INTRA-URBAN INDUSTRIAL MIGRATION

INTRA-URBAN INDUSTRIAL MIGRATION:
A SIMULATION MODEL OF PLANT
SITE SELECTION

By

JOSEPH AJIBOYE OLAGBAIYE, B.A., M.A.

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree
Doctor of Philosophy

McMaster University
April, 1971

DOCTOR OF PHILOSOPHY (1971)
(Geography)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Intra-Urban Industrial Migration: A Simulation Model of Plant Site Selection and Its Application to Metropolitan Toronto

AUTHOR: Joseph Ajiboye Olagbaiye, B.A. (University of Ibadan)
M.A. (University of Waterloo)

SUPERVISOR: Dr. Leslie J. King, Professor and Chairman

NUMBER OF PAGES: ix, 174

SCOPE AND CONTENTS:

A simulation model is developed for predicting the distribution of plant site selections by migrant firms within an urban area for a defined period of time. The model is based on the assumption that a particular migrant plant (k) from origin i will locate at potential destination j depending upon the attributes of j, distance between i and j, and the space requirement level of the plant as determined by its industry type and employment characteristics.

The model is operated by using the Monte Carlo method. The parameters of the model are derived empirically. These parameters are then incorporated in a formal application of the model to Metro Toronto for the period 1966-67. A chi-square goodness of fit test between the predicted and empirical distributions, as well as a contiguity ratio test performed on the residuals, shows that the differences between the two distributions may have been produced by chance.

ACKNOWLEDGEMENTS

Dr. Leslie J. King, Professor and Chairman of the Department of Geography, McMaster University, deserves my sincere gratitude for his supervision of this thesis. His rich experience in the application of theoretical models to geographical problems has considerably enhanced solutions to the difficult aspects of the thesis.

I am equally grateful to the following members of the supervisory committee: Professors D. L. Anderson, and J. F. Betak, both of the Department of Geography, McMaster University, for their constructive ideas and editorial comments on the study; Professors I. Z. Chorneyko (Mathematics Department) and Georges Potvin (Geography Department). Professors P.L. Simons and P. A. Ambrose who also advised on the study deserve my gratitude.

I also thank the Regional Development Branch of the Ontario Department of Treasury and Economics for its financial support for the study.

Several persons were contacted personally for suggestions, information and data in conducting the study. I owe them a debt of gratitude. They include Professors Donald Kerr of the University of Toronto and D. M. Ray of the State University of New York at Buffalo; Messrs. John Hall, Regional Assessment Commissioner, City of Toronto; H. G. Courtman, Clerk of Borough, York; D. Graham Emslie, Development Officer, City of Toronto; M. Bradshow of the City of Toronto Planning Board; D. L. Newman, Development Officer, Borough of North York; R. L. Walton, Development Officer, Scarborough; G. M. Flemming, Commissioner

of Buildings, Scarborough; D. F. Paterson, Deputy Clerk, Borough of Etobicoke; W. A. Wilson, General Manager, Metro Toronto Industrial Commission; Kenneth A. Craig of the Metro Toronto Industrial Commission; D. B. Kirkup, Research Director, Metro Toronto Real Estate Board; M. C. Feldman, President, Teela Market Surveys, Toronto; S. A. Craig, President, The Rubin Industrial Development Corporation, Toronto; James E. Farr, Vice President, W. H. Bosley and Co. Real Estate Ltd., Toronto; John M. Carton, Manager, Appraisal Department, Gibson Willoughby Ltd., Toronto; and Miss D. M. Tucker, Clerk, Borough of East York.

Much correspondence was exchanged with various individuals. In this connection, I am particularly thankful to Professor F. R. Pitts, University of Hawaii; Messrs. L. H. Greensword, Metro Toronto Assessment Commissioner; H. D. Potter and D. L. Ralston of the Dominion Bureau of Statistics, Ottawa; T. J. Hodgins, Manager of the Board of Trade of Metro Toronto; J. H. Miller, Ontario Sales Manager of the Stanston Pipes Ltd.; Kenneth Philp, Senior Consultant, A. E. Lepage Ltd., Toronto; R. H. Davie, Treasurer, Borough of Etobicoke; D. C. Little, Treasurer, Borough of East York; G. E. Mitchell, Treasurer, Borough of York; T. V. Powell of the Public Utilities Commission, Scarborough; W. M. Campbell, Commissioner of Finance of the City of Toronto; B. Elwood, Director of the Research Division of the Metro Toronto Planning Board; and J. R. Delaney, Chief of the Field Services Section, Ontario Department of Trade and Development.

My thanks also go to the Mayors of the six boroughs in Metro Toronto for allowing certain abstractions to be made from some non-public records; all the firms which responded to my questionnaires; several of my colleagues who have made constructive suggestions on the study; and

the staff of the computer centre of McMaster University for their efficient service and programming assistance.

Finally but not the least, I owe my wife, Esther, profound gratitude. Besides typing the original manuscripts and many corrected versions of the thesis, she has given me all her personal encouragement and support. Her own interest in the study has given me both pleasure and inspiration.

TABLE OF CONTENTS

TABLE OF CONTENTS (contd.)

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION TO THE STUDY

In recent decades, industrial location research has emphasized the spatial dynamics of manufacturing, more specifically, the problem of industrial migration.[1] This emphasis can be explained in terms of two interrelated areas of interest in the topic. First, the process of industrial migration is related to the question of industrial redistribution which is among the most generally discussed economic problems of today, especially in the industrial nations. This discussion is carried on not only among the general public but also among economists, labor leaders, businessmen and politicians. As far back as 1929, Friedrich remarked: "In a nation-wide agitation for power development in the United States, for example, the argument is quite generally used that it will 'decentralize' industries".[2] Similarly, Fuchs (1962), referring to the relative shift of manufacturing among regions in the United States, observes: "These changes have had a significant impact on the political, social and economic life of the nation. The consequences for businessmen, labor leaders, and government officials have been strong,

---

[1] See, for example, F. E. Ian Hamilton, "Models of Industrial Location," in Socio-Economic Models in Geography, edited by Richard J. Chorley and Peter Haggett (London: Methuen and Co. Ltd., 1967), chapter X, 410-12.

[2] Carl J. Friedrich, Alfred Weber's Theory of Location of Industries (Chicago: University of Chicago Press, 1929), p. xiii.

direct and sometimes painful".[1]

Second, the growing problem of industrial migration affords the economic geographer the opportunities for constructing and testing spatial hypotheses to explain or predict the spatial patterns resulting from the migration process. In doing this, he is likely to receive financial and other incentives from the policy makers who are also interested in the problem.

Perhaps, one may also argue that industrial migration is less complex to study than the problem of industrial location in general. This may be so because "effective location factors are . . . most clearly indicated when industries move" (Schumacher, 1937).[2] In a similar vein, Losch (1954) commented:

> It is easier to discuss such migrations of industries than to give reasons for their original locations, because as a rule they are more clearly and rationally motivated. Furthermore, one can rely upon exact calculations in comparing the new with the old locations.[3]

One may also argue that industrial migration processes bring into focus certain factors in a more forceful manner than is done by the

---

[1] Victor R. Fuchs, "Statistical Explanations of the Relative Shift of Manufacturing Among Regions of the United States", Regional Science Association: Papers and Proceedings, VIII (1962), p. 105.

[2] Hermann Schumacher, "Location of Industry", Encyclopaedia of the Social Sciences, IX (New York: The Macmillan Co., 1937), p. 586.

[3] August Losch, The Economics of Location, translated from the 2nd revised edition (New Haven: Yale University Press, 1954), p. 377.

location of entirely new industries. For example, the effect of a firm's financial, personal and other ties to its source area on locational selection can be studied better by focussing on industrial migration since the source area is more specifically demonstrated.

The foregoing arguments provide the rationale for the interest of this study in the area of industrial migration. However, before a more specific definition of the study problem is presented, it is pertinent to examine a number of issues which are taken into account in the definition.

Problem and Objective

Over the past two decades, models have been increasingly applied to geographic problems.[1] These applications emphasize rigor, precision and duplicability. Complexities of the real world situation are simplified for better understanding.

Industrial migration is a complex process. Yet, the lack of models is a major shortcoming in industrial migration studies. Ian Hamilton (1968) observed this problem by stating: "While several models of population migration have been developed..., industrial counterparts are virtually lacking. The main reason lies in the different migration processes involved".[2]

---

[1] For example, see Brian J. L. Berry and Duane F. Marble (eds.), Spatial Analysis (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), xi, 512 pp.; especially pp. 13-23; and Leslie J. King, Statistical Analysis in Geography (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1969), xii, 288 pp.

[2] F. E. Ian Hamilton, op. cit., p. 410.

The question of industrial migration processes raises three important issues. First, there are different methods of migration. For example, industrial migration may involve relocation of complete establishments, relocation which is phased over time, consolidation of different operations existing in different locations at a single location and the establishment of a branch plant.

Industrial migration thus involves a number of methods by which distributional changes of industries may be effected in any given area. However, the term industrial migration is not synonymous with some other terms which have also been used to describe distributional changes. Thus, Linge (1963) uses the term "diffusion" to refer to the spread of industries (from the inner zone to the outer zone of an urban area according to his example).[1] Diffusion may be due to differences in the growth of new industries with the greater growth occurring in the outer zone, and the process of "deconcentration" whereby the firms already established in the inner zone partly or wholly shift their productive capacity to the outer zone. The methods of industrial migration and those of deconcentration are essentially similar in the sense that they both involve origins and destinations. Nevertheless, industrial migration does not necessarily involve the inner zone as the only origin area as Linge's definition of deconcentration seems to imply.

---

[1] G. J. R. Linge, "The Diffusion of Manufacturing in Auckland, New Zealand". Economic Geography, 39 (1963), 23-30; Various other terms have been used to describe distributional changes, for example, decentralization, dispersion, and locational shift, see Wilbur Zelinsky, "A Method for Measuring Change in the Distribution of Manufacturing Activity: The United States, 1939-1947," Economic Geography, 34 (April, 1958), 2, p. 108.

Keeble (1968) uses the term "migrant factories" to refer to branch plants and relocated plants.[1] His analysis shows that both types of migrant factories are essentially similar in their broad industrial structures and migration patterns. For example, the frequencies of movement in both cases decline with increasing distance from the source area. Similarly, both types of migrant firms show particular concern for proximity to the source area for such reasons as desire to retain the existing labour market and raw material sources, unwillingness to involve directors in too great a change, and the need for proximity to existing firms in the source area. On the basis of these observations, there is some justification in treating relocated and branch plants within the same theoretical framework as it is done in the present study.

The second issue is the question of the spatial dimension which is involved in a particular type of industrial migration. For example, industrial plants may migrate within the same urban areas as is illustrated in the studies by Kerr and Spelt (1958, 1965)[2], Logan (1964)[3], and Linge (1963)[4] or

---

[1] D. E. Keeble, "Industrial Decentralization and the Metropolis: the North-West London Case," *Institute of British Geographers: Transactions*, 44 (1968), 1-54.

[2] Donald Kerr and Jacob Spelt, "Manufacturing in Suburban Toronto," *Canadian Geographer*, XII (1958), 11-19; and *The Changing Face of Toronto (Ottawa: Department of Mines and Technical Survey, 1965)*, 129-39.

[3] M. I. Logan, "Manufacturing Decentralization in the Sydney Metropolitan Area," *Economic Geography*, XL (1964), 151-62; and "Suburban Manufacturing: *A Case Study*," *The Australian Geographer*, IX (Sept., 1964), 4, 223-34.

[4] G. J. R. Linge, *op. cit.*, pp. 23-39.

between different urban areas or different regions, for example, Zelinsky (1958)[1] and Fuchs (1962).[2]

The third issue concerns the question of the push-pull factors involved in the migration of plants from one location to another. The push factors are those which motivate plants to migrate, for example, congestion, outmoded facilities, rising property taxes and restrictive local regulations. The pull factors are the advantages which are offered by any particular location, for example, favourable property taxes, availability of hydro, water and sewer, transportation facilities and labour (Hoover and Vernon, 1962).[3]

At any given location, migration may be effectively motivated when the push factors outweigh the pull factors. The choice of a new location may then depend on where the pull factors exert the greatest weight, that is, where a particular location offers the maximum advantage assuming that location decisions are economically rational. It is to be mentioned, however, that the final selection of such a location may depend on the locational (space) requirement of a manufacturing plant as determined by its changing characteristics such as size of employment and type of product. To a large extent, the push-pull factors would also vary with the type of migration involved.

The various issues raised above suffice to show that theoretical model building of industrial migration may be frustrated by such complexities. Hence, any related analysis should be strictly defined within some particular

---

[1] Wilbur Zelinsky, op. cit., pp. 95-126.

[2] Victor R. Fuchs, op. cit., pp. 105-126; and "The Determinants of the Redistribution of Manufacturing in the United States since 1929", The Review of Economics and Statistics, 44 (1962), 167-177

[3] E. M. Hoover and Raymond Vernon, Anatomy of a Metropolis (New York: Garden City, Double-day Anchor, 1962), 21-57.

contexts to make it tractable. Such definitions imply simplicity which is in keeping with the spirit and purpose of model building. Haggett (1965) comments:

> In model building we create an idealized representation of reality in order to demonstrate certain of its properties. Models are made necessary by the complexity of reality... They convey not the whole truth but a useful and apparently comprehensive part of it.[1]

It is with this thought in mind that the objectives of this study are now examined.

The overriding objective of the study is to develop an operational model for simulating plant site selections by migrant firms in an urban area. An operational model is one which can be calibrated to fit real world situations. Smith (1971) points out that any such model generally consists of three structural elements: 1) the variables embedded in mathematical formulas indicating relationships; 2) parameters or numerical constants; and 3) an algorithm or computational method required to find a solution.[2] The present study illustrates these three elements. The variables are measures of the attractiveness of a location site and the distance of that site to the origin of a plant. In addition, there are space requirement constraints posed by individual plants. The parameters may be considered as the specific weights of the attributes and the distance variable. The solution method is by simulation and different computations are involved in the simulation

---

[1] P. Haggett, "The Changing Concepts in Economic Geography," in Frontiers in Geographical Teaching, edited by R. J. Chorley and Peter Haggett (London: Methuen and Co., Ltd., 1965), chapter VI, pp. 106-7.

[2] David M. Smith, Industrial Location: an economic geographical analysis (New York: John Wiley and Sons, Inc., 1971), pp. 160.

procedure. These structural elements are elaborated later in this study.

Two important considerations emerge in developing an operational model. First, a model must be consistent with theory and it should use a suitable method of solution. These two considerations constitute the background against which the literature review in chapter II is to be presented.

The second consideration affecting model formulation is the strategy of establishing parameters for data for one time period and then using such parameters in the model to predict outcomes for another time period as a test of the model's validity. This is an accepted research strategy in social sciences and it is as close as one can come in such studies as this one to matching the experimental method of of the physical sciences. Artle (1965), for example, states:

> If the existing information permits, an alternative is to partition the available data into two sub-sets - one sub-set to be used for implementing the model empirically, and the other sub-set to be used for testing the model. Needless to say, such partitioning must be made in nonrandom fashion. Otherwise, one does not test the model, but only the device for the random process.[1]

In a similar vein, Lowry (1965) presents a similar argument:

> The more accessible alternative is <u>ex post facto</u> prediction: Take the state of the world in 1950 as a starting point and apply the model by forecasting for 1960, then compare the forecast values to observed values for 1960.[2]

---

[1] Roland Artle, <u>The Structure of the Stockholm Economy</u> (New York: Cornell University Press, 1965), p. xxxix.

[2] Ira S. Lowry, "A Short Course in Model Design", <u>Journal of the American Institute of Planners</u> (May, 1965), 2, p. 164.

The strategy outlined above is reflected in this study by establishing the parameters for the model using the 1964-65 data and incorporating these parameters for testing the model for the period 1966-67. In this way, a problem of circularity is avoided.

Another aspect of the objective for this study has to do with the generality of a model. To be most useful a model must be fairly general. In relation to industrial location, a general model may be defined as one which can be applied to any industry. Smith (1971) stresses the importance of such a model by stating:

> In industrial location analysis, a model might be constructed largely on the basis of observed conditions in a particular industry, in an attempt to shed light on that specific case;... But far more useful and important are general models that can be fitted to any industry. These models form a logical extension of industrial location theory.[1]

In the present study, the simulation model under consideration will be made applicable to any industry. This means that the particular characteristics of individual migrant plants will be taken into consideration in the simulation procedure.

