COMPUTER MODELLING OF BOOMTOWN HOUSING
THE FORT McMURRAY STUDY

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Introduction

A plan looks to the future. Town planning requires the anticipation of an expected pattern of change through time; it also presumes that town officials can anticipate the consequences of actions that they might take to guide or manage future developments for the good of local residents. These simple observations are especially relevant for planners who must make analyses and recommendations for resource boomtowns in the sparsely populated areas of Canada.

As these towns experience rapid resource development in their regions, they often exhibit some common characteristics which have come to be known collectively as "boomtown phenomena". Among these characteristics are a large initial influx of construction-worker families; severe shortages of housing, commercial services, and public facilities with consequent high prices, crowding, and social malaise; fiscal stress and high tax rates; reduced worker morale and productivity; and, in some cases, a final "bust" phase where demands and prices may collapse. Planners who must try to anticipate these phenomena and reduce their adverse impacts are faced with the problem that the various phases in the boom-bust cycle can be extremely brief when compared with the pace of events in a "normal" town that has a stable or slowly growing economic base.

Time lags in the responses of markets and institutions to incremental changes, which may be insignificant in the normal evolution of a town, can become important in the case of a boomtown. Because of these time lags, the precise timing of the driving economic forces and impact-mitigating policies can have profound effects on the pattern of town evolution. If, for example, town officials had completely reliable information several years in advance of the initiation of a large project (e.g., information concerning its
construction schedule, size of work force, and subsequent developments) they could begin developing needed public facilities in advance, thereby counteracting the time-lag and the shortages that would otherwise occur. The problem for planners, in the absence of such perfect information, is to anticipate the likely time sequence of events and the probable response of institutions and markets that are unaccustomed to the rapid pace of a construction boom. The models used for this purpose, be they informal or mathematical, must account for the way a town can change over time while still representing the "inertia" or "momentum" built up from previous decisions by public and private officials.

This paper provides a brief sketch of a formal, mathematical model that has been developed to simulate the changes that a boomtown undergoes as it responds to rapid development. The purpose of the model is to help industry and government decision-makers anticipate the effects of various proposals thought to be of assistance in dealing with the severe problems that occur in boomtowns. This model is an extension and adaptation of a prototype, generic model called BOOM1 [3], that was developed at Los Alamos Scientific Laboratory in order to help assess the local impacts of rapid development of western U.S. coal reserves, as required by the 1975 U.S. Coal Assessment Act. One of the present co-authors subsequently extended the housing sector portion of the model, resulting in a model called BOOMH [11]. Other extensions have been made by other research groups as well [8;9], and the model has been critically reviewed [12].

This generic model has recently been applied to a test case in Alberta, the new town of Fort McMurray, during the Syncrude planning and construction phase of 1971-1979. Syncrude is a consortium of oil companies and governments formed for the mining of oil sands in Northeastern Alberta. The objective of this exercise was to see if the model, with its constant parameters specified for Alberta conditions and its variables initialized to appropriate values for the Fort McMurray of 1971, could "track" the actual growth pattern that occurred from 1971 to 1979. If it could, confidence in its use as a possible planning tool for future boomtowns would be increased.

In the following two sections brief discussions of the generic models BOOM1 and BOOMH are presented. These are necessarily abbreviated, since full technical description is not possible within a paper of this scope. Some results of the Fort McMurray test application are presented in the final section.1

1 More of the technical details, for the housing sector of BOOMH, are included in an appendix available from the authors.

The Booml Model

This family of models utilizes the system dynamics methodology of Forrester [4], which had previously been used to model settlements ranging in scope from a city [5] to the world [6]. System Dynamics is "that branch of control theory which deals with socio-economic systems, and that branch of Management Science which deals with problems of controllability" [4]. Alternatively, it may be defined as "a method of analyzing problems in which time is an important factor, and which involve the study of how a system can be defended against, or made to benefit from, the shocks which fall upon it from the outside world" [1:2]. In the case of the boomtown system, the shock takes the form of the massive influx of construction workers needed to build new facilities.

In studying how towns might defend themselves against the adverse effects of such shocks, special recognition is given to chains of interactions which close on themselves to form "feedback loops", since it is known that these loops control the temporal behaviour of the system variables.

A negative feedback loop, where the effects of an exogenous increase in any variable propagate through the loop and return to cause a decrease in that variable, tends to stabilize the behaviour of the system, whereas a positive feedback loop is self-reinforcing and tends to force the system variables away from their equilibrium values.

