowment lands (UELs) that included about 1012 hm^2 (2500 acres) at 25 units/hm^2 (10 units/acre) in an upper income area of the city of Vancouver,
3. The freeing of all agricultural land for potential development, and
4. An increase in the maximum densities to 50 units/hm^2 (20 units/acre) for single family and 250 units/hm^2 (100 units/acre) for multifamily.

The sharp rise shown in Figure 5 was caused by changing the unusable agricultural land to usable vacant land. Figure 6 shows the effect of the various policy options on two different subareas of the region: Region 1 is the central downtown area, and region 14 is one of the large outlying suburban districts. The repealing of the freeze on the farm land (item 3 above) produced less construction in the central area but increased construction in the land that was available. Figures 7 and 8 show the effects of two of these interventions on one specific region and a comparison of each region to the modified base run. Figure 7 shows the effect of the UEL development in region 2, which contains UEL. Figure 8 shows a comparison of the construction in region 1 with and without the upzoning (item 4 above).

INTERIM CONCLUSIONS

Since the model is still evolving, firm conclusions are neither possible nor relevant. One overall observation that seems justified by the results presented above is that the model has definitely improved as a device for testing policy impact during the past year. The housing start estimates that result from equations 2 and 3 are much closer to actual starts than those generated by the earlier forms of the model. This greater accuracy in estimating total starts improves the reliability of all the other estimates in subareas since the estimates depend on a good forecast of total starts.

Given the accuracy of the macrospatial housing start equations, the dynamic demolition subroutine will provide a more reliable microspatial allocation of these start estimates. The older noneconomic use of land can now be replaced over time by use of the demolition algorithm. Thus, the accessible land in the central city that is in demand is free for redevelopment. The resulting evolution of the lower density and desirable subareas of the Vancouver region closely reflects recent history and trends. The fact that the current model generates an evolutionary pattern that resembles the

Figure 3. Structural changes in model for total construction by time.