Finally, it is to be admitted that the model under consideration is a fairly simple one. This simplicity is reflected in three ways. First, the plants to be located and their origins are given. Thus the model is not concerned with generating movement of plants for the reasons to be stated later in this chapter. Second, the model is concerned only with plants migrating within the same urban area, specifically, Metropolitan Toronto. Third, only two types of migration are considered. These include relocation of complete establishments and

---

[1] David M. Smith, *op. cit.*, p.159.

branch plant location. All plant migrations of these two types are included in the analysis. Relocations which are phased over time and consolidation of different establishments at a single location are not considered since they do not fit strictly into the framework to be developed for this study.

Having now discussed the objectives for this study, it is pertinent to point out its limitations. One source of limitation is the fact that the study does not consider migration decisions since the plants to be located are given. This lack of consideration is partly explained by the attempt to simplify the problem as already pointed out. Another explanation lies in the fact that the reasons for choosing particular sites are easier to study than the factors motivating migration. These factors are related to such micro-economic considerations as rising production costs, scale economies, and pricing policies of individual firms. Micro-economic data may be difficult to obtain partly because they involve book-keeping records of individual firms, and partly because they cannot be easily represented by simple proxies.

Another limitation of the study is that the model under consideration is not based on the theory of decision-making processes. Therefore, it is to be admitted that, in the context of industrial migration, the study does not provide answers to the interrelated questions of alternate courses of action perceived , outcome perceived, personal preferences, guiding principles and objectives on which Isard (1969) has focussed attention in his general framework of decision-making.[1]

---

[1] Walter Isard, General Theory: Social, Political, Economic and Regional (Cambridge, Mass.: The M.I.T. Press, 1969), chapter V, pp. 160-221.

The third limitation is the fact that the study is not designed to test particular classical theories although a knowledge of these theories is regarded as fundamental in developing the hypotheses for the study as it will be shown later in chapter II. Given this procedure, the bulk of the research can be described as empirical investigation. Nevertheless, the author is convinced of the need for such an investigation. This conviction is further strengthened by the following recent declaration by Karaska and Bramhall (1969) referring to location research on partial equilibrium and general equilibrium theories:

> It is our conviction that the research relating to these two approaches has reached a stage of maturity in which a set of relationships more adequate than that currently employed may be deduced... We consider it extremely important that the analysis be firmly grounded in reality, and heavily dependent upon empirical information. Also, we feel that the analysis must reflect the complex, spatial interrelationships of the "region"; hence the logic of abstract models is a requisite ingredient.[1]

Model building, unlike theoretical formulation, often involves certain constraints as a matter of practical necessity. To a large extent, these constraints are admitted in this study. The relation of the model builder to such constraints, compared with the theorist, has been succinctly described by Lowry (1965):

> The model builder,..., is concerned with the application of theories to concrete cases, with the aim of generating empirically relevant output from empirically based input. He is constrained, as the theorist is not, by considerations of cost, of data availability and accuracy, of timeliness, and of the client's

---

[1] Gerald J. Karaska and David F. Bramhall, Locational Analysis for Manufacturing: A Selection of Readings (Cambridge, Mass.: The M. I. T. Press, 1969), p. 3.

> convenience. Above all, he is required to be specific, where the theorist is vague. The exigencies of his trade are such that, even given his high appreciation of "theory," his model is likely to reflect its theoretical origins only in oblique and approximate ways. Mechanisms that "work," however mysteriously, get substituted for those whose virtue lies in theoretical elegance.[1]

Perhaps, the fourth limitation of the study arises from the solution method, Monte Carlo simulation, used in operating the model. This method of solution, which is explained and justified in reviewing the literature in chapter II, is simple, time-consuming and does not allow for mathematical elegance as is the case with the analytic solution.

Within the context of the objectives and the limitations defined for this study, it is necessary to explain two significant terms frequently used in the study. First, the term "manufacturing plant" is here defined as a single establishment using power driven machines and human labour to produce a product by mechanically or chemically transforming raw materials into a new form.[2] A manufacturing plant (or establishment) may contain more than one building but such buildings must be at the same location point, functionally-linked and under the control of the same firm.

---

[1] Ira S. Lowry, op. cit., p. 160.

[2] Based on Dorothy Muncy, Space for Industry, Technical Bulletin, No. 23 (Urban Land Institute, July, 1954), pp. 8-9.

The second term concerns a conceptual measure: the 'standard industrial unit (SIU)'. This standard measure allows for industrial land and industrial floor space to be jointly expressed in some floor area equivalence. Thus, for example, a vacant piece of land will be converted to its floor area equivalence taking into consideration the ratio of industrial floor area to land area which is permitted by the planning authority of the area where the piece of land is located.

Admittedly, the amount of floor area to be regarded as a standard unit remains an open question and may require a subjective judgement since what is standard for one industry may not be standard for another. What is more important is the fact that any unit chosen is only a basis for converting different forms of industrial space to units of assessed vacancy.

In this study, a standard industrial unit is assumed to be equal to 5,000 square feet of floor space area.[1] A plant occupying 2,500 square feet is thus assigned half a unit, one occupying 10,000 square feet, two units, and so on.

The standard industrial unit measure is used in this study in relation to two types of estimates: 1) the spaces required by individual plants; and 2) the potential vacancy levels for individual destination areas at any point in time.

---

[1] This unit corresponds to the Ontario Department of Trade and Industry's minimum space requirement for a manufacturing establishment to be listed in its Annual Ontario Industrial Review.

The Study Area

The area used in developing and testing the model in this study is Metropolitan Toronto (henceforth cited as Metro Toronto). Metro Toronto covers an area of 241 square miles. The area is bounded on the south by Lake Ontario. On the east and west, it is bounded by the township of Pickering and the Town of Mississauga respectively, and on the north by the rural townships of Vaugham and Markham (Figure 1).

The study area is connected with the rest of Canada through a network of major highways (400, 401, and 403) and railroads (the CNR and the CPR). The area is also served by the Toronto International Airport located very close to the western boundary in the adjoining town of Missisauga, and the Toronto Harbour which has an international status.

Metro Toronto was formerly administered at the local level by thirteen area Municipalities. These former municipalities were regrouped into six boroughs on January 1, 1967. The former thirteen area Municipalities vary widely in area, population, and manufacturing employment (Table 1).

The study area as defined above should be distinguished from other definitions of the Toronto region. The Metropolitan Toronto Planning Area, for example, embraces the study area and, in addition, the adjoining areas to the west, east, and north.[1] Similarly, the Census Metropolitan Area covers a more extensive region than the study area.[2]

---

[1] Metropolitan Toronto Planning Board, Metropolitan Plan Review, Report No. 1: Existing Land Use (1966), Map 2.

[2] Dominion Bureau of Statistics, 1966 Census of Canada, Vol. 1, 1-16 (Ottawa: March 1968), c-34.

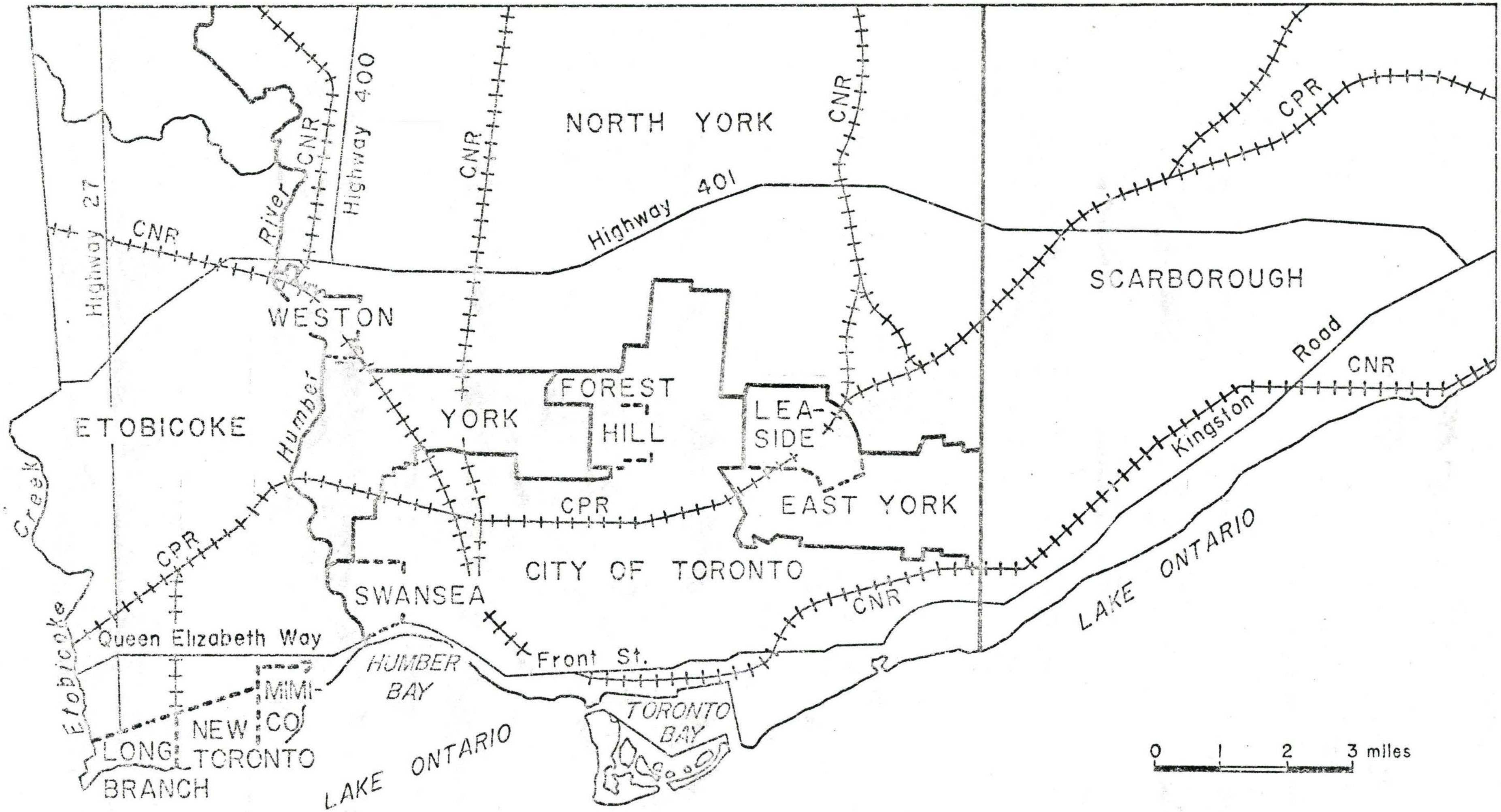


Figure I: Map of Metropolitan Toronto

TABLE 1

AREA, POPULATION AND MANUFACTURING EMPLOYMENT OF THE FORMER THIRTEEN AREA MUNICIPALITIES OF METRO TORONTO

Municipality	Percentage of Total		
	Area in sq. miles	Population 1966	Manufacturing employment, 1964
Township of Scarborough	29.0	14.8	8.3
Township of North York	28.3	21.2	14.4
Township of Etobicoke	18.6	11.7	11.9
City of Toronto	14.6	35.3	50.3
Township of York	3.3	7.2	4.4
Township of East York	2.4	3.9	2.2
Town of Leaside	1.0	1.1	3.3
Village of Forest Hill	.6	1.2	.1
Town of New Toronto	.5	.7	2.9
Village of Swansea	.5	.5	.3
Town of Mimico	.4	1.0	.5
Town of Weston	.4	.6	.9
Village of Long Branch	.4	.7	.5

Source: H. Carl Goldenberg, Report of the Royal Commission on Metropolitan Toronto (Toronto: June, 1965), p. 1; and data from Metropolitan Toronto Planning Board (Research Division).

Because of the growth of industries which has occurred in areas adjoining Metro Toronto in recent years, especially in the town of Mississauga, one can argue that a larger area than is covered in the present study can allow a greater number of destinations to be considered. This is a reasonable argument but the limited area definition which is used in the study is based on the consideration that data are more properly coordinated and more readily available for the six area Municipalities (formerly thirteen) making up the study area. This is so because many of the Metro Toronto government agencies whose data are vital to this study, for example, Metro Toronto Real Estate Board and Metro Toronto Assessment Department, operate for the six municipalities. Some additional rationale for the choice of the study area is provided below.

First, certain previous studies by Kerr and Spelt (1958, 1965)[1] and more recently by Collins (1970)[2] suggest that Metro Toronto illustrates the processes of intra-urban industrial migration to a large degree. Thus Collins declares that his analyses tend to support

> the notion of increasing concentration in and around Metropolitan Toronto rather than widespread decentralization ... Clearly discernible, however, has been the tendency for plants to relocate from the City of Toronto to its suburbs and other centres ...[3]

---

[1] Kerr and Spelt, "Manufacturing in Suburban Toronto," _op. cit._, and _The Changing Face of Toronto_, _op. cit._, pp. 129-39.

[2] Lyndhurst Collins, _Markov Chains and Industrial Migration. Forecasting Aspects of Industrial Activity in Ontario_, Ph. D. Thesis (Toronto University of Toronto; 1970), Chapter V, pp. 156-206.

[3] _Ibid._, pp. 202-3.

The studies by Kerr and Spelt focus attention on a number of factors influencing the decisions to migrate and to choose particular sites.

Second, Metro Toronto is an urban industrial complex of great significance in Canada. For example, in terms of market potential, possible growth pole effects, and the percentage of Canadian manufacturing by value added, the study area is foremost among all the Canadian Metropolitan Areas.[1]

Third, as one of the oldest Canadian manufacturing centres, Metro Toronto has long experienced the problem of plant migration on a large scale. Many factors contributed to the early industrial development of Metro Toronto in the nineteenth century: a growing local market, as a transportation focus for upper Canada, personal initiative, the opening up of western Canada, and the formation of the Canadian Manufacturers' Association.[2] By the end

---

[1] D. Michael Ray, et. al., The Socio-Economic Dimensions and Spatial Structure of Canadian Cities, a report on the first phase of a C. M. H. C. project (University of Waterloo, Summer, 1968), pp. 39-44; and Canada Year Book (Ottawa, 1967), 697-8. A growth pole is an economic self-sustaining area. Such an area must possess multiplier effect, external economies, and a net gain in production factors. Market potential is a measure of aggregate accessibility of a location to the national market. Value added by the manufacturing process is the value of total shipments and other operational revenues less total costs of materials, fuel used, and purchases of products and materials for resale in the same condition, all adjusted for inventory changes where required.

[2] For further discussion of these factors, see Kerr and Spelt, The Changing Face of Toronto, op. cit., 129-39.

of World War II, the problems of congestion, outmoded facilities, rising property taxes and changes from war time to post-war time production led to the migration of plants from the city of Toronto to the new, or post-war, suburban areas of Etobicoke, North York, Scarborough, East York and York.[1]

Fourth, the existence of old and new industrial districts in Metro Toronto provides good examples of contrasts in the forces which can be studied in relation to the problem of intra-urban manufacturing migration.[2] These contrasting forces are reflected in the differing characteristics of the individual manufacturing areas. The new industrial districts are easily distinguished from the old by their single storey factories surrounded by extensive lawns and parking lots. The new industrial areas are found mainly in the post-war suburbs, that is, the Boroughs of Scarbourough, East York, North York, York, and Etobicoke. By contrast, the old industrial districts are located in the City of Toronto and the old municipal areas of Leaside, Mimico and Swansea.

Finally, the choice of Metro Toronto as the study area allows certain spatial consequences of the existence of many local authorities to be studied in relation to the choice of plant sites. For example, the fact that the area Municipalities enjoy considerable autonomy in the assessment of property tax and in the establishment of water and hydro power rates may be important in the migration decisions of manufacturing firms.

---

[1] Ibid.

[2] Kerr and Spelt, "Manufacturing in Suburban Toronto," op. cit., 11-19; "Manufacturing in Downtown Toronto," Geographical Bulletin, X (1967), 4-20; and Economic Atlas of Ontario (Department of Geography, University of Toronto, 1969), Map 5.

Having discussed the reasons for the choice of the study area, its division into areal units for the purpose of the study may now be examined. The study area has been divided into 161 sub-areas following major roads and municipal boundaries to establish a spatial framework for developing and testing the model under consideration. A coordinate system of division is not used because of the desire to retain municipal boundaries, since as noted earlier, many of the variables investigated in the study vary among municipalities. Furthermore, a coordinate system of division would cut across manufacturing concentrations which should best be retained as single units.