Figure 1 shows the sectors of BOOM 1 and one of the several feedback loops in the model. This particular loop represents an exasperating chain of interrelationships that is thought to degrade the quality of life in a boomtown. The Denver Research Institute investigators [2] present the phenomenon in this manner:

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.

The cause/effect relationships cited by the investigators are shown as arrows in Figure 1, and the sign at the head of each arrow
indicates whether the cause and effect variables change in the same (+) or in opposite (-) directions. Since the overall effect of the feedback loop is self-reinforcing, a (+) is placed in the middle of the loop to label it as a positive feedback loop. The quantitative relationship between "Facilities per Capita" and "Productivity of Construction Workers" is modelled through the use of an adverse boomtown index of the form

\[
BT1 = 0.2 \text{ (fractional current housing shortage)} + 0.2 \text{ (fractional current retail services shortage)} + 0.2 \text{ (fractional current public services shortage)} + 0.4 \text{ (fraction of current population that is temporary)}
\]

where the fractions are computed by the corresponding sectors of BOOM1. The weight values were specified on the basis of a small survey of expert opinion and should be adjusted if further evidence so indicates.

The current productivity of construction workers is then computed as a function of the smoothed index ABTI, where the assumed productivity function is shown in Figure 2. Again, this function is specified on the basis of rather limited data (the Rock Springs case) and should be adjusted if more data become available.

The Boomtown Housing Problem and The BOOMH Model

Families across North America are feeling the effect of increasing housing prices. In small towns that experience rapid growth the housing problem is made worse by the following unique factors:

- unavailability or inflated cost of skilled construction labour;
- difficulties in assembling suitable land in time for housing development;
- lack of water and sewer facilities in time to permit housing development;
- high risk associated with the variability in population during construction of energy facilities and the uncertainty associated with a "one-industry" town;
- limitations on local housing entrepreneurial skills; and
- limitations on local home mortgage funds.

The combination of nation-wide trends in housing costs and these unique boomtown factors have caused housing shortages to be one of the most acutely and widely felt impacts of the rapid population growth accompanying development.

Many kinds of planning and regulatory policies have bearing on the boomtown housing problem. An insistence on proper zoning and high standards for all development can prevent the "instant slum" that may develop if temporary housing is placed haphazardly on land that is not adequately serviced. Such high standards may, however, imply such a lengthy approval process that the housing supply response is effectively choked off, again demonstrating the effect of time delays in boomtown evolution. A careful assessment of the effectiveness of various housing assistance proposals requires an understanding of the complex interrelationship between the supply and demand for housing under boomtown conditions. The boomtown housing model described here was developed to help provide that understanding.

This model differs from BOOM1 only in that the housing sector is treated in more detail, in order to permit studies-by-simulation of some of the issues mentioned above. The new housing sector focuses on three aspects of the boomtown housing market:
PRODUCTIVITY AS A FUNCTION OF AVERAGE BOOMTOWN INDEX

Figure 2

Productivity Multiplier

Y-axis: Productivity Multiplier
X-axis: ABTI
1. Supply and demand for permanent housing
2. Supply and demand for temporary housing
3. Use and value of land.

Permanent housing represents an aggregate of housing types ranging from single-family-detached to apartment units, while temporary housing is exclusively identifiable with mobile homes. Land values are distinguished according to whether the land is already developed for permanent or temporary housing, is immediately ready for development, or is expected to be developed some years in the future.

Outlined in the following tables and paragraphs are the causal links between housing-sector variables that are assumed in the model. This is done merely to give an example of the kinds of structural assumptions and reasoning that are incorporated in this model. Similar outlines are available for the other sectors of BOOM1 [3], but are not given here.

**Permanent Housing**
The key assumptions governing the supply and demand for permanent housing are listed in Table 1. The interplay between the supply and demand factors is as follows:

### Table 1

**ASSUMPTIONS FOR PERMANENT HOUSING**

<table>
<thead>
<tr>
<th>Demand Factors</th>
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<tbody>
<tr>
<td>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.</td>
<td>2. Shelter payments depend on market price of housing, property tax rates, and mortgage interest rates.</td>
<td>3. Market price of housing rises or falls in response to variations in the vacancy rate.</td>
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<td>Supply Factors</td>
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<tr>
<td>1. Builders plan projects on the basis of a shortfall of housing stock as compared with the number of permanent-type families.</td>
<td>2. Planned rate of starts will be reduced or nullified if unit costs rise to approach or exceed market price of finished unit.</td>
<td>3. Building cost depends on productivity of labor that may decline under adverse boom conditions.</td>
<td>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.</td>
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</table>
Supply and demand for permanent housing may be characterized in the form of a "word and arrow" diagram as shown in Figure 3. This diagram focuses on only two of the key feedback loops of the model (a diagram showing all the variables and interconnections on one page would be incomprehensible). These loops operate to control the stock of housing as follows:

**The supply loop** reacts to a housing shortage whenever the housing price rises to a sufficient level that a favourable 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 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 via changes in the vacancy rate and market price as well. A more severe shortage is reflected in lower vacancy rates which 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.

**Temporary Housing**
In many of the simulation runs with BOOMH, the number of families grows much more rapidly than the stock of permanent housing. Under such circumstances, a strong market for temporary housing is created. The key assumptions governing the behaviour of the temporary housing market are listed in Table 2. Notice that several of the assumptions in Table 2 are similar to corresponding assumptions governing the supply and demand for permanent housing. Indeed, the supply and demand for temporary housing is controlled by a pair of feedback loops that act in the same way as the loops shown in Figure 3.

**Use and Value of Land**
BOOMH keeps track of the use of land for two reasons. First, exhaustion of easily serviceable land can drive up the costs of bringing water and sewer services to new housing developments in many communities. This is especially true when towns are located in mountainous terrain or in areas where large tracts of land are not available for development. Secondly, the rapid conversion of "raw" land to permanent use imparts a speculative value to the remaining land with potential for conversion. As Table 2 indicates, a high speculative value of "raw" land may slow the development of temporary housing as investors hold the "raw" land, waiting for higher profits available from conversion to permanent use. Table 3 lists the assumptions for the land speculation model.

**Legend:**
- A increases B
- A decreases B

**Figure 3**
SUPPLY AND DEMAND FOR PERMANENT HOUSING
Table 2

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 rates, 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.

Table 3

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.

Parameters of the Model and Results

for Fort McMurray, 1971-1979

The value of each constant parameter of the BOOMH model, as applied to Fort McMurray, is described in a separate technical report [13]. In some cases, the parameter estimates were obtained from discussions with local officials; in other cases, secondary sources were used; and for some parameters the authors’ judgement was used to specify a plausible parameter value. This was done without regard to the expected outcome of the test-case simulation run. The generic structure of the BOOMH model was retained in all sectors. Initial values of the model variables, for 1971, were obtained from census data and other town statistics. These include employment by sector; mean income; and stocks of housing, retail facilities, and public facilities.

The “driving input” to the model was taken as the expected employment at the Syncrude project, both of construction workers and permanent workers. The model-predicted number of construction jobs is computed for each year by an equation that applies to the nominal input number the labour-productivity factor referred to previously.

The impact-mitigating policies that were actually planned and implemented in Fort McMurray during this period were also specified for the model. These include company-sponsored development of more than 4000 units of housing and advanced planning and development of town infrastructure, with capital grants from provincial government. A further, major reduction of impact on the town was achieved by the provision of job-site dormitories for approximately 85 per cent of Syncrude construction workers at all times. Since these policies were planned from the beginning, they would have been specified for a model simulation that might have been run in 1971 had the model been available and in use as a policy-assessment tool.

Results of the “test case” run are shown in Figures 4, 5, and 6. Shown are the computer-generated predictions of Syncrude construction jobs, town population growth, housing demand and supply, and housing prices (the latter in constant 1971 dollars). Also shown in Figure 4 are the patterns of Syncrude jobs and population that actually occurred. Note that these projections extend to 1988.
This was done so that the “downside” behaviour of the model could be examined. The assumed additional driving input to the model from 1979 to 1988 consists of the new construction and operating jobs that are expected to be generated by the proposed Syncrude and Suncor expansion programs, but with no new oil sands projects.

Examining Figure 4, it is apparent that the model-predicted town population does not “track” perfectly with the actual census data. The agreement is very good until 1975, but there is a shortfall of about 3000 persons arising in that year. This deviation does not increase thereafter, as the curves rise in parallel fashion. The model is actually fairly successful in tracking population growth of this rapidity. A consultant’s forecast [10] of final town population, made in 1973, was 15,000 persons, whereas the actual 1978 population was 24,580 and the model “population” is 23,129 for the end of 1978.