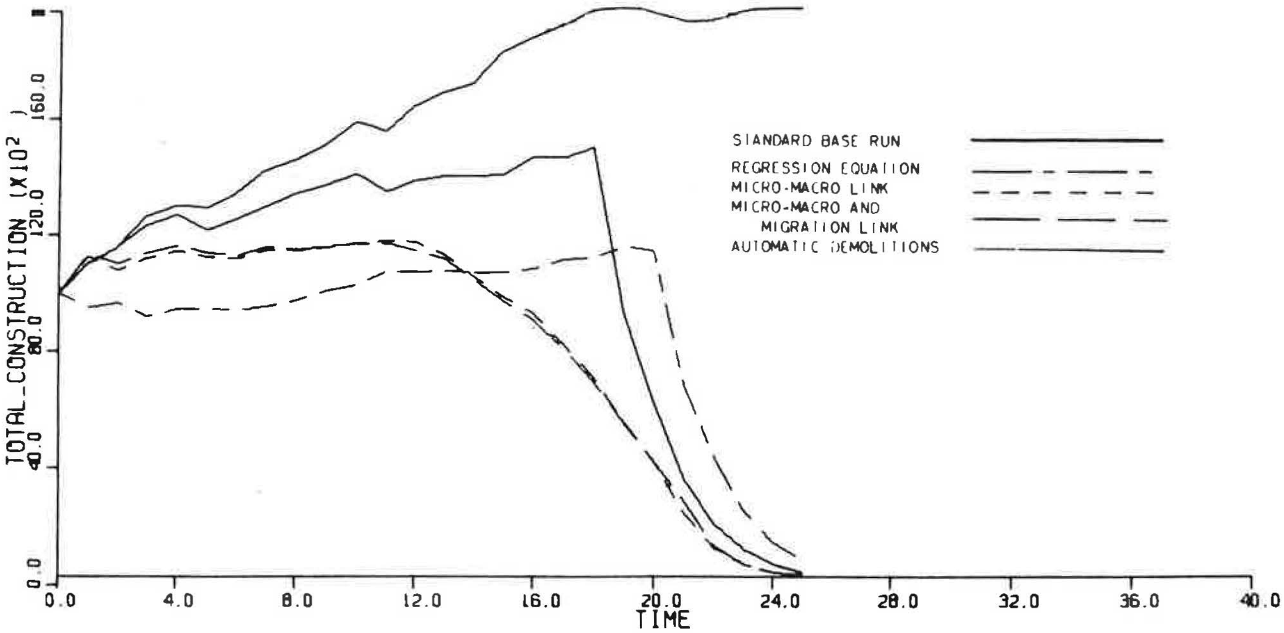
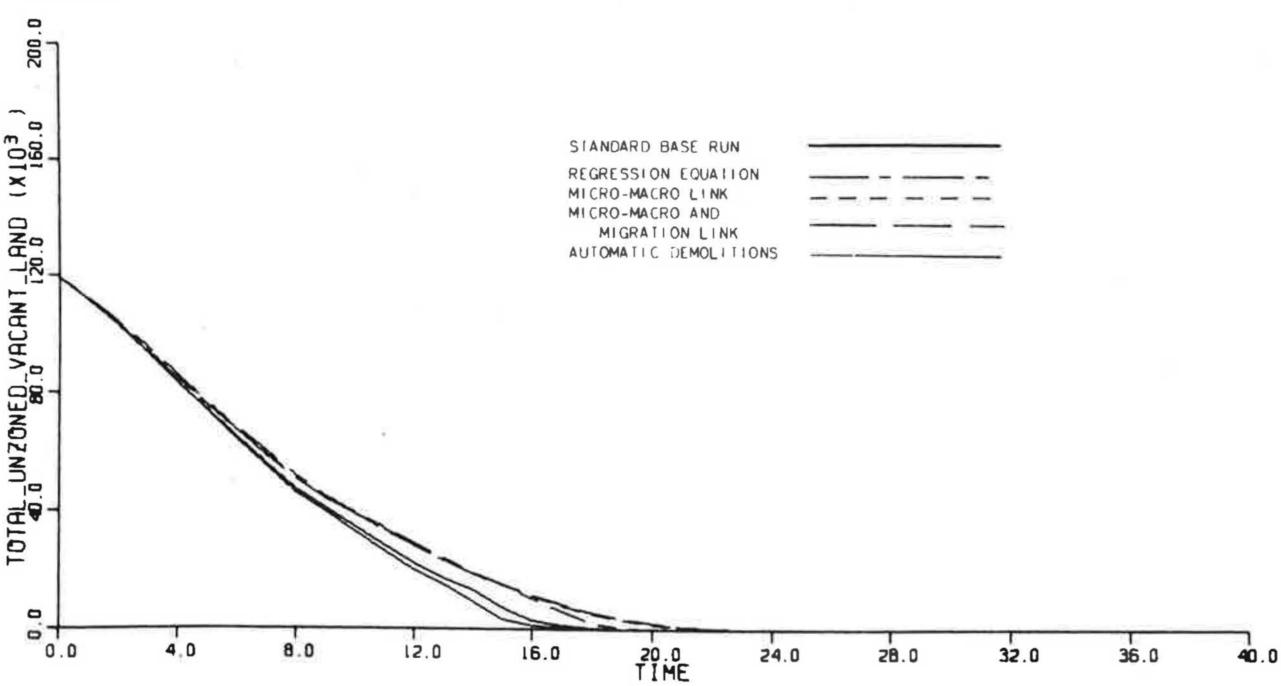


Figure 4. Structural changes in model for total unzoned vacant land by time.



actual pattern is a good measure of the usefulness of the model for examining the policies that change the trend. It is almost true that there are no such things as counter-intuitive behaviors of models, only programming errors (5). As the computer codes are refined, the models will invariably exhibit an intuitively sensible behavior that can provide a basis for comparing the output generated under structural or quantitative interventions.

One final conclusion relates to the need for empirical estimation of the remaining ad hoc (e.g., uncalibrated) portions of the model in which such estimation is likely to be productive and data are likely to be collectable. The great improvement in the quality of the output that resulted from the estimates of equations 2 and 3 leads us to conclude that similar improvements await the estimation of some of the other components in the model. The economic model is probably the most important to work on in this respect. Estimation of the microallocation functions should be high on any priority list for empirical work. These conclusions are summarized by noting that the performance of the model

1. Is greatly improved over the past year because of structural changes in estimating regional housing (by type) and by the inclusion of a dynamic demolition algorithm,

Figure 5. Effect of policy options on total unzoned vacant land by time.

