RESIDENTIAL DEVELOPMENT: A MICROSPATIAL ALLOCATION MODEL

by

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ABSTRACT

The focus of this study was the development and testing of a micro-spatial supply model which could explain and predict the allocation of residential development to subareas within a region. This involved a three step process.

The first step was a review of the literature to determine what criteria were considered important in the location of residential development. Two types of location criteria were found to be important. The first of these criteria were intuitive accessibility measures used in other modelling studies. The second type of criteria were potential supply criteria suggested as important by surveys of residential developers.

The second step involved the measuring and testing of various potential supply and accessibility measures to see which were important in explaining the allocation of residential development within the Greater Vancouver Regional District (GVRD). From these tests a microspatial allocation function was derived which could be tested in a large scale urban model of the GVRD.

The third step involved incorporating the microspatial allocation function into the supply sub-model of a large urban model and running the model for four simulated years. The simulated data was then compared with actual data before and after the inclusion of the allocation function. Finally, the results of the tests were compared to similar studies which had compared simulated data with actual data.

The test results indicate that approximately 50% of single family development and approximately 75% of multiple family development could be explained by potential supply measures. Accessibility measures were of little significance in explaining single family development, and explained only about 10% of multiple family development.

The results of testing the microspatial allocation functions in a large urban model were not as encouraging as the explanatory tests. Generally, the results of tests which compared actual data with simulated data indicate that the increase in performance with the microspatial allocation function was marginal. However, compared to similar studies the results are acceptable.

In general, the study indicates that behavioural studies of the role played by developers combined with analytical models of this behaviour may provide considerable insight into the nature of the development process. It also lends strong supporting evidence to the suggestion that government organizations have been effective in allocating growth by their servicing and zoning policies.

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Chapter 1

INTRODUCTION

Most of the residential location and land-use models developed to date can be characterized as metropolitan growth or extension models. The very first of these models, such as the one developed for the Chicago Area Transport Study, which was described by Hamburg and Creighton in the Journal of the American Institute of Planners in May 1959,[1] provided fairly simple forecasts of the future demands for transportation facilities, often made by estimating the future demands for housing and other urban land uses based on existing land use patterns and the observed demand for existing transport facilities.

With the increasing availability of electronic computers during the early 1960's and the realization that patterns of metropolitan land use could be explained and predicted by mathematical models, land-use modelling efforts began to grow in both complexity and size. Most of the large Canadian, U.S. and British city planning departments experimented with large land-use and transportation models which would probably cost several million dollars each today.[2]

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[1] J.R. Hamburg and R.L. Creighton, "Predicting Chicago's Land Use Pattern," Journal of the American Institute of Planners, Vol. 25, No. 2 (May 1959), pp. 67-72.

[2] Examples of the American experience are: Ira S. Lowry, A Model of Metropolis (Santa Monica, California: The Rand Corporation, 1964) and Bay Area Simulation Study (BASS) (Berkeley, California: Centre for Real Estate and Urban Economics, The University of California, 1968). The British experience is well summarized in the works of Alan G. Wilson, including: Urban and Regional Models in Geography and Planning (London: John Wiley, 1974) and A.G. Wilson, P.H. Rees and C.M. Leith (eds.) Models of Cities and Regions (London: John Wiley, 1977). The general experience is well

Even though there has been extensive research into various types of land use models, no consensus of opinion regarding the best model to use emerges from the literature on land use models. Many authors stress the constant state of revision and refinement which they feel is an important part of land-use modelling. This constant state of revision, testing and refinement has led to a great diversity of land-use models, each with its own particular weaknesses and strengths.

The three major classes of present models are: descriptive models, predictive models and planning models.[3] Within each of these applications various modelling structures such as market sensitive, non-market sensitive, behavioural, non-behavioural and integrated have been attempted. The resulting literature is vast and no attempt will be made here to survey it all. For the interested reader, general discussions of land-use models, including bibliographies of some length, are contained in the works of Boyce _et al._,[4] Brown _et al._,[5] Kresge and Roberts,[6] Goldberg

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summarized in: S.H. Putman, "Urban Land and Transportation Models: A State-of-the-Art Summary," _Transportation Research_, Vol. 9 (1975), pp. 187-202 and J.R. Pack, "The Use of Urban Models: Report on a Survey of Planning Organizations," _Journal of the American Institute of Planners_, Vol. 41, No. 3 (May 1975), pp. 191-99.

[3]For a detailed description of these three types of applications see: Ira S. Lowry, "A Short Course in Model Design," _American Institute of Planners Journal_, Vol. 31 (May 1965), pp. 158-166.

[4]D.E. Boyce, N. Day and C. McDonald, _Metropolitan Plan Making_ (Philadelphia: Regional Science Institute, 1972).

[5]H. James Brown _et al._, _Empirical Models of Urban Land Use: Suggestions on Research Objectives and Organization_ (New York: National Bureau of Economic Research, 1972).

[6]David T. Kresge and Paul O. Roberts, _Systems Analysis and Simulation Models_ (Washington, D.C.: The Brookings Institute, 1971).

and Davis,[7] Stephen Putman and Alan Wilson.[9]

The criticisms of residential location and land use models are far too varied and abundant to be effectively summarized here. However, the important criticisms which have evolved are: (1) the almost exclusive concentration on the demand side of the housing market, and (2) the lack of convincing behavioural content.[10] Admittedly some models have attempted to incorporate supply, but the dominant theme in most models is that supply reacts to demand, and that demand for a subarea of a region is measured by the accessibility of the region to such factors as employment and shopping. The heavy reliance of land use models on independent variables which reflect accessibility is indicated by Table 1. Not all of these variables were included in all models, and the dependent variables used varied between models. However, the table does indicate the types of variables which were used depending on data availability.

Even though the dominant theme in many land-use and transportation models has been that supply reacts to demand, and that demand for a subarea of a region is related to the accessibility of the subarea to such factors as employment and shopping; there have been models developed which do incorporate supply variables into a housing market model. Examples of these models are: (1) the Bay Area Simulation Study

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[7]Michael A. Goldberg and H.C. Davis, "An Approach to Modelling Urban Growth and Structure," Highway Research Record, No. 435 (1973), pp. 41-55.

[8]Stephen H. Putman, "Urban Land Use and Transportation Models: A State-of-the-Art Summary," Transportation Research, Vol. 9 (1975), pp. 187-202.

[9]Alan G. Wilson, Urban and Regional Models in Geography and Planning (London, England: John Wiley, 1974).

[10]An excellent summary of the problems associated with land use and transportation models is contained in: H. James Brown et al., Empirical Models of Urban Land Use: Suggestions on Research Objectives and Organization (New York: National Bureau of Economic Research, 1972), especially Chapter 9.

Table 1

ACCESSIBILITY AND EXISTING LAND-USE MODELS

TYPICAL INDEPENDENT VARIABLES

1. Amount of existing development
2. Marginal land not in urban use
3. Proportion of poor soil
4. Zoning
5. Socio-economic status
6. Availability of services
7. Proximity to non-white areas
8. Access to work areas
9. Total travel time to all areas
10. Access to other residential development
11. Straight line distance to CBD
12. Travel time to CBD
13. Distance to nearest major street
14. Distance to nearest playground
15. Distance to nearest shopping
16. Distance to nearest school
17. Residential amenity
18. Assessed value

TYPICAL DEPENDENT VARIABLES

1. Population by various income groups and employment classes
2. Population density by the various classes of 1
3. Single family and multiple family housing completions during a time period
4. Total land in urban use
5. Dwelling density by structure type and overall
6. Changes over time in each of the above

(BASS),[11] (2) The Southeastern Wisconsin Regional Planning Commission Study,[12] (3) the Inter-Institutional Policy Simulator Study (IIPS) at the University of British Columbia,[13] and (4) the NBER Urban Simulation Model.[14]

Exceptions to the lack of behavioural content in large land use models are not well documented in the literature on land-use modelling. Admittedly, studies of consumers and producers have been made, and some attempts have been made to test the results of these studies empirically, such as the studies by Kaiser at the University of North Carolina,[15] and Moore at the University of British Columbia.[16] However, to my knowledge no studies of the micro behaviour of developers or consumers have been used to derive empirical relationships which are useful in large scale land use models.

This lack of convincing behavioural content in land use models, and

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[11] Bay Area Simulation Study (BASS) (Berkeley, California: Centre for Real Estate and Urban Economics, The University of California, 1968).

[12] A Land Use Plan Design Model: Volume One - Model Development, Technical Report No. 8 (Milwaukee: Southeastern Wisconsin Regional Planning Commission, January 1968).

[13] Michael A. Goldberg, "Simulation, Synthesis and Urban Public Decision Making," Management Science, Vol. 20, No. 4 (December 1973), Part II, pp. 629-643.

[14] G.K. Ingram, J.K. Kain, and J.R. Ginn, The Detroit Prototype of the NBER Urban Simulation Model (New York: National Bureau of Economic Research, 1972).

[15] Edward J. Kaiser, A Producer Model for Residential Growth: Analyzing and Predicting the Location of Residential Subdivisions (Chapel Hill, N.C.: Institute for Research in Social Science, University of North Carolina, November 1968), p. 1.

[16] Richard A. Moore, A Development Potential Model for the Vancouver Metropolitan Area (Unpublished MBA Thesis, The University of British Columbia, 1972).

the heavy concentration of these models on the demand side of the housing market, led to the conclusion that large scale land use models could be improved if convincing behavioural content could be incorporated into the supply side of the housing market. Accordingly, the purpose of this study was to investigate the potential usefulness of behavioural content in the supply section of a large land use model by:

(1) using the results of developer surveys to determine which location criteria developers considered important in their location decision;

(2) testing the important location criteria identified in (1) using regression analysis to determine which location criteria were useful in explaining the allocation of regional (macro) single and multiple family housing development to subareas within the region;

(3) developing regression equations based on the results of (2) which could easily be incorporated in the supply sub-model of a large land-use model to test their effectiveness in predicting the future allocation of residential housing development;

(4) testing the regression equations developed in (3) in a large scale model and comparing the model output before and after the inclusion of the regression equations.

Chapter two discusses the results of three developer surveys and two attempts which were made at measuring and testing the location criteria deemed important by the survey respondents. The first study discussed was undertaken by Edward J. Kaiser at the University of North Carolina during 1968,[17] while the other two studies discussed were undertaken by Michael A. Goldberg at the University of British Columbia during 1972

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[17]Kaiser, A Producer Model.

and 1975.[18] The two attempts which were made at empirically testing the results of these surveys were undertaken by Kaiser on the North Carolina survey results, and by Richard Moore[19] on the results of Goldberg's 1972 survey.

Chapter three discusses the procedures used to test various residential developer location criteria and the results obtained. Specifically this chapter discusses: (1) the measurement of the dependent variables; (2) the measurement of the residential developer location criteria variables tested, including those suggested as important by the developer surveys and the accessibility measures suggested as important by the literature; and (3) the results obtained from the regression tests.

Chapter four describes the land use model used to test the regression equations derived from the developer surveys. Then Chapter five discusses the derivation of the regression equations and the output of the model before and after their inclusion. Finally, Chapter six presents a summary of the results of the study and discusses the implications of these results for policy decisions and future research.

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[18]The first survey is summarized in Michael A. Goldberg, "Residential Developer Behaviour: Some Empirical Findings," Land Economics, Vol. 50, No. 4, (Feb. 1974) pp. 85-89. The second survey is summarized in Michael A. Goldberg and Daniel D. Ulinder, "Residential Developer Behaviour 1975: Additional Empirical Findings," Land Economics, Vol. 52, No. 3 (August 1976), pp. 363-370. A detailed discussion of both surveys is contained in Michael A. Goldberg and Daniel D. Ulinder, "Residential Developer Behaviour: 1975," Housing: It's Your Move, Vol. II, Technical Reports (Vancouver, B.C.: Urban Land Economics Division, Faculty of Commerce and Business Administration, University of British Columbia, 1976), pp. 241-382.

[19]Moore, A Development Potential Model.

Chapter 2

IMPORTANT SUPPLY CRITERIA: THE DEVELOPER SURVEYS

1. Introduction

Two exceptions were previously noted to the lack of behavioural content in land use models.[1] Included in these two studies were three separate surveys of developers which were undertaken in an attempt to determine important developer location criteria. The first of these surveys was undertaken by a North Carolina group in 1965,[2] while the two other surveys were undertaken by groups at the University of British Columbia in 1972 and 1975.[3] This chapter discusses the results of these three developer surveys and the attempts made to test their results.[4]

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[1] A summary of the University of British Columbia studies is contained in, Michael A. Goldberg, "Simulating Cities: Process, Product and Prognosis," Journal of the American Institute of Planners (April 1977), pp. 148-157; while a summary of the University of North Carolina studies is contained in E.J. Kaiser and S.F. Weiss, "Public Policy and the Residential Development Process," Journal of the American Institute of Planners, Vol. 36 (1970) pp. 30-37.

[2] Shirley F. Weiss et al., Residential Developer Decisions (Chapel Hill, N.C.: Institute for Research in Social Science, University of North Carolina, April 1966).

[3] A complete discussion of the 1975 survey and a comparison with the 1972 survey is contained in: Michael A. Goldberg and Daniel D. Ulinder, "Residential Developer Behaviour: 1975," Housing It's Your Move, Vol. II, Technical Reports (Vancouver, B.C.: Urban Land Economics Division, Faculty of Commerce and Business Administration, University of British Columbia, 1976) pp. 241-382.

[4] See Edward J. Kaiser, A Producer Model for Residential Growth: Analyzing and Predicting the Location of Residential Subdivisions (Chapel Hill, N.C.: Institute for Research in Social Science, University of North Carolina, November 1968) and Richard W. Moore, A Development Potential Model for the Vancouver Metropolitan Area (Unpublished M.B.A. Thesis, The University of British Columbia, 1972).

2. The North Carolina Survey

The group at the University of North Carolina began their land use modelling efforts in the early 1960's by attempting to develop land use models based on accessibility measures and existing patterns of urban land use.[5] However, they realized the need for increased behavioural content on the supply side of their models early in their modelling efforts. Consequently, they undertook a survey of developers in 1965 to ascertain their actual development location criteria.[6] The justification for the North Carolina investigation into the behaviour of developers is very aptly summed up by Edward J. Kaiser in a 1968 monograph reporting on his empirical testing of developer location criteria.

> Why focus a research thrust upon the developer? One reason is that in spite of the important role played by the developer in the conversion of open land to urban residential use, he has been relatively ignored by investigators of residential growth. The viewpoint of the household as the consumer of residential services which flow from the residential package has been the dominant viewpoint in research concerning residential growth. Yet a substantial portion of new purchasers buy in speculatively built residential subdivisions. In this important segment of residential growth, the developer has already made the initial speculative commitment to a location. Consequently, the idealized consumer's choice in residential location is limited in actuality by the availability of suitable housing structure and location alternatives determined by residential developers.[7]

3. Kaiser's Tests of the North Carolina Survey Results

From the North Carolina interviews and a review of other literature

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[5] F. Stuart Chapin Jr. and Shirley F. Weiss, Factors Influencing Land Development (Chapel Hill, N.C.: Center for Urban and Regional Studies, University of North Carolina, August 1962).

[6] Shirley F. Weiss et al., op. cit.

[7] Kaiser, op. cit., p. 1.

Kaiser hypothesized that the variables presented in Table 2 would influence developer location to some extent. He found that contrary to previous popular opinions, institutional supply constraints were the most significant explanatory variables for the existence of subdivision. Location characteristics including accessibility measures were next, and the physical site characteristics had little or no significance.[8]

Kaiser's contribution is worth noting as he laid the ground work for investigating the locational criteria of developers by surveys, and for testing these criteria empirically. However, Kaiser's choice of a dependent variable which measured only the dichotomy between subdivision, or no subdivisions within a subarea of the region during the time period, rather than a dependent variable which measured the actual amount of residential development, is a major drawback to applying his results to larger scale urban land-use modelling. A more meaningful dependent variable would have been a measure in units, acres, or both, of the actual amount of residential development which occurred within subareas of the region during the time period.

4. The 1972 University of British Columbia Survey

A group at the University of British Columbia involved in a large urban modelling project called IIPS (for Inter-Institutional Policy Simulator) also realized the need for more behavioural and supply content in their model.[9] Consequently, they undertook an interview survey of sixty-three residential developers in the Vancouver area during the summer

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[8] Ibid., p. 19.

[9] For a summary of these studies see footnote 1 for this Chapter and footnote 18 for Chapter 1.

Table 2

KAISER'S RESEARCH RESULTS

Dependent Variable	
Did an area receive subdivision (Yes, No)	
Independent Variables	
Institutional Characteristics	
1. Availability of public utilities	most significant
2. Zoning protection	most significant
Locational Characteristics	
1. Socio-economic rank	spotty significance
2. Distance to CBD	spotty significance
3. Distance to nearest major street	spotty significance
4. Distance to nearest elementary school	spotty significance
5. Accessibility to employment areas	spotty significance
6. Amount of contiguous residential development	spotty significance
Physical Characteristics	
1. Proportion of marginal land	not significant
2. Proportion of poor soil	not significant

SOURCE: Edward J. Kaiser, A Producer Model For Residential Growth: Analysing And Predicting The Location Of Residential Subdivisions (Chapel Hill, N.C.: Institute for Research in Social Science, University of North Carolina, 1968).

of 1972.[10] The survey was concerned with various aspects of the development process including factors important in the site selection process. The results of the site location question are summarized in Table 3. A copy of the actual question asked developers and detailed tables of the results are presented in Appendix A.

5. Richard Moore's Testing of the 1972 Survey Results

After the survey was completed, Richard Moore of the University of British Columbia attempted to use the survey results to devise a model whereby the spatial allocation of new housing units in the Greater Vancouver Regional District (GVRD) could be explained.[11] His approach involved using the developer survey as a rough guide to the importance of the proposed location decision factors. He concluded that those factors which were of average or greater than average importance were potential determinants of the location of new housing development.[12]

In order to ascertain the degree of importance of each location criterion developers, Moore attempted to obtain a measure of each criterion that developers collectively stated was of above average importance. Table 3 presents the criteria developers stated were of above average importance broken down by developer type. Of these criteria Moore was able to obtain measures for census tracts in the GVRD of: (1) zoning, (2) travel time to central business district shopping, (3) price of land and (4) the availability of developable land. He then derived relative

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[10] Goldberg and Ulinder, op. cit.

[11] Richard A. Moore, op. cit.

[12] See Richard A. Moore, op. cit., pp. 52-53 for a description of the scope and methodology of his study.