The 161 areal units are then divided into <u>destination</u> sub-areas where it is possible for a manufacturing plant to be located during a given time period, and those where it is not. Destination sub-areas are primarily designated "industrial" in the zoning regulations or by-laws.[1]

The other sub-areas are ineligible for receiving migrated or new manufacturing plants. This may be a consequence of any one of a number of factors: 1) the area is already in non-industrial land uses such as commercial or residential; 2) the area is an industrial one that has been rezoned as non-industrial, 3) the area is industrial but is not available for further industrial use as is the case with the Toronto Harbour

---

[1] Some other areas are included on the basis of discussion with the Development Officers of individual Municipalities. The number of destination subareas changes from one time period to the other because of zoning ammendments.

Area which is excluded from industrial development by the Toronto Harbour Commission; or 4) the area may be zoned for future industrial development but during the period of time under consideration, it is not provided with basic services such as hydro, sewer and water as is the case with certain areas in the Boroughs of Etobicoke, North York and Scarborough. Since a manufacturing plant cannot be located in any of these four types of areal units, they are not considered as members of the population of destination sub-areas.

The <u>origin</u> sub-areas are determined on the basis of observations of the origins of plants which migrated in a given time period. In this way, any destination sub-area can become an origin sub-area as well. Also, any industrial area currently rezoned as non-industrial can be an origin but not a destination sub-area.

The foregoing procedures allow three types of manufacturing sub-areas to be identified in this study (Figure 2): origin sub-areas only; destination sub-areas only;and origin and destination sub-areas. Figure 3 shows the plant migration pattern for the period 1966-67.

Outline of the Study

Having defined the problem, the objectives and the study area, an outline of the study as developed in the remaining chapters of this thesis is now provided.

In chapter II, there is given a review of the literature which is considered to be relevant to the problem under consideration. The review focuses on location theory and approaches to modelling in the relevant area of urban growth and locational processes.

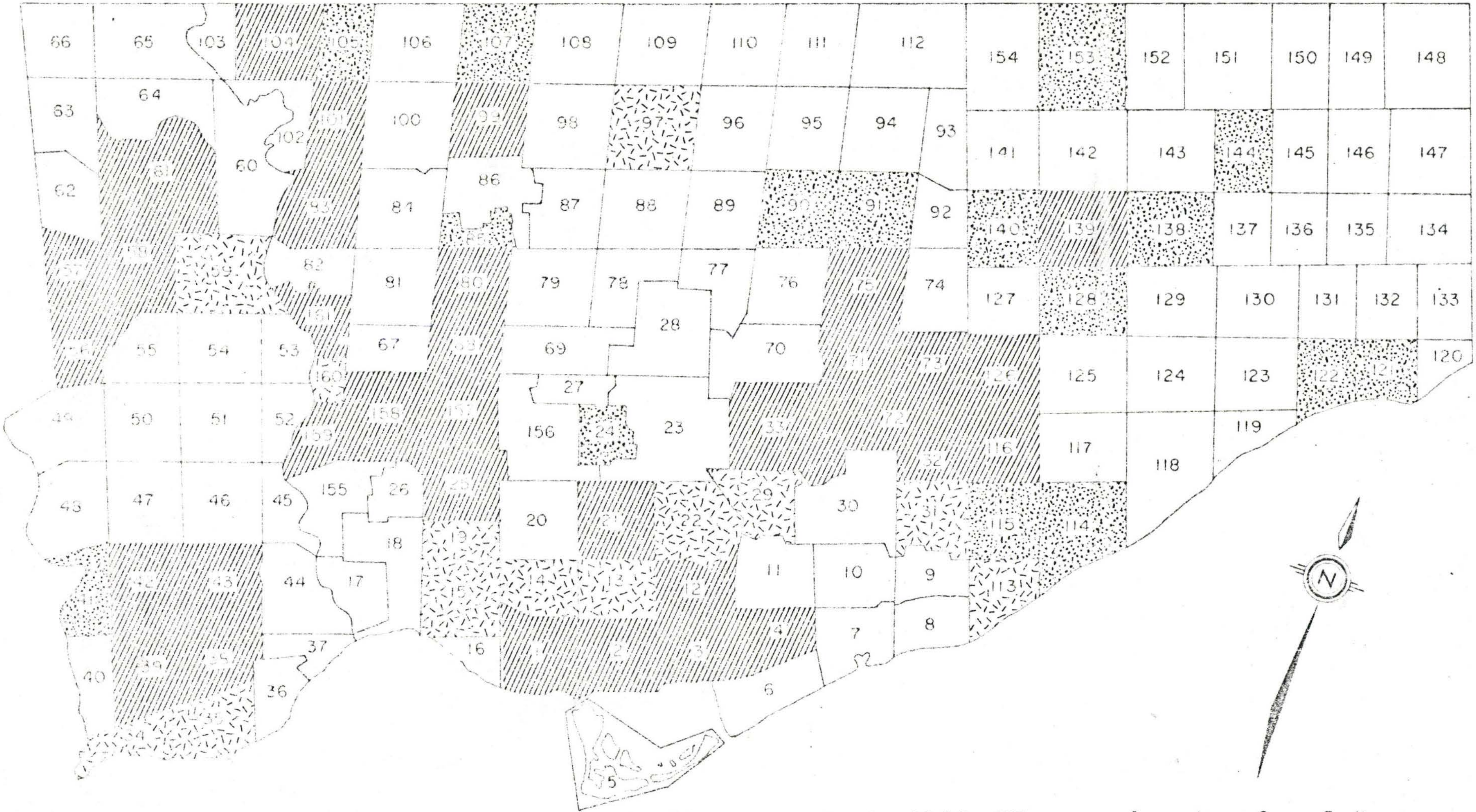


Figure 2: Manufacturing Sub-Areas identified for the Study, 1966-67

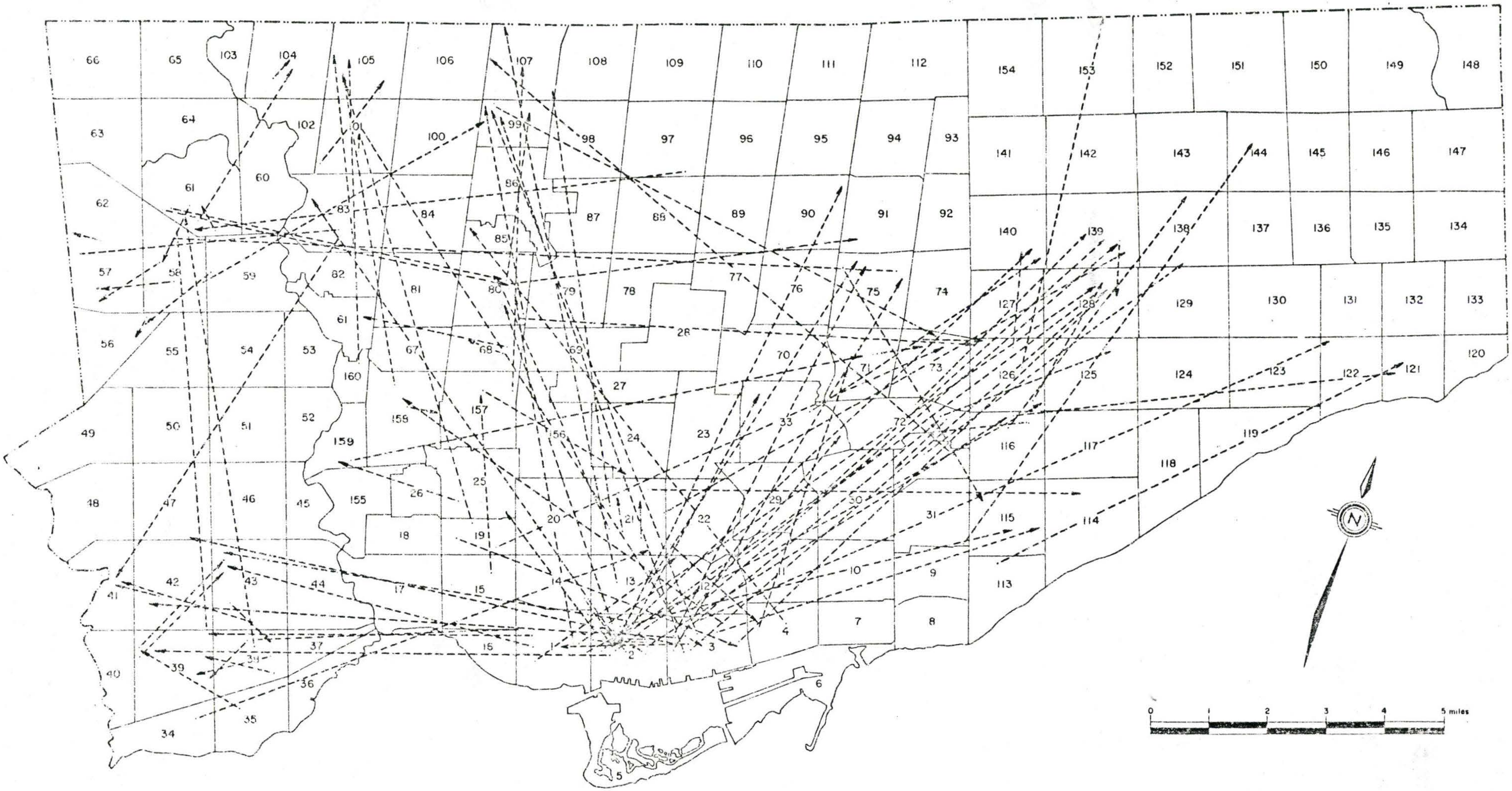
▨ Origin

▩ Destination

▧ Origin / Destination

FIG. 3

OBSERVED PATTERN OF PLANT MIGRATION, 1966-67



Chapter III is concerned with presenting the model. The model is described, and it elements and the underlying assumptions are discussed.

In chapter IV, the problem of estimating the probabilities of the simulation model is discussed. In this regard, the different variables are measured and their weights and significance are determined by applying a multiple linear regression analysis to the 1964-65 data. These regression estimates provide the basis for estimating the probabilities which are essential in the model. In addition to the problem of estimating the probabilities, the estimates of the other elements of the simulation model, specifically the space requirement levels of different plants and the vacant industrial spaces available at different destination sub-areas, are discussed.

Chapter V is concerned with running and evaluating the model. The model is tested for Metro Toronto using the period 1966-67. One hundred runs of the simulation model are performed.

The average outcome of the 100 simulation runs is compared with empirical data. A chi-square goodness of fit test is performed on the differences between the average outcome of the model and empirical data. In addition, a contiguity ratio test is performed to determine whether or not the spatial arrangement of the residuals encountered in the study is a random one.

The conclusion to the study provides a summary of the thesis, outlines the basic accomplishments, focuses on the possible planning implications, possible lines of investigation and the problems of data encountered.

CHAPTER II

REVIEW OF THE LITERATURE

As discussed in the last chapter, a model must acknowledge two important considerations aside from the simplicity criterion: 1) it must be at least consistent with theory; and 2) it must use a solution method which is realistic or appropriate. The purpose of this chapter is to rationalize the present study by reviewing the relevant literature along these two lines of consideration. Thus, in the first place, a review of location theory is provided with particular reference to industrial migration especially as it relates to site selection in the urban setting. Specific empirical studies illustrating the theory are also discussed. In the second place, approaches to modelling in the area of urban locational processes are examined in an attempt to justify the solution method used in this study.

Location Theory

Classical attempts to provide theoretical explanation for "industrial" location focus on two major theories: the minimum transportation cost and the land rent theories. Relationships between these two theories are discussed in the more recent literature.

The minimum transportation cost theory has been discussed extensively in industrial location since the seminal work of Alfred Weber in 1909.[1]

---

[1] Carl J. Friedrich, Alfred Weber's Theory of the location of Industries (Chicago: University of Chicago Press, 1929), chapter III, 41-94; also, see chapter VI, pp. 173-226 which discusses total orientation of manufacturing industry.

In Weber's version of the theory, a manufacturing establishment will be located at a point where the aggregate transportation costs of raw material and finished product are minimal subject to such modifications as may arise from agglomerative and deglomerative forces as well as labour costs. Agglomerative and deglomerative forces are those forces which tend to concentrate or disperse industries and are discussed later in this review.

The key variables in Weber's framework are distance and the weight of the goods to be carried. Thus, transportation cost is measured in ton miles. For a unit weight of commodity, transportation cost increases directly with distance from a given reference point such as the market or the source of raw material.

Weber considered the implication of the minimum transport cost framework for urban industrial location by introducing a local system of service with a central railway station from where goods are transported by trucks to district units within the local area.[1] Thus, each district enters into the total industrial orientation whether as a point of material deposit or as a place of consumption. In a situation where the railway station enters as a point of material deposit, it would be the minimum transportation cost point for an industry for which the material in question is the decisive factor in location. In Weber's terms, this would mean that much weight loss is involved in the processing.

One important element of the minimum transport cost theory is the location triangle model. "A difficulty with this model was that it

---

[1] *Ibid.*, pp. 86-7.

required graphical or analog methods for solution, since the determination of the minimum transport cost point in a location polygon does not submit to straightforward analytical methods".[1]

Nevertheless, the "concept" of minimum transport cost has practical implications for industrial location. With particular reference to urban industrial location, for example, Haig (1927)[2], Pred (1964)[3], and Moses and William, Jr. (1967)[4] point out that the early concentration of industries in central cities was influenced by the cost advantages offered by location at railway terminals. These advantages were due to the fact that the scale economies of railway transportation were concentrated at centrally located terminals.

The advent of the truck, especially in the present century, has been an important factor in breaking the transport cost advantages of the railway terminals. The use of truck has also been facilitated by the growth of freeway facilities. Pred (1964) argues that "central congestion and the flexibility of movement afforded by freeways often

---

[1] Benjamin H. Stevens and Carolyn A. Brackett, Industrial Location, Bibliographic Series Number Three (Regional Science Research Institute, 1967), p. 5; see also C. J. Friedrich, op. cit., pp. 49-59.

[2] Robert M. Haig, Major Economic Factors in Metropolitan Growth and Arrangement (New York: Committee on Regional Plan of New York and its Environs, 1927), p. 39.

[3] Allan Pred, "The Intrametropolitan Location of Amerian Manufacturing," Association of American Geographers: Annals, 54 (June, 1964), 2, pp. 165-80, see pp.165-67 especially.

[4] Leon Moses and Harold F. Williamson, Jr., "The Location of Economic Activity in Cities," American Economic Review, 57 (1967), 211-221.

permits efficient local marketing from relatively peripheral points..."[1] In a similar vein, Block (1955) has also commented in relation to Los Angeles:

> The system of freeways operating in the metropolitan area has also caused industry to locate farther away from the central city. With regard to truck transportation available along the freeways, many industries have found that they can operate quite efficiently at a greater distance from the heart of the city.[2]

In Metropolitan Boston, Manners (1960) also has observed that highway construction has led to the relocation of many industries from the centre of the city.[3] The importance of trucking and highways to industrial location has also been discussed in many other studies, for example, Fellman (1950)[4], Chinitz (1960)[5], and Moses and Williamson, Jr. (1967).[6]

---

[1] Allan Pred, op. cit., p. 176.

[2] E. M. Kitagawa and D. J. Bogue, Suburbanization of Manufacturing Activity within Standard Metropolitan Areas (Oxford: Scripps Foundation for Research in Population Problems, and the Population Research Training Centre, 1955), p. 97, comment by one of the local analysts, Carleton Block.

[3] Gerald Manners, "Decentralization in Metropolitan Boston," Geography, XLV (1960), 276-85.

[4] Jerome D. Fellman, Truck Transportation Patterns of Chicago (Chicago: University of Chicago, Department of Geography, 1950), p. 77.

[5] Benjamin Chinitz, "The Effect of Transportation Forms on Regional Economic Growth," Traffic Quarterly, XIV (1960), 129-42.

[6] Moses and Williamson, Jr., op. cit.

Barloon (1965) stresses the high service standards, rather than the low cost characteristic, of modern transportation on industrial location.[1] He comments:

> The locationally liberating influence of high transportation service standards is derived from the particular character of those modes emphasizing premium service rather than low cost of movement. These modes include air cargo, TOFC service, some aspects of high-speed, long-haul rail carriage, and, most emphatically of all, highway transportation. Most of these modes represent the superior service standards of small lot movement, short door to door delivery time, and a high predictability of arrival time, all peculiarly suited to the type of cargo I have been describing. Their rapid development is associated with a greater latitude of industrial site selection both as between regions of the country and, within any particular region, as between particular localities and sites.[2]

The increasing flexibility which modern transportation facilities have brought on industrial location tends to suggest that the problem of plant site selection, as far as the transportation factor is concerned, may be rightly considered by examining the accessibility of particular sites to such facilities as highways and airports since these developments have considerably modified the theoretical transport cost location pattern.