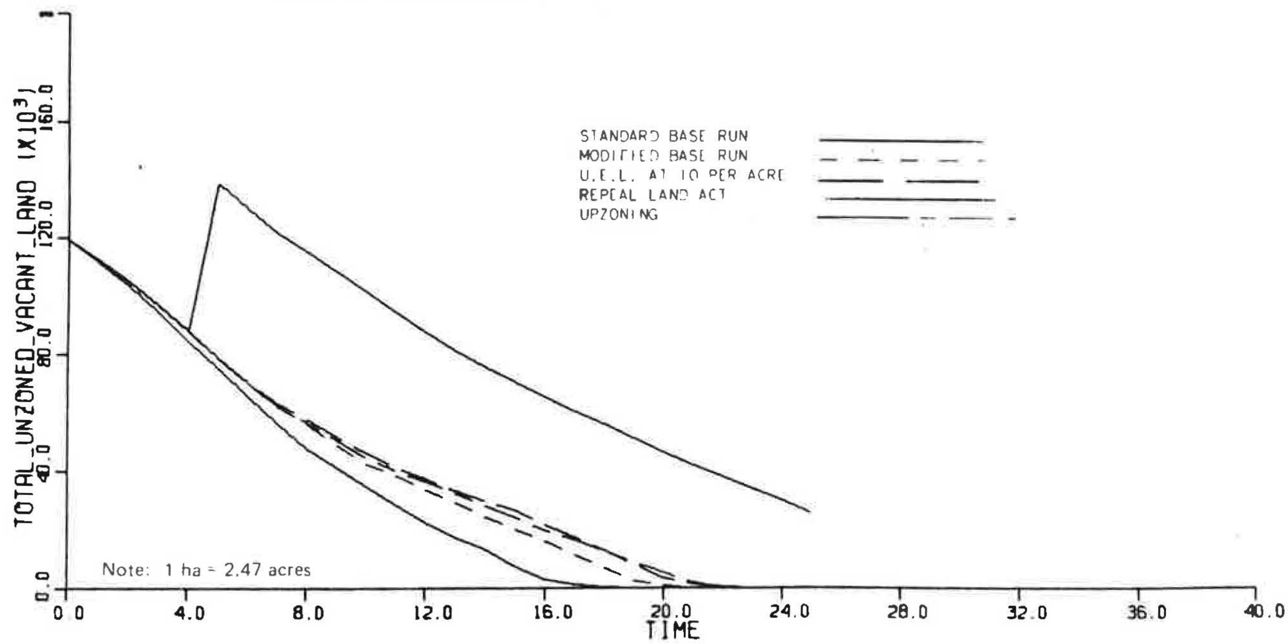


Figure 6. Effect of policy options on housing units for regions 1 and 14 by time.