Table 3

1972 SURVEY RESULTS

IMPORTANT LOCATION DECISION CRITERIA

Single Family Housing Developers

		MEAN	S.D.
* 1.	Proper zoning	3.49	0.97
* 2.	Price of land	3.38	0.81
3.	Access to trunk sewer	3.29	0.89
* 4.	Availability of developable land	2.91	1.00
5.	Nearness to schools	2.51	1.01
6.	Nearness to major shopping	2.29	1.01
7.	Nearness to major roads	2.07	1.19

Multiple Family Housing Developers

		MEAN	S.D.
* 1.	Proper zoning	3.45	0.86
2.	Access to trunk sewers	3.34	1.02
* 3.	Price of land	3.13	1.12
* 4.	Availability of developable land	3.00	1.12
5.	Nearness to major roads	2.36	1.17
6.	Size of the site	2.34	1.12
7.	Nearness to schools	2.16	1.26
8.	Nearness to major shopping	2.05	1.13

* Denotes criteria measured and tested by Moore.

SOURCE: Richard A. Moore, A Development Potential Model For The Vancouver Area (unpublished M.B.A. Thesis, The University of British Columbia, 1972) p. 63-64.

importance weights for these criteria, fitting them into the two general categories of: (1) measures of attractiveness and (2) measures of unused and total housing supply potential. Moore obtained his weights for the dependent variables of: (1) unit completions of single family detached housing and (2) unit completions of single family attached and apartment housing combined by using bivariate and multi-variate regression analysis. The regression coefficients were used as weights, which when applied to the characteristics of each census tract were intended to provide a ranking of relative development potential.

The results of Moore's analysis are presented in Tables 4 and 5. Table 4 presents the results of the measures of attractiveness in explaining the amount of single and multiple family housing development for the two time periods of 1961 to 1966 and 1966 to 1971. The only independent variable which seems to be significant in explaining the amount of development is the amount of underdeveloped land, a supply criteria.

Table 5 presents the results of unused and total housing development potential as independent variables. These measures of potential supply were calculated for both single and multiple family supply as follows.

(1) Total potential (units) = Land zoned for the particular use in acres times the maximum permitted zoning density for the use in units per acre.

(2) Unused potential (units) = Total potential of (1) in units minus the number of existing units.

The results of Table 5 indicate that total potential supply is more significant than unused potential supply, however, both are quite significat especially for the time period 1966 to 1971. Moore explains the lower R^2 for 1961 to 1966 is probably a result of using zoning data of 1970 to calculate total and unused potential. Moore sums up the significance of his results in the concluding comments of his paper by saying;

Table 4

REGRESSION RESULTS "MEASURE OF ATTRACTIVENESS"

Completions	$\bar{r}^2$	Student t Statistics		
		1/Price**	Time	Underdeveloped Land
sfd 61-66	0.09	-0.56	-0.40	2.73
sfd 61-66*	0.14	-0.53	-0.55	3.16
sfd 66-71	0.36	-0.86	0.83	4.76
sfd 66-71*	0.05	-0.48	1.19	1.51
apt 61-66	0.10	-0.71	3.66	0.62
apt+sfa 61-66	0.16	-0.58	3.36	2.95
apt 66-71	0.15	2.32	2.04	0.44
apt+sfa 66-71	0.05	0.88	1.65	0.15

*In these tests allowance was not made for acreage zoned for apartments but not yet occupied by apartments. The area was assumed to be occupied entirely by single detached housing. This was done to test the possibility that errors resulting from approximations in calculating this amount were preventing obtaining meaningful statistics.

**Price = Price level of land per unit if housing in 1964 and 1969. 1964 price used for 61-66 change and 1969 price used for 66-71. Time = Travel time to CBD for 1963 and 1968. Underdeveloped land = Land zoned for a use (acres) - land in use (acres). Measured for 1970. sfd = single family detached housing. apt + sfa = apartment and single family attached housing combined.

SOURCE: Richard A. Moore, <u>A Development Potential Model For The Vancouver Area</u> (Unpublished M.B.A. Thesis, The University of British Columbia, 1972) p. 88.

Table 5

REGRESSION RESULTS OF "UNUSED AND TOTAL POTENTIAL"

Completions = a + b x Unused Potential

Completions	a	σ_a	t_a	b	σ_b	t_b	$\bar{r}^2$	Degrees of Freedom
sfd 1961-66	19824.1	5744.3	3.45*	1.62	0.50	3.26*	.18	43
sfd 1966-71	93.9	83.6	1.12	0.0675	0.0074	9.12*	.66	43
apt+sfa 1961-66	4082.8	3807.8	1.07	11.79	1.29	9.11*	.41	118
apt+sfa 1966-71	15994.7	3822.9	4.18*	14.17	1.54	9.19*	.41	118
apt 1966-71	16602.9	3749.0	4.43*	13.89	1.48	9.39*	.42	118

Completions = c + d x Total Potential

Completions	a	σ_a	t_c	d	σ_d	t_d	$\bar{r}^2$	Degrees of Freedom
sfa 1961-66	16738.7	5947.4	2.81	1.70	0.47	3.63*	.22	43
sfd 1966-71	2.89	91.8	0.03	0.063	0.0072	8.73*	.64	43
apt+sfa 1961-66	2048.0	3673.0	0.56	10.65	1.05	10.17*	.46	118
apt+sfa 1966-71	11449.0	3546.0	3.23	11.61	1.01	11.49*	.53	118
apt 1966-71	12164.5	3394.0	3.58	12.61	1.04	12.11*	.55	118

*$P(t>2.62)_{118} = 0.005$, $P(t>2.70)_{43} = 0.005$

SOURCE: Richard A. Moore, A Development Potential Model For The Vancouver Area (Unpublished M.B.A. Thesis, The University of British Columbia, 1972) p. 89.

> The importance of the significant results concerning the number of housing unit completions as a function of potential (determined by the amount of residentially zoned land) lies in the reaffirmation of planner's power of directing development and redevelopment through zoning. That the price of land and travel time from the central business district did not appear to be significant determinants of the location of new housing allows the planner to discount the importance of these factors in his formulation of the city plan.[13]

6. The 1975 University of British Columbia Surveys

Concern for the smooth operation of the housing market in British Columbia led a group at the University of British Columbia to undertake a variety of studies concerning the structure of the housing market in the province during the summer of 1975. One of the studies undertaken within this framework was an extension of the 1972 developer survey by Goldberg and Ulinder.[14] The original developer survey was expanded and the sample size increased to 140 developers from throughout the province. The results of the question which was asked developers regarding the site selection decision are summarized in Table 6. A copy of the actual question asked developers and detailed tables of the results are contained in Appendix A. From these results Goldberg and Ulinder conclude:

> In contradiction to the findings of Kaiser and Weiss[15] in the Greensborough, North Carolina area, developers in British Columbia appear to regard supply variables as being more critical to their decision-making than demand determinants .... Developers require adequately serviced and appropriately zoned land. The availability of such land goes a long way to temper their location decision.[16]

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[13] Ibid., p. 97.

[14] Goldberg and Ulinder, op. cit.

[15] Kaiser and Weiss, op. cit.

[16] Goldberg and Ulinder, op. cit., p. 300.

Table 6

1975 SURVEY RESULTS

IMPORTANT LOCATION DECISION CRITERIA

Single Family Housing Developers

		MEAN	S.D.
* 1.	Proper zoning	3.32	1.08
2.	Price of land	3.23	0.96
* 3.	Access fo trunk sewers	2.93	1.29
* 4.	Availability of developable land	2.78	1.01
* 5.	Nearness to schools	2.42	1.08
6.	Nearness to major roads	2.10	1.09
7.	Character of site	2.05	1.25

Multiple Family Housing Developers

		MEAN	S.D.
* 1.	Proper zoning	3.17	0.94
2.	Price of land	3.03	0.97
* 3.	Access to trunk sewer	3.06	1.09
* 4.	Availability of developable land	2.78	1.07
5.	Size of site	2.40	1.01
6.	Nearness to major road	2.23	0.88
7.	Character of surrounding area	2.23	1.19
* 8.	Nearness to schools	2.06	0.94

*Denotes criteria measured and tested in this study.

SOURCE: Michael A. Goldberg and Daniel D. Ulinder, "Residential Developer Behaviour: 1975," Housing: It's Your Move, Vol. II, Technical Reports (Vancouver: Urban Land Economics Division, Faculty of Commerce and Business Administration, The University of British Columbia, 1976) p. 280-281.

7. Summary

As a result of the studies by Kaiser, Moore, and Goldberg and Ulinder the heavy reliance of land-use models on the demand side of the housing market is questionable. The developer surveys reviewed here demonstrate the importance of four supply factors in the development location decision: (1) proper zoning, (2) access to sewers, (3) availability of developable land, and (4) price of land.

Implicit in these findings is the role of government, since governments provide zoning, and in many cases the infrastructure as well. In the 1975 survey, questions were asked about difficulties in obtaining approvals, and it was found that nearly half of those surveyed had encountered such difficulties. Over 80% of these difficulties were with local governments. Also when asked which factors were instrumental in the decision to proceed with development, more than two-thirds of the developers listed government as being most important. As a result of these observations, it is clear that a fifth location criteria is also very important in the site location decision, namely, local government attitudes and actions.[17]

Considering the developer survey results summarized in this chapter, residential location as perceived by residential developers is considerably different from residential location as described by the literature, and as simulated by many housing models which have stressed demand. Accessibility in its various forms dominates the literature, yet received little

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[17]The work done by Larry S. Bourne, "Urban Structure and Land Use Decisions," Annals of American Geographics, Vol. 66, No. 4 (1976) pp. 531-547 supports this as does the work of Kaiser and Weiss, op. cit.

attention in the developer surveys summarized here.[18]

This divergence of opinion between the literature and the developer survey results summarized here needs to be reconciled before a true understanding of the factors which shape the urban environment can be obtained. The following chapter attempts to do just this. It summarizes the procedures used in, and the results obtained from, empirical tests of various site location criteria, including those suggested by the developer surveys and the accessibility criteria suggested as important by the literature.

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[18]Works by William Goldner, "The Lowry Model Heritage," Journal of the American Institute of Planners, Vol. 41, No. 3 (1975) pp. 191-195, and Stephen H. Putman, "Urban Land Use and Transportation Models: A State of the Art Summary," Transportation Research, Vol. 9 (1975) pp. 187-202 stress the importance of accessibility as does the pioneering work of Ira A. Lowry, A Model of Metropolis (Santa Monica, California: Rand Corporation, 1964) and the more recent work by John F. Kain and John M. Quigley, Housing Markets and Racial Discrimination (New York, N.Y.: National Bureau of Economic Research, 1975).

Chapter 3

EMPIRICAL ANALYSIS

1. Introduction

As outlined in Chapter two, the key locational variables stressed by developers were: proper zoning, access to sewers, availability of developable land and the price of land. However, many studies reported in the literature suggest that accessibility of an area to such variables as employment and shopping determines the amount of residential development it will receive.[1] These studies suggest that measures of accessibility to shopping and employment such as straight line distance, travel time by automobile and gravity formulations based on straight line distance or travel time are important.[2]

In an attempt to reconcile the difference between the developer survey results and the existing literature which suggests accessibility is important, regression tests were conducted on dependent variables which measured the spatial allocation of regional housing development, and independent variables which measured potential supply and accessibility. The method of testing these empirical relationships involved the following seven steps: (1) developing the hypotheses to be tested, (2) deciding on a test region, (3) deciding on a time period suitable for testing, (4) deciding on dependent variables and obtaining data for them, (5) deciding on independent

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[1] See footnote 18 for Chapter 2 for a summary of studies which suggest the importance of accessibility measures.

[2] See Appendix D for a discussion of the gravity formulation procedure and references which summarize the literature on this topic.

variables and obtaining data for them, (6) bivariate regression tests of individual independent variables, and (7) multivariate regression tests of groups of independent variables.

2. Hypotheses Tested

As the present study was concerned with the need to empirically test the results of the developer surveys discussed in Chapter two, and to reconcile the difference between these results and the existing literature which suggests accessibility is the important determinant of residential development, the following two hypotheses were developed and tested using regression analysis.

Hypothesis 1: The potential supply of developable single and multiple family housing land explains the spatial allocation of single and multiple family housing development to subareas within the GVRD. Specifically, the more accurately one is able to define the potential supply, the greater will be the explanatory precision. For example, a measure of land which is vacant, sewered and zoned for a particular use will have much better explanatory precision than a measure of vacant and zoned land, or vacant land.

This hypothesis suggests a stepwise combination of three measures which have been previously used independently into one measure which is potentially much more representative of the actual preferences of developers. If, as the developer survey results suggest, developers do not hold substantial inventories of land, buying only when they are ready to develop or build, then the best measure of potential supply should be a measure of that land which is vacant, accessible to sewers and zoned for the desired use. Previous measures used for land-use modelling have included independent measures of vacant land, access to sewers (usually in a yes-no criteria for the subarea) and zoning, but as far as can be determined no models have been reported which combine these criteria to produce a net figure in acres.

Hypothesis 2: Measures of accessibility: specifically nearness to schools, nearness to employment and nearness to shopping, contribute little to an explanation of the allocation of residential housing development to subareas within the GVRD.

This hypothesis goes one step further than previous research in the GVRD as it suggests testing more than one accessibility measure in an attempt to determine if accessibility measures in general are insignificant in explaining the allocation of residential development to subareas within the GVRD.

3. The Test Region

The metropolitan region chosen for testing the empirical relationship between the spatial distribution of housing development and potential supply and accessibility measures was the Greater Vancouver Regional District (GVRD) as outlined on the map in Appendix B. This region is divided into fifteen municipal areas which each have a local government which controls the building process through local development by-laws. All of these municipal areas, with the exception of White Rock (municipality 14), were further divided by the GVRD Planning Department, the regional planning body, into a total of 161 smaller planning areas which reflect general administration or neighbourhood boundaries. (The boundaries of these areas are outlined on the map in Appendix B.) In many cases these areas are an aggregation of census tracts, however, this is not always the case as some census tracts are quite large and the GVRD Planning Department felt smaller areas would be more representative.

The reason for choosing the GVRD and the 161 planning areas within the GVRD for the empirical analysis were: (1) the University of British Columbia developer surveys discussed in Chapter two were conducted within the GVRD, (2) it was close and accessible for observation and data gathering, (3) GVRD planning department land use data as described in Table 7 was available for the region and the subareas, and (4) the IIPS urban model was constructed and tested using these areas which provided convenient comparison checks and data availability.

4. The Time Period

The time period chosen for the analysis was the period from 1966 to 1971. This time period was chosen for the following reasons: (1) GVRD planning department land use data was available for this period and it was possible to calculate the dependent variables and some of the independent variables from this data, (2) GVRD planning department land use data was not complete for 1961, (3) it was possible to measure the other variables for the period 1966 to 1971, but hard to find good information for 1961 to 1966, and (4) using this time period allowed the results to be used in the IIPS urban model for prediction purposes and testing against actual data in 1975.

5. The Dependent Variables

The dependent variables chosen for the analysis were: (1) the percentage of the total GVRD change of single family housing stock which a subarea received during the period 1966 to 1971, and (2) the percentage of the total GVRD change of multiple family housing stock which a subarea

Table 7

DATA BASE OBTAINED FROM

THE GREATER VANCOUVER REGIONAL DISTRICT

The following data were obtained for 1961, 1966 and 1971 for each of the 161 residential subareas outlined on the map in Appendix B.

Land Use Data in Acres

1. Total area
2. Roads
3. Vacant
4. Residential
5. Commercial
6. Institutional
7. Utility and open space
8. Private open space
9. Farms
10. Water

Residential Data

1. Stock of single family detached units (units)
2. Single family detached land use (acres)
3. Single family detached density (units per acre in use)
4. Stock of duplex units (units)
5. Duplex land use (acres)
6. Duplex density (units per acre in use)
7. Stock of apartment units (units)
8. Apartment land use (acres)
9. Apartment density (units per acre in use)

received during the period 1966 to 1971. Reliable data were sought on the actual number of housing starts and completions rather than the stock of units, but unfortunately starts and completions data are only collected and published for municipal areas. As a result, the dependent variables were calculated from the GVRD planning department land use data using the three steps outlined below.

(1) The total GVRD single and multiple family housing stock for 1961, 1966 and 1971 were calculated from the GVRD Planning Department land use data described in Table 7 by summing all the values for the individual subareas. These values are listed in Table 8.

(2) The total GVRD change in single and multiple housing stock for 1966 to 1971 were calculated by subtracting the total stock values for 1966, as calculated in (1) above, from the corresponding values for 1971. These values are listed in Table 8.

(3) The percentage of the GVRD change in single and multiple family housing stock was calculated by dividing the change in single and multiple family housing stock for each of the 161 subareas by the corresponding total value for the region, as calculated in (2) above, and then multiplying this value by 100. Descriptive statistics on these variables are presented in Table 9.

6. The Independent Variables

The independent variables selected for the analysis were various measures of potential supply and accessibility which were suggested by the developer surveys and the existing literature. Since the developer surveys suggested that developers require land which is vacant, zoned correctly, sewered and priced correctly, the first step was to obtain reliable information on these variables. The amount of vacant land was easily obtained from the GVRD Planning Department data described in Table 7, but measures of zoning, sewers and the price of land presented a more difficult problem.

Initially it was hoped that some form of zoning information would be available for each of the three time periods for which land use data was available. However, when attempting to obtain zoning maps from the fifteen

Table 8

DEVELOPMENT DATA

TOTAL REGIONAL STOCK AND CHANGES IN THE STOCK*

Total Units		
1971	SF	222,768
	MF	98,461
	TOTAL	321,229
1966	SF	198,966
	MF	54,636
	TOTAL	253,602
1961	SF	192,446
	MF	34,133
	TOTAL	226,579
Changes in the Stock		
1966-1971	SF	23,802
	MF	43,825
	TOTAL	67,627
1961-1966	SF	6,520
	MF	20,503
	TOTAL	27,023

*Based on GVRD Planning Department land use data. SF is single family units including duplex. MF is multi family units including row housing.

Table 9

DESCRIPTIVE STATISTICS ON

THE DEPENDENT VARIABLES

VARIABLES	MEAN	STANDARD DEVIATION	LOW	HIGH
Y_1: Subarea percentage of the regional change in SF stock 1966-1971	0.64	1.10	-0.81	6.84
Y_2: Subarea percentage of the regional change in MF stock 1966-1971	0.64	1.60	-0.02	15.82

separate municipalities it became readily apparent that this information was not going to be available, and that information for 1971 was going to be hard enough to obtain. The difficulties arose because there does not exist a standard zoning by-law or map for the entire region, actual zoning definitions varied between municipalities, and as zoning maps are updated through time the old ones are usually discarded or become unavailable. As a result of these difficulties, it was decided to concentrate on obtaining 1971 zoning maps and make the assumption that zoning did not change greatly over the period 1966 to 1971. Admittedly a tenuous assumption, especially for some areas, but about all that could be done if some measure of zoning was to be obtained. Placing the zoning information on a map of uniform scale represented a time consuming activity, but one which involved no other problems.