The "concept" of minimum transport cost has also found ap[illegible] application in the market area theory which places emphasis upon spatial competition for markets under the assumption that production costs are

---

[1] Marvin J. Barloon, "The Interrelationship of the Changing Structure of American Transportation and Changes in Industrial Location", Land Economics, 41 (1965), 169-79.

[2] Ibid., p. 173.

a spatial constant (Smith and Lee, 1970).[1] Under this condition, the most efficient location is determined where the difference between total revenue and total cost is maximized.

Further locational implication of this theory is demonstrated by Losch (1954) by contending that market areas are efficient where producers are located in the centre, i.e., where market areas are hexagonal in shape.[2] With such a central location, distribution costs are minimized given the assumptions of uniform population density, f.o.b. pricing (i.e., the price of the good which the consumer pays is equal to the price at the point of production plus the cost of transportation to the consumer), and identical demand for all consumers.

Under the condition of free entry, Losch extends his analysis to develop a system of hexagonal market areas. In this system, excess profit is eliminated, thus ensuring the maximum number of producers with each producer locating as far as possible from the other producers. A spatial equilibrium is achieved when all producers are equally spaced on the landscape. In this situation, each producer's market boundary, i.e., the real range of the good (Christaller, 1933) is defined by the boundary beyond which a consumer would be supplied by a

---

[1] David M. Smith and Tso-Hwa Lee, A Programmed Model for Industrial Location Analysis (Department of Geography, Southern Illinois University, April, 1970), 2-4.

[2] August Losch, op. cit., pp. 105-37. See also John B. Parr and Kenneth G. Denike, "Theoretical Problems in Central Place Analysis", Economic Geography, 46 (1970), 4, 568-586.

competitor.[1]

In considering the implication of the foregoing theory for intra-urban industrial location, one would tend to suggest that the theory favours the central location argument especially for industries serving the entire market area (Haig, 1927).[2] Pred (1964) criticizes this argument in a somewhat convincingly-worded statement:

> In relation to the problem of intrametropolitan industrial location, the contentions of all the maximum accessibility or central location proponents, and some of the market area theorists, dwindle still further in relevance when it is realized that: The markets served by some metropolitan manufacturers are discontinuous, non-local and distant; that transportation costs are immaterial to site selection decisions in many industries; and that no account is taken of the desirability of core locations for specific kinds of industries.[3]

Losch did recognize the possibility of discontinuous markets (i.e., discontinuous population) by assuming nucleated agricultural villages. This assumption leads to the conclusion that a small amount of excess profit and the existence of different sizes of market areas is possible.[4] In the context of intra-urban industrial location or migration, one may see the relevance of these conclusions in the distribution of markets in the different parts of a metropolitan region

---

[1] W. Christaller, Central Places in Southern Germany, translated by C. Baskin (Englewood Cliffs: Prentice-Hall Inc., 1966), p. 54.

[2] Robert M. Haig, op. cit., p. 39.

[3] Allan Pred, op. cit., p. 171.

[4] August Losch, op. cit., pp. 114-120.

as a factor in industrial location pattern.

It may be noted here that another modification is introduced into Losch's market area system via the concentrating effect of agglomeration economies since these economies lead to lower production costs.[1] The meaning and the implications of these economies for intra-urban industrial migration are discussed later in this review.

The theory of land rent may now be considered as it relates to urban industrial plant site selection. The theory of land rent was originally developed in connection with the problem of agricultural location and a convenient reference to begin with is Von Thunen (1826).[2] Unlike Adam Smith, Von Thunen distinguished between actual land rent and pure land rent.[3] The former includes interests accruing to a piece of land as well as to the value of investment put into improving the land. This is what Von Thunen called "estate rent". Pure land rent refers to that portion of actual land rent which is attributable to the intrinsic and locational qualities of land. It is this pure rent which Von Thunen regarded as land rent.

In considering the effect of grain price on land rent, Von Thunen showed that the value of grain fell with increasing distance from the market.[4] Since the locational qualities of land were assumed

---

[1] Ibid., pp.68-84.

[2] Johann Henrich Von Thunen, Von Thunen's Isolated State, edited by Peter Hall, translated by Carla M. Wartenberg (London: Pergamon Press Ltd., 1966), chapter 5a, 18-22.

[3] Ibid.

[4] Ibid., p. 31.

to correspond to distance from the market, Von Thunen was in fact demonstrating that land rent would decline as distance from the market increases.

This inverse relationship between land rent and distance has been extended to the theory of urban land use. Thus, Isard (1956)[1], Garrison, et. al. (1959)[2], Alonso (1964)[3] and Richardson (1969)[4] have all stressed the phenomenon of declining urban land rent gradient from the city core.

These authors have discussed a number of relevant theories behind this phenomenon. In the first instance, it is suggested that the core of a city offers the maximum accessibility not only to the urban market but also to terminal and other facilities usually found in optimum concentration in city centers. Because of the desire for accessibility to such facilities, demand for land by industries and service firms is always high in the centre relative to the periphery of an urban area. The result is higher land prices in the urban centre than in the periphery.

---

[1] Walter Isard, Location and Space Economy (New York: The M.I.T. Press and John Wiley and Sons, Inc., 1956), p. 205.

[2] W. Garrison, et. al., Studies of Highway Development and Geographic Change (Seattle, 1959), p.64.

[3] William Alonso, "Agricultural Rent Functions and Bid Price Curves of the Urban Firm" in Location and Land Use: Toward a General Theory of Land Rent (Cambridge, Mass.: Harvard University Press, 1964), 35-58.

[4] Harry W. Richardson, Regional Economics (New York: Praeger Publishers, Inc., 1969), chapter VI, 119-145.

In the second place, agglomeration of industrial and service firms takes place in the urban centre itself since land is demanded in small parcels to minimize the capital costs of location. This high agglomeration tends to generate deglomerative forces in the form of rising land value (Weber, 1909) and traffic congestion which in turn would cause activities to migrate to other parts of the urban area.[1]

Minimum transport cost and land rent theories have long been treated as complementary theories.[2] In fact, "many linear programming formulations now exist in which the dual of minimizing of transport costs is the maximizing of rents and in the early and simplest forms of agricultural and urban rent theories this complementarity was stressed".[3] With particular reference to urban industrial location, Logan (1964) demonstrates this complementarity by stating:

> The case study has suggested that the intra-urban location of manufacturing can be understood in terms of a combined Weberian-Von Thunen model. Because accessibility is important and space so limited, some firms are forced to locate away from the "best" site. There are many imperfections arising especially from the restricted supply of land and government controls which restrict the firm in its choice. But the final solution is not isolated; the ability of firms to substitute in many directions is very great and the location decision is only part of the total production decision within the firm.[4]

---

[1] C. J. Friedrich, op. cit., pp. 131-2.

[2] William Alonso, "A Reformulation of Classical Theory and Its Relation to Rent Theory," Regional Science Association: Papers and Proceedings, 19 (1967), pp. 23-44.

[3] Ibid., p. 39.

[4] M. I. Logan, "Suburban Manufacturing...," op. cit., p. 234.

However, Alonso (1967) points out that there is a key difference in rent and transport cost theories, namely that rent theory deals with competition for the use of space and location theory does not.[1] The argument continues:

> Whereas the transport cost functions increase monotonically from the source, the rent surface may well have many peaks and pits . . . Rent and transport cost will be complementary in rent theory only if severe assumptions are made about everything else being constant, including such things as value of sales and constant technical coefficients, including that for land. This will be so much the same reason that the minimizing of transport costs in location theory is an objective valid only in those tautological cases in which everything else is held constant.[2]

Alonso's major conclusion then is that rent theory deals with the competition of land-users for the right to occupy the land. The study of competition for land involves a "bid-price" surface, i.e., a pattern of land values such that the firm is indifferent among locations.

Theoretically, the optimal location of a firm is the point where the surface of actual prices is tangent to the lowest bid price surface with which it comes in contact. This point is unlikely to minimize transport costs plus rents. Since there are differences in the quantities of land demanded by firms, the bid-price surfaces cannot be directly compared. For this reason, Alonso suggests that the locational pull of land rent should be standardized per unit of land, a suggestion that is reflected in this study by using variables based on cost of industrial land per acre as part of the attributes of a location site.

---

[1] William Alonso, "A Reformulation of Classical Theory...," op. cit., p. 40.

[2] Ibid. pp. 40 and 44.

The study by Liddle (1968) also discusses substitution between land rent and transportation costs.[1] In addition, Liddle suggests that other forms of substitution are possible, for example between location and space or between "land costs" and other production costs. . In discussing the influence of land costs on the location of manufacturing in Metro Toronto and its surrounding areas, Liddle distinguishes between "economic rent" and "land price". A site's economic rent is the price which a firm is willing to pay for a site and this is determined by the attributes of the site to the particular firm, for example, distance to the firm's market and raw material, economic attitude and proximity to the required labour. Thus the economic rent for the same site would vary for different firms. Land price (i.e., land cost) is the market value per unit of land. Since it is fixed through the market mechanism of supply and demand, it cannot be influenced by a particular firm. It is therefore the same for all firms.

In his description of land cost distribution in Metro Toronto and its surrounding areas, Liddle derives two patterns of variation. First, the gradient of land cost per unit area is very steep up to 40 minutes of travel from the Toronto core. Beyond this, there is a gradual decline.[2] Second, the slopes of land cost gradients vary in different directions.[3] For example, the gradient of serviced industrial

---

[1] David B. Liddle, The Intrametropolitan Location of Manufacturing and the Industrial Land Market: A Case Study of the Toronto Region, M.A. Thesis (Toronto: University of Toronto, 1968), see chapter III, 36-55.

[2] Ibid., p. 71.

[3] Ibid., p. 74.

land cost drops off much faster east of Yonge Street than it does in the western sector. This observation reflects the influence of the Toronto international Airport, highways 400 and 401 and the Queen Elizabeth Way. These facilities tend to push up the values of land on the western sector. By way of comparison, Seyfried (1963)[1] and Yeates (1965)[2] have found similar sectoral variations in the slopes of urban land rent gradients in their respective studies.

In general, Liddle finds that costs of industrial lands are lower on the outskirts than in the city.[3] He observed that this factor, coupled with ready availability of land, has accounted for the greatest growth of industries occurring on the outskirts of the city. One additional factor reinforcing this growth is the fact that distribution of property and business taxes tends to display a similar variation with distribution of land values. Thus, property and business taxes are lower on the outskirts of the city than in the city itself.[4]

The suggestion that land rent depends on the locational qualities of land deserves further elaboration in the context of industrial migration being considered. Theoretically, locational qualities are assumed to reflect accessibility to the urban core. This may be a justified assumption if all urban facilities and all urban population are concentrated in the core area and if all firms seek accessibility to these facilities and the population.

---

[1] W R. Seyfried, "The Centrality of Urban Land Values," Land Economics (1963), 39, 275-85.

[2] M. Yeates, "Some Factors Affecting the Spatial Distribution of Chicago Land Values, 1910-60". Economic Geography (1965), 41, 57-70.

[3] Liddle, op. cit., chapter IV, pp. 56-82.

[4] Ibid., p. 96.

However, in reality, different parts of an urban area often possess some different levels of facility and population concentration. Moreover, the siting of such transportation facilities as airport and highway terminals in an urban area may create nuclei for development and peaks of high land values (Berry, et al., 1963).[1] Accessibility to any of these nuclei may thus have some impact on the distribution of land values in urban areas. For this reason, it is important to note that the theoretical gradient of urban land values may be significantly modified by the particular attributes of individual sites, aside from distance to the core. In this study, the emphasis is placed on the market price of land rather than on the theoretical gradient.

Aside from industrial land cost, there are many other attributes which are important to a firm's decisions to select a particular site. In general, such attributes represent opportunities for reducing production costs. These advantages may be described as "external economies". External economies may be defined as "the economies (advantages) that a firm can obtain through the use of facilities external to iteself".[2] Such advantages would imply reduced service fees owing to the use of a divisible service, the whole unit of which a firm may not be able to provide for itself in an economic way. On this ground, power, water, sewage, police and fire protection services provided in an urban area constitute sources of external economies. The question of external economies also overlaps into such facilities as

---

[1] B. J. L. Berry, et. al., Commercial Structure and Commercial Blight, Research Paper, 85 (Chicago: University of Chicago, Department of Geography, 1963), see in particular the generalized land value surface of a city, p. 14.

[2] E. M. Hoover and Raymond Vernon, Anatomy of a Metropolis (New York: Garden City, Double-day Anchor, 1962), p. 45.

highway and airport terminals and industrial lands which are discussed above. Another source of external economies arises when a small firm uses the services offered by a larger firm, that is, when a small firm secures the advantages of scale economies (Vernon, 1957).[1]

Hoover (1937) identifies two components of external economies.[2] These include: 1) localization economies, that is, "economies for all firms in a single industry at a single location".[3] Examples of such economies may include interfirm services, mutual stimulation, and [illegible] complementary use of labour; and 2) urbanization economies which are enjoyed by all industries at a given location, for example, inter-industry input-output and technological relations, use of auxiliary services (banking, insurance and other financial services, for example), and urban facilities like water, hydro and sewer. These two components of external economies, along with large scale economies resulting from the size of individual firms, make up agglomeration economies.

Losch (1954) stresses the importance of agglomeration economies to urban industrial location.[4] The major effect of these economies is urban-industrial concentration (agglomeration). The concentration effect of agglomeration economies on intra-urban industrial migration can be demonstrated in two ways: 1) the attraction of potential sites with

---

[1] Raymond Vernon, "Production and Distribution in the Large Metropolis", Annals of the American Academy of Political and Social Sciences, 314 (1957), 15-29, see pp. 22-23 in particular.

[2] E. M. Hoover, Location Theory and the Shoe and Leather Industries (Cambridge, Mass.: Harvard University Press, 1937), 90-91.

[3] Ibid.

[4] August Losch, op. cit., 68-76.

relatively high levels of opportunities for realizing these economies to migrating firms, and 2) the attraction of origin sites and the effect of this on the distance moved by migrating firms. The question of movement-distance relationship is discussed later in this review.

It may be pointed out that industrial concentration resulting from agglomeration economies can also create diseconomies, for example, rising land values (Weber, 1909),[1] traffic congestion and scarcity of land. On the one hand, these forces are important in motivating industrial migration. On the other hand, they do affect the relative attraction of potential destinations to migrating firms in a negative way. Thus, in this study, an inverse relationship is assumed between land cost, or change in land cost, and the attractiveness of a potential destination.

Judging from the concentration effect of agglomeration economies, it can be argued that the level of industrial concentration at a particular site is an indicator of the force or agglomeration economies operating at that site. It is this reason that leads the author to consider level of industrial concentration as one attribute of a manufacturing sub-area. The measurement of industrial concentration is discussed later in this study.

The important question of origin-destination relationship may now be examined. Industrial migration may properly be regarded as one form of migration. In this connection, it may be noted that, for different forms of migration, the hypothesis of inverse relationship between

---

[1] Carl J. Friedrich, op. cit. 131-2.

frequencies of movement and distance moved always holds.[1]

With particular regard to industrial migration, the inverse relationship has been demonstrated at the inter-regional and the intra-urban levels. At the inter-regional level, the works of Ray (1965, 1967)[2] and Keeble (1965, 1968)[3] represent important contributions. Ray focuses on the location of United States subsidiaries in Canadian cities. The inverse relationship of distance to this form of inter-regional industrial migration is best demonstrated by the interactance decay and the sectoral penetration concepts. The interactance decay concept hypothesizes that the total number of Ontario's subsidiaries controlled from any United States city is inversely proportional to its distance from the province and directly

---

[1] Richard L. Morrill, "The Distribution of Migration Distances," Regional Science Association: Papers and Proceedings, XI (1963), 75-84; G. Olsson, "Distance and Human Interaction: A Migration Study," Geografiska Annaler, XLVII (1965), 3-43; Gerald A. P. Carrothers, "An Historical Review of the Gravity Potential Concepts of Human Interaction," Journal of the American Institute of Planners, XXII (1956), 94-102; and Torsten Hagerstrand, "A Monte Carlo Approach to Diffusion," in Spatial Analysis, op. cit., 368-84.

[2] D. M. Ray, Market Potential and Economic Shadow, Published Ph. D. Thesis (Chicago: University of Chicago, 1965); and Regional Aspects of Foreign Ownership of Manufacturing in Canada (University of Waterloo, 1967), see in particular pp.81-96. Also, see a critique of the market potential and economic shadow concept by Lyndhurst Collins in Canadian Geographer, vol. XII (1967), 3, 180-82.