Part of the reason for the model discrepancy is evident in the Syncrude construction workforce curves of Figure 4. The expected peak employment that was fed to the model was 5,137 workers. The model, after computing the labour productivity factor, predicts a peak of about 5,600 workers, and the actual peak workforce was 7,865 in July of 1977. This was caused, in part, by the need to “catch up” on the construction schedule after a temporary slowdown in 1976 when there was uncertainty as to whether the project might be cancelled. The direct effect on town population is a smaller discrepancy than this, however, since most of these workers were housed at the job site. Other indirect effects of the construction boom must be assumed to account for the major part of the error in the population prediction. One of the unmodelled effects is the movement of unemployed people to an area which is about to boom, in numbers far greater than the number of new jobs that will actually be available, as happened in the Alyeska pipeline construction project in Alaska. This also happened in Fort McMurray in 1975, and the phenomenon is one of the “prediction problems of the first kind”. Nevertheless, simulation runs could be prepared which test the effect of various assumed numbers of such migrants.

Figure 5 shows the model-generated stocks of occupied standard housing and the number of families resident in town who occupy this housing. For most of the period, the difference between “families” and “standard housing” remains less than 395 units, which is the number of substandard units that were present in 1971 and are occupied by the low-income families who have not been able to qualify for standard housing. Thus, the model predicts almost no absolute shortage of housing in Fort McMurray during the Syncrude construction boom, except for the final years 1978-1979. Examination of other model outputs shows that years 1978-79 are characterized by a nearly adequate quantity of housing, but, as an
Fort McMurray test-case run.
- Run with alternative policies, no prebuilding of public facilities or company housing.
Figure 5

MODEL-PREDICTED HOUSING UNITS NEEDED (FAMILIES) AND HOUSING UNITS OCCUPIED

- • Fort McMurray test-case run.
- Run with alternative policies, no prebuilding of public facilities or company housing.

(Thousands)


Families

Occupied Standard Housing
aftermath of the boom phase, at such high prices that some families in town cannot afford to occupy housing units of their own. The computed vacancy rate is consequently rather high during this period (about 10 per cent during 1979) and prices are decreasing in constant-dollar terms.

These observations also agree reasonably well with the actual housing situation in Fort McMurray during the period. Thanks to good planning by public and private officials, the adverse impacts of the Syncrude project on the Fort McMurray housing market were relatively modest, given the rates of growth that took place. There were only brief periods, generally in summer months when construction activity hit seasonal peaks, when some new residents were living in unserviced and unapproved lodgings (such as tents in the town park areas). There was also some doubling-up of service-sector families during other periods, but at the same time there was empty housing in the subsidized (company) sector so there was no housing shortage in the aggregate.

The actual vacancy rate in 1979 was also rather high, about 10 per cent for permanent housing units, and the supply is adequate. Average market price for a standard 1000-square-foot bungalow is estimated at $70,000 in 1978, which, when deflated to 1971 dollars by the national cost-of-living index, comes to $39,900. The model-predicted price peaks at $38,229, at the beginning of 1979, as shown in Figure 6.

It may be noted that the model “predicts” a drop of about 13 per cent in constant-dollar housing price during 1973. Considering the rise of almost 11 per cent in the consumer price index for the year, this still corresponds to a slight drop in current dollars, which probably did not occur in the Fort McMurray housing market. In fact, 1973 was a year of rapid inflation in the Canadian housing market generally. Reasons which have been cited [7] include a growing general perception of real estate as being a good hedge against inflation, with expectation of superinflation in housing prices due to continuing shortages of serviced lots in Canadian municipalities. Needless to say, the computer model described here does not account for local price changes that may be caused by general speculative activity of this sort.

Sensitivity Tests with Alternative Policies

In addition to the standard “validation run” of the model, with policy options approximating as closely as possible those that were actually implemented, two further runs have been made to see what might have happened under other alternatives. In the first of these runs, the pre-planning and front-end financing of town infrastructure that was actually done is eliminated and the model only
Model-Generated
Market Price of
Permanent Housing,
1971 Dollars

□ Fort McMurray test-case run.
△ Run with alternative policies, no prebuilding
   of public facilities or company housing.