Obtaining the information on sewered land presented the least difficulty as each municipality in the region provided me with detailed maps of trunk and lateral sewers for 1971. From consultation with several engineering firms and municipal engineers who were actively involved in subdivision and development work it was found that land within 500 feet of a trunk or lateral sewer was deemed unusable. More distant land was too expensive to sewer without development in between. To make the sewer information compatible with the zoning data it was transferred to maps of the same scale and size as the zoning data.

The proceeding procedure, while tedious and time consuming, did provide reliable maps of zoning and sewered land from which the amount of vacant and zoned and vacant zoned and sewered land was calculated. The amount of vacant and zoned land was calculated by subtracting the amount of land in use from a particular zoning type from the total amount of land zoned for that type. The amount of vacant, zoned and sewered land was calculated by the following two step process. First, zoning maps were overlayed on sewer maps and a measure of that land which was zoned and sewered was obtained. Second, the amount of land in use for each zoned and sewered type was subtracted from the total amount of land zoned and sewered for that type.

Obtaining information on prices turned out to be a task of some magnitude. To obtain data on prices for each of the 161 analysis cells would have required a detailed analysis of all transactions within the GVRD over the time period or the use of some statistical sampling procedure which would produce acceptable results. Due to the complexities surrounding the measurement of reliable price data, price was dropped from the analysis, and concentration was centred on analysing the effects of potential supply measures.[3]

Three sets of potential supply variables were computed to test the effectiveness of potential supply in explaining the allocation of housing growth. These three sets of potential supply variables were measures of potential supply from vacant land, vacant and zoned land, and vacant, zoned and sewered land. These three sets of potential supply measures were used to determine if the more general measure of potential supply (vacant land) or the more specific measures (vacant and zoned land or vacant, zoned and sewered land) produced better explanations. To determine the effects of density, the potential supply for the three sets of variables discussed

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[3]See S.W. Hamilton, "House Price Indices: Theory and Practice," Housing: It's Your Move, Vol. II, Technical Reports (Vancouver, B.C.: University of British Columbia, Faculty of Commerce and Business Administration, Urban Land Economics Division, 1976) for a discussion of the problems involved in obtaining and using measures of housing prices.

above was computed in both acres and units. The actual variables which were computed and tested are summarized in Table 10 and described in detail in Appendix C.

Three general measures of accessibility were suggested as important by the existing literature: accessibility to schools, accessibility to employment and accessibility to shopping. Within each of these three types of accessibility measures more specific measures such as straight line distances, travel times and gravity formulations were also suggested. Table 11 summarizes the actual variables which were computed for this analysis, and Appendix D explains their computation in detail.

7. The Bivariate Regression Tests

To test hypothesis one for single and multiple family housing development eleven bivariate regression equations of the form Y = a+bX were formulated and tested using ordinary least squares regression analysis.[4] These tests were divided into the two independent variable groups of: (1) potential housing supply in acres and (2) potential housing supply in units. The results of the eleven regression tests are presented in Tables 12 and 13. Table 12 presents the results for the dependent variable of percentage of GVRD single family development and Table 13 presents the results for percentage of GVRD multiple family development.

The results presented in Table 12 support hypothesis one for single family housing development. As the potential supply in both acres and

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[4]See Norman H. Nie, C. Hadlai Hull, Jean F. Jenkins, Karin Steinbrenner and Dale H. Bent, SPSS (Statistical Package for the Social Sciences) (Toronto: McGraw Hill Co., 1975) Chapter 20, pp. 320-367 for a detailed description of the regression subprogram used including the actual formulas used in calculating the regression statistics produced by the program.

Table 10

SUMMARY OF INDEPENDENT VARIABLES

MEASURES OF POTENTIAL SUPPLY

(1) Measures of Potential Single Family (SF) Supply in Acres

X_1 -- Vacant

X_2 -- Vacant and Zoned SF

X_3 -- Vacant, Zoned and Sewered SF

(2) Measures of Potential SF Supply in Units

X_4 -- Vacant in Acres x SF Density in Units per Acre

X_5 -- (Vacant and Zoned SF in Acres) x SF Density in Units per Acre

X_6 -- (Vacant, Zoned and Sewered in Acres) x SF Density in Units per Acre.

(3) Measures of Potential Multiple Family Supply (MF) in Acres

X_7 -- Vacant and Zoned MF

X_8 -- Vacant, Zoned and Sewered MF

(4) Measures of Potential Multiple Family Supply in Units

X_9 -- (Vacant in Acres) x MF Density in Units per Acre

X_{10}-- (Vacant and Zoned MF in Acres) x MF Density in Units per Acre

X_{11}-- (Vacant, Zoned and Sewered (MF) in Acres) x MF Density in Units per Acre

Table 11

SUMMARY OF INDEPENDENT VARIABLES

MEASURES OF ACCESSIBILITY

(1) Nearness to Schools

X_{12}-- Service Employment

X_{13}-- Access to Schools 1 - Gravity Formulation - Exponent = 1.0

X_{14}-- Access to Schools 2 - Gravity Formulation - Exponent = 2.0

(2) Nearness to Employment

X_{15}-- Total Employment

X_{16}-- Access to Employment 1 - Gravity Formulation - Exponent = 1.0

X_{17}-- Access to Employment 2 - Gravity Formulation - Exponent = 2.0

(3) Nearness to Shopping

X_{18}-- Travel Time to CBD

X_{19}-- Straight Line Distance to CBD

X_{20}-- Straight Line Distance to Closest Large Shopping

X_{21}-- Straight Line Distance to Second Closest Large Shopping

X_{22}-- Wholesale and Retail Trade Employment

X_{23}-- Access to Shopping 1 - Gravity Formulation - Exponent = 1.0

X_{24}-- Access to Shopping 2 - Gravity Formulation - Exponent = 2.0

Table 12

BIVARIATE REGRESSION RESULTS

PERCENT SF DEVELOPMENT BY POTENTIAL SUPPLY MEASURES

INDEPENDENT VARIABLES	R^2	STANDARD ERROR OF ESTIMATE	SIGNIFICANCE LEVEL	CONSTANT	COEFFICIENT	STANDARD ERROR OF COEFFICIENT
(1) <u>Potential Supply in Acres</u>						
Vacant	0.00280	1.08127	0.25381	0.68062	-0.00002	0.00003
Vacant and zoned SF	0.03964	1.0611	0.00594	0.46048	0.00039	0.00015
Vacant, sewered and zoned SF	0.24595	0.94025	0.00001	0.18577	0.00182	0.00025
(2) <u>Potential Supply in Units</u>						
Vacant x SF density	0.00009	1.08273	0.45174	0.65724	0.00000	0.00001
(Vacant and zoned SF) x SF density	0.06205	1.04865	0.00077	0.38179	0.00013	0.00004
(Vacant, sewered and zoned SF) x SF density	0.17784	0.98180	0.00001	0.24660	0.00031	0.00005

Table 13

BIVARIATE REGRESSION RESULTS

PERCENT MF DEVELOPMENT BY POTENTIAL SUPPLY MEASURES

INDEPENDENT VARIABLES	R^2	STANDARD ERROR OF ESTIMATE	SIGNIFICANCE LEVEL	CONSTANT	COEFFICIENT	STANDARD ERROR OF COEFFICIENT
(1) Potential Supply in Acres						
Vacant and zoned MF	0.45933	1.16773	0.00001	0.14420	0.03608	0.00312
Vacant, sewered and zoned MF	0.46308	1.16367	0.00001	0.15019	0.03628	0.00312
(2) Potential Supply in Units						
Vacant x MF density	0.00000	1.58809	0.49584	0.62951	0.00000	0.00001
(Vacant and zoned MF) x MF density	0.70296	0.86553	0.00001	0.30174	0.00068	0.00004
(Vacant, sewered and zoned MF) x MF density	0.70319	0.86519	0.00001	0.30445	0.00068	0.00004

units is defined with more precision the explanatory power, as measured by the R^2 statistic, increases. Not only does the R^2 statistic increase, but the standard error of the estimate decreases, the significance level as measured by an F test increases, and the constant decreases. Density does not seem to be an important element in explaining single family growth allocation as in all the cases in Table 12 the potential supply in units has a lower level of explanation, as measured by the R^2 statistic, than the potential supply in acres. This does not discount the importance of residential density in allocating growth, but rather indicates that the availability of developable land, rather than the number of units which can be built on the available land, is a more important criteria in determining the allocation of single family detached housing development.

In general the results of Table 12 tend to indicate that potential supply is not the only important criteria in explaining the allocation of single family detached housing development. The maximum R^2 statistic which could be obtained is 0.19527. This indicates that only about twenty percent of the allocation of single family detached housing development can be explained by the subarea characteristic of the amount of land available which is accessible to sewers and zoned for the required use. This does not discount the importance of this criteria in explaining the allocation of single family growth, but rather tends to indicate that there are other criteria which are also important.

The results presented in Table 13 generally support hypothesis one for multiple family housing development. As the potential supply in both acres and the number of units is defined with more precision the explanatory completeness, as measured by the R^2 statistic, increases. However, the increase in explanatory completeness by further defining the potential supply, in both acres and the number of units, from that potential supply which is vacant and zoned, to that which is vacant, sewered and zoned is marginal. The R^2 statistic increases very little in both cases and the significance level does not increase at all. This result probably occurs because most land which is zoned multiple family is accessible to sewers. What is probably important here is the size and quality of the existing sewers, especially if the new development involves demolition of existing single family housing or development in an area which has a predominance of single family housing.

To test hypothesis two for multiple and single family housing development, thirteen regression equations of the form $Y = a+bX$ were formulated and tested for each dependent variable using the independent variables summarized in Table 11. The results of the twenty-six regression tests are presented in Tables 14 and 15. Table 14 presents the results for the percent of single family development and Table 15 presents the results for the percent of multiple family development.

The results presented in Table 14 support hypothesis two for single family housing development. All measures of accessibility have very low R^2 statistics, and no measure is significant at the 0.05 probability level as measured by F test probability.

The results presented in Table 15 tend to refute hypothesis two for multiple family housing development. All of the measures of accessibility are significant at the 0.01 level and have R^2 statistics ranging from 0.05164 to 0.14064. The explanatory completeness of the measures is relatively low, but one cannot refute their significance based on the results of Table 15. The amount of wholesale-retail trade employment in the subarea is the most significant variable with an R^2 statistic of

Table 14

BIVARIATE REGRESSION RESULTS

PERCENT SF DEVELOPMENT BY ACCESSIBILITY MEASURES

INDEPENDENT VARIABLES	R^2	STANDARD ERROR OF ESTIMATE	SIGNIFICANCE LEVEL OF F	CONSTANT	COEFFICIENT	STANDARD ERROR OF COEFFICIENT
(1) Nearness to Schools						
Service employment	0.00123	1.08212	0.33068	0.63614	0.00001	0.00003
Access to schools 1	0.00772	1.09745	0.13545	0.87964	-0.00003	0.00002
Access to schools 2	0.00168	1.10078	0.30403	0.67785	-0.00007	0.00013
(2) Nearness to Employment						
Total employment	0.00002	1.08277	0.47609	0.64895	0.00000	0.00002
Access to employment 1	0.00857	1.09698	0.12297	0.90067	-0.00001	0.00001
Access to employment 2	0.00255	1.10030	0.26378	0.69254	-0.00004	0.00006
(3) Nearness to Shopping						
Travel time to CBD	0.01672	1.07369	0.05213	0.32777	0.01197	0.00733
Straight line distance to the CBD	0.00553	1.07978	0.17570	0.51680	0.01345	0.01439
Straight line distance to closest large shopping	0.00055	1.08249	0.38490	0.69174	-0.01651	0.05633
Straight line distance to second closest large shopping	0.00625	1.07940	0.16103	0.46636	0.04454	0.04484
Wholesale and retail trade employment	0.00054	1.08249	0.38594	0.63706	0.00003	0.00011
Access to shopping 1	0.01026	1.09604	0.10196	0.90667	-0.00007	0.00005
Access to shopping 2	0.00391	1.09955	0.21682	0.70315	-0.00024	0.00031

Table 15

BIVARIATE REGRESSION RESULTS

PERCENT MF DEVELOPMENT BY ACCESSIBILITY MEASURES

INDEPENDENT VARIABLES	R^2	STANDARD ERROR OF ESTIMATE	SIGNIFICANCE LEVEL OF F	CONSTANT	COEFFICIENT	STANDARD ERROR OF COEFFICIENT
(1) Nearness to Schools						
Service employment	0.05164	1.54655	0.00199	0.47957	0.00012	0.00004
Access to schools 1	0.11336	1.49537	0.00001	-0.75530	0.00014	0.00003
Access to schools 2	0.11777	1.49165	0.00001	0.04040	0.00080	0.00018
(2) Nearness to Employment						
Total employment	0.07637	1.52628	0.00021	0.38437	0.00009	0.00003
Access to employment 1	0.10337	1.50377	0.00002	-0.73095	0.00006	0.00001
Access to employment 2	0.10257	1.50444	0.00002	0.04858	0.00036	0.00009
(3) Nearness to Shopping						
Travel time to CBD	0.09058	1.51446	0.00006	1.73530	-0.04087	0.01034
Straight line distance to CBD	0.07514	1.52726	0.00024	1.35893	-0.07267	0.02035
Straight line distance to closest large shopping	0.05889	1.54062	0.00103	1.23621	-0.25129	0.08017
Straight line distance to second closest large shopping	0.06725	1.53376	0.00048	1.52171	-0.21436	0.06371
Wholesale and retail trade employment	0.14064	1.47219	0.00001	0.27923	0.00076	0.00015
Access to shopping 1	0.09089	1.51420	0.00006	-0.56190	0.00029	0.00007
Access to shopping 2	0.07842	1.52455	0.00018	0.15096	0.00156	0.00043

0.14064. Access to schools 2 with an R^2 statistic of 0.11777 and travel time to the CBD with an R^2 statistic of 0.09058 follow clearly behind.

8. Multivariate Regression Tests

To determine which combination of the factors tested in the bivariate analysis produced the best overall level of explanatory completeness, a multivariate linear regression equation of the form $Y = a + b_1X_1 + b_2X_2 \ldots + b_nX_n$, where X_1 to X_n were the independent variables used in the bivariate tests, was formulated for each dependent variable. The testing of the equations was done with a stepwise multiple regression program which produced a listing of the independent variables presented in the order of their relative contribution to the overall explanation of the dependent variable, as measured by the change in the R^2 statistic. The results of these two tests are presented in Tables 16 and 17. Table 16 presents the results of the single family detached housing development test and Table 17 presents the results of the multiple family housing development test.

The results of the single family development test indicate that the independent variable found to have the most explanatory power in the bivariate tests, potential supply in acres of that land which is vacant, sewered and zoned, contributed the most to the overall explanation of the dependent variable. The other measures of potential supply contributed little to the overall explanation. What is interesting to note is the increase in the explanatory power of the travel time to the CBD variable. Although the increase in explanatory power is quite small, this variable was the most significant next to the measure of vacant, sewered and zoned land. The low explanatory power of the other potential supply measures is probably a result of the high degree of correlation between these variables and the variable which measures vacant, sewered and zoned land. In general

Table 16

MULTIVARIATE REGRESSION ANALYSIS

PERCENT SF DEVELOPMENT BY ALL VARIABLES

Dependent variable - Percent of GVRD single family development 1966-71

INDEPENDENT VARIABLES	R SQUARE	RSQ CHANGE	B	STD ERROR B	F
VACANT, ZONED AND SEWERED SF - ACRES	0.24122	0.24122	0.1368072E-02	0.00117	1.361
TRAVEL TIME TO CBD - MINUTES	0.25679	0.01557	0.8268921E-01	0.03733	4.906
ACCESS TO SCHOOLS 2	0.28683	0.03004	-0.2464372E-02	0.00204	1.453
ST LINE DIST TO CBD - MILES	0.29452	0.00769	-0.5378951E-01	0.04487	1.437
WHOLESALE RETAIL TRADE EMPLOYMENT	0.29822	0.00370	0.8814089E-04	0.00027	0.108
ACCESS TO SHOPPING 2	0.30550	0.00727	-0.1174476E-02	0.00341	0.119
ACCESS TO TOTAL EMPLOYMENT 2	0.30951	0.00401	0.1199301E-02	0.00114	1.108
SERVICES EMPLOYMENT	0.31210	0.00259	0.1037121E-03	0.00009	1.219
ST LINE DIST TO SHOPPING 2 - MILES	0.31399	0.00189	0.7101113E-01	0.06982	1.034
ACCESS TO SCHOOLS 1	0.31808	0.00409	0.6802957E-03	0.00041	2.715
ACCESS TO SHOPPING 1	0.32679	0.00872	-0.1122239E-02	0.00089	1.605
VACANT AND ZONED SF X SF DENSITY	0.32938	0.00258	-0.2778456E-03	0.00024	1.369
VACANT AND ZONED SF - ACRES	0.33260	0.00322	0.8524318E-03	0.00081	1.118
VACANT, ZONED AND SEWERED SF X SF DENSITY	0.33549	0.00290	0.2169167E-03	0.00031	0.488
ST LINE DIST TO SHOPPING 1 - MILES	0.33668	0.00118	-0.3463134E-01	0.06843	0.256
66 - LAND USE - VACANT - ACRES	0.33683	0.00015	0.6536372E-05	0.00003	0.036
TOTAL EMPLOYMENT	0.33695	0.00011	-0.1267629E-04	0.00008	0.024

Constant 0.8615223 Overall F ratio 38.62561 Significance level 0.00001

Table 17

MULTIVARIATE REGRESSION ANALYSIS

PERCENT MF DEVELOPMENT BY ALL VARIABLES

Dependent variable - Percentage of GVRD multiple family development 1966-71

INDEPENDENT VARIABLES	R SQUARE	RSQ CHANGE	B	STD ERROR B	F
VACANT SEWERED AND ZONED MF X MF DENSITY	0.70319	0.70319	0.6812641E-03	0.00007	107.635
WHOLESALE RETAIL TRADE EMPLOYMENT	0.71643	0.01324	0.8584336E-03	0.00024	12.695
ACCESS TO SHOPPING 2	0.71975	0.00332	-0.7392394E-02	0.00287	6.653
ACCESS TO TOTAL EMPLOYMENT 1	0.72770	0.00795	-0.7025615E-04	0.00021	0.115
VACANT SEWERED AND ZONED MF	0.73090	0.00320	-0.4917833E-02	0.00417	1.391
SERVICES EMPLOYMENT	0.73188	0.00098	0.8824156E-04	0.00008	1.191
TOTAL EMPLOYMENT	0.73567	0.00378	-0.1128640E-03	0.00007	2.684
ACCESS TO SCHOOLS 2	0.73598	0.00032	0.2451570E-02	0.00124	3.932
ACCESS TO SHOPPING 1	0.73900	0.00302	0.1765642E-02	0.00107	2.712
ACCESS TO SCHOOLS 1	0.74199	0.00299	-0.5615504E-03	0.00037	2.260
TRAVEL TIME TO CBD - MINUTES	0.74295	0.00096	-0.1342376E-01	0.01811	0.549

Constant -3.771183 Overall F ratio 4.21485 Significance level 0.00001 the results of the multiple regression test for single family development indicate that the site characteristic combination of potential supply in acres of that land which is zoned, sewered and vacant and travel time to the CBD in minutes provide the best level of explanation with an R^2 statistic of about 0.25. This result tends to indicate that single family development occurs to a larger extent in those areas which have available vacant, sewered, and zoned single family land and have lower travel times by automobile to the CBD.