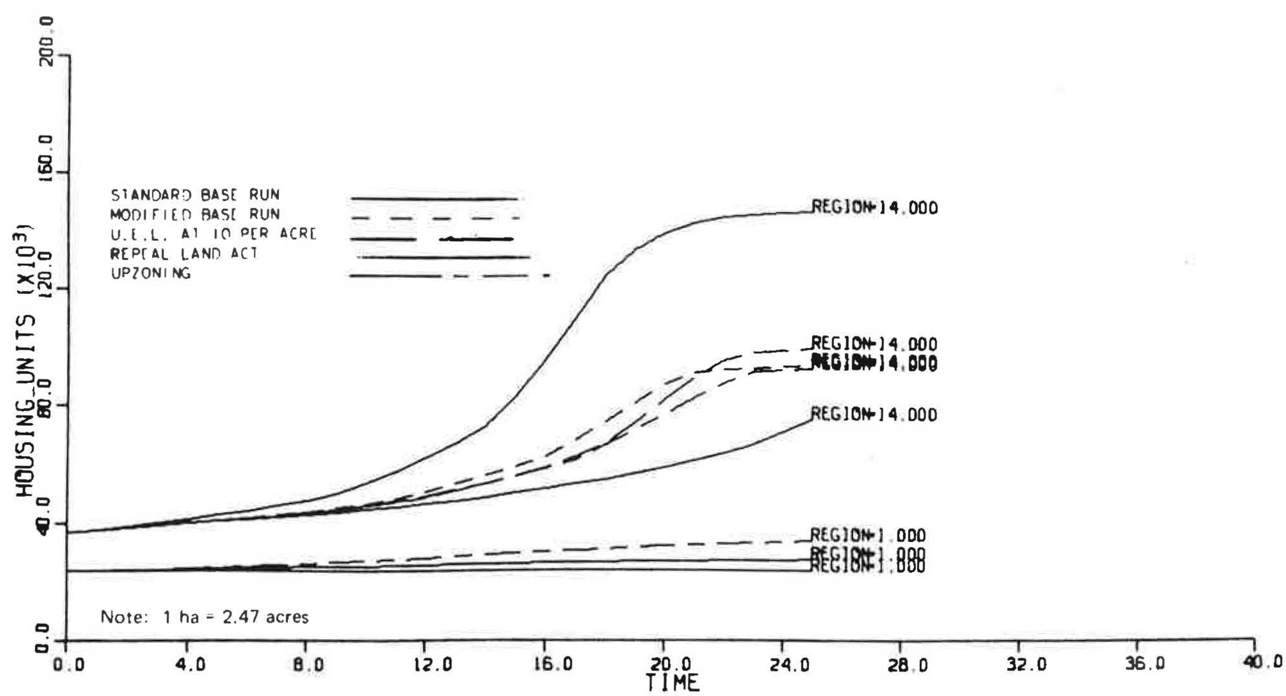


Figure 7. Intervention of university endowment land option on housing units by time and by region.

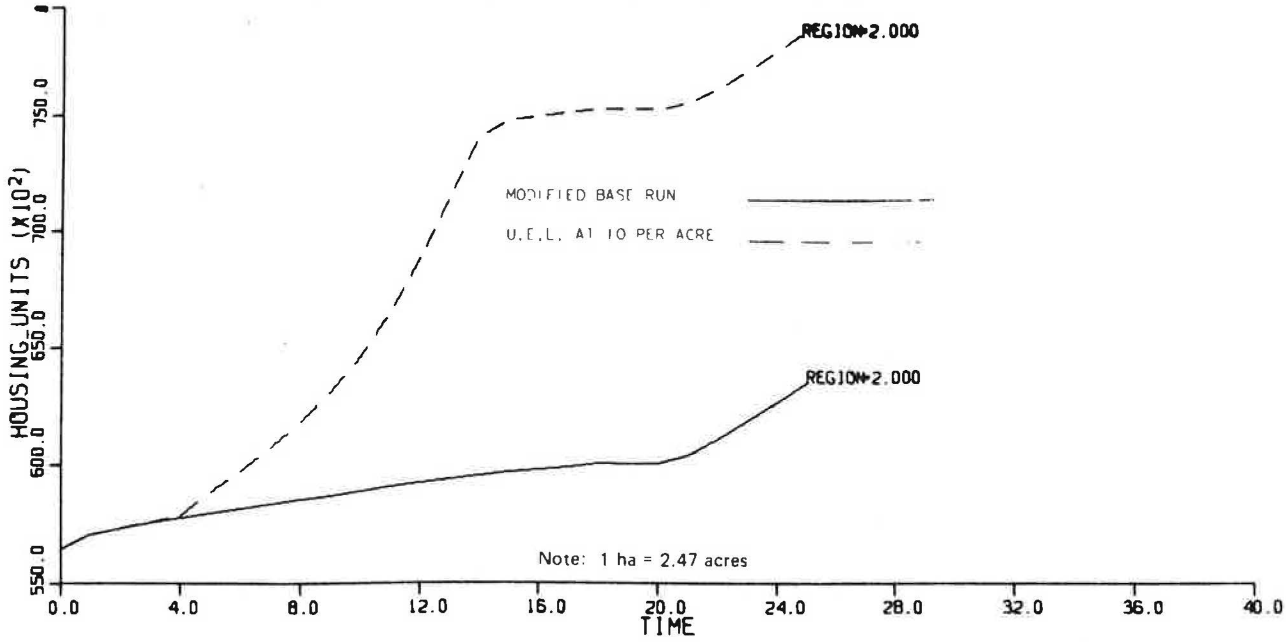
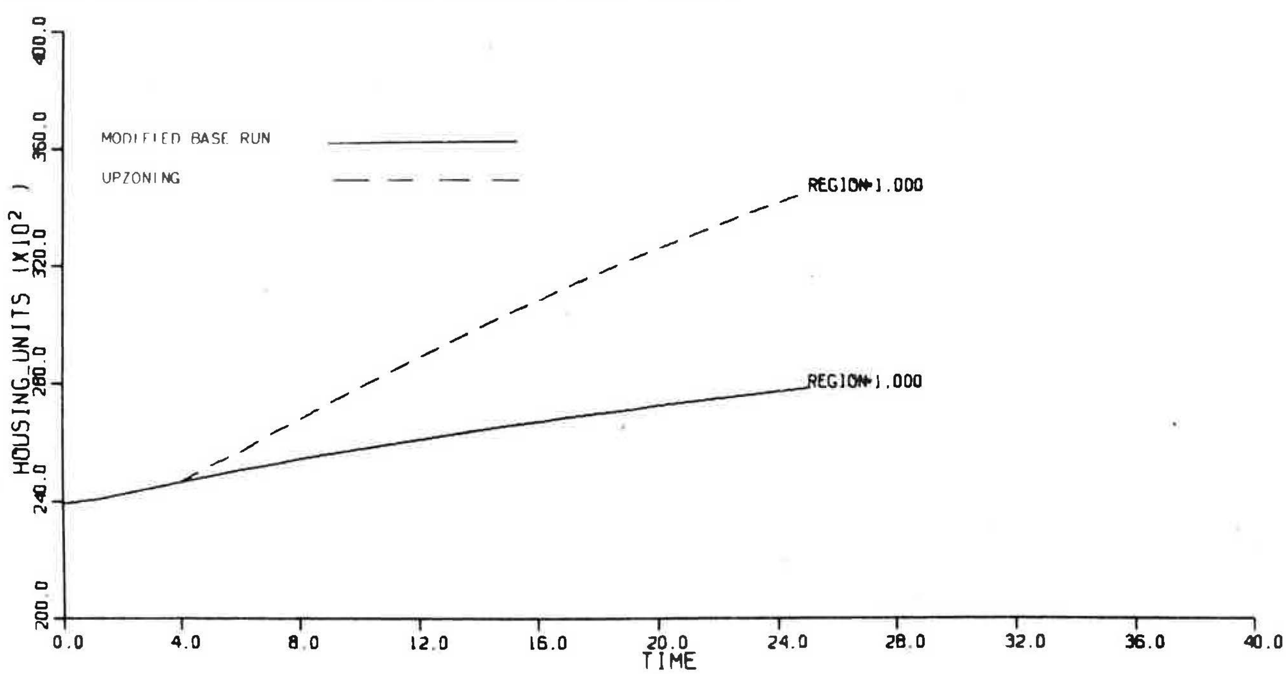