[3] D. E. Keeble, "Industrial Migration from North-West London, 1940-64," Urban Studies, 2 (1965), 15-32; and "Industrial Decentralization and the Metropolis: the North-West London Case," Institute of British Geographers: Transactions, 44 (1968), 1-54.

proportional to its size. The sectoral penetration concept hypothesizes that there is a distinct relationship between the distance of the subsidiary and the parent company from the international boundary. Perhaps, the inverse relationship is also implied by the sectoral affinity hypothesis which states that a subsidiary tends to be located in the geographic sector linking the parent company to the primary regional market centre.

The inverse relationship is explicable by the fact that branch plants are less able to move far from their source areas for financial and other reasons. For example, management costs tend to increase the farther away a subsidiary is located from its parent firm. In this connection, distance represents a surrogate for costs.

Keeble focuses on industrial decentralization from the North-West London area. Using the examples of relocated firms and branch plants, he distinguishes between two patterns of migration in terms of distance. One pattern is defined by the migration of plants within 100 miles of the source area. This pattern is designated as Metropolitan zone migration. The other pattern, i.e., the Provincial zone migration, is defined by migration of plants to places beyond the 100 miles radius.

For the Provincial Zone migration, which is one form of inter-regional migration, Keeble observes that the distance decay gradient is steeper for relocated firms than for branches. He explains this contrast by the fact that relocated plants are generally smaller, less able to move far from their source areas for financial and other reasons. In addition, economic disincentives to migration increase much more rapidly with distance from London for relocated firms than for branch plants. Such economic disincentives may take many forms, for example, loss of market or export outlet, loss of labour pool, and loss of key managerial and technical staff. Above all, directors of relocated firms tend to avoid getting involved personally in the locational consequences of their decisions.

Of particular importance to the problem of plant migration is the particular attention which Keeble focuses on such characteristics as industry type, size and type of migrating firms. In this connection, Keeble has demonstrated the need to take into account the influence of plant characteristics on migration patterns. In the present study, industry type and size of employment are considered. However, no distinction is made between branch and relocated plants since the study is concerned with a fairly general model. Moreover, these two types of migration can be treated in the same theoretic framework.

The inverse relationship between distance and frequencies of plant migration is also demonstrated at the intra-urban (or intra-metropolitan) level, for example, Keeble (1965, 1968),[1] Collins (1966)[2] Kerr and Spelt (1965),[3] and Moses and Williamson, Jr. (1967).[4]

---

[1] Ibid.

[2] Lyndhurst Collins, Industrial Migration and Relocation: A Study of European Branch plants with Special Reference to Metropolitan Toronto, M. A. Thesis (Toronto: University of Toronto, 1966), see pp. 118-123.

[3] Donald Kerr and Jacob Spelt, The Changing Face of Toronto (Ottawa: Geographical Branch, Department of Mines and Technical Surveys, 1965), 129-139.

[4] Moses and Williamson, Jr. op. cit.

In the Metropolitan Zone migration identified by Keeble in the North-West London study, plants do not move far from the source area. Again, the reasons are financial and personal, for example, possibility of retaining the existing labour and market, proximity to parent companies, unwillingness to involve firm directors in too great a change and proximity to directors' homes.

Similar reasons are also cited by Collins based on relocations of 52 European branch plants in Metro Toronto. In addition, Collins suggests that personal knowledge of an available site in the same geographic sector through which a president commutes between his home and place of work is also an important factor. In this connection, Collins is suggesting a president's familiarity with his intervening opportunities (Stouffer, 1940).[1]

The contribution by Kerr and Spelt is succinctly summarized in the following statement:

> An analysis of plant movement within Metropolitan Toronto shows that industries that have built up an association in one part of the city prefer to remain as near as possible to the old location when selecting a new site in the suburbs. Nearly all of the plants in south Etobicoke that originated in Metropolitan Toronto have moved from the western half of the city. Similarly, nearly all the firms that moved to Scarborough came from the eastern half.[2]

---

[1] S. A. Stouffer, "Intervening Opportunities: A Theory Relating Mobility and Distance", American Sociological Review, 5 (December, 1940), 845-67.

[2] Kerr and Spelt, The Changing Face of Toronto, op. cit., 138-9.

Moses and Williamson, Jr. in their Chicago study of plant migration note that origin-destination distance reflects the costs associated with the linkage between these two sites. They elaborate:

> As distance moved increases, especially ties with suppliers of raw materials and services, labour supply, and customers may be attenuated . Costs may then have to be incurred to establish new ties. If so, firms would not be set loose when they decided to move. Instead, there would be factors unrelated to the attributes of potential destination areas which influence whether location there is optimal. The distance which a potential destination is from the firm's origin appears to be a good proxy for these factors.[1]

The foregoing rationale suffices to demonstrate that one would expect the distribution of migrant firms to fall off as distance increases from the origin. This is as true at the inter-regional level as it is at the intra-urban level. In the present study, distance between any given origin and any destination is one of the many factors considered in relation to the problem of plant site selection. In this regard, the hypothesis of inverse relationship is postulated between the attraction of a potential destination and the distance between that destination and any origin which is under consideration.

In summary, the location theory reviewed above demonstrates that the problem of plant site selection in an urban area is not totally explained by a particular theory. In addition, no particular theory is without modifications when the complexity of an urban system is considered. A convenient and fruitful approach in using the knowledge of the various theories to examine the problem of intra-urban plant site selection would, therefore, appear to be that of considering the specific factors suggested by

---

[1] Moses and Williamson, Jr., op. cit., pp. 216-7.

the theories to assess the relative attractiveness of potential destinations. Many of these factors have been indicated already in specific theoretical contexts. For a given potential destination, these factors may include accessibility to particular transportation facilities such as highways and airports; a set of cost factors, for example, costs of industrial land, hydro and water, and property and business taxes; level of manufacturing concentration; accessibility to the labour force; and origin-destination distance. In addition to these factors, one should take into account the characteristics of individual plants as they relate to their space requirements. All of these factors are considered more specifically later in this thesis.

Approaches to Modelling

Industrial migration is one important aspect of urban growth and location processes. The problem of modelling industrial migration may, therefore, be considered in the general context of these processes. In this regard, various approaches to modelling may be examined.

One approach is that which utilizes a system of equations to obtain solutions to locational problems. Such a system may be based on a set of regression (linear and non-linear) equations as illustrated by Seidman's study (1964) which discusses an activities allocation model.[1] The model uses linear and non-linear regression equations in a series of five year progressions to predict growth of residential, commercial and industrial activities for a nine county region under consideration in the period

---

[1] David R, Seidman, Report on Activities Allocation Model (Penn Jersey Transportation Study, November, 1964), pp.1-4.

1960-85. The model consists of seven sub-models each of which determines either the location of a given type of activity or the amount of land that this activity uses. Two of the sub-models are concerned with industrial allocation. One of these determines the changes in the distribution of employees according to standard industrial codes (SIC) at the two digit level. The other one determines the amount of new industrial land used by each of these SIC groups.

The study by Steger (1965), which is concerned with an urban renewal model for Pittsburgh, also uses a system of equations.[1] These equations are based on linear programming and are used to obtain solutions which maximize a given objective function. These solutions relate to the location and relocation of new and moving households and businesses given some budget constraints. The three major assumptions of the model are implemented in a sequential manner as shown below: 1) employment opportunities are directly responsible for most development decisions; 2) various types of site oriented employment will gravitate to specified areas of the city according to location criteria including, for example, present employment clusters, land use policies, access by various transportation nodes, and assessment patterns; and 3) households tend to locate at prescribed distances from work, and commercial service employment tends to cluster at locations within prescribed distances from households.

---

[1] Wilbur A. Steger, "The Pittsburgh Urban Renewal Simulation Model," Journal of the American Institute of Planners (May, 1965), 2, 144-50.

As illustrated by these two studies, the system of equations approach may allow for iterative solutions or recursive progressions whereby changes in a given locational process are portrayed over time. By this method, predictions for a given period can be affected by the previous time period (Lowry, 1965).[1] Nevertheless, the system of equations approach is not without its problems. For example, factors which cannot be directly or conveniently expressed in quantitative terms are often neglected. In the context of intra-urban plant site selection, such factors are illustrated by personal preferences and the effect of particular characteristics of individual plants.

Another approach to modelling is the analytic method. In this regard, "the set of equations constituting the model is resolved by analysis into a direct relationship between the relevant output variables and and the set of input variables; intervening variables drop out of the 'reduced form' equations" (Lowry, 1965).[2]

The analytic approach is most successful where the location model under consideration possesses complete logical structures, that is, the relationship among the factors which affect the location process can be defined in precise mathematical terms uncomplicated by nonlinearities and discontinuities. For reasons of personal preferences and plant characteristics mentioned above, the model of intra-urban plant site selection cannot be reduced into such complete logical structures. In addition, the analytic

---

[1] Ira S. Lowry, " A Short Course in Model Design," Journal of the American Institute of Planners (May, 1965), 2, p. 162.

[2] Ibid.

approach is not a particularly suitable method for handling the feedback processes which characterize many aspects of urban growth and location processes (Forrester, 1969).[1]

Another alternative to modelling urban growth and locational processes is the stochastic approach. There are two common variants of this approach: Markov Chains and Monte Carlo simulation. These are discussed in the following sections.

A Markov Chain model involves a stochastic process which Kemeny, et. al. (1959) describe as follows:

> A Markov Chain process is determined by specifying the following information: There is a given set of states (S_1, S_2,..., S_r). The process can be in one and only one of these states (or classes) at a given time, and it moves successively from one state to another. Each move is called a step. The transition probability P_{ij} which gives the probability that the process will move from S_i to S_j is given for every ordered pair of states. Also, an initial starting date is specified at which the process is assumed to begin.[2]

From this succinct definition, it follows that the Markov Chain model is characterized by a matrix whose elements are the transitional probabilities between ordered pairs of states. In his Markov Chain analysis of industrial migration in Ontario, Collins (1970), distinguishes between two types of Markov matrix: 1) the structural type whose states are defined by categories of size of total employment.[3] The structural states

---

[1] Jay W. Forrester, Urban Dynamics (Cambridge, Mass.: The M.I.T. Press, 1969), pp. 9-14 and 107-114, discusses examples of negative and positive feedback processes operating in urban growth and location.

[2] J. G. Kemeny, et. al., Finite Mathematical Structures (New York: Prentice-Hall Inc., 1959), p. 148.

[3] Lyndhurst Collins, Markov Chains and Industrial Migration, op. cit., chapter IV, pp. 90-155 and chapter V, pp. 156-206; and Markov Chains and Geographical Applications (a paper presented for the International Geographical Union on Quantitative Methods, Sept., 1970), p. 25.

are based on an "optimum classification derived for analysing the log-normal distribution which is assumed to be generated by a simple stochastic process".[1] 2) The spatial matrix whose states are defined by six broad 'regional' classifications: Toronto City, Toronto Suburbs, Large Urban, Large Urban Suburbs, Small Urban and the Rest of Ontario.

Collins makes two major uses of the Markov Chain matrix (structural and spatial). First he obtains an insight into the dynamics of structural and spatial changes taking place between 1961 and 1965.[2] This he does by developing for each type of Markov Chain matrix a series of one year tally matrices (i.e., 1961/62, 1962/63, etc.), for the period 1961-65. Second, Collins uses the Markov Matrix for a base year (1962 for the structural and 1967 for the spatial) to predict structural and spatial distributions for each year up to 1975.[3]

Although Collins work shows that the Markov Chain approach may have good potential for application in industrial migration studies, the question of using Markov simulation for projecting future distribution involves some very limiting assumptions which become more critical where small areal units are concerned as is the case in the present study. For example, the assumption that transitional probabilities are invariant over time (stationarity) is unrealistic since the attributes of an area, such as the level of facilities, the amount of vacant land available and the

---

[1] Collins, Markov Chains and Industrial Migration, op. cit., p. 126.

[2] Ibid., chapters IV and V, pp. 90-206.

[3] Ibid., chapter IV, pp.207-255.

level of industrial concentration may vary over time. In addition, the assumption that a transition process depends only on the two states involved amounts to an oversimplification of locational problems which often involve a great deal of interdependencies among locations. These considerations make the Monte Carlo technique particularly appealing for application in this study.

Monte Carlo simulation is that branch of experimental mathematics which is concerned with "random sampling from a known probability distribution function" (King, 1969).[1] There are two essential steps in the sampling procedure. First, a set of random numbers is substituted for a random variable in direct proportion to the value of that random variable and it is assumed that such random numbers could have been produced by a suitable random process. Second, a random number is generated and the location, area or object possessing that random number is sampled or assigned some value. It is possible to build some constraints into this sampling procedure (Hagerstrand, 1968).[2]

Hammersley and Handscomb (1965) show that the Monte Carlo methods may be used to handle probabilistic or deterministic problems.[3] A probabilistic

---

[1] Leslie J. King, Statistical Analysis in Geography (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1969), p. 229.

[2] Torsten Hagerstrand, "A Monte Carlo Approach to Diffusion", op. cit., pp. 375-77.

[3] J. M. Hammersley and D. C. Handscomb, Monte Carlo Methods (London: Methuen and Co. Ltd., repr., 1965), pp. 1-9.

problem involves observing random numbers which are chosen in such a way that they directly simulate the physical random processes of the original problem and inferring the desired solution from the behavior (or distribution) of these random numbers. This procedure may be likened to drawing a random sample from a given population.

In the case of a deterministic problem, such as is illustrated by this study, the process under consideration is described by some suitable probability function which is developed in accordance with the written theory behind the process. The sampling procedure is then applied to this function.

Certain features of the Monte Carlo simulation, which make it a suitable method for approaching the problem of intra-urban plant site migration, are considered below. One major feature of the Monte Carlo simulation, as with the other types of simulation, is the iterative solution method. In this regard, solutions are obtained step by step. The iterative method is more suitable than an analytical solution "For models lacking complete logical closure, or whose structures are overburdened with incomplete mathematical relationships" (Lowry, 1965).[1] As already pointed out, the factors affecting intra-urban plant site selection cannot all be conveniently defined by precise mathematical relationships which the analytic method requires.

The iterative method is also a useful procedure for handling locational interdependence, or the impact of the past events on the future location, in

---

[1] Ira S. Lowry, op. cit.

a more explicit manner than the analytic method. This is achieved by using the solution for a previous time period as inputs for computing the solution for a subsequent time period.

Another feature of the Monte Carlo simulation is that it allows for a set of explicitly assumed factors and random elements to be handled in a locational process. The explicitly assumed factors are used to determine the probabilities assigned to individual locations while the random elements are expressed through the random operational procedure.

The use of the Monte Carlo simulation model for predicting locational behaviour is justified on the ground that human decisions are subject to random as well as non-random elements. This argument reflects the point of view that optimal solutions to location problems may be unrealistic where such problems involve human decisions. This view is discussed or at least reflected in a number of studies: for example, Alchian (1950),[1] Tiebout (1957),[2] Simon (1956),[3] Pred (1967),[4] and Wolpert (1964, 1965).[5] From the evidence provided in these studies, it can be concluded that random elements enter into decision making under three conditions: 1) where many factors are involved making precise

---

[1] Armen Alchian, "Uncertainty, Evolution and Economic Theory," Journal of Political Economy, LVIII (1950), pp. 211-221.

[2] C. M. Tiebout, "Location Theory, Empirical Evidence and Economic Evolution," Regional Science Association: Papers and Proceedings, III (1957), pp. 74-86.

[3] Herbert A. Simon, Models of Man (New York: John Wiley and Sons, Inc., 1957), p. 198.

[4] Allan Pred, Behavior and Location: Foundations for a Geographic and Dynamic Location Theory, Part I, Lund Studies in Geography, Series B, 27 (Sweden: The Royal University of Lund, 1967), pp. 65-121.

[5] J. Wolpert, "The Decision Process in Spatial Context," Association of American Geographers: Annals, LIV (1964), pp. 537-58; and "Behavioral Aspects of the Decision to Migrate," Regional Science Association: Papers and Proceedings, XV (1965), pp. 159-69.

relationships difficult to express; 2) the influence of personal attributes such as awareness, perception, psychological characteristics, social status, which make many decisions subjective; and 3) limited availability of information and limited ability to use information.

Having now considered the essential features and the advantages of the Monte Carlo simulation method, some examples of studies, which have used this method in the area of urban growth and locational processes, may be cited for further illustration.

One important study in this area is that of Putnam (1967).[1] Putnam develops a model to simulate allocation of new industrial facilities in Pittsburgh. To locate an industrial facility, the model first computes an index of maximum desirability for each city tract, based on the sum of four attributes. If there is a single most desirable tract, the facility is located. Where there is a set of equally desirable tracts, the model uses a Monte Carlo technique to select one of them. The four attributes used are 1) assessed value of lands and buildings, 2) availability of industrial land; 3) structural density based on the ratio of employment to floor area; and 4) industrial clustering based on the amount of industrial types and adjacent industrial types.