The results of the multivariate regression test for multiple family development indicate that the independent variable found to have the most explanatory power in the bivariate tests, potential supply in units of that land which is vacant, zoned and sewered, contributed the most to the multivariate tests as well. The variable which contributed the next largest change to the R^2 statistic was the amount of wholesale-retail trade employment in the subarea. This variable had the highest explanatory power of the accessibility measures tested with the percentage of multiple family development. These results are reasonable, as the test indicates that multiple family residential growth will be allocated to subareas within the region based on their relative multiple family housing potential in units and their access to shopping.

To test for the effects of differing municipal government boundaries on the allocation of growth it was decided to introduce dummy variables for the fifteen different municipal areas into the multivariate regression equations. The dummy variables were created by treating each municipality as a separate variable. All cases were then assigned either a 1 or 0 on all fifteen dummy variables depending upon the municipality a particular case was in. Only fourteen dummy variables were included in the initial regression equations because the inclusion of all dummy variables would render the equation unsolvable. This occurs because the Kth dummy variable is completely determined by the first K-1 dummy variables entered into the regression equation. The results of these tests are presented in Tables 18 and 19. Table 18 presents the results for single family housing development and Table 19 presents the results for multiple housing development.

The results of the dummy variable regression tests for single family housing development indicate that a measure of the municipal area in which a subarea is in contribute significantly to the explanation of the allocation of single family housing development. The dummy variable for Delta had the highest level of explanatory power, contributing 0.16 to an overall R^2 statistic of 0.55. The dummy for Port Coquitlam came next, contributing 0.01 to the overall R^2 statistic. The other dummy variables contributed very little to the overall explanatory power of the regression equation. What is interesting to note is that the travel time to the CBD variable which had a small level of explanatory power in the multivariate test without the dummy variables added almost nothing to the overall R^2 statistic when the dummy variables were added.

The results of the dummy variable regression test for multiple family housing development indicate that a variable which measures the municipal area a subarea is in does not contribute very much to the overall explanatory power of the regression equation. The only dummy variable which contributed significantly to the overall R^2 statistic was the dummy for New Westminster. However, this dummy variable only contributed 0.02164 to an overall R^2 statistic of 0.77734. The dummy variable for Burnaby was the next highest dummy variable contributor with a contribution of only 0.01237 to the overall R^2 statistic.

Table 18

MULTIVARIATE REGRESSION ANALYSIS

PERCENT SF DEVELOPMENT BY ALL VARIABLES INCLUDING DUMMIES

Dependent variable - Percentage of GVRD single family development 1966-71

INDEPENDENT VARIABLES	R SQUARE	RSQ CHANGE	B	STD ERROR B	F
VACANT, ZONED AND SEWERED SF - ACRES	0.24122	0.24122	0.9361461E-03	0.00117	0.639
DUMMY FOR DELTA	0.40886	0.16763	1.671065	0.51555	10.506
DUMMY FOR POT COQUITLAM	0.42152	0.01267	0.3596446	0.67680	0.282
ST LINE DIST TO SHOPPING 2-MILES	0.43349	0.01197	-0.9149567E-01	0.06503	1.980
VACANT AND ZONED SF - ACRES	0.45219	0.01869	0.1318997E-02	0.00080	2.744
DUMMY FOR WHITE ROCK	0.46186	0.00967	0.6377572E-02	1.02681	0.000
VACANT, ZONED AND SEWERED SF X SF DENSITY	0.47174	0.00989	0.2300018E-03	0.00031	0.545
DUMMY FOR NEW WESTMINSTER	0.47985	0.00811	-1.181597	0.62682	3.553
SERVICES EMPLOYMENT	0.48739	0.00753	0.2073907E-03	0.00009	5.026
DUMMY FOR RICHMOND	0.49328	0.00589	0.1835884	0.53796	0.116
DUMMY FOR WEST VANCOUVER	0.49658	0.00330	-0.2842274	0.70491	0.163
DUMMY FOR BURNABY	0.49992	0.00334	-0.5952601	0.57959	1.055
DUMMY FOR SURREY	0.50429	0.00437	-0.9119587	0.51428	3.144
ST LINE DIST TO CBD - MILES	0.50658	0.00229	0.2900630E-01	0.05116	0.322
WHOLESALE RETAIL TRADE EMPLOYMENT	0.51066	0.00407	0.1609102E-03	0.00025	0.429
TOTAL EMPLOYMENT	0.51661	0.00595	-0.4657817E-04	0.00007	0.386
VACANT AND ZONED SF X SF DENSITY	0.51873	0.00212	-0.2788653E-03	0.00023	1.423
DUMMY FOR COQUITLAM	0.52112	0.00239	-0.5432559	0.52640	1.065
DUMMY FOR NORTH VANCOUVER DISTRICT	0.52262	0.00150	0.5763792E-01	0.65464	0.008
ACCESS TO SCHOOLS 1	0.52441	0.00178	0.1522633E-02	0.00076	3.999
TRAVEL TIME TO CBD - MINUTES	0.52826	0.00386	0.8025377E-01	0.04108	3.817
ACCESS TO SHOPPING 2	0.53609	0.00783	-0.3622215E-02	0.00315	1.319
DUMMY FOR VANCOUVER	0.53765	0.00155	-1.106012	0.74805	2.186
DUMMY FOR UEL	0.54175	0.00410	-1.204330	0.85628	1.978
ACCESS TO TOTAL EMPLOYMENT 2	0.54341	0.00166	0.1871227E-02	0.00191	0.956
ACCESS TO TOTAL EMPLOYMENT 1	0.54423	0.00081	-0.4646637E-03	0.00032	2.077
ACCESS TO SCHOOLS 2	0.55002	0.00579	-0.4027572E-02	0.00303	1.768
DUMMY FOR NORTH VANCOUVER CITY	0.55117	0.00115	-0.4481629	0.77685	0.333
LAND USE - VACANT - ACRES	0.55154	0.00037	-0.2006549E-04	0.00006	0.114
VACANT X SF DENSITY	0.55165	0.00012	0.3680496E-05	0.00002	0.041
DUMMY FOR PORT MOODY	0.55178	0.00013	-0.1236871	0.65111	0.036

Constant 5.707769 Overall F ratio 5.04332 Significance level 0.00001

Table 19

MULTIVARIATE REGRESSION ANALYSIS

PERCENT MF DEVELOPMENT BY ALL VARIABLES INCLUDING DUMMIES

Dependent variable - Percentage of GVRD multiple family development 1966-71

INDEPENDENT VARIABLES	R SQUARE	RSQ CHANGE	B	STD ERROR B	F
VACANT SEWERED AND ZONED MF X MF DENSITY	0.70319	0.70319	0.6568841E-03	0.00007	89.255
DUMMY FOR NEW WESTMINSTER	0.72483	0.02164	1.391461	0.60365	5.313
DUMMY FOR BURNABY	0.73720	0.01237	0.4222648	0.54734	0.595
WHOLESALE RETAIL TRADE EMPLOYMENT	0.74420	0.00700	0.7922483E-03	0.00024	11.252
DUMMY FOR NORTH VANCOUVER CITY	0.74695	0.00275	0.6711012	0.69905	0.922
TOTAL EMPLOYMENT	0.74914	0.00219	-0.1434157E-03	0.00007	4.226
SERVICES EMPLOYMENT	0.75323	0.00409	0.1958440E-03	0.00008	5.896
DUMMY FOR SURREY	0.75522	0.00199	-0.2617915E-01	0.44656	0.003
ACCESS TO SHOPPING 2	0.75767	0.00245	-0.1950441E-02	0.00303	0.413
ACCESS TO SCHOOLS 2	0.76405	0.00638	0.3081235E-02	0.00141	4.795
DUMMY FOR UEL	0.76561	0.00156	-0.9116244	0.76464	1.421
ACCESS TO SHOPPING 1	0.76833	0.00272	0.6460985E-03	0.00042	2.371
VACANT SEWERED AND ZONED MF	0.76987	0.00154	-0.3818018E-02	0.00458	0.695
DUMMY FOR VANCOUVER	0.77210	0.00223	-0.3330903	0.61826	0.290
ACCESS TO TOTAL EMPLOYMENT 2	0.77383	0.00173	-0.1747542E-02	0.00116	2.261
DUMMY FOR NORTH VANCOUVER DISTRICT	0.77507	0.00124	0.5706422E-01	0.57074	0.010
DUMMY FOR RICHMOND	0.77560	0.00053	0.4169512	0.49698	0.704
TRAVEL TIME TO CBD - MINUTES	0.77615	0.00055	0.1560097E-01	0.03267	0.228
DUMMY FOR WHITE ROCK	0.77648	0.00033	-0.2045367	0.97532	0.044
DUMMY FOR PORT MOODY	0.77677	0.00029	0.3937059	0.63307	0.387
DUMMY FOR DELTA	0.77706	0.00030	0.2716559	0.47827	0.323
DUMMY FOR COQUITLAM	0.77716	0.00009	0.1880862	0.48796	0.149
DUMMY FOR WEST VANCOUVER	0.77727	0.00011	0.1940317	0.60348	0.103
DUMMY FOR PORT COQUITLAM	0.77734	0.00007	0.1297625	0.63937	0.041

Constant -1.888343 Overall F ratio 19.49214 Significance level 0.00001

In general the regression results of the dummy variable tests suggest that municipal boundaries are a significant factor in explaining the allocation of single family housing development, while they are not a significant factor in explaining the allocation of multiple family housing development. However, when the dummy variables are included in the single family development equation, the travel time to the CBD variable becomes insignificant in its contribution to the overall R^2 statistic.

9. Conclusion

In Chapter two of this paper it was stated that as a result of studies by Kaiser, Moore, and Goldberg and Ulinder the heavy reliance of land use models on the demand side of the housing market seemed questionable. More convincing behavioural research and empirical testing of this behavioural research was required. These statements were the foundations on which the hypotheses tested in this study were based. The hypotheses were designed to test: firstly, if the supply side criteria of the housing market identified by developers were significant in explaining the spatial allocation of GVRD single and multiple family housing development to subareas within the GVRD; and secondly, how well selected accessibility measures explained the spatial allocation of housing development. In this section, the relevant findings of this study with respect to each of the hypotheses tested are summarized.

Hypothesis 1: The potential supply of single and multiple family housing land explains the spatial allocation of single and multiple family housing development to subareas within the GVRD. Specifically, the more accurately one is able to define the potential supply, the greater will be the explanatory precision. For example, a measure of that land which is vacant, zoned and sewered will have much better explanatory precision that a measure of vacant and zoned land, or vacant land.

The bivariate regression results generally support this hypothesis. However, potential supply seems to be much more important in explaining the spatial allocation of multiple family housing development than single family housing development. Also, potential supply in units is most important for multiple family housing development, while potential supply in acres is most important for single family housing development. This tends to suggest that density of development is more important to multiple family housing developers than to single family housing developers. This is definitely an area for future behavioural research and specific questions on density should be included in future surveys of developers. As far as can be ascertained this variable has not been explicitly included in surveys of developers to date, although responses to questions regarding zoning may include some implicit regard for zoned density.

The bivariate regression results generally support the statement that a more specific definition of supply will provide a better explanation of the spatial allocation of growth. This was found to be true for single family housing development, but not so true for multiple family housing development. For multiple family housing development a further definition of supply from that land which is zoned and vacant, to that land which is zoned, sewered and vacant is marginal. This is probably due to the fact that most land which is zoned multiple family dwelling is sewered or very close to an existing sewer.

Hypothesis 2: Measures of accessibility: specifically nearness to schools, nearness to employment and nearness to shopping, contribute little to an explanation of the allocation of residential housing development to subareas within the GVRD.

The bivariate regression results support this hypothesis for single family housing development, but do not support the hpothesis for multiple family housing development. The results for single family housing development indicate that all of the accessibility measures tested here have very little importance in explaining the spatial allocation of single family housing development. This outcome could be a result of the high level of accessibility enjoyed by many parts of the region, rather than a direct contradiction of the theory that accessibility shapes land use.

The results of the bivariate regression tests for multiple family housing development with the accessibility measures indicate that all of the accessibility measures tested here have a significant, but small role in explaining the spatial allocation of multiple family housing development. The amount of wholesale-retail trade employment had the highest level of explanatory power, access to schools using the gravity formulation with an exponent of 2 was next, followed by travel time to the CBD. The value of the R^2 statistic varied from a low of 0.05164 to a high of 0.14064.

The results of the multivariate regression tests indicate that the most important variables in explaining the allocation of single family housing development were: (1) the potential supply in acres of that land which is vacant, zoned single family dwelling, and accessible to sewers and (2) the municipality in which the subarea is located. If the dummy variables representing municipal areas which were introduced into the regression equation are an adequate proxy for differing municipal supply policies, then the multiple regression results lend strong supporting evidence to the statement by Goldberg and Ulinder that supply constraints are very critical to developers and hence to the spatial allocation of growth.

If one disregards the significance of the dummy variables for multiple family development, which is quite small overall, then the results of the multivariate tests for multiple family development indicate that the most important variables in explaining the allocation of multiple family development were: (1) the potential supply in units of that land which is zoned multiple family dwelling and vacant, and (2) the amount of wholesale-retail trade employment in the subarea. The results suggest that multiple family development will be allocated to subareas within a region based on their relative multiple family housing unit potential and their access to shopping.

The analysis discussed in this Chapter indicate that behavioural research studies can be effectively used in defining criteria to explain the spatial allocation of housing development. Specifically, supply side criteria identified by developers as being important in the spatial allocation of housing development were tested and found to be significant. The significance levels varied between structure types, but tend to indicate that land use models which rely heavily on the demand side of the housing market for the spatial allocation of growth may be very inadequate. These results must be qualified by the fact that they represent only a specific period in time, and are not the results of dynamic time series tests. However, they do suggest that during the time period studied supply criteria were important in allocating regional housing development to subareas within the region. This result does not support many previous studies done outside the GVRD which have found that demand side criteria measured through accessibility variables are very important in explaining the allocation of growth.

The implications of this analysis for policy decisions are twofold. Firstly, the analysis lends strong supporting evidence to the suggestion that municipal organizations have been effective in allocating growth to those areas where supply exists which is serviced and appropriately zoned. Secondly, policy decisions which use measures of the future spatial allocation of growth based on demand oriented models may be grossly inadequate. In designing policies and future research studies, developers and government organizations should realize the extreme importance of supply and the effectiveness of the many government organizations in controlling it.

The research discussed in this chapter suggests that further behavioural studies of the role played by the developer, combined with analytical models of this behaviour, may provide considerable insight into the past and future allocation of housing development. The following chapter outlines the attempt made at combining the behavioural analyses of the developer surveys and the empirical analysis presented in this chapter into an operational model of the GVRD.

Chapter 4

THE TEST MODEL FRAMEWORK

1. Introduction

The statistical analysis presented in Chapter three illustrates the explanatory power of the various potential supply and accessibility measures tested. However, it does not indicate the ability of these criteria to predict the future allocation of growth. Given the importance of estimating the future pattern of residential growth for local planning, private development and regional housing policy; the results of Chapter three were incorporated into the supply side of an existing simulation model to see what explanatory power they had. This chapter describes the model framework used. The following chapter describes the extensions made to the model and the results of running the model and comparing the output to actual data.

2. General Overview of the Model

The original model was developed nearly a decade ago by a group of researchers at the University of British Columbia who set out to develop a large scale simulation model for the Vancouver region.[1] The researchers

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[1]The model framework and its major components and objectives have been documented at some length elsewhere. This chapter is a summary of these works. The interested reader is directed to the following studies which provide a detailed review of the original model framework and subsequent revisions. See Michael A. Goldberg, "Simulation, Synthesis and Urban Public Decision-Making," Management Science, Vol. 20, No. 4 (December 1973) Part II, pp. 629-643; Michael A. Goldberg and Jeffery M. Stander, "Analysis of Output and Policy Applications of an Urban Simulation Model," Transportation Research Record, Vol. 582 (1976) pp. 61-71; Michael A. Goldberg and Douglas A. Ash, "Continued Development of the Vancouver Model," Transportation

realized the need for a new approach to developing models, as the models which had been developed were beginning to show serious shortcomings. These models tended to be difficult to use, operated quite outside the traditional bureaucratic/political framework, and were of highly variable quality.[2]

In response to these shortcomings, modelbuilders at the University of British Columbia teamed up with representatives of several levels of government to jointly develop an urban and environmental simulation model capable of providing needed policy insights. The study was called IIPS (for Inter-Institutional Policy Simulator). By bringing together academics and civil servants it was hoped that more useful and realistic policy models might be designed and used. Accordingly, the objectives of the IIPS project were two-fold: (1) to develop a modelling framework for model building; and (2) to develop models capable to dealing with key subsystems of the Greater Vancouver Regional District (GVRD) urban environment, but which could be transferable elsewhere.[3]

Figure 1 provides an overview of the various interacting model elements which were to be included in the original IIPS effort.[4] As indi-

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Research Record, Vol. 617 (1977) pp. 55-61; and Michael A. Goldberg and H.C. David, "An Approach to Modelling Urban Growth and Spatial Structure," Highway Research Record, Vol. 435 (1973), pp. 42-53

[2]Two papers which criticize existing models and argue for a reorientation of urban modelling are: Douglas B. Lee, Jr., "Requiem for Large-Scale Models," Journal of the American Institute of Planners, Vol. 39, No. 3 (1973) pp. 163-178; and A.H. Voelker, Some Pitfalls of Land-Use Model Building, ORNL-RUS-1 (Oak Ridge, Tennessee: Oak Ridge National Laboratory, 1975).

[3]See Michael A. Goldberg, "Simulation, Synthesis," pp. 629-31.

[4]Ibid., p. 632.