Figure 8. Intervention of upzoning option on housing units by time and by region.



2. Is more realistic because of the improvement in output and policy-testing flexibility,

3. Is more usable and useful because of the above, and

4. Still needs considerable empirical work on a number of key elements such as the regional employment forecasts and the housing and employment location algorithms.

CAVEATS

We strongly feel that models should not be sold as cure-all products. If any selling is to be done, it should be directed toward alerting users and potential users to the weaknesses and limitations of the model. Several authors (8, 9) provide excellent alerts to the unsuspecting and unknowing public who use models. Such warnings should be sounded at regular intervals, since recent survey work (10) reveals that models are used more widely (and we suspect less critically) than had been generally believed. Perhaps a skull and crossbones should be made to grace each page of output along with a warning from the Urban General (the Surgeon General's counterpart) that programming and models can be injurious to your health.

The intelligent and productive use of models (and of technology as a whole) can only proceed if the fundamental weaknesses of the models are acknowledged. Models are abstractions from reality and as such are imperfect and incomplete representations of that reality. To explicitly consider these weaknesses is to go far in the direction of overcoming them.

CONTINUING WORK

Throughout the process of developing these models and of writing a description of them over the past several years, we have stressed the need for an evolutionary approach to model building. We have accomplished this process under the IIPS corporate establishment or on our own. The latter approach appears to be the most productive, since it is the slowest and least visible way to proceed. Visibility breeds bigness, bigness breeds organization, and organization breeds product orientation.

Because we have chosen to take a more limited view of and approach to the continued development of the models, we have not lost sight of the dangers of success that are akin to those that accompany visibility. Our progress is far from revolutionary, but it does represent a continual series of evolutionary changes in the reliability, usefulness, and usability of the models.

For the future, we hope to begin with improvements in the technical details of the models and end with improvements in access to and use of the models. Refinement along the lines mentioned earlier that stressed the empirical estimation of key elements is most important. We have recently obtained detailed information from the 1971 Canadian census and are in the process of obtaining improved employment and land use data. With such data at our disposal, we anticipate further empirical analysis to be completed during the year and the results incorporated into the models.

As the models become more useful, we hope that policy makers, politicians, and citizens will take advantage of the opportunities afforded by having working and useful models in Vancouver. Of all the possible directions that lie ahead in our modeling process, we hope that an increased use of the models is the most likely. It is only through widespread use, criticism, and reuse that we can carry on the process of model development that we have envisioned.

ACKNOWLEDGMENT

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