Figure 6
MODEL-PREDICTED PRICE OF PERMANENT-TYPE HOUSING
(1000 SQ. FT. HOUSE, 1971 DOLLARS)
generates public facilities as a response to shortfalls, with the lags that typically occur. Furthermore, the preconstruction of housing by the Syncrude consortium for its permanent employees was eliminated for this run. These results are also shown in Figures 4, 5, and 6. In Figure 4, we observe that town “population” grows less rapidly in the period 1975-77 than it did in the standard run, because the extra town jobs/population that were engaged in prebuilding public facilities and housing during the period are missing in this run. Population growth is more rapid in 1978, however, as the permanent operating employees arrive and “catch-up” construction takes place in the town. There is also predicted a severe housing shortage of about 3,000 units during 1978-79, as is evident from Figure 5. Surprisingly, however, the price of permanent housing (Figure 6) reaches a peak of only $33,892 (1971 dollars) in 1978 for this run, as compared with $38,229 for the validation run.

The last result seems counter-intuitive, at first glance. Examination of model output and model structure, however, reveals why this happens; indeed the outcome does makes sense and is consistent with conclusions that have been reached independently by others who have examined the overall effects of company housing. Essentially, the company-subsidized housing is served by a large share of the town’s available infrastructure during the boom phase of town growth, limiting the capacity of speculative builders to build other, non-subsidized housing. The company housing is made available only to company employees, however, leaving the remainder of town families to compete for the small supply of non-subsidized housing. The market-clearing price for this housing turns out to be higher than the price that would obtain if the entire supply of housing were available on an equitable basis to all residents.

Suppose that a town has 8,000 families, 3,000 units of subsidized permanent housing, and 3,000 units of nonsubsidized permanent housing; of the 5,000 nonsubsidized families fully 2,000, or 40 per cent, must fail to qualify for a house. If, on the other hand, all 6,000 units of housing were on the same market, only 25 per cent of the 8,000 total families must fail to qualify. The qualifying income, and hence housing price, must clearly be higher in the former case. The implication of this is that the presence of subsidized housing may impose a real financial cost upon those residents who are not eligible for it, compared with their situation in a free housing market. Of course, the elementary calculations given here can be done without the aid of a complex computer model, but note that the assumption was made that the same number of housing units would be supplied in both cases. This is clearly unrealistic, since the primary role of company housing is to help increase the supply in a situation where it would otherwise be grossly inadequate, as demon-
strated in Figure 5. If ones tries to relax this assumption, the calculations quickly become non-elementary, and the conclusion of the previous paragraph is by no means intuitively obvious.

Higher property taxes, in the run without prebuilding and front-end financing of infrastructure, also serve to hold down housing prices; these peak at $566 per year, compared with $361 for the validation run. This accounts for approximately $1500 of the $4500 difference between peak housing prices for the two runs, using the mortgage-industry formulas for the relationship between IPT shelter payments and purchase price for a qualified buyer.

A further run was made in which, in addition to the absence of pre-planning and company housing as in the above run, the job-site lodgings for construction workers are assumed to be absent. The results in this case show an extreme example of the classic, pathological boom/bust cycle. Model “town population” rises to a peak of more than 34,000 in early 1978, most of whom are housed in trailers, falling back to the 23,000 level in early 1979. The boomtown index (ABT1, described previously) peaks at about 0.79 for this run, whereas it peaks at 0.21 for the previous run and at 0.11 for the basic run that corresponds to actual outcomes. Thus we would conclude that the provision of job-site lodgings had the most significant and beneficial effect on the quality of life in the town.

Conclusions

The simulation model BOOMH, which had been developed as a generic boomtown growth model based on the system dynamics methodology, has now been found to be adaptable to a real boomtown and to be reasonably successful in reproducing major features of the construction boom that occurred with the 1973-79 Syncrude project near Fort McMurray, Alberta. Although the generic model was intended only for testing the differential sensitivity of boomtown indicators to various impact-mitigating policies, the fact that it “tracks” a real situation fairly well, when the real initial conditions and policies are specified, lends some credibility to the model and allows some confidence in its use as a policy-testing device.

Computer simulation runs made with other policy scenarios suggest that the provision of company housing, restricted to company employees, may have negative implications for the non-company sector of town population at the same time as it is having positive effects on the total housing supply. It would perhaps be better to have the kind of extensive front-end planning and infrastructure financing that went into Fort McMurray, but without restrictions on eligibility of any town resident to occupy the resulting housing. A further run shows that the provision of job-site lodgings for single construction workers made the major contribution to-

wards helping to avoid the classic, catastrophic boom/bust cycle in Fort McMurray.

Work with this model is continuing. It is expected that, in the immediate future, the model will be applied to some policy advisory questions related to further development of the Athabasca Tar Sands.

References