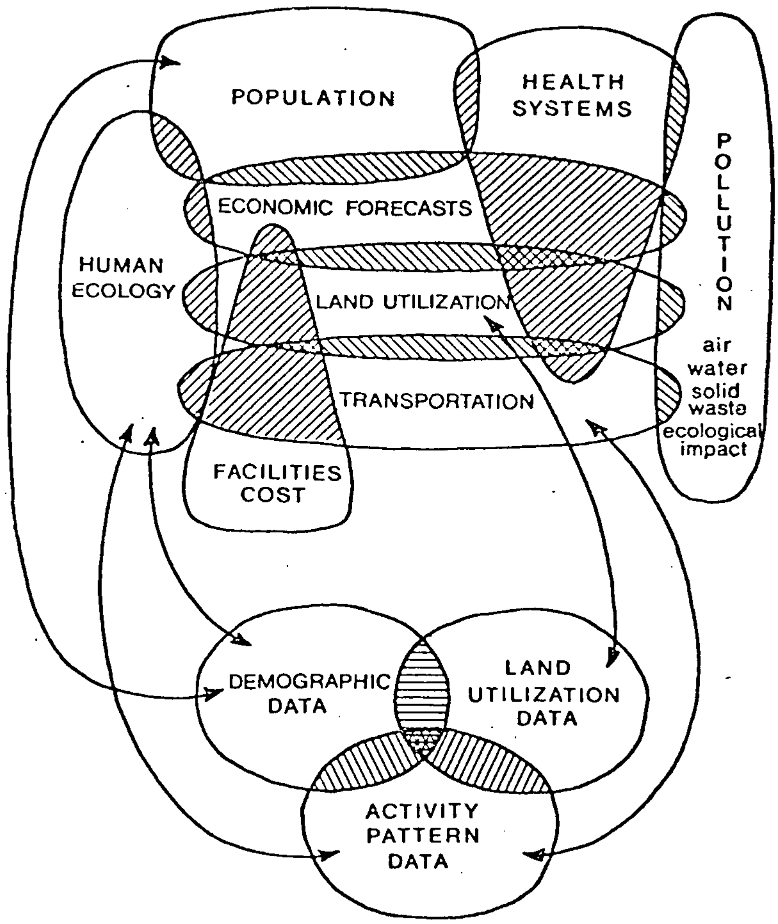

Figure 1

DIAGRAM OF RELATIONSHIP BETWEEN THE IIPS SUBGROUPS cated by Figure 1, intra-urban transportation and land use models were central to the overlapping elements. These two submodels distributed activities spatially and were therefore considered to be prime vehicles for analysing the spatial impacts of various land use, transportation and environmental policies. The original researchers considered housing to be of greatest importance as residences represented the largest single user of land. Accordingly, development of a useful housing model took priority. The modelling problem, and the resulting land use model, were partitioned into four separate elements: macro supply and demand; and microspatial supply and demand.

3. General Overview of the Sub-Model Structure

Lacking a suitable set of submodels to forecast macro supply and demand separately, the original IIPS model assumed supply and demand were equal.[5] Demand/supply was estimated for each year in the simulation by a reasonably straightforward trend procedure which produced new single and multiple family housing totals for the region.

Given regional totals, the microspatial components of the model allocated them to subareas of the region using quite separate algorithms for supply and demand. As there was no constraint that micro supply was to equal micro demand, the final step in each iterative period was to allocate excess micro demand to areas of excess micro supply until microspatial supply equalled microspatial demand.

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[5]Michael A. Goldberg, Housing, Employment, Land Use and Transportation: A Regional Simulation Model, Urban Land Economics Reprint Series, Report #2 (Vancouver, B.C.: Urban Land Economics Division, Faculty of Commerce and Business Administration, University of British Columbia, 1974), p. 6-8.

Figures 2, 3 and 4 set out diagramatically the original submodels of the IIPS model which are of interest here.[6] The four interacting models represented are: (1) land use, including housing and employment location; (2) transportation, including trip generation, distribution and mode split; (3) employment forecast; and (4) population forecast. The regional forecasts of population and employment were used to provide estimates of new economic activity and housing which were then allocated to the subareas by the land use models.

The amount of new economic activity and the amount of new housing were allocated in the following manner. Given a travel time matrix and regional forecasts of population and employment, the IIPS model first allocated eighteen different types of employment to the subareas and calculated the amount of land used.[7] Next the population estimate was combined with the previous period housing activity to provide the totals of new single and multiple family housing to be located during the iteration. Then the totals of new single and multiple family housing were allocated to the subareas using an intuitive allocation algorithm based on the travel time matrix. Finally, given the new location of jobs and people, the transportation model recalculated trips and travel times, and the model moved on to the next iteration.

4. Macro Housing Sub-Model

The original macro housing model produced a figure for total single and multiple family housing development by crudely estimating the housing

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[6]Figures 2 and 4 - Goldberg, Housing, Employment, Land Use, p. 4 and 7; Figure 3 - Goldberg and Davis, *op. cit.*, p. 51.

[7]For a detailed description of the sub-models which allocated new employment, recreation facilities and open-space see: Goldberg and Davis, *op. cit.*, pp. 48-50. A summary of these models based on the above work is contained in Appendix E.

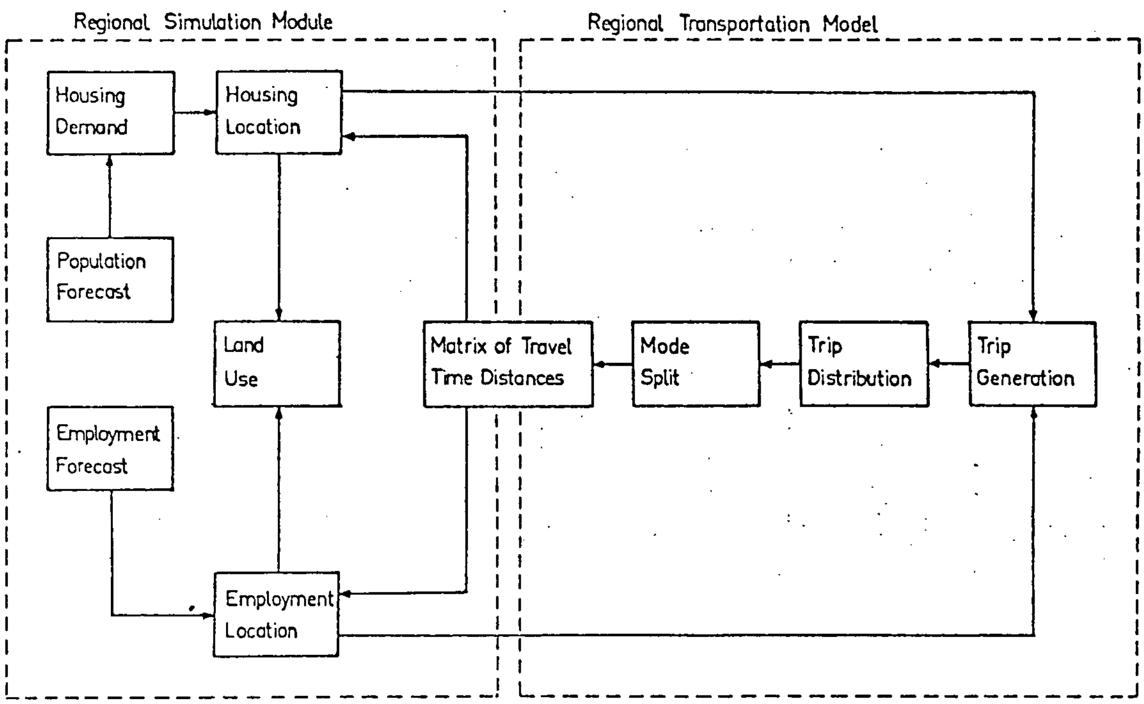
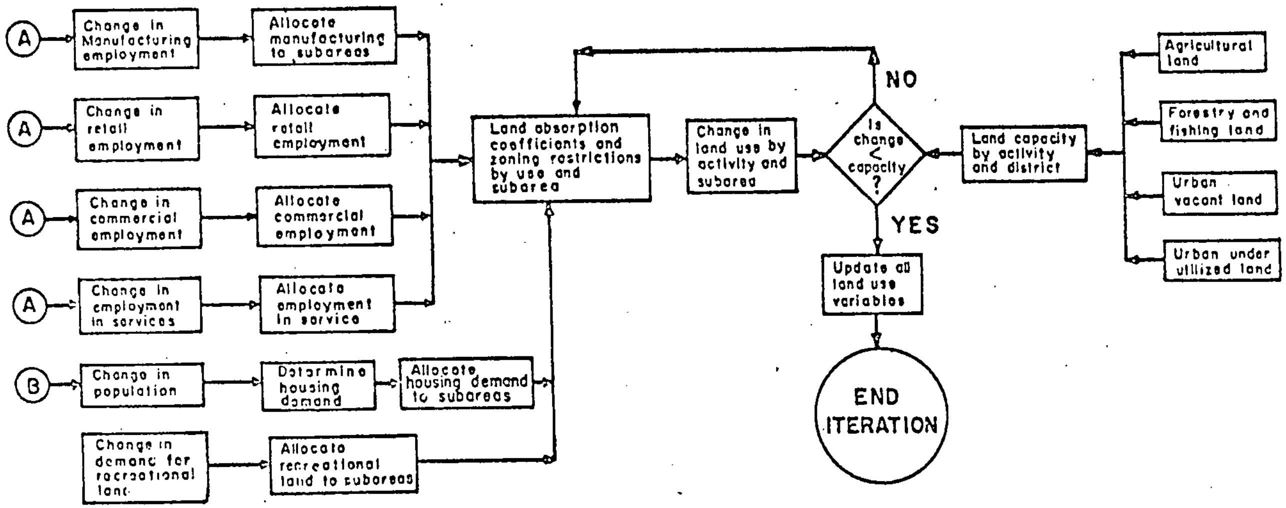


Figure 2

THE INTERACTION BETWEEN THE MODULE AND

THE REGIONAL TRANSPORTATION MODEL



(A) Employment changes from Economic Model

(B) Change in Population from Population Model

Figure 3

LAND USE MODELS

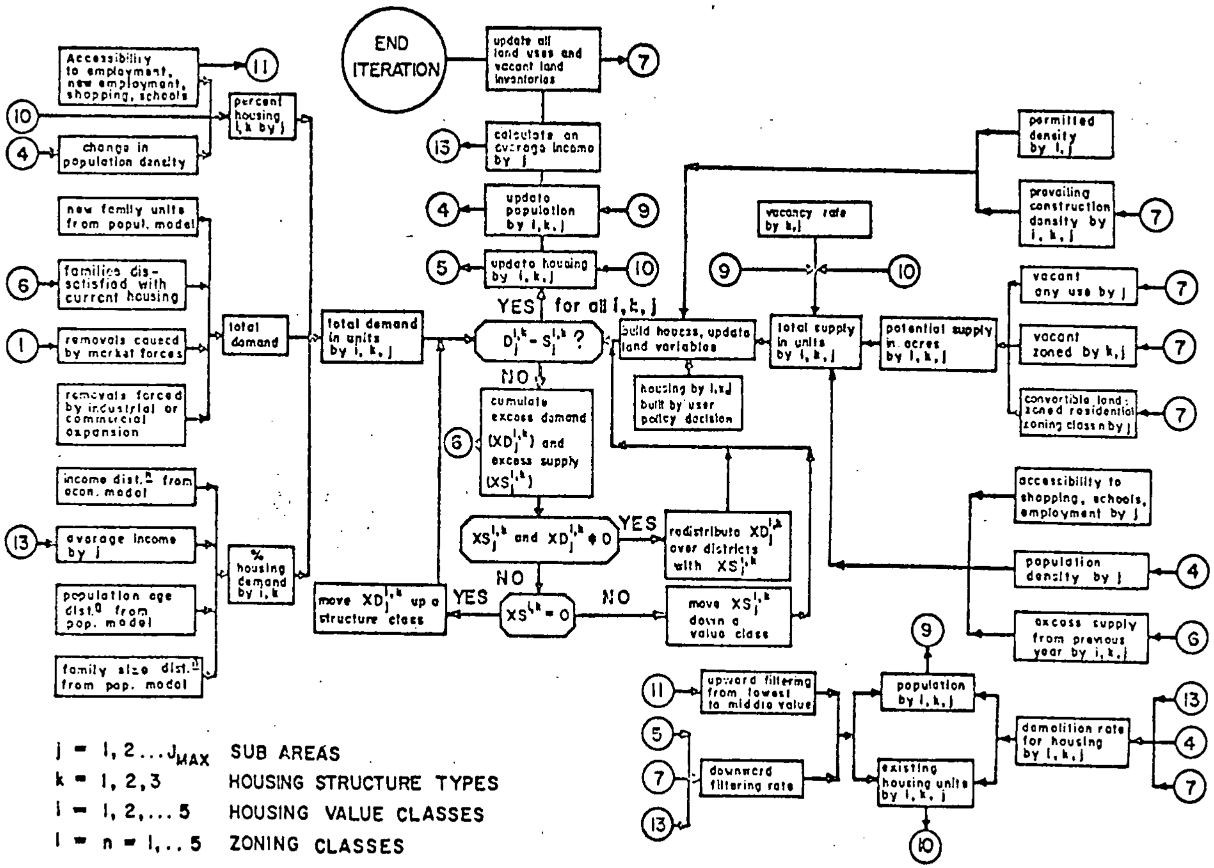


Figure 4

HOUSING MODEL

unit increment directly from the population sub-models which estimated annual increments to the stock of households. Equating household formation with housing development was a quick and easy way to derive forecasts of the amount of housing development, but did not allow for the existence of vacancies. Accordingly the next phase of model development included vacancies in the macro sub-model.

New macro supply was changed to equal the number of new households plus a demand for vacancies. The demand for vacancies was introduced to allow for inventories to meet short-run adjustments.[8]

Equation (1) below sets out the actual supply relationship used:

$$NS_t = TNH_t - THH_{t-1} \times VACRAT_t(THH_t) - VACRAT_{t-1}(THH_{t-1}) \qquad (1)$$

where

NS_t = total new supply for the period t

$THH_{t,t-1}$ = total households in period t and t-1

$VACRAT_{t,t-1}$ = weighted average vacancy rate over the preceding three periods.

If NS_t was negative then a small number of units were still built. This reflected the fact that the construction of new residential units does not stop even if there exists a large inventory of unsold or unoccupied units.

The initial approaches described above were largely *ad hoc* procedures which disaggregated the total new housing stock into total new single and multiple family housing stock for the region. The next phase of model development improved on these *ad hoc* techniques by developing two regression

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[8] Goldberg and Ash, *op. cit.*, p. 56.

equations, one for single family, and one for multiple family, which replaced the *ad hoc* macro forecast and allocation procedures in the model.

Equations (2) and (3) described below replaced equations (1) in the model structure.[9]

$$HS^m_t = \underset{(0.132)}{0.139HS^m_{t-1}} + \underset{(0.087)}{0.397HS^m_{t-2}} + \underset{(0.039)}{0.095POP_{t-1}} - \underset{(0.038)}{0.047POP_{t-2}} \quad (2)$$

$R^2 = 0.358$ F Statistic (5,107) = 100.443

$$HS^s_t = -31.0 + \underset{(0.112)}{0.25HS^s_{t-1}} - \underset{(0.117)}{0.129HS^s_{t-2}} + \underset{(0.023)}{0.051POP_t} + \underset{(0.025)}{0.070POP_{t-1}} + \underset{(0.023)}{0.045POP_{t-2}} \quad (3)$$

$R^2 = 0.894$ F Statistic (6,106) = 283.939

where

$HS^m_{t,t-1,t-2}$ = multiple family housing starts for periods t, t-1, t-2 for the region

$HS^s_{t,t-1,t-2}$ = single family housing starts for periods t, t-1, t-2 for the region

$POP_{t,t-1,t-2}$ = population for periods t, t-1, t-2 for the region.

This is the version of the macro housing sub-model which is used in the present version of the IIPS model.

5. Microspatial Housing Sub-Models

The three original microspatial housing submodels, demand, supply and market resolution, are presented diagramatically in Figure four, and are described in detail below.

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[9] Ibid., p. 57. Since these equations formed part of a large simulation system, the independent variables had to be capable of being forecast internally. Consequently, monetary and financial variables such as interest rates, money supply and other measures of credit conditions could not be used since they could not be generated within the model. The equations were based on pooled cross-section time-series data on housing starts compiled by Central Mortgage and Housing Corporation for the GVRD.

a. Demand. The original allocation of total demand to the subareas was done on the basis of an allocation function which contained the following variables: access to employment, access to shopping, size of the current housing stock, average family size, income, age distribution and the rate of household formation. The resulting demand $D_j^{i,K}$ was demand in subarea j, for housing type K and value class i. This process was an ad hoc intuitive formulation which remains unchanged in the present version of the model.

b. Supply. The original allocation of total supply to the subareas was done on the same basis as demand except that the following variables were used in the allocation function: actual and allowable densities, available land, accessibility to employment, accessibility to shopping, excess supply, and the number of occupied units. The resulting supply, $S_j^{i,K}$ was supply by subarea j, structure type K, and value class i. This allocation procedure was a largely ad hoc intuitive formulation based on rules of thumb suggested by the literature and in common use in the region. The functional forms of the variables were essentially unproven hypotheses about the likely relationships between the zonal variables and housing development.

The major problem with these rather crude allocation methods was the demolition of existing improvements as the older core areas, or newer under improved areas, approached the economic redevelopment stage.[10] The redevelopment of these areas could not be adequately modelled by the original model. The original researchers found this problem difficult to model except by

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[10]This is a rather complex problem which is important for models of Canadian cities. For example see: Robert W. Collier, Contemporary Cathedrals (Montreal, Quebec: Harvest House, 1974); and City of Vancouver, Urban Renewal Study (Vancouver, B.C.: City of Vancouver, Planning Department, 1969).

direct policy intervention.[11] This type of approach led to no change, or a slight increase in density, in areas which were actually being developed at much higher densities. This was a serious weakness of the original sub-model formulations.

After studying a number of areas in the region which had been rezoned, the IIPS researchers established that a demolition rate of 2-3% per year of the stock prevailed over the previous decade in areas which were rezoned and subsequently redeveloped. The researchers working on the model developed a demolition algorithm which mimicked the demolition process by comparing actual density to the allowable density and the unsatisfied demand from the previous iteration. This demolition algorithm was combined with the intuitive allocation algorithm described previously to produce the supply by subarea, value class and structure type.

This was the stage of development of this sub-model which existed when the present work began. A detailed summary of the revisions to this sub-model and the results of testing various versions of the model are presented in Chapter five.

c. Market resolution. In the original model formulations, macro demand and supply were assumed to be equal.[12] However, differences between supply and demand by structure type and value class for each subarea were reconciled by cumulating excess demand and reallocating it to areas with excess supply. Excess demand was first allocated to other subareas with similar housing (by type and class). If no similar housing was available, demand was

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[11] Goldberg and Ash, op. cit., p. 57.