The North Carolina studies which focus on residential development may also be cited for further illustration. For example, Chapin Jr. (1965)

---

[1] Stephen H. Putnam, "Intra-Urban Industrial Location Model: Design and Implementation," Regional Science Association: Papers and Proceedings, XIX (1967), pp. 199-214.

discusses a model for simulating residential development.[1] The model distributes households to areal units (cells) which are attractive for residential development in each successive growth period, using Donnelly's linear form of sampling with replacement.[2] This distribution is made on a probabilistic rather than deterministic basis to take into account the chance factors operating in the process. Each iteration of the simulation routine involves a reassessment of the attractiveness of each cell based on changes in non-residential land uses in the preceding period. The locating variables incorporated into the model, along with their respective weights , are determined using a multiple regression analysis.

The attractiveness of a cell for residential development is based on assessed value and a given set of priming factors including 1) accessibility to work areas; 2) availability of public sewerage; 3) accessibility to the nearest major street; and 4) accessibility to the nearest elementary school.[3] The operation of the model involves the use of the Monte Carlo technique in making an <u>ex post facto</u> prediction of 1960 residential distribution from a starting date of 1948.

Perhaps the only serious objection to the study is the obvious case of circularity. This circularity is introduced by evaluating the inputs into the model (variables, parameters and other empirical specifications) and operating the model for the same time period, i.e., 1948-60. As noted

---

[1] F. Stuart Chapin, Jr., "A Model for Simulating Residential Development," <u>Journal of the American Institute of Planners</u> (May, 1965), 2, 120-25.

[2] Thomas G. Donnelly, F. Stuart Chapin, Jr. and Shirley F. Weiss, <u>A Probabilistic Model for Residential Growth</u> (Institute for Research in in Social Science, University of North Carolina, 1964), 1-17.

[3] <u>Ibid.</u>

in the introduction to this thesis, one could avoid such problems by estimating parameters from data for one time period and then using such parameters in the model to predict outcomes for another time period as a test of the model's validity.

The studies reviewed above suffice to show that the Monte Carlo simulation technique is an acceptable strategy in modelling aspects of urban growth and locational processes, industrial migration not exempted. In addition, these studies demonstrate that in using this strategy, it is possible to use a variety of deterministic techniques, such as linear programming and regression, in the assessment of attractiveness levels for different locations. It is on the basis of such attractiveness levels that probabilities are assigned to different locations.

Summary

The review of literature presented in this chapter focuses attention on two major questions.. First, there is the question of the relevance of location theory to the problem of intra-urban plant site selections by migrant firms. In this connection, it is shown that no particular theory provides the total answer since any theory is subject to modifications arising from the dynamics of the real world situation which, in the urban context, is illustrated by the process of urbanization. Nevertheless, the review does provide a knowledge of certain aggregate factors which could be considered as important to the problem of plant site selection. These factors may be classified into three sets: 1) attributes of a site such as costs of services provided on the site, property and business taxes, availability of industrial land, and accessibility to labour force and major transportation facilities; 2) distance between an origin and a potential site (destination); and 3) characteristics of the migrating plant such as industry type and size of employment. These sets of factors are discussed more specifically in the next chapter.

Second, the review focuses on the essential features and advantages of the Monte Carlo simulation technique as a strategy in solving the problem of plant site selection. This strategy is shown to be quite realistic in the particular context of intra-urban plant migration when compared with the Markov Chain model which has also been used in a number of geographic analyses. Examples of studies which use the Monte Carlo simulation method in the related area of urban location and growth processes are also cited as evidence that this technique is an accepted strategy. The next chapter is concerned with presenting the simulation model for intra-urban plant site selection by migrant firms as developed for this study.

CHAPTER III

PRESENTING THE SIMULATION MODEL FOR INTRA-URBAN PLANT SITE SELECTION

In reviewing the literature in the last chapter it was shown that the choice of a location site (destination) by a migrant firm could be understood in terms of three sets of factors: destination attributes, distance between an origin and a destination, and characteristics of the migrating firm. In addition, the rationale for a simulated solution was presented.

In this chapter a formal simulation model of intra-urban site selection is presented, assuming migration of plants. It must be pointed out that the presentation of the simulation model is strictly verbal and it is not intended to discuss the problems of statistical estimates.

The simulation model is presented under four headings: the general framework, the assumptions of the model, the simulation procedure and the elements of the model. These are now discussed in the following sections.

The General Framework

To place the model under consideration into a broader perspective, the three sets of factors outlined above should be related to a general framework. Such a general framework can be explained in terms of three components.

Component I is comparative place utility which refers to "the place utility of one node relative to that of all other nodes" in a given system of migration (Brown, 1968).[1] This component partly determines which of the total population of nodes become destination nodes.

In the context of the problem of plant site selection under consideration, this component is represented by the attributes of a manufacturing sub-area, for example, accessibility to highways, airports, and labour; availability and cost of industrial land and services; property and business taxes; and level of industrial concentration. These attributes represent the opportunities for external economies to be earned by a firm locating at a manufacturing sub-area. They thus define the attractiveness of a sub-area to any migrating firm irrespective of its origin.

Component II refers to the area or environment in which the migration takes place. This component includes the attributes expressing the relationship between an origin and a destination such as distance, a factor that is also considered in this study.

Component III refers to the characteristics of the item being located which, in this study, is the manufacturing plant. Size, product type and country of control are some examples of such characteristics. In this study, plant characteristics are expressed through the space requirement levels assigned to individual plants.

---

[1] Lawrence A. Brown, *Diffusion Processes and Location: A Conceptual Framework and Bibliography*, *Bibliographic Series No. 4* (Regional Science Research Institute, 1968), p. 17. For further discussion of these components, see pp. 1-48.

Assumptions of the Model

The simulation model is based upon three simple assumptions. These assumptions respectively involve the three sets of factors discussed above.

1. It is assumed that the attractiveness of a destination (j) to any industry migrating from any origin (i) depends upon the comparative place utility of the destination. As indicated above, the comparative place utility of a destination (location), in an intra-urban context, is made up of a number of specific attributes which in the majority of the cases reflect opportunities for earning external economies.

The specific assumptions relating to these attributes depend on the manner in which they are measured. Where the attributes are measured in terms of cost, rate or distance, an inverse relationship is assumed, for example, cost of industrial land per acre, industrial mill rate, water and hydro power rates, and distance to a major highway. The variations in costs and rates in the study area reveal the fact that the area Municipalities enjoy certain autonomy in the provision of industrial services and in the assessment of property taxes. However, it is compatible with the assumption under consideration to further assume that the quality of these industrial services is uniform in the study area. For example, the types of services available on a piece of industrial land, such as water supply, hydro, sewer, fire and police protection, are assumed to be the same. Similarly, the efficiency by which these services are performed in terms of say, frequency or reliability, is also assumed to be uniform.

2. It is assumed that the attractiveness of a destination (j) to any industry migrating from a particular origin (i) is inversely related

to the distance between i and j. This assumption is based on the rationale discussed in the review of the literature in the last chapter.

The specific factors emerging from the above two assumptions taken together are summarized below in the particular context of the study area by using thirteen variables as measures of attractiveness of destination j given origin i. It is to be recalled that a destination j is any possible sub-area for plant location. The thirteen variables and their assumed directions of relationship are discussed below. However, the measurement of these variables is not discussed here since it is more consistent to discuss this topic in the next chapter which is concerned with the problem of statistical estimates.

Variables 1 and 2 are measures of manufacturing diversification and manufacturing concentration respectively. These variables are assumed to reflect the level of industrial development which in turn represents the potential of a sub-area for offering urbanization economies arising from inter-industry input-output relations or linkages. As indicated earlier, manufacturing linkages are an important source of external economies which in themselves are part of agglomeration locational forces. As Karaska (1969) expresses it: "one important element of the external economies is the spatial juxtaposition of mutually dependent enterprises".[1]

Following the argument above, the two variables can be considered as possible surrogates for the manufacturing linkage potential of a sub-area.

---

[1] Gerald J. Karaska, "Manufacturing Linkages in the Philadelphia Economy: Some Evidence of External Agglomeration Forces," Geographical Analysis, 1 (October, 1969), 4, p. 357.

An assumption of positive relationship to the attractiveness of a destination is thus postulated for each of the two variables.

Variables 3, 4 and 5 are costs associated with industrial land at a destination sub-area. These variables are, respectively, cost of (serviced) industrial land per acre for a given period, for example, 1966-67; absolute change in cost of industrial land per acre over the past six years; and relative change in the cost of industrial land per acre over the same period.[1]

These cost variables serve as a dual measure. On the one hand, they reflect the market value basis for the assessment of industrial property taxes. The use of direct assessed values for this purpose suffers from the limitation of not keeping pace with market trends. Moreover, assessed values, even for adjacent industrial property occupying similar areas can vary radically for such factors as age, quality of buildings, types of products and the floor level occupied.[2]

On the other hand, the variables directly measure the prevailing or the changing prices of industrial land in the various manufacturing sub-areas. Demand for industrial land in a destination sub-area can be discouraged by the mere fact that prices are high even when the tax implications have not been considered. The assumption pertaining to the direction of relationship between each of these variables and the attractiveness of a destination sub-area is a negative one.

---

[1] A serviced industrial land is one which is zoned for industrial use and which is provided with basic industrial facilities including sewer, access road, rail extension, hydro and water.

[2] These criticisms are confirmed by the development officers of the various municipal departments in the study area.

Variables 6 and 7 are industrial mill rate and absolute change in industrial mill rate over the past six years respectively. These variables are assumed to be negatively related to the attractiveness of a destination sub-area for the reasons discussed below.

The basis of a local municipal property tax is its mill rate, that is, the rate payable per $1,000 of assessed property value. For the municipality of Metro Toronto, assessment of property is undertaken by the Metropolitan Assessment Department. The mill rate, once obtained, becomes the basis for determining the taxes to be paid on each property (realty tax). The mill rate which is applicable to business enterprises is called the commercial (industrial) mill rate.

In addition to the property tax, a business enterprise also pays business tax which is also determined by applying the mill rate to a certain percentage of the assessed property value, depending on the need of the municipality. Thus, the mill rate is of very great concern to a manufacturing firm in selecting a location or site.[1] The mill rate varies according to years and municipalities, and slight differences can become very significant in the overall assessed taxes of any firms.

Variables 8 and 9 respectively measure the rate of hydro and the cost of water supplied to industrial firms at a sub-area. Because these variables are fairly stable over time, no change variables are associated with them. As with the industrial mill rate, however, they vary according to municipalities. It is assumed that these variables are negatively related to the attractiveness of a destination sub-area.

---

[1] This fact is confirmed by many of the manufacturers interviewed and by John Hall, Area Supervisor, Assessor's Division of Metro Toronto Assessment Department. See also Financial Times of Canada, Industrial Location (June 17, 1968).

Variable 10 is road distance from a manufacturing sub-area to the nearest major highway. It is assumed that this variable is negatively related to the attractiveness of a destination sub-area. As noted earlier in the literature review, highways have become important locational attractions for industries since they make transportation more flexible, thus reducing the traditional ties of industries to city centres, and promote regional access.

Variable 11 is access of a manufacturing sub-area to the Toronto International Airport. This Airport is located close to the western border of Metro Toronto in the Town of Mississauga. The Airport has become an important factor in the location of industries in certain parts of Metro Toronto, especially in those parts which have direct major access to the Airport.[1] It is assumed that access of a destination sub-area to the Airport will have a positive effect on the attractiveness of that destination.

Variable 12 is labour force potential, that is a measure of accessibility of a manufacturing sub-area to labour force. It is assumed that this variable is positively related to the attractiveness of a destination sub-area.

Variable 13 is air distance between an origin and a destination sub-area and it is assumed to be negatively related to the attractiveness of a destination.

---

[1] This fact is supported by the results of the survey conducted.

The foregoing assumptions are now summarized below.

X_1 measure of manufacturing diversification (positive),
X_2 measure of manufacturing concentration (positive),
X_3 cost of industrial land per acre (negative),
X_4 absolute change in the cost of industrial land per acre over the past six years (negative),
X_5 relative change in the cost of industrial land per acre over the past six years (negative),
X_6 industrial mill rate (negative),
X_7 absolute change in industrial mill rate over the past six years (negative),
X_8 industrial hydro rate (negative),
X_9 cost of industrial water consumption (negative),
X_{10} road distance to the nearest major highway (negative),
X_{11} access to the Toronto International Airport (positive)
X_{12} measure of labour force potential (positive), and
X_{13} air distance between an origin and a destination sub-area (negative).

These thirteen variables are used in a multiple regression analysis to determine the attractiveness of destination j. The inclusion of variable X_{13} means that the index of attractiveness will differ for the same destination depending upon the origin under consideration.

3. Finally, it is assumed that individual industrial plants have different space requirements reflecting their individual characteristics, especially industry type and size of employment. In the plant site selection process, these characteristics are assumed to be reflected through the space requirement constraint posed by individual plants. Thus, the space requirement levels of different plants are determined on the basis of their classifications in a framework defined by these two characteristics. The choice of these two characteristics is explained in discussing statistical estimates in the

following chapter.

The Simulation Procedure

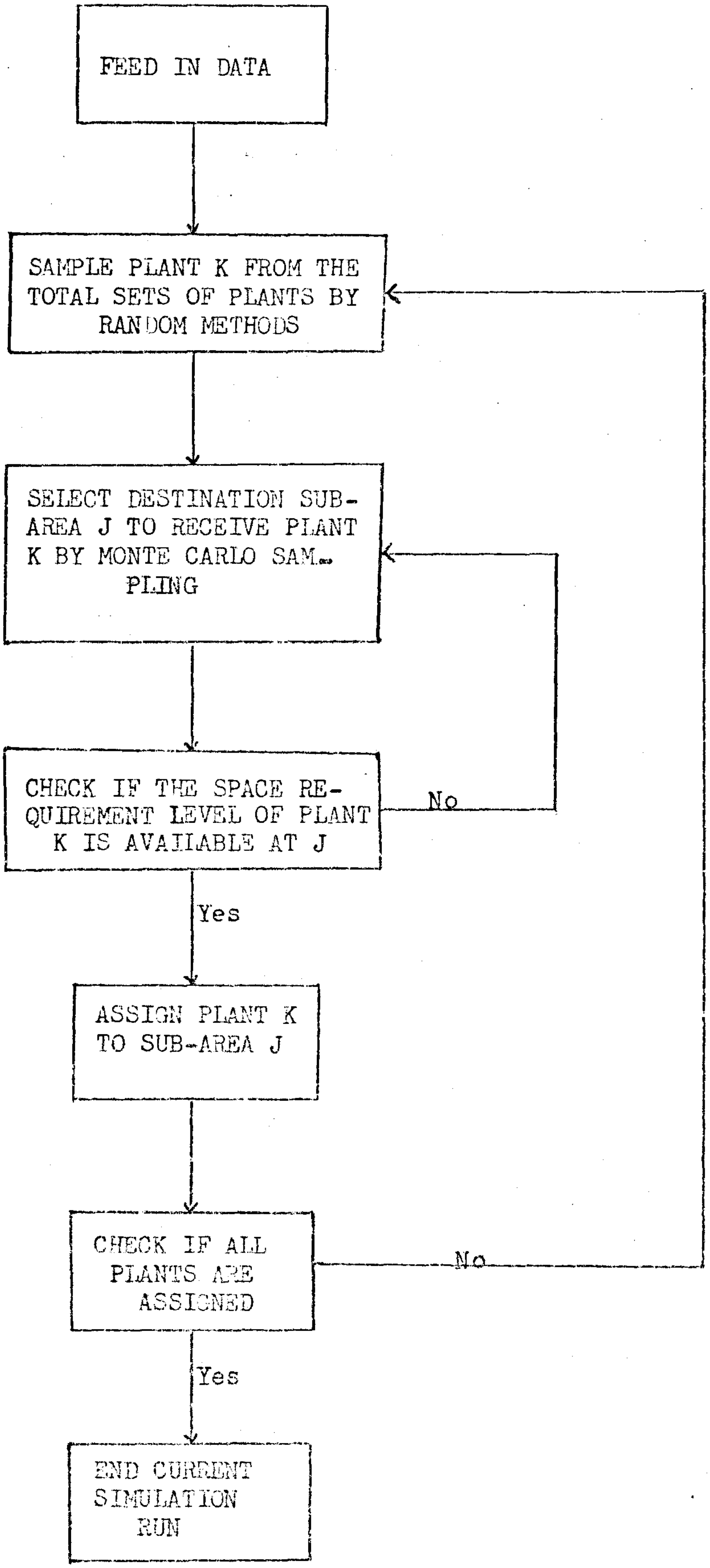
The simulation procedure involves the following iterative steps (Figure 4):

1. A random routine (RANDU) in used to sample one plant (k) for location from among the total set of plants to be located (assigned) by the model. These plants are exogenous to the model. Each plant is equally likely to be selected using this routine and a plant is selected only once in a particular simulation run (a simulation run is complete when no plant remains to be located, that is, when all the plants have been successfully assigned). Once the plant is selected, the area in which it is presently located becomes the origin (i) relative to which the attractiveness levels of possible destination sub-areas are determined.