[12] Goldberg, "Housing, Employment, Land Use," p. 7.

allocated to those areas that had housing of the same value class, but any structure type. If there was no such housing available, the excess was allocated to subareas with the originally desired structure type, but the next lower value class. This process continued until all excess demands were allocated.

If there was excess supply in any subareas, the excess housing was assigned to the next lower value class to mimick the effects of competition and price cutting. In this way excess supply moved down through the value classes. Excess demand, however, moved across structure types within the same value class, unless no housing existed in any subarea of the desired value class, in which case demand moved down one value class and then across the structure types again if necessary. This market mechanism remains unchanged in the present version of the model.

6. Extensions

The revised IIPS model, as described in the foregoing sections of this chapter, was the urban model used to test the empirical results of Chapter three. The empirical results of Chapter three were incorporated into the microspatial supply sub-model described in this chapter to test their ability to predict future patterns of urban growth, and to further develop the microspatial supply sub-model with the results of actual behavioural studies. The following chapter describes the method used to incorporate the results of Chapter three into the microspatial supply sub-model, and also describes the results of testing the output of various versions of the overall model against actual land-use data for the 1971-1975 period.

Chapter 5

TESTING MICROSPATIAL SUPPLY REVISIONS

1. Introduction

To observe the behaviour of the model described in Chapter four with microspatial supply revisions incorporating the results of Chapter three, four versions of the model were formulated and tested. This chapter first describes these versions of the model, and then presents the results of testing their simulated output with actual data. The chapter concludes with a comparison of these results and the results of other studies which have tested simulated output against actual data.

2. Models Tested

a. Model 1 - The Original Model. This was the original model as described in Chapter four. It was based on largely *ad hoc* formulations derived from intuition and rules of thumb in common use in the region.

b. Model 2 - Code and Data Update. This version followed directly from the original model with a number of minor changes. Firstly, minor coding errors were corrected and the model subjected to careful comparison of the computer code and the underlying concepts. Secondly, the data base of the model was updated from 1970 to 1971 to make use of the 1971 GVRD land use data and the zoning and sewer data described in Chapter three. Finally, the land supply variable for each subarea in the microspatial supply allocation routines was changed from vacant land to vacant, zoned and sewered land.

c. Model 3 - New Regression Equations. The *ad hoc* micro spatial supply equations of Model 1 were replaced by two single equation estimators which were derived from the results presented in Chapter three. The microspatial supply allocation function was thus reduced to the following two equations:

$$PCDEV^{s}_{jt} = 0.189 + \underset{(0.00025)}{0.00182}(POTSUP^{s}_{jt}) \quad R^2 = 0.246 \quad F(2,165) = 51,208 \quad (1)$$

$$PCDEV^{m}_{jt} = 0.304 + \underset{(0.00004)}{0.0007}(POTSUP^{m}_{jt}) \quad R^2 = 0.703 \quad F(2,165) = 371,964 \quad (2)$$

where:

$PCDEV^{s}_{jt}$ = percentage of 1966-1971 single family housing development in GVRD that was accounted for by subarea j

$PCDEV^{m}_{jt}$ = percentage of 1966-1971 multiple family housing development that was accounted for by subarea j

$POTSUP^{s}_{jt}$ = potential supply of land for single family development in subarea j as given by the number of acres of properly zoned, sewered and vacant land in j

$POTSUP^{m}_{jt}$ = potential supply of land for multiple family development given by number of acres of properly zoned, sewered and vacant land in subarea j and by the allowable density of development.

d. Model 4 - New Regression Equations with Dummies. This version of the model builds directly on Model 3 with an important change: $PCDEV^{sf}_{jt}$ was changed so that it was a function of the municipality within which the development takes place as well as the POTSUP variable. The rationale for this specification was derived from the behavioural work described in Chapter two and the empirical analysis presented in Chapter three. This work suggested that municipal government constraints were considered by developers to be a significant factor in selecting the location for development. As a result of these findings, dummy variables for municipal areas were introduced into the allocation equations of Model 3 to produce the following two microspatial allocation equations:

$$PCDEV^{sf}_{jt} = \underset{}{0.229} + \underset{(0.00024)}{0.0017}\ POTSUP^{sf}_{jt} - \underset{(0.283)}{0.359}\ DUMMY1 - \underset{(0.303)}{0.508}\ DUMMY2$$

$$+ \underset{(0.313)}{1.608}\ DUMMY3 - \underset{(0.419)}{0.789}\ DUMMY4 - \underset{(0.512)}{0.371}\ DUMMY5 - \underset{(0.315)}{0.191}\ DUMMY6$$

$$+ \underset{(0.524)}{0.730}\ DUMMY7 - \underset{(2.33)}{0.173}\ DUMMY8 - \underset{(0.233)}{0.094}\ DUMMY9 - \underset{(0.350)}{0.0495}\ DUMMY10$$

$$+ \underset{(0.869)}{0.834}\ DUMMY11 - \underset{(0.523)}{0.453}\ DUMMY12$$

$$R^2 = 0.451 \qquad F(14,153) = 9.167 \qquad (3)$$

where:

$PCDEV^{sf}_{jt}$ = percent of 1966-71 single family development occurring in subarea j

$POTSUP^{sf}_{jt}$ = potential supply of land measured by vacant, zoned and sewered acres in subarea

DUMMY1 = Burnaby

DUMMY2 = Coquitlam

DUMMY3 = Delta

DUMMY4 = New Westminster

DUMMY5 = North Vancouver City

DUMMY6 = North Vancouver District

DUMMY7 = Port Coquitlam

DUMMY8 = Surrey

DUMMY9 = Vancouver

DUMMY10 = West Vancouver

DUMMY11 = White Rock

DUMMY12 = University Endowment Lands

Dummy variables proved to be insignificant for the other municipalities in the region and were not included.

Using dummy variables did not materially improve the explanatory power of equation 2 and it remained unchanged from Model 3.

$$PCDEV^{mf}_{jt} = 0.304 + \underset{(0.00004)}{0.0007} (POTSUP^{mf}_{jt}) \qquad (4)$$

$$R^2 = 0.703 \qquad F(2,165) = 371.964$$

where:

$PCDEV^{mf}_{jt}$ = percent of 1966-71 multiple family development occurring in subarea j

$POTSUP^{mf}_{jt}$ = potential supply of multiple family units in subarea j as measured by appropriately zoned, sewered and vacant land and the existing multiple family density in j.

e. Model 5 - Model 4 With Actual Macro Data. The four models described previously all relied on a macro supply forecast which was allocated to the subareas. However, tests of this macro forecast with actual data over the period 1972-1976 indicated that the forecast was not very accurate as Table 20 indicates, the forecasts were low in every year for both single and multiple family units. The single family forecast was the worst with up to a 44% deviation. The multiple family forecast was not as bad, although deviations ranged from 9% to 35%. As a result of the poor macro model performance, Model 5 was developed to isolate the microspatial model from poor macro model performance. This model is identical to Model 4 except it uses actual data in place of the macro housing forecasts.

3. Testing the Models

As the five models described previously were based on 1966-71 data, more recent data was required to test the simulation output of the models.

Table 20

MACRO MODEL COMPARISONS

	ACTUAL COMPLETIONS		MODEL COMPLETIONS		% DEVIATION	
YEAR	SF	MF	SF	MF	SF	MF
1972	6073	8103	4615	6752	-0.23	-0.17
1973	7088	7865	3998	6715	-0.44	-0.15
1974	5451	6586	4074	5584	-0.25	-0.15
1975	5762	6070	4256	5524	-0.26	-0.09
1976	6751	7955	4374	5176	-0.35	-0.35

SOURCE: C.M.H.C. Housing Statistics

The required data was obtained from the Greater Vancouver Regional District in the form of 1975 land-use and housing data for the subareas used in the tests.

To test the relationship between the simulated output and the actual data, the models were run for four simulated years beginning with 1972 and ending with 1975. The results of the simulations were then compared with the actual data by running the following regression tests:

$$PH^{sf}_{j,1975} = a_1 + b_1 AH^{sf}_{j,1975} + \mu_1 \quad (5)$$

$$PH^{mf}_{j,1975} = a_2 + b_2 AH^{mf}_{j,1975} + \mu_2 \quad (6)$$

where:

$PH^{sf}_{j.1975}$ = predicted stock of single family housing in subarea j in 1975

$AH^{sf}_{j,1975}$ = actual stock of single family housing in subarea j in 1975

$PH^{mf}_{j,1975}$ = predicted stock of multi-family housing in subarea j in 1975

$AH^{mf}_{j,1975}$ = actual stock of multi-family housing in subarea j in 1975

a_i, b_i = parameters to be estimated

u_i = error terms.

The results of the regression tests described above are presented in Table 21. These tests indicate that all the models performed well as the R^2 statistics are all high and the F statistics are all significant at the 0.001 level. Table 22 presents other measures of goodness of fit such as Theils inequality coefficient, Spearman's rank correlation coefficient and several other measures of error terms which generally support the results presented in Table 21.

Table 21

MODEL TEST REGRESSION RESULTS FOR STOCK OF UNITS

Dependent Variable - Model Prediction
Independent Variable - Actual Data

TEST	R	R^2	Standard Error of Estimate	F	Significance Level of F	Intercept	Coefficient	Standard Error of Coefficient
Stock of Single Family Units								
Model 1	0.973	0.948	317.54	2804.91	0.001	-7.086	0.898	0.017
2	0.970	0.941	375.98	2493.61	0.001	104.716	1.003	0.020
3	0.974	0.947	358.02	2864.15	0.001	91.591	1.023	0.019
4	0.976	0.954	341.48	3207.19	0.001	72.872	1.033	0.018
5	0.976	0.952	347.06	3099.42	0.001	78.500	1.032	0.019
Stock of Multi-Family Units								
Model 1	0.978	0.956	451.200	3337.81	0.001	46.402	0.891	0.015
2	0.991	0.981	296.691	8145.20	0.001	-42.108	0.916	0.010
3	0.990	0.980	286.569	7632.18	0.001	-6.296	0.856	0.010
4	0.989	0.978	301.254	6920.60	0.001	-1.985	0.857	0.010
5	0.986	0.973	337.045	5615.54	0.001	60.601	0.864	0.012

(N = 157)

Table 22

MODEL TEST RESULTS ACTUAL AGAINST MODEL FORECASTS FOR THE STOCK OF UNITS

TEST	Spearman Correlation	Mean Error	Mean Square Error	Root Mean Square Error	Theil U Statistic	Fraction of Error Due to:		
						Bias	Different Variation	Different Co-Variation
Stock of Single Family Units								
Model 1	0.9469	153.2	257.3	382.3	0.097	0.061	0.091	0.748
2	0.9668	-108.8	229.5	389.1	0.091	0.078	0.017	0.905
3	0.9713	-125.3	224.3	378.8	0.088	0.110	0.040	0.850
4	0.9720	-120.3	204.1	363.3	0.085	0.111	0.056	0.834
5	0.9721	-124.6	209.1	369.8	0.086	0.114	0.054	0.832
Stock of Multi-Family Units								
Model 1	0.8772	49.1	277.0	517.4	0.108	0.009	0.158	0.833
2	0.9101	116.3	205.7	373.1	0.078	0.097	0.224	0.679
3	0.9040	132.8	239.8	459.9	0.099	0.083	0.471	0.446
4	0.8975	127.7	247.7	466.2	0.100	0.075	0.447	0.478
5	0.8761	59.2	266.1	465.8	0.099	0.016	0.389	0.595

(N = 157)

However, using regression tests, such as those described by equations 5 and 6, which are based on the stock of units forecast over a short period of time is not really an adequate test of the performance of the models. Because of the short forecast period and the many micro areas used much of the stock in each subarea in 1975 is made up of the 1971 stock. A more rigorous test of the performance of the models is a comparison of the simulated change in the stock over the 1972 to 1975 period with the actual change in the stock. By using the change in the stock the dampening effect of the large stock which remains unchanged is eliminated and the ability of the models to properly place new units is more adequately tested.

To test the models simulated change in the housing stock with the actual change in the housing stock, the following regression tests were run:

$$\Delta PH^{sf}_{j,1975} = a_3 + b_3 \Delta AH^{sf}_{j,1975} + \mu_3 \tag{7}$$

$$\Delta PH^{mf}_{j,1975} = a_4 + b_4 \Delta AH^{mf}_{j,1975} + \mu_4 \tag{8}$$

where:

$\Delta PH^{sf}_{j,1975}$ = predicted change in stock of single family houses in subarea j between 1971 and 1975

$\Delta AH^{sf}_{j,1975}$ = actual change in stock of single family houses in subarea between 1971 and 1975

$\Delta PH^{mf}_{j,1975}$ = predicted change in stock of multi-family housing in subarea j between 1971 and 1975

$\Delta AH^{mf}_{j,1975}$ = actual change in stock of multi-family housing in subarea j between 1971 and 1975

a_i, b_i = parameters to be estimated

μ_i = error terms

As can be seen from Tables 23 and 24, the results of these tests indicate that the models did not predict the change in stock of units as well as the stock of units. The initial <u>ad hoc</u> model was the best at predicting the change in stock, but had an R^2 of only 0.209 compared to an R^2 of 0.948 for the stock of single family units. For the change in multiple family units, Model 2 performed the best, but had an R^2 of only 0.120 compared to an R^2 of 0.956 for the stock of multiple family units. Overall, Model 4 performed the most consistently, followed closely by Model 5.

From a preliminary inspection of the results of Tables 23 and 24 it may seem strange that Model 5 is less consistent than Model 4 when the macro supply figures of Model 5 are correct and the figures for Model 4 are incorrect. However, this discrepancy is easily resolved when one considers that the stock in period "t" is composed of the stock in period "t-1" plus the new supply minus demolitions. Since the new macro supply is known, and the stock in "t-1" is known, the inconsistency must lie in the amount and location of demolitions. This was found to be the case, and is a serious problem with the models which is discussed in detail in the following chapter.

In general, the results presented in Tables 21, 22, 23 and 24 are not very encouraging. Although improvements did occur in the performance of the models, the measures of performance presented in these tables tend to indicate that the increase in model performance was marginal. Consequently, one wonders whether the increase in model performance was worth the effort. I feel that although the improvements may not seem all that impressive, the unquantifiable increase in knowledge of the inner workings of the models and the modelling process were by themselves justifiable reasons for pursuing an increase in performance. Also, when compared to other studies which have compared simulated model output with actual data, the results presented here are not as discouraging.

4. Comparison of the Results with Other Studies

An extensive review of the modelling literature produced a large number of studies which reported on the design and calibration of models on historical and cross-sectional data. The types of models varied from simple regression models[1] to quite complex linear programming[2] and simultaneous equation models.[3] The methods of testing the models varied, but the results of the calibration tests were usually quite impressive. However, only two studies could be found which reported on the testing of simulated output data with actual data.

The first study which compared simulated data with actual data was conducted by A.H. Voelker at the Oak Ridge National Laboratory.[4] Although the tests of the simluated data with actual data are not described in detail, it appears that the test period is less than ten years, and that over this period the model consumed 20% more land than was actually consumed. Voelker concludes by stating that future testing of the model

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[1]Williard B. Hansen, "An Approach to the Analysis of Metropolitan Residential Extension," Journal of Regional Science, Vol. 3, No. 1 (1961) pp. 37-55.

[2]John D. Herbert and Benjamin H. Stevens, "A Model for the Distribution of Residential Activity in Urban Areas," Journal of Regional Science (Fall 1960) pp. 21-36.

[3]Donald N. Steinnes and Walter D. Fisher, "An Econometric Model of Intraurban Location," Journal of Regional Science, Vol. 14, No. 1 (1974) pp. 65-80.

[4]A.H. Voelker, "A Cell-Based Land-Use Model," ORNL/RUS-16 (Oak Ridge, Tennessee: Oak Ridge National Laboratory, May 1976).

Table 23

MODEL TEST REGRESSION RESULTS FOR CHANGE IN THE STOCK OF UNITS

Dependent Variable - Model Prediction
Independent Variable - Actual Data

TEST	R	R^2	Standard Error of Estimate	F	Significance Level of F	Intercept	Coefficient	Standard Error of Coefficient
Change in Single Family Units								
Model 1	0.457	0.209	253.802	40.954	0.001	-140.090	0.348	0.054
2	0.116	0.013	94.284	2.112	0.148	128.376	0.029	0.020
3	0.286	0.082	119.268	13.795	0.001	143.541	0.095	0.026
4	0.392	0.154	141.319	28.129	0.001	137.157	0.161	0.030
5	0.359	0.123	139.819	22.866	0.001	141.844	0.143	0.030
Change in Multi-Family Units								
Model 1	0.447	0.120	446.568	38.721	0.001	87.160	0.459	0.074
2	0.713	0.508	169.495	160.495	0.001	46.252	0.352	0.028
3	0.422	0.178	146.376	33.588	0.001	83.735	0.140	0.024
4	0.373	0.139	127.711	25.088	0.001	88.100	0.143	0.029
5	0.354	0.126	251.614	22.293	0.001	143.144	0.196	0.042

(N = 157)

Table 24

MODEL TEST RESULTS ACTUAL AGAINST MODEL FORECASTS FOR CHANGE IN THE STOCK OF UNITS

TEST	Spearman Correlation	Mean Error	Mean Square Error	Root Mean Square Error	Theil U Statistic	Fraction of Error due to: Bias	Different Variation	Different Co-Variation
Change in Single Family Units								
Model 1	0.1256	153.2	257.3	382.2	0.557	0.161	0.054	0.785
2	0.1256	-108.8	229.5	389.1	0.730	0.078	0.511	0.411
3	0.4148	-125.3	224.3	378.8	0.672	0.110	0.432	0.458
4	0.4738	-120.3	204.1	363.3	0.626	0.110	0.367	0.523
5	0.4632	-124.6	209.1	369.8	0.637	0.114	0.366	0.520
Change in Multi-Family Units								
Model 1	0.2504	49.08	277.0	517.4	0.479	0.009	0.001	0.990
2	0.4790	116.3	205.7	373.1	0.455	0.097	0.424	0.479
3	0.4772	132.8	239.8	459.9	0.618	0.083	0.493	0.424
4	0.4526	127.7	247.7	466.2	0.607	0.075	0.410	0.515
5	0.4629	59.23	266.1	465.8	0.533	0.016	0.215	0.769

(N = 157)

output with actual data is a high priority, but awaits the development of improved data bases.[5]

The second study which compares simulated data with actual data was conducted by Professor Stephen Putman at the University Pennsylvania.[6] This study was much more detailed than Voelker's study and compared the output from Putman's model and the widely used EMPIRIC model with actual data. Both of these models were calibrated for the Minneapolis - St. Paul region and were run for the period 1960-1970. The results of testing the output of these models with actual data for the stock of housing by income class are presented in Table 25.[7] Although the R^2 statistics are quite high, ranging from 0.699 to 0.844, they refer to the stock of housing rather than the change in the stock of housing. As suggested earlier in this chapter, a much more demanding test would be on the change in stock between 1960 and 1970.

A number of national econometric models have also been subjected to tests of simulated data against actual data.[8] In general, the results of these tests have been rather poor, especially when one considers that these models tend to predict rather stable aggregated macro variables such as GNP. A study done by Victor Zarnowtiz at the National Bureau of Economic Research in the U.S. found that tests of simulated GNP with

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[5] Ibid., pp. 17-19.

[6] Stephen H. Putman, Laboratory Testing of Predictive Land-Use Models: Some Comparisons (Washington, D.C.: U.S. Department of Transportation, October, 1976).

[7] Ibid., p. 32.

[8] See H. Theil, Economic Forecasts and Policy, Second Revised Edition (Amsterdam: North Holland Publishing Company, 1965) and Shlomo Maital, What Do Economists Know: Predicted Accuracy, Causality and Structure of Experts' Expectations (Jerusalem: Foerder Institute of Economic Research, 1977).

Table 25

1960 - 1970 COMPARISONS OF EMPIRIC & DRAM: ACTUAL VS. PREDICTED

Household Type	EMPIRIC R^2	DRAM R^2
LIQ - lower income	0.918	0.750
LMIQ - lower middle	0.941	0.828
UMIQ - upper middle	0.889	0.844
HIQ - upper income	0.829	0.699

with actual GNP averaged errors of as much as 40% over as short a time period as eight quarters.[9] He also found that as the time period increased, and the variables became more disaggregated, the performance of the models declined rapidly.

Considering the results of the studies discussed above, the results of testing the models described in this chapter are not as discouraging as one would first suspect. Given the highly disaggregated nature of the model output (housing by two structure types and 167 areas for four years) the results of testing the simulated output with actual data are acceptable, and are comparable to or better than other similar studies.

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[9]Victor Zarnowitz, An Appraisal of Short-Term Economic Forecasts, Occassional Paper 104 (New York, N.Y.: National Bureau of Economic Research, 1967).

Chapter 6

CONCLUSIONS

The results of this study indicate that behavioural research studies can be effectively used in defining criteria to test in empirical models of the spatial allocation of housing development. Specifically, supply side criteria identified by developer surveys as being important in explaining the spatial allocation of growth were tested and found to be important. Accessibility measures which were suggested by the literature as important in explaining the allocation of housing development were tested and found to be of marginal importance. The significance levels varied between the measures tested, but tend to indicate that land use models which rely heavily on the demand side of the housing market for the spatial allocation of growth may be inadequate. These results must be qualified by the fact that they represent only a specific period in time, and are not the results of dynamic time series tests. However, they do suggest that during the time period studied supply criteria were important in explaining the allocation of regional development to subareas.

From a preliminary inspection of the test results presented in Chapter three it may seem strange that accessibility measures were not very important in explaining the allocation of housing development. However, if one considers that land in the Greater Vancouver Regional District (GVRD) is widely held, and that markets are competitive, this apparent inconsistency can be resolved.

The basic tenets of urban land economics suggest that in a competitive market situation the most accessible housing will demand the highest economic rent and capital value. However, if the cost of producing a marketable commodity in each location is the same, including developers' profit, then the differences in land value should soak up excess profits and make the developer indifferent to location. Developers should be indifferent to location because the price bid for land will be highest in the most accessible areas and lower in peripheral less accessible areas. Therefore, the trade-off between access and price will be identical at all locations and the developer will locate in his area of preference. If developers are mainly small operators as the developer surveys suggest,[1] then they are most likely to located in areas they know which have a supply of developable land.

Another possible reason for the marginal importance of accessibility in the GVRD is the relative stability of the transportation network over the last twenty years. During this period there have been no significant transportation improvements except for the opening of the Trans Canada Highway freeway in 1961. Consequently, travel patterns and accessibility have remained reasonably constant. This is in direct contrast to the U.S. experience which has involved massive freeway building. Most of the modelling work done to date has been in the U.S., and therefore may overstress the applicability of accessibility importance to other areas.

While accessibility is important in models which determine the final value of housing, accessibility is not necessarily an important criteria

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[1]Michael A. Goldberg and Daniel D. Ulinder, "Residential Developer Behaviour: 1975," Housing It's Your Move, Vol. II, Technical Reports (Vancouver, B.C.: Urban Land Economics Division, Faculty of Commerce and Business Administration, University of British Columbia, 1976) p. 277.

for developers who build housing. Developers appear to be primarily interested in land availability, rather than developing in accessible locations.

In general, the results of testing the output of a predictive urban model with microspatial supply allocation functions derived from potential supply measures were not encouraging. Although improvements did occur in the performance of the model, the results of testing simulated data with actual data tend to indicate that the improvement in model performance was marginal. Consequently, one wonders whether the increase in model performance was worth the effort. Although the answer to this question is subjective, I feel that the unquantifiable increase in knowledge of the inner workings of the model and the development process by themselves justified the effort. Also, when one considers the highly disaggregated nature of the model output (housing by two structure types and 167 areas for four years) the results themselves are acceptable, and are comparable to or better than similar studies. However, several problems remain for future study.

The first problem is the availability of data. The most serious deficiency in the data base is the number of housing starts by subarea in the region. As a result of this deficiency, the new microspatial supply equations were estimated using changes in the stock of housing units, rather than the number of new units. Thus these equations include new additions to the stock along with demolitions and conversions of existing units. However, the allocations in the models run on single and multiple family housing starts. As a result, there is an inconsistency which needs to be resolved. There are two methods of resolving this problem. First, estimate the allocations by subarea using actual starts data, and second, use the formulation devised but add a demolition and conversion algorithm. Unfortunately the data to apply either of these approaches is not available.

Without accurate data on which to develop accurate demolition and conversion algorithms, the models tested in this study are continually building new units without accurately removing or converting the existing stock. As a result, two types of errors occur. Error one occurs in subareas where there is sufficient land to build new units, but the demolition of existing stock is also significant. In this situation the models tend to overestimate the stock because they do not accurately consider the removal of existing units. Error two occurs in subareas where there is little land for development, but there is a significant amount of demolition. In this situation the models tend to underestimate development because they do not accurately consider the potential supply of land due to demolitions. Error two seems to be the most significant error as an examination of residuals produced from the tests indicates that errors are worst in the high density older areas of the region where demolitions are an important factor.[2]

Similar difficulties as those described above arise because of conversions of single detached units to higher density. Where the models predicted no building, there may have actually been a considerable amount of conversions. In such a case there would actually be a potential supply

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[2]For details see: City of Vancouver Planning Department, "Demolition Report" (Vancouver, B.C.: City of Vancouver Planning Department, August 24, 1977). This study indicates that during the period January 1, 1973 to February 1, 1977 there were over 12,000 housing starts in the City of Vancouver and 4,492 demolitions. Consequently, demolitions are of some importance in the allocation of growth to the 31 subareas of the GVRD which are in Vancouver. The problem is compounded because there does not seem to be any consistent pattern to the demolitions.

of new units, but no vacant land to build these units on.

The net result of the foregoing considerations is that there is a need to understand the dynamics of the standing stock. Not only is this required for the models described here, but for other simulation studies as well. Research studies are needed to study the demolition, renovation and conversion of the existing stock. Such activities, while not necessarily changing the number of units in the stock or the density of the stock, may have considerable impact on the character of an area.

The second problem is the land absorption coefficients (LAC) which convert housing units to acres of land used. These LAC's are at the heart of the market mechanism as they are part of the tests which determine the amount of available land for development. In accurate land absorption coefficient can combine with the dynamics of demolitions to produce models which use land too rapidly or not rapidly enough. Better estimates of LAC's are needed if the models described here, and similar simulation efforts, are to be able to forecast land use and housing allocation correctly.

The problems associated with land absorption coefficients can be seen from an examination of Tables 26 and 27. These tables are analogous to Tables 21 and 23, only they report on tests of the predictive accuracy of the models with respect to acres rather than units. The results are generally lower, illustrating the errors introduced by unreliable LAC's.

The final problem which remains is the two short time periods over which the allocation functions were developed and the model tested. Not only were these two periods quite short, but they were also quite different. The 1966-71 period over which the allocation functions were developed was one of steady economic growth, while the 1971-75 period was a period

Table 26

MODEL TEST REGRESSION RESULTS FOR THE STOCK OF ACRES

Dependent Variable - Model Prediction
Independent Variable - Actual Data

TEST	R	R^2	Standard Error of Estimate	F	Significance Level of F	Intercept	Coefficient	Standard Error of Coefficient
Stock of Single Family								
Model 1	0.892	0.795	118.694	602.220	0.001	17.015	0.963	0.039
2	0.967	0.967	64.473	2211.064	0.001	15.773	1.002	0.021
3	0.970	0.940	63.518	2446.537	0.001	5.447	1.039	0.021
4	0.974	0.948	59.948	2812.053	0.001	1.586	1.051	0.020
5	0.973	0.947	61.870	2776.307	0.001	2.122	1.078	0.020
Stock of Multi-Family								
Model 1	0.788	0.620	20.625	253.133	0.001	3.290	0.821	0.052
2	0.897	0.804	11.848	636.598	0.001	1.090	0.748	0.030
3	0.912	0.832	9.605	770.264	0.001	0.811	0.667	0.024
4	0.912	0.832	9.667	766.708	0.001	0.878	0.670	0.024
5	0.910	0.828	10.031	747.085	0.001	1.084	0.686	0.025

(N = 157)

Table 27

MODEL TEST REGRESSION RESULTS FOR CHANGE IN THE STOCK OF ACRES

Dependent Variable - Model Prediction
Independent Variable - Actual Data

TEST	R	R^2	Standard Error of Estimate	F	Significance Level of F	Intercept	Coefficient	Standard Error of Coefficient
Change in Single Family								
Model 1	0.042	0.002	103.976	0.268	0.606	19.371	0.069	0.134
2	0.084	0.007	22.690	1.108	0.294	29.309	0.031	0.029
3	0.163	0.027	28.469	4.249	0.041	28.266	0.037	0.037
4	0.324	0.105	34.846	18.190	0.001	26.200	0.192	0.045
5	0.324	0.105	44.391	18.191	0.001	33.304	0.244	0.057
Change in Multi Family								
Model 1	0.222	0.050	18.313	8.073	0.005	5.584	0.274	0.096
2	0.375	0.141	7.470	25.412	0.001	2.428	0.198	0.039
3	0.372	0.138	3.087	24.986	0.001	1.375	0.081	0.016
4	0.370	0.137	3.293	25.565	0.001	1.462	0.086	0.017
5	0.373	0.139	4.201	25.066	0.001	1.813	0.111	0.022

(N = 157)

of high inflation. During the 1971-75 period the housing market took off on a major inflationary spiral, and housing types and densities changed. Consequently, the development and test periods need to be extended to longer periods so that a more consistent and applicable model can be developed. Unfortunately, the data is not available at the present time.

Even if one takes the preceding problems into account, the research described in this paper suggests that future behavioural studies of the roles played by residential developers and municipal governments, combined with analytical models of this behaviour, may provide considerable insight into the residential development process. However, the results must be qualified by the fact that the tests were conducted in a specific area over a short period, and are not necessarily applicable to all regions or time periods.

In general, the results of this study lend supporting evidence to the suggestion that municipal governments have been effective in allocating growth by their servicing and zoning policies. Consequently, future research studies should also be directed at understanding the decision making process of these governments if a true understanding of the development process is to be obtained.

In conclusion, this study has taken a supply perspective to residential development to overcome the shortcomings of earlier demand-oriented approaches. However, the supply perspective should not be viewed as an end in itself, but rather as a part of the evolutionary process of modelling the urban environment. Demand must also be considered explicitly, and with the same detail, so that in future studies both demand and supply can be combined.

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Appendix A

DEVELOPER SURVEY QUESTIONS AND TABLES OF THE RESULTS

Table A-1

QUESTION II-3 1972 DEVELOPER SURVEY

I will now read you a list of factors generally considered important in the location of site selection decision. Would you please indicate the relative importance of each in the same manner as before.

1. Availability of developable land
2. Room for expansion
3. Price of land
4. Size of the site
5. Nearness to major roads
6. Nearness to major shopping areas
7. Nearness to bus routes
8. Nearness to schools
9. Nearness to employment
10. Slope of the site
11. Holding qualities of the soil
12. Access to trunk sewer
13. Proper zoning

Ranking

(0) unimportant

(1) fairly important

(2) of average importance

(3) very important

(4) essential

TABLE A-2

Evaluation of Location Factors
By Developers of Single Family Dwellings
(Per cent of Respondents in Parentheses)

Location Factors	Unimportant (0)	Fairly Important (1)	Average Importance (2)	Very Important (3)	Essential (4)	Mean	Standard Deviation
Proper Zoning	2(4.4)	0(0.0)	3(6.7)	9(20.0)	31(68.9)	3.49	0.97
Access to Trunk Sewer	1(2.2)	1(2.2)	1(2.2)	23(51.1)	19(42.2)	3.29	0.81
Price of Land	1(2.2)	1(2.2)	3(6.7)	15(33.3)	25(55.6)	3.38	0.89
Availability of Developable Land	1(2.2)	3(6.7)	9(20.0)	18(40.0)	14(31.1)	2.91	1.00
Nearness to Schools	3(6.7)	4(8.9)	9(20.0)	25(55.6)	4(8.9)	2.51	1.01
Nearness to Major Roads	7(15.6)	6(13.3)	12(26.7)	17(37.8)	3(6.7)	2.07	1.19
Nearness to Major Shopping Areas	4(8.9)	4(8.9)	14(31.1)	21(46.7)	2(46.7)	2.29	1.01
Size of Site	9(20.5)	7(15.9)	10(22.7)	14(31.8)	4(9.1)	1.93	1.30

Source: Richard A. Moore, A Development Potential Model For The Vancouver Area (Unpublished MBA Thesis, The University of British Columbia, 1972), p. 64.

TABLE A-3

Evaluation of Location Factors By Developers of Multiple Family Dwellings

(Per cent of Respondents in Parentheses)

Location Factors	Unimportant (0)	Fairly Important (1)	Average Importance (2)	Very Important (3)	Essential (4)	Mean	Standard Deviation
Proper Zoning	1(2.6)	0(0.0)	3(7.9)	11(29.0)	23(60.5)	3.45	.86
Access to Trunk Sewer	2(5.3)	1(2.6)	0(0.0)	14(36.8)	21(55.3)	3.34	1.02
Price of Land	2(5.3)	1(2.6)	4(10.5)	13(34.2)	18(47.4)	3.16	1.08
Availability of Developable Land	1(2.6)	3(7.9)	8(21.0)	9(23.7)	17(44.7)	3.00	1.12
Nearness to Schools	6(16.2)	4(10.8)	9(24.3)	14(37.8)	4(10.8)	2.16	1.26
Nearness to Major Roads	4(10.5)	4(10.5)	9(23.7)	16(42.1)	5(13.2)	2.36	1.17
Nearness to Major Shopping Areas	5(13.5)	5(13.5)	12(32.4)	13(35.2)	2(5.4)	2.05	1.13
Size of Site	3(7.9)	5(13.2)	11(29.0)	14(36.8)	5(13.2)	2.34	1.12

Source: Richard A. Moore, A Development Potential Model For The Vancouver Area (Unpublished MBA Thesis, The University of British Columbia, 1972), p. 63.

Table A-4

QUESTION 6.4 1975 DEVELOPER SURVEY

I will now read you a list of factors generally considered important in the location or site selection decision. Would you please indicate relative importance of each in the same manner as before.

1. Availability of developable land
2. Room for expansion
3. Price of land
4. Size of the site
5. Nearness to major roads
6. Nearness to bus routes
7. Nearness to major shopping areas
8. Nearness to schools
9. Nearness to employment
10. Slope of the site
11. Holding qualities of the soil
12. Access to trunk sewer
13. Proper zoning
* 14. Character of the surrounding area (existing or potential)
* 15. Other (please specifiy)

Ranking

(0) unimportant
(1) fairly important
(2) of average importance
(3) very important
(4) essential

* Denotes a factor not included in the 1972 survey.

TABLE A-5

Evaluation of Location Factors
By Developers of Single Family Dwellings
(Percent of Respondents in Parentheses)

Location Factors	Unimportant (0)	Fairly Important (1)	Average Importance (2)	Very Important (3)	Essential (4)	No Response	Mean	Standard Deviation
Proper Zoning	4(6.2)	0(0.0)	4(6.2)	17(26.2)	35(53.8)	5(7.7)	3.32	1.08
Price of Land	3(4.6)	0(0.0)	4(6.2)	26(40.0)	27(41.5)	5(7.7)	3.23	0.96
Access to Trunk Sewer	7(10.8)	2(3.1)	3(4.6)	24(36.9)	24(36.9)	5(7.7)	2.93	1.29
Availability of Developable Land	3(4.6)	5(7.7)	5(7.7)	36(55.4)	11(16.9)	5(7.7)	2.78	1.01
Nearness to Schools	6(9.2)	4(6.2)	14(21.5)	31(47.7)	5(7.7)	5(7.7)	2.42	1.08
Size of Site	13(20.0)	2(3.1)	18(27.7)	23(35.4)	4(6.2)	5(7.7)	2.05	1.25
Nearness to Major Road	7(10.8)	11(16.9)	16(24.6)	21(32.3)	5(7.7)	5(7.7)	2.10	1.16
Character of Surrounding Area	7(10.8)	8(12.3)	19(29.2)	22(33.8)	3(4.6)	6(9.2)	2.10	1.09

Source: Michael A. Goldberg and Daniel D. Ulinder, Housing: It's Your Move, Vol. II, Technical Reports (Vancouver: Urban Land Economics Division, Faculty of Commerce and Business Administration, The University of British Columbia, 1976), p.281.