2. For this origin i, a probability vector P_j ($j = 1, 2, \ldots, n$) is computed. Each element p_j of this vector is the probability that <u>any</u> plant, irrespective of its characteristics, migrating from origin i will go to destination j. This probability p_j depends upon the attractiveness of j, given i. This attractiveness in turn is a linear function of the 13 variables explicitly considered in the study.

3. The choice of a destination j in which to locate the selected plant is sought. This is done using Monte Carlo sampling from a set of random numbers which are established consistent with the probability vector P_j as illustrated in the following hypothetical example.

Figure 4: The Simulation Procedure



Destination Sub-area	Vector P_j	Random Number
1	.021	0-20
2	.052	21-72
3	.034	73-107
4	.003	108-110
5	.012	111-122
.	.	.
.	.	.
.	.	.
50	.012	988-999

Sum = 1.00

In the Monte Carlo sampling, the destination sub-area which is selected is the one having the generated random number. Using the hypothetical example, if the random number 74 is generated, then destination 3 is the one selected.

4. The space requirement of the plant being located, which is determined according to its classification on a given set of characteristics, is checked against the vacant industrial space available or remaining at the selected destination j. If the space required is equal to, or less than that available at the destination, the plant is assigned to the destination. Otherwise, a new destination is selected by generating a new random number. The process continues until the plant can be successfully located.

5. At the end of each successful assignment, checks are carried out to determine if all plants have been assigned. The simulation run is complete if this is the case. Otherwise, another plant is sampled for location from among those remaining to be located, and the location is determined as described in steps 1 to 4 above. After each assignment, the space available in the different destination sub-areas is revised.

The Elements of the Model

There are four sets of elements of the simulation model: measures of attractiveness of the different destinations ($\hat{a}_j$'s) expressed relative to each given origin (i); the set of probabilities (p_j's) which are dependent on $\hat{a}_j$'s; a measure of space required by a particular type of plant (u_k); and a measure of vacant industrial space available at each destination (u_j). These elements are discussed below.

The $\hat{a}_j$'s are based on the attributes of destination sub-areas and their distances to any origin i under consideration. Symbolically, for a given i, each element ($\hat{a}_j$) of the vector A_j may be represented as

$$\hat{a}_j = f(X_{1j}, X_{2j}, \ldots., X_{13j}),$$

Where $X_{1j}, X_{2j}, \ldots, X_{13j}$ are measures of the attributes of destination j. It is to be recalled that X_{13} is the distance variable between i and j. The element $\hat{a}_j$ is to be defined as a linear function of these thirteen variables. The linear model and related assumptions are discussed later in the study.

The p_j's are the probabilities assigned to destination sub-areas j for a given origin sub-area i. Each element p_j expresses the probability that <u>any</u> type of plant migrating from origin i will go to destination j. Where the sub-area i is also a possible destination, i=j. The probability p_j is derived as a function of the attractiveness of j given i, that is to say, $p_j = f(\hat{a}_j)$, where $\hat{a}_j$ is the measure of attractiveness. Specifically, for a given origin i, $p_j = \hat{a}_j / \sum_{j=1}^{n} \hat{a}_j$.

The element u_k is the standard industrial unit (SIU) measure of the amount of space required by a particular plant k. The SIU measure, which was explained in chapter I of this thesis, is based on the classification of plant k on industry type and size of employment characteristics as it will be shown in the next chapter.

The element u_j is the SIU measure of vacant industrial space (vacant land and vacant floor space) at destination j. By checking u_k against u_j, it can be determined whether or not a particular plant k can be accommodated at a selected destination j.

In conclusion, this chapter is concerned with a general presentation of the model. The general framework for the model and the related assumptions have been discussed. In addition, the simulation procedure and the elements of the model have been described. The next problem is to statistically estimate the individual elements of the model in the context of the study area. These estimates are attempted in the next chapter.

CHAPTER IV

ESTIMATING THE PROBABILITIES AND THE SPACE CONSTRATINTS

In this chapter, the elements of the model are estimated in a statistical sense. The four elements under consideration include the $\hat{a}_j$'s, the p_j's, the u_k and the u_j. Before discussing the estimates of these elements, it is pertinent to indicate the sources of data.

Sources of Data

Three major sources of data are used in estimating the elements. These sources are discussed below.

1. Scott's Ontario Directory of Industry. This Directory is published every other year starting from 1958. The Directory is used in many aspects of the data collection. One major use is comparison of information for individual manufacturing establishments as contained in the various editions of the Directory from 1958 to 1969. From this comparison, it was possible to trace the addresses and obtain the characteristics of the migrant plants in each of the periods considered in this study. The other two uses of this source include: obtaining the names of the top officials of the firms to which questionnaires were addressed; and random sampling of plants used in analysing certain aspects of the study.

2. Government and Private Agencies connected with industrial development and census materials in the study area. The most important

of these agencies include the following:

a) The various municipal departments in the study area. These departments provide the data on such aspects as industrial hydro rate and industrial water rate, as well as information relating to zoning regulations, building regulations and control of industrial land uses.

b) The City of Toronto Planning Department which supplies the data on vacant industrial land and floor areas in the City of Toronto.

c) Metro Toronto Planning Board which provides aerial photo and land use maps for the study area.

d) Metro Toronto Assessment Department which supplies the data on industrial mill rates for individual municipalities on a yearly basis. It also supplies data on land and floor areas occupied by certain manufacturing establishments.

e) Metro Toronto Industrial Commission. This commission provides the 1968 market price data for industrial areas in the study area. The Commission also publishes for each month the District News Letter which provides information on new and "migrant" industrial establishments. This source of information is used as a supplement to the Scott's Ontario Directory of Industry discussed above.

f) Metro Toronto Real Estate Board which supplies information on industrial building permits for individual municipalities in the study area.

g) Dominion Bureau of Statistics, Census Division, Ottawa. The Bureau provides data on population characteristics of the study area on the census tract basis.

h) Teela Market Surveys Limited, Toronto. This company provides information on industrial purchases in the study area on a yearly basis. The information shown for each property includes location, areal dimensions, prices paid, state of use, the seller, the purchaser and certain technical data.

3. A survey of migrant plants. The purpose of this survey is to obtain some information which is useful in obtaining aggregate measures of the factors explicitly considered in the study. For example, in measuring labour force potential, variable X_{12}, and the amount of space required by particular migrant plants at their new locations, the survey was found useful. In addition, the survey lends additional support to the importance of the aggregate factors suggested by location theory. However, the scope of the survey as designed extends beyond the information that is actually used in measuring the variables and the results are summarized in Appendix B for the interested reader.

The survey is based on the migrant plants observed in the study area in the period 1962-65. The period represents an extension of the period 1964-65 which is used in establishing the parameters of the model. The use of the period 1962-65 for the survey is to ensure that sufficient observations are obtained for drawing reliable conclusions.

The survey was conducted by mailing questionnaires (Appendix A) to migrant firms.[1] The decision to mail the questionnaires was influenced by the fact that a considerable amount of time and money was involved in the

---

[1] The questionnaires were addressed by name to the president or the general manager of each firm. The names of these officials were obtained from the <u>Scott's Ontario Directory of Industry.</u> Each questionnaire mailed was accompanied by a letter of introduction and a self-addressed and stamped envelope.

other aspects of the data collection: for example, the collection of data and information from the agencies listed above.

Altogether, 200 questionnaires were sent out to these firms, including a test sample of ten. The test sample showed a response of 40 per cent, compared with the overall response of 42.5 per cent (85 firms).

Having now indicated the sources of data used, the statistical estimate of the individual elements of the model may be discussed.

Measures of Attractiveness

It should be recalled that $\hat{a}_j$ is assumed to be a linear function of the thirteen variables listed in the last chapter. The assumed directions of relationship of these variables have also been spelled out.[1] The measurement of these variables is discussed below.

The Variables

The measurement of the variables discussed here is not an easy task. Two significant limitations should be borne in mind in evaluating the technique and the basis of measuring some of these variables. First, direct data are not available in all cases. Therefore, secondary sources have to be used to obtain surrogates or to estimate the variables in question. Second, the difficulty of measuring certain of the variables in terms of time, money, and energy must also be borne in mind. In certain cases, a more elaborate and detailed measurement not only will equal a full research task, but also, will require both thousands of research dollars and many years to carry out.

---

[1] *Supra*, pp. 61-65.

It is to be added at this juncture that all the variables are transgenerated. In this regard, the value assigned to each destination j on any variable is expressed as a percentage of the sum of that variable over all j destinations. The variables are listed in Appendices C and D.

Manufacturing Diversification and Manufacturing Concentration (X_1 and X_2)

As noted earlier, these variables are simple surrogates for manufacturing development in a sub-area and, hence, the potential of a sub-area for offering economies through input-output relations or linkages. Such relations have been directly measured in other studies by means of input-output coefficients.[1] Unlike these other studies, the present study is not concerned only with manufacturing linkages and cannot afford the time and the money which the elaborate input-output measure requires.

The two surrogates under consideration are obtained from a simple random sampling of manufacturing establishments in the study area. The sample size is 400 compared with a total population of approximately 5,000.[2] The sample size that gives a required amount of precision or error can be determined where a measure of a sample's characteristic is being

---

[1] Gerald J. Karaska, "Manufacturing Linkages in the Philadelphia Economy", op. cit., 354-69; John N. H. Britton, "A Geographical Approach to the Examination of Industrial Linkages," The Canadian Geographer, XIII (1969), 3, 185-98; and P. D. McGovern, "Industrial Development in the Vancouver Area," Economic Geography, XXXVII (July, 1961), 198-206.

[2] The list of establishments used is contained in the Scott's Directory of Ontario Industry, 1964-65 and 1966-67 editions.

used as an estimate or parameter of the population (Freund, 1967).[1] Such a characteristic may be related to size, age, cost or height and the measure involved may be, say, the mean or the standard deviation. However, the sample which is under consideration here is not concerned with making such an inference. The main objective is the distribution of the observations in the sample according to areal units. In the context of this objective, there is no formula for determining the sample size that gives a desired precision. The sample size of 400, which represents roughly eight per cent of the total population, is considered to be large enough for making a reliable estimate. Moreover, the sample size represents the point beyond which repetitions of random numbers are more frequently encountered. Thus to include more observations may make the sample less truly random since an increasing number of sampled random numbers will come to be rejected. It is for the reasons above that the sample size of 400 is used in estimating the surrogates under consideration.

The degree of manufacturing concentration in a sub-area is determined by the frequency of sample plants observed to locate in that sub-area. The degree of diversification for the same area is determined by the total number of different products produced by the observed sample establishments.

---

[1] John E. Freund, Modern Elementary Statistics, third edition, (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967), p. 223.

In this regard, a four digit SIC code represents a type of product.[1]

Cost of Industrial Land (X_3, X_4 and X_5)

The data used in computing the cost of industrial land per acre are the prices actually paid for individual purchases of industrial lands, as contained in the Teela Market surveys records for Metro Toronto. These records are kept for each year and they show for each sale transaction, the acreage, the price paid, the date of purchase, the terms of payment and some other technical information.

To compute the cost of industrial land per acre at a given manufacturing sub-area for a given time period, the total value of industrial land purchased in that sub-area for the given period is divided into the total number of acres purchased. Where a single transaction is observed during the period in question, and it is discovered that the value involved is unrepresentative, a corrected value is obtained by cross-checking against the values for adjacent or contiguous manufacturing areas with similar locational advantage, such as lying on the same road, and against the 1968 market price list supplied by the Metro Toronto Industrial Commission. In this way, the estimate of cost of land in the manufacturing sub-area concerned is improved.

Industrial Mill Rate (X_6 and X_7)

The mill rate is the rate payable per $1,000 of assessed property value and it is estimated by dividing the total expenditure required by a

---

[1] The use of the four digit SIC in classifying industrial products is discussed in the introductory sections of the Scott's Directory of Ontario Industry, 1966-67 and 1968-69 editions. See also United States, Department of Commerce, Census of Manufactures, 1967: Special Report - Concentration Ratios in Manufacturing (February, 1971), p. SR2-1, for a discussion of the four digit SIC in relation to product classification.

municipality into the assessed value of lands and buildings in that municipality. The required expenditure is the sum total of the various estimates of the municipal local government departments. The mill rate which is applicable to business enterprises is called the commercial (industrial) mill rate (Table 2).

Industrial Hydro Rate and Cost of Industrial Water Consumption (X_8 and X_9)

The industrial hydro rate (X_8) is based on every kw. of demand (Table 3), i.e., on every 300 hours of demand. This basis of assessment applies to every municipality in Ontario. However, the water rate is much more complex. There is no uniform structure of assessment. Besides, the billing dates vary for different municipalities. For example, Scarborough and Etobicoke (and former New Toronto) have a monthly billing system, North York has a bi-monthly one, and Toronto and York, a quarterly system.

The industrial water variable (X_9) is expressed as the cost of one million gallons of industrial water consumption. The use of this denominator is made necessary to take into account all the possible variations in the rate structures of individual municipalities. In addition, the representatives of utility commissions were consulted to verify the range of costs actually paid by manufacturing firms for some selected billing dates. In Etobicoke, where a monthly billing system was in operation, quite a few industries fell within the range of the costs used in this study (Table 3).

Road distance to a Major Highway (X_{10}).

This variable is expressed as the road distance from the central point of the manufacturing portions of a destination sub-area to the nearest

TABLE 2

INDUSTRIAL MILL RATES[a] FOR THE THIRTEEN FORMER MUNICIPALITIES[b] OF METRO TORONTO 1962-67

Municipality	Rates					
	1962	1963	1964	1965	1966	1967
City of Toronto	68.25	71.97	76.55	81.85	88.40	99.42
East York	62.06	64.84	70.96	75.04	78.46	88.20
Etobicoke	57.44	59.70	63.46	66.51	76.08	90.87
North York	61.93	80.32	69.53	74.50	80.32	92.09
Scarborough	69.37	71.96	77.08	80.11	87.09	96.94
York	62.32	66.05	72.24	75.58	81.75	95.23
Forest Hill	57.41	59.29	65.32	68.44	73.60	. .
Leaside	47.38	52.58	58.10	59.86	62.18	. .
Long Branch	57.44	59.70	66.34	70.67	80.40	. .
Mimico	57.44	59.70	63.59	66.86	76.41	. .
New Toronto	57.44	59.70	60.10	66.27	75.39	. .
Swansea	54.52	54.76	61.27	63.76	66.83	. .
Weston	58.85	62.84	66.41	70.20	72.86	. .
Average for Metro Toronto	59.37	63.34	66.99	70.74	76.91	93.79

a: per $1,000 of assessed property value

b: the thirteen municipalities were amalgamated into six boroughs in 1967; hence the rates for this year are given for the six boroughs only.

Source: Metro Toronto Assessment Department.

TABLE 3

INDUSTRIAL HYDRO RATE[a] AND INDUSTRIAL WATER COST[b] ACCORDING TO THE FORMER MUNICIPALITIES OF METRO TORONTO

Municipality	Rate	
	Hydro cents	Water $
City of Toronto	3.25	329.50
North York	3.18	331.36
Forest Hill	2.82	400.00
East York	2.91	424.00
Swansea	3.27	362.50
York	3.00	375.00
Weston	3.18	375.00
Leaside	3.25	330.00
Scarborough	3.27	350.10
Etobicoke	3.18	357.01
New Toronto	2.91	300.00
Mimico	2.73	350.00
Long Branch	2.82	252.60

a: per 1 kw. of demand

b: for the first one million gallons of water used.

Source: The Hydro Electric Power of Ontario, Annual Reports for the Years 1965 and 1966; and Data supplied by Municipal Departments.

junction at which it is possible to merge into a major highway. The following are regarded as major highways for the purpose of measuring this variable: the Gardiner and the Spadina Expressways, the Queen Elizabeth Way, the Don Valley, and the Highways 27, 400 and 401.[1]

The concept of accessibility can be expressed in different forms: time, physical, or road distance.[2] In this study, the use of road distance is largely due to convenience. No superiority is necessarily implied for this measure compared with the other forms. Time distance for which data are not available may possibly be a more realistic measure of accessibility than road distance.