TABLE A-6

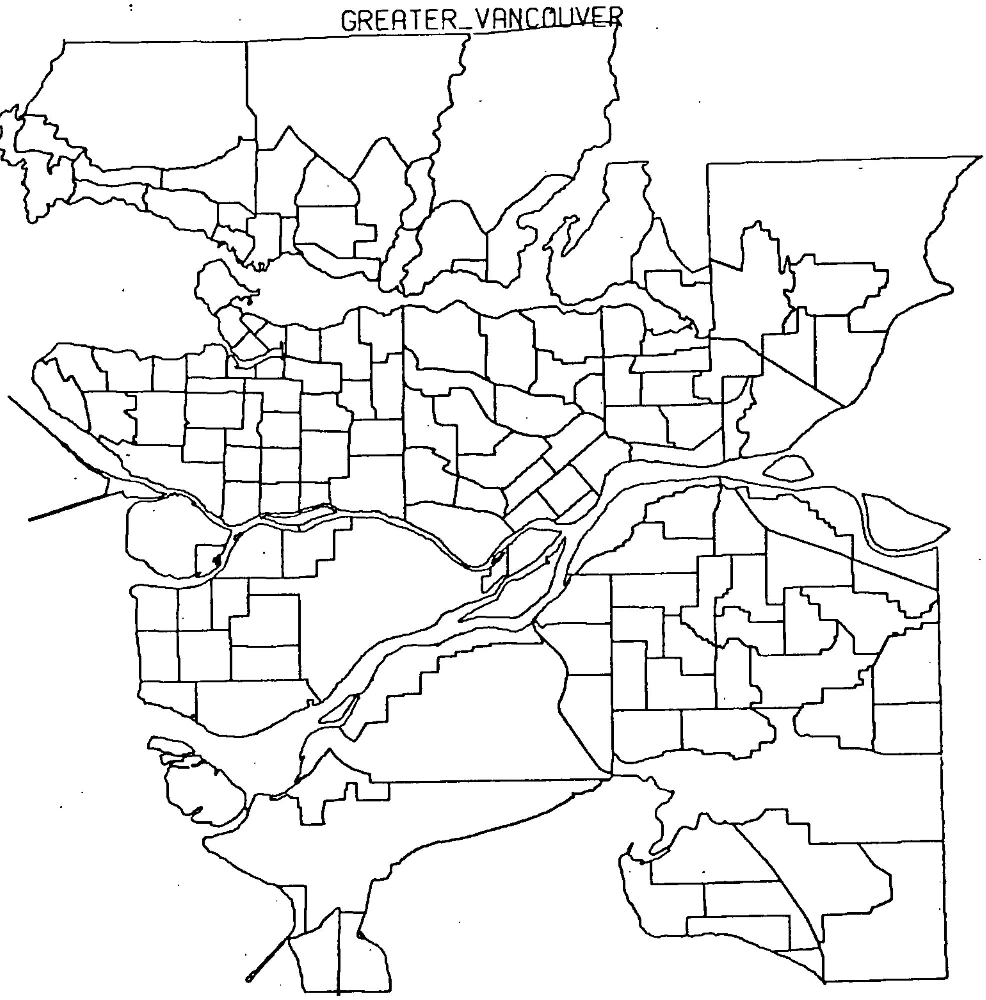
Evaluation of Location Factors
By Developers of Multiple Family Dwellings
(Percent of Respondents in Parentheses)

Location Factors	Unimportant (0)	Fairly Important (1)	Average Importance (2)	Very Important (3)	Essential (4)	No Response	Mean	Standard Deviation
Proper Zoning	1(2.5)	1(2.5)	4(10.0)	15(37.5)	15(37.5)	4(10.0)	3.17	0.94
Price of Land	1(2.5)	2(5.0)	4(10.0)	17(42.5)	12(30.0)	4(10.0)	3.03	0.97
Access to Trunk Sewer	2(5.0)	2(5.0)	2(5.0)	16(40.0)	14(35.0)	4(10.0)	3.06	1.09
Availability of Developable Land	2(5.0)	3(7.5)	4(10.0)	19(47.5)	8(20.0)	4(10.0)	2.78	1.07
Nearness to Schools	1(2.5)	8(20.0)	17(42.5)	6(15.0)	3(7.5)	5(12.5)	2.06	0.94
Size of Site	2(5.0)	4(10.0)	10(25.0)	16(40.0)	3(7.5)	5(12.5)	2.40	1.01
Nearness to Major Road	0(0.0)	8(20.0)	13(32.5)	12(30.0)	2(5.0)	5(12.5)	2.23	0.88
Character of Surrounding Area	3(7.5)	8(20.0)	6(15.0)	14(35.0)	4(10.0)	5(12.5)	2.23	1.19

Source: Michael A. Goldberg and Daniel D. Ulinder, Housing It's Your Move, Vol.II., Technical Reports (Vancouver: Urban Land Economics Division, Faculty of Commerce and Business Administration, The University of British Columbia, 1976), p.280.

Appendix B

MAP OF THE GVRD


GREATER_VANCOUVER

Appendix C

DETAILED DESCRIPTION OF THE INDEPENDENT VARIABLES USED IN THE EMPIRICAL ANALYSIS DESCRIBED IN CHAPTER THREE

The independent variables selected for the analysis in Chapter three and the methods used to calculate them are explained below. Measures for each of these variables were obtained for the 161 subareas used in the analysis.

MEASURES OF POTENTIAL SUPPLY

(1) Measures of Potential Single Family Supply in Acres

X_1 -- Vacant. Measures the amount of vacant land in acres for 1966. Obtained from the GVRD land use data.

X_2 -- Vacant and zoned single family (SF). Measures the amount of land in acres which was vacant and zoned for SF uses. Calculated by subtracting the amount of land in SF uses (single detached and duplex) in 1966 from that zoned for SF uses.

X_3 -- Vacant, sewered and zoned SF. Measures the amount of land in acres which was vacant, zoned for SF uses, and was within 500 feet of existing sewer development. Calculated by subtracting the amount of land in SF uses in 1966 from that zoned SF and within 500 feet of existing sewer development.

(2) Measures of Potential SF Housing Supply in Units

X_4 -- Vacant x SF density. Measures the potential SF housing supply in units. Calculated by multiplying the existing SF density in units per acre for 1966 by the amount of vacant land in acres for 1966.

X_5 -- (Vacant and zoned SF) x SF density. Measures the potential SF housing supply in units. Calculated by multiplying the existing SF density in units per acre for 1966 by the amount of land which was vacant and zoned as calculated for X_2.

X_6 -- (Vacant, zoned and sewered SF) x SF density. Measures the potential SF housing supply in units. Calculated by multiplying the existing SF density for 1966 in units per acre by the amount of land which was vacant, zoned and sewered as calculated for X_3.

(3) Measures of Potential Multiple Family (MF) Land Supply in Acres

X_7 -- Vacant and zoned MF. Measures the amount of land in acres which was vacant and zoned for MF uses. Calculated by subtracting the amount of land in MF uses from that land zoned for MF uses.

X_8 -- Vacant, zoned and sewered MF. Measures the amount of land in acres which was vacant, zoned for MF uses, and was within 500 feet of existing sewer development. Calculated by subtracting the amount of land in MF uses from that land zoned for MF uses, and within 500 feet of existing sewer development.

(4) Measures of Potential MF Housing Supply in Units

X_9 -- Vacant x MF density. Measures the potential MF housing supply in units. Calculated by multiplying the existing MF density in units per acre by the amount of vacant land as calculated for X_1.

X_{10}-- (Vacant and zoned MF) x MF density. Measures the potential MF housing supply in units. Calculated by multiplying the existing MF density for 1966 in units per acre by the amount of land which was vacant and zoned as calculated for X_7.

X_{11}-- (Vacant, zoned and sewered) x MF density. Measures the potential MF housing supply in units. Calculated by multiplying the existing MF density for 1966 in units per acre by the amount of land which was vacant, zoned and within 500 feet of existing sewer development as calculated for X_8.

MEASURES OF ACCESSIBILITY

(1) Nearness to Schools

X_{12}-- Service employment. Measures the number of people employed in service industries within the subarea. Obtained from 1971 Census information contained in the IIPS data base.

X_{13}-- Accessibility to schools 1. Measures the accessibility to service employment by the accessibility potential formulation described in Appendix B. The activity variable used was service employment and the distance exponent was set at 1.0.

X_{14}-- Accessibility to schools 2. Same calculation procedure as X_{13} except that the distance exponent was set at 2.0.

(2) Nearness to Employment

X_{15}-- Total employment. Measures the number of people employed in each subarea. Obtained from 1971 Census information contained in the IIPS model data base.

X_{16}-- Accessibility to employment 1. Measures the accessibility to total employment by using the accessibility potential formulation described in Appendix B. The activity variable used was the total employment of the subarea and the distance exponent was set at 1.0.

X_{17}-- Accessibility to employment 2. Same calculation procedure as X_{16} except that the distance exponent was set at 2.0.

(3) Nearness to Shopping

X_{18}-- Travel time to the CBD. Measures the travel time to the CBD in minutes. Extracted from the IIPS model travel time matrix of automobile travel times between subareas within the GVRD.

X_{19}-- Straight line distance to the CBD. Measures the straight line distance in miles to the central business district as defined by the intersection of Georgia and Granville streets.

X_{20}-- Straight line distance to closest large shopping area. X_{19} and X_{20} measure the distance in miles in large shopping areas. These two variables were calculated by identifying the large shopping areas in the GVRD, plotting them on a map, and then measuring the straight line distance in centimetre between the centroid of each subarea and the two closest shopping areas. The distance in miles was obtained by multiplying the centimetre distance by the scale on the map.

X_{21}-- Straight line distance to the second closest large shopping area. Measurement of this variable explained in X_{20} above.

X_{22}-- Wholesale and retail trade employment. Measures the number of people employed in wholesale and retail industries within the subarea. Obtained from 1971 census information contained in the IIPS model data base.

X_{23}-- Accessiblity to shopping 1. Measures the accessibility to total school employment by using the accessibility potential function described in Appendix B. The activity variable used was the amount of service employment in the subarea and the distance exponent was set at 1.0.

X_{24}-- Accessibility to shopping 2. Same calculation procedure as X_{23} except that the distance exponent was set at 2.0.

Descriptive statistics for these variables are presented in Tables C-1, C-2 and C-3.

Table C-1

DESCRIPTIVE STATISTICS

MEASURES OF POTENTIAL SINGLE FAMILY HOUSING SUPPLY

VARIABLE	MEAN	STANDARD DEVIATION	LOW	HIGH
(1) Potential Supply in Acres				
X_1: Vacant	1275.98	2551.75	0.00	14568.64
X_2: Vacant and zoned SF	487.32	550.30	0.00	3084.83
X_3: Vacant, sewered and zoned SF	252.67	293.67	0.00	1279.74
(2) Potential Supply in Units				
X_4: Vacant x SF density	4226.61	8219.19	0.00	56435.64
X_5: (Vacant and zoned SF) x SF density	2081.07	2084.99	0.00	12259.08
X_6: (Vacant, sewered and zoned SF) x SF density	1280.51	1446.35	0.00	7285.18

Table C-2

DESCRIPTIVE STATISTICS

MEASURES OF POTENTIAL MULTIPLE FAMILY HOUSING SUPPLY

VARIABLE	MEAN	STANDARD DEVIATION	LOW	HIGH
(1) Potential Supply in Acres				
X_7: Vacant and zoned MF	13.36	29.67	0.00	188.46
X_8: Vacant, sewered and zoned MF	13.12	29.62	0.00	188.46
(2) Potential Supply in Units				
X_9: Vacant x MF density	5096.22	25093.70	0.00	310311.75
X_{10}:(Vacant and zoned MF) x MF density	477.57	1943.02	0.00	20324.25
X_{11}:(Vacant, sewered and zoned MF) x MF density	473.61	1943.33	0.00	20324.25

Table C-3

DESCRIPTIVE STATISTICS

ACCESSIBILITY MEASURES

VARIABLE	MEAN	STANDARD DEVIATION	LOW	HIGH
(1) Nearness to Schools				
X_{12}:Service employment	1299.23	3134.12	0.00	28718.00
X_{13}:Access to schools 1	9925.50	3895.76	4744.5	22497.84
X_{14}:Access to schools 2	726.96	763.71	127.69	5306.68
(2) Nearness to Employment				
X_{15}:Total employment	2802.64	5316.95	0.00	43202.00
X_{16}:Access to employment 1	21648.08	8182.71	10365.55	46398.06
X_{17}:Access to employment 2	1640.36	1500.97	279.64	8941.61
(3) Nearness to Shopping				
X_{18}:Travel time to CBD	26.83	11.81	0.00	53.50
X_{19}:Straight line distance to CBD	9.94	6.01	0.20	25.59
X_{20}:Straight line distance to closest large shopping	2.39	1.54	0.20	7.56
X_{21}:Straight line distance to second closest large shopping	4.14	1.92	0.98	11.020
X_{22}:Wholesale and retail trade employment	516.28	983.86	0.00	8030.00
X_{23}:Access to shopping 1	4078.02	1637.20	1859.89	8999.89
X_{24}:Access to shopping 2	312.58	293.05	47.29	1799.08

Appendix D

CALCULATION OF THE ACCESSIBILITY MEASURES

The procedure used to calculate accessibility in this study was similar to that used in 1959 by Walter Hansen.[1] Specifically, the formulation states that the accessibility at point 1 to a particular activity at area 2 (say employment) is directly proportional to the size of the activity at area 2 (number of jobs), and inversely proportional to some function of the distance separating point 1 from area 2. The total accessibility to an activity, such as employment, at point 1 is the summation of the accessibility to each of the individual areas around point 1. Therefore, as more and more jobs are located nearer to point 1, the accessibility to employment at point 1 will increase.

This formulation is known as the gravity or potential concept of interaction,[2] and can be expressed generally by the following mathematical formulation:

$$_1A_2 = \frac{S_2}{T^x_{1-2}}$$

where

$_1A_2$ is the relative measure of accessibility at Zone 1 to an activity in Zone 2;

S_2 equals the size of the activity in Zone 2; i.e., number of jobs, people etc.;

T_{1-2} equals the travel time or distance between Zones 1 and 2;

x is an exponent describing the effect of the travel time between the zones.

If there are more than two zones involved the formula becomes:

$$A_1 = \frac{S_2}{T^x_{1-2}} + \frac{S_3}{T^x_{1-3}} + \ldots + \frac{S_n}{T^x_{1-n}}$$

n = number of zones.

This was the formula which was used to calculate the variation in accessibility between areas.

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[1] Walter G. Hansen, "How Accessibility Shapes Land use," Journal of the American Institute of Planners, Vol. 25, No. 2 (May 1959) pp. 73-76. This appendix is basically an extraction from this article.

[2] For an excellent summary of the history of the gravity and potential concepts of interaction see: Gerald A.P. Carrothers, "An Historical Review of the Gravity and Potential Concepts of Human Interaction," Journal of the American Institute of Planners, Vol. 22, No. 2 (Spring 1956) pp. 94-102.

Most of the controversy concerning empirical gravity or potential formulations has surrounded the question of what the function of distance should be. It is generally agreed, and empirical examination indicates, that an exponential function should be used. That is, the measurement of distance separating the various areas should be raised to some power. However, empirical tests of gravity models have resulted in exponent values that range from 0.5 to almost 3.0. As a result of this inconsistency in exponent values, I decided to test two separate accessibility formulations. The first used an exponent value for x of 1.0, while the second used an exponent value for x of 2.0. The travel time measure used was the travel time in minutes by auto for 1971 between the zones as obtained from the IIPS data base.

Appendix E

EMPLOYMENT, RECREATION AND OPEN-SPACE SUB-MODELS

1. Employment Location Sub-Models

In the original IIPS model, employment was divided into eighteen industry groups which were located on the basis of the locational criteria of the industry.[1] Since there were regularities within certain groups of employment, the locational model was divided into the following four major sub-groups:

a. manufacturing and wholesaling

b. retail trade

c. services

d. agriculture, forestry and fishing.

a. Manufacturing and Wholesaling. These employment activities were disaggregated into seven industrial sectors which were allocated to subareas on the basis of attractiveness for a given industry.[2] The attractiveness is given by:

$$A_j^k = \sum_{k=1}^{k} S_{ij} W_i^k \qquad (1)$$

where A_j^k is the attractiveness of zone i to industry k

S_i^j is ith site factor in zone j

W_i^k is the weight attached to site factor i by industry k

These attractiveness indices were calculated for those zones which had industrially zoned land and possessed certain essential factors such as deep water access for petroleum refining, railroad access, and warehousing and storage facilities. They were then normalized and used to allocate employment to subareas by an allocation function and a land absorption coefficient (LAC) which converted subarea employment to land use. If there was insufficient land the excesses were reallocated to subareas of excess supply. This sub-model has received little change over the years and remains virtually the same in this revised IIPS model in use today.

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[1]This appendix is a condensation of material contained in Michael A. Goldberg and H.C. Davis, "An Approach to Modelling Urban Growth and Spatial Structure," Highway Research Record, Vol. 435 (1973), pp. 48-50.

[2]The approach used here was developed from these earlier works: Stephen H. Putman, "Intra-Urban Employment Forecasting Models: A Review and Suggested New Model Construct," Journal of the American Institute of Planners, Vol. 38, No. 4 (1972) pp. 216-230; and Michael A. Goldberg, "Bay Area Simulation Study: Employment Location Models," The Annals of Regional Science, Vol. 2, No. 2 (1968) pp. 161-176.

b. Retail Trade. Retail trade was originally allocated using a gravity model formulation.[3] This formulation generated measures of potential demand for retail trade in each subarea which were compared with the actual retail trade in each zone. Excesses and deficits were changed gradually over time, rather than instantly, in an attempt to account for the lags and inertia which occur in practice.

As in the manufacuring and wholesaling sub-group, the newly allocated employment was converted to land use via an allocation function and the appropriate LAC. If a subarea had excess demand, the excess demand was reallocated to subareas with excess supply. This sub-model has also received little change or refinement and remains the same as originally developed in the present version of the IIPS model.

c. Services. In the absence of decisive research findings in this area, the original sub-model allocated services to subareas using a modified gravity and intervening opportunity model. This sub-model has not been revised and remains the same in the present version of the model.

d. Agriculture, Forestry and Fishing. When the original sub-model was developed all three of these industries were declining in the region. The assumption was made that these declines would continue and that their land would be converted to urban uses. Decline factors were selected for each industry and future declines were estimated using these factors. In the present model this sub-model is also unchanged from its original conception.

2. Recreation and Open-Space Sub-Models

Recreation and open-space determination was carried out in an extremely simplistic fashion. Two types of parkland were considered: local/neighbourhood parks; and regional parks. For each type of park a four by two matrix of park land coefficients was constructed to correspond with the two structure types and four value classes of housing. These two land absorbtion matrices were constructed from current planning practice at the time and were subject to change for policy testing purposes. The matrices were used to calculate the total number of acres of local and regional parks required and to allocate these acres to the subareas. This sub-model remains unchanged in the present version of the model.

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[3]The model closely paralleled those done previously by: David L. Huff, "A Probability Analysis of Shopping Centre Trading Areas," Land Economics, Vol. 53, No. 1 (1963) pp. 81-90; T.R. Lakshmanan and W.G. Hansen, "A Retail Market Potential Model," Journal of the American Institute of Planners, Vol. 31, No. 2 (1965) pp. 134-143; and J.D. Forbes and A.G. Fowler, "Simulation of a Gravity Model," The Annals of Regional Science, Vol. 3, No. 1 (1969) pp. 86-95.