Access to the Toronto International Airport (X_{11})

This factor is measured as a binary by assigning a value of one to manufacturing sub-areas where the Airport is assumed to have a locational influence and a value of zero to the other sub-areas.[3] The rationale for this approach has two explanations. First, the Airport is not mentioned in all manufacturing sub-areas as having locational influence. Many of the migrant firms mentioning this factor as being important are those which have direct major highway access to the Airport. The second explanation

---

[1] These highways were selected after consultation with Metro Toronto Road Department officials. Spot checks were also conducted to determine accessibility to the highways through major road arteries leading to them.

[2] Gunnar Olsson, "Distance and Human Interaction: A Migration Study", Geografiska Annaler, XLVII (1965), 3-43.

[3] This assumption is based on the field survey of migrant firms.

arises from the fact that the influence of the Airport does not appear to be related to sheer distance, since two firms located at equal distance from the Airport may express entirely opposed opinions as to the influence of the Airport on their locational selections. Such differences in opinions tend to reflect differences in the types of access route connecting them with the Airport. This consideration, perhaps, makes it unrealistic to express this variable as a function of distance from the Airport. Also, since the Airport is located outside the study area, areal contiguity with the Airport cannot be used as an indicator of its influence.

Labour Force Potential (X_{12})

The labour force potential at a manufacturing sub-area is the sum of labour force in each census tract within a defined radius of the sub-area divided by the distance from the central point of manufacturing sections in the sub-area to the census tract. The census tract is used because data are available at this level of spatial aggregation. Mathematically, the relationship may be expessed as

$$P_j = \sum_{i=1}^{n} L_i \, D_{ij}^{-1},$$

where P_j is the labour force potential at sub-area j,

L_i is the labour force in census tract i,

D_{ij} is air distance between i and j, and

n is the number of census tracts located within the defined radius of sub-area j.

The labour force potential is thus a gravity potential formulation. The concept of gravity potential is so widely discussed and applied in geographic or planning literature that it is unnecessary to discuss it here.[1]

---

[1] For example, see Gerald A.P. Carrothers, "An Historical Review of the Gravity Potential Concepts of Human Interaction," *op. cit.*, 94-102; and C.D. Harris, "Market as a Factor in the Localisation of Industry in the United States," *Association of American Geographers: Annals*, XLIV (Dec., 1954), 315-55.

Two problems had to be solved before computing the labour force potential as described above.

The first problem is the lack of labour force data for 1964 and 1966, the years relative to each of which the labour force potential is measured.[1] The labour force for these years is estimated on the basis of 1961 data.

The 1966 data are estimated as follows:

$$L_i^{66} = (L_i^{61}/P_i^{61}).P_i^{66} ,$$

where L_i^{66} = estimated labour force in census tract i in 1966,

L_i^{61} = labour force in census tract i in 1961,

P_i^{61} = population 15 years or over in census tract i in 1961, and

P_i^{66} = population 15 years or over in census tract i in 1966.

The 1964 labour force data are estimated by interpolating the 1961 and the estimated 1966 data. All estimates are made on the basis of the census tracts defined in 1961.

The second problem is to define an objective radius for each manufacturing sub-area within which the labour force potential is computed. From the field survey, the ranges at which manufacturing firms draw 75 per cent of their permanent employees are obtained. These are compiled and analysed on the basis of four major regions into which the study area is divided. The regional grouping is necessary to obtain sufficient number of observations for reliable estimates since each manufacturing

---

[1] The labour force data for these years are not gathered by the Dominion Bureau of Statistics, Ottawa; correspondence with D.L. Ralston, Associate Director, Census Division, Dominion Bureau of Statistics, Ottawa.

sub-area contains few respondent firms. The grouping is based on similarities in the characteristics of manufacturing sub-areas such as age of industrial development and building structure on the one hand, and on the broad patterns of geographic location on the other.[1] For example, region 1 contains the older industrial sub-areas of the City of Toronto, East York, York and former Mimico. The other regions are respectively the new industrial sub-areas of Etobicoke, North York (including former Leaside) and Scarborough.

Table 4 summarizes the statistics for the four regions. On the basis of these statistics, the median, which has the same value as the mode in each region, is used to determine the radius. The radius defined for each region is used in calculating the labour force potential of any destination sub-area in such a region.

The use of different catchment areas in computing the labour force potential measure is rationalized by the fact that such differences tend to reflect the factor of geographic situation. The fact that the catchment area for region A is smaller than those of the other regions may reflect differences in densities of population and traffic. For example, Latham and Yeates (1970) show that the gross residential gradient density for Metro Toronto declines with increasing distance from the centre of Toronto although there is a tendency for the central density to decline over time, as is apparent from the increasing concavity of the gradient

---

[1] A tour of industrial sections of the study area was undertaken for three days to observe the structural characteristics of the industrial buildings such as height of buildings, number of floor levels, aging conditions, etc. See also Kerr and Spelt, Economic Altlas of Ontario (Department of Geography, University of Toronto, 1969), Map 5.

surfaces for different years.[1]

Kenyon (1960) also shows that residential distribution of employees of a given plant is related to a) the pattern of settlement density, and b) the patterns of roads and highways, and that since a and b are interrelated, a complex model emerges.[2] Furthermore, he emphasizes that plants located outside city cores tend to draw employees from a larger area than do city plants. The statistics provided in Table 4 confirm this observation.

Distance Between Origin i and Destination j (X_{13})

This variable is expressed by air distance between the central point of origin sub-area i and destination sub-area j. It is conceivable that distance can be expressed in other forms: for example, road distance and time distance.

The main reason for using air distance has to do with the geometric patterns of roads in the study area. These patterns are such that relative distance between pairs of locations in the study area can be fairly approximated to air distances. A detailed road map of Metro Toronto

---

[1] Robert F. Latham and Maurice H. Yeates, "Population Density Growth in Metropolitan Toronto," Geographical Analysis, 2 (April, 1970), 2, 177-85.

[2] J. B. Kenyon, Industrial Localization and Metropolitan Growth: The Paterson-Passaic District. Ph. D. Thesis (Chicago: University of Chicago Press, 1960), chapter VIII.

TABLE 4

SUMMARY STATISTICS PERTAINING TO THE SEVENTY-FIVE PERCENT CATCHMENT RADIUS OF INDUSTRIAL EMPLOYEES

Region	No. of Observations	Catchment Radius in Miles			
		Range	Mode	Median	Average
A	17	1.5 - 10	5	5	5.74
B	19	4.0 - 30	10	10	11.53
C	18	4.0 - 20	10	10	11.17
D	19	3.0 - 20	10	10	10.26
Metro Toronto	73	1.5 - 30	10	10	9.76

Note:- Region A: industrial areas of the City of Toronto; East York excluding former Leaside; York and former Mimico,

Region B: industrial areas of Etobicoke excluding former Mimico,

Region C: industrial areas of North York and former Leaside,

Region D: industrial areas of Scarborough.

Source: Based on the questionnaire, Appendix A.

will reveal not only a thick net-work of an east-west and south-north grided system, but also a great number of streets and major roads which are superimposed upon the system diagonally. These include, for example, certain sections of Dundas Street West, Weston Road, Highway 401, Don Valley Parkway, and O'Connor Drive; and Kingston, Albion and Danforth Roads.

The thick network of streets and major roads also implies greater flexibility in travel patterns, especially of workers. On this premise, it can be argued that air distance can be a more objective measure of relative distances in the study area than a measure confined to selected routes. Table 5 shows that observed frequencies of plant migration generally decrease as air distance increases.

TABLE 5

OBSERVED FREQUENCIES OF PLANT MIGRATION AND AIR DISTANCE MOVED

Distance in Miles	Frequencies		
	1962-63	1964-65	1962-65
2.000 or less	37	28	65
2.001 - 4.000	14	21	35
4.001 - 6.000	15	20	35
6.001 - 8.000	22	16	38
8.001 -10.000	4	9	13
10.001 -12.000	4	4	8
12.001 -14.000	0	2	2
14.001 -16.000	0	3	3
16.001 -18.000	1	0	1
TOTAL:	97	103	200

Source: Based on the information taken from <u>Scott's Directory of Ontario Industry</u>, Editions: 1962, 1964, 1966.

The Multiple Regression Analysis

The combination of the thirteen variables discussed above is set up as a multiple linear regression model, that is, for any given origin (i), the attractiveness of a destination (j) as measured by the element $\hat{a}_j$ is given as

$$\hat{a}_j = a + b_1 X_{1j} + b_2 X_{2j} + \ldots + b_{13} X_{13j}$$

The regression analysis is necessary to determine the parameters of the model, that is, the constant term a and the parameters b. Each parameter b measures the change in the dependent variable resulting from a unit increase in the respective independent variable when the other independent variables are held statistically constant. In the example of the regression model under consideration, the dependent variable is given by $\hat{a}_j$. The change in the dependent variable caused by a unit increase in an independent variable may be positive or negative depending upon the direction of the relationship of that independent variable. Thus the parameter b allows the assumed direction of relationship of any independent variable to be verified with regard to a dependent variable under consideration. However, the relationship exhibited by a parameter b in a multiple regression model may not necessarily be the same when the relationship is considered in a simple regression model or a simple correlation analysis. Another usefulness of the parameter b is that it allows the statistical significance of the corresponding independent variable to be determined in the model.

Before considering the multiple linear regression model, it is to be recalled that $\hat{a}_j$ is the measure of attractiveness of destination j for a given origin i. This is an abstract measure for which it is necessary to substitute an observable fact. An observable fact which can be used to replace $\hat{a}_j$ is F_j (i), that is, the number of plants observed to migrate from origin i to j for a given period of time. To consider plant migrations in relation to each origin i in the context of the regression analysis under consideration raises the problem that the regression estimates may have to be made as many times as there are origins. This is not considered a logical and valid procedure for three reasons.

First, in the context of this study, such estimates may not be reliable because of very few observed cases of migration from each particular origin i, in most cases, one or two. This means that for most of the destinations, $F_j(i)$ would be zero. Second, many estimates of the same parameter would amount to an indeterminate solution since there is no way of telling which of the estimates is the best one to use. To take the average of the estimates may also be an unusual procedure in a regression analysis. Lastly, the explanatory variables, with the exception of origin-destination distance, do not vary with origins. It thus appears that the solution may be simplified by performing a single regression analysis if plant migrations to destination j are considered in relation to all origins and an average estimate substituted for the distance variable (X_{13}).

This procedure is used in the analysis. The variable F_j, that is, the total number of migrant plants located at j from all origins for a given period of time, is treated as the dependent variable. The distance variable is considered as the average estimate of distance moved by plants migrated to a destination j (D_j). This estimate is obtained as:

$$D_j = (\sum_{i=1}^{n} D_{ij})/n,$$

where D_{ij} is the distance moved by a plant from i to j and n is the number of plants migrated from all origins to j.

Before examining the results of the regression analysis, it is pertinent to discuss one other point. This is the question of the assumption of linearity. A multiple linear regression model is based on the assumption that there is linear relationship between the variables. This assumption is verified in this analysis by examining the plots of the residuals against each of the input variables including the dependent variable.[1] If the plot shows any form of systematic variation or relationship (for example, curvilinear) with a variable, it could indicate the need for extra terms in the model, the need for weighted least squares or error in the calculation such as not removing linear effect of X_j. These systematic forms of variation and the related corrections are discussed by Draper and Smith (1966).[2]

---

[1] In this connection, see BMD02R Program, W.J. Dixon (ed.), Publications in Automatic Computation (University of California, 1968), 233-54.

[2] N. R. Draper and H. Smith, Applied Regression Analysis (New York: John Wiley and Sons, Inc., 1966), pp. 90-2.

In the present analysis, an examination of the residual plots does not appear to reveal pronounced abnormality, particularly curvilinearity. It is thus assumed that the linearity assumption is not seriously violated.

The multiple regression analysis under consideration is performed using data for the period 1964-65. It is to be recalled that data for this period are used for establishing the parameters which are later incorporated in the operation of the simulation model for the period, 1966-67. The overall results of the analysis are shown below in Tables 6 and 7. These results are discussed below.

The simple correlation coefficients among the variables are shown in Table 6. Two questions are discussed in relation to these coefficients: relationships between the dependent and the independent variables in the light of the assumptions stated earlier and relationships among the independent variables.

Concerning the first question, the assumptions of directions of relationship are verified in a large number of cases, specifically in nine out of the thirteen variables: X_2, X_4, X_5, X_7, X_9, X_{10}, X_{11}, X_{12} and X_{13}. The assumptions are not verified in the remaining four cases. However, the simple correlation coefficients are generally low ranging from a low of .036 to a high of .410. Perhaps these low coefficients are not surprising having regard for the fact that 104 migrant plants and 50 subareas (observations) are involved in the analysis.

The second question focuses on relationships among the independent variables. In this regard, the problem of multicollinearity is to be examined since this is important to the model being developed in this study. Multicollinearity is the "name given to the general problem

TABLE 6

MATRIX OF SIMPLE CORRELATION COEFFICIENTS BETWEEN THE VARIABLES

	Independent Variables													Dependent Variable
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	
X_1	1.000													
X_2	.389	1.000												
X_3	.209	.437	1.000											
X_4	.009	.073	.412	1.000										
X_5	-.093	-.226	-.271	.549	1.000									
X_6	.018	.026	.364	-.107	-.100	1.000								
X_7	.174	.166	.382	.187	.066	.482	1.000							
X_8	.044	.147	-.079	-.297	-.291	.056	-.205	1.000						
X_9	-.141	-.138	-.297	.114	.253	-.299	.073	-.387	1.000					
X_{10}	-.078	-.204	-.077	.114	.269	.209	.271	.030	.116	1.000				
X_{11}	.083	-.010	-.340	-.188	.045	-.521	-.260	-.230	-.024	-.193	1.000			
X_{12}	.086	.180	.716	.384	-.375	.217	.271	.024	-.279	.146	-.236	1.000		
X_{13}	-.102	-.226	-.420	-.054	.343	.006	-.132	.177	-.064	.034	-.036	-.446	1.000	
Dep. Var.	-.180	.410	.086	-.123	-.284	.164	-.176	.036	-.291	-.304	.118	.173	-.231	1.000

Based on data
for 1964-65

N = 50

which arises when some or all of the explanatory variables in a relation are so highly correlated one with another that it becomes very difficult, if not impossible, to disentangle their influences and to obtain a reasonably precise estimate of their relative effects" (Johnston, 1960).[1] Blalock (1963) explains that "whenever, the correlation between two or more independent variables is high, the sampling error of the partial slopes and partial correlations will be quite large".[2]

The point that is not clarified by the statements above is how high should a correlation be before multicollinearity becomes serious. If one were to assume a correlation coefficient of .5 or higher, then, there are few cases of multicollinearity in the analysis under consideration (Table 6). These examples are the correlation coefficients between variables 3 and 12 (.716), 4 and 5 (.549), and 6 and 11 (-.521). These coefficients yield simple coefficients of determination (r^2) of .513, .301 and .271 respectively.

It thus appears that multicollinearity does not pose a serious problem in this study and it is good judgement to retain all of the independent variables. This approach can be rationalized on three important grounds.

First, to make an "equation useful for predictive purposes we should want our model to include as many X's as possible so that reliable fitted values can be determined" (Draper and Smith, 1966).[3] In a related vein,

---

[1] J. Johnston, Econometric Methods (New York: McGraw Hill Book Company, 1960), p. 201.

[2] H. M. Blalock, Jr., "Correlated Independent Variables: The problem of Multicollinearity", Social Forces, 42 (1963), 233-37.

[3] Draper and Smith, op. cit., p. 163.

Swamy (1970)[1] argues that "It is unlikely that interindividual differences observed in a cross section sample can be explained by a simple regression equation with a few independent variables. In such situations, the coefficient vector of a regression model can be treated as random to account for interindividual heterogeneity" (see also Klein, 1953).[2]

Second, as argued by Johnston (1960)[3] and Christ (1966),[4] intercorrelation of explanatory variables is not a serious issue in a model designed for forecasting provided the relationships among the variables may reasonably be expected to continue in the future. This argument, in fact, illustrates the basic approach and assumption of the present study.

Third, a number of econometricians have not regarded multicollinearity as all that a serious problem in model building. Thus Haavelmo (1950) has in fact argued that the estimate of σ^2 is not impaired by the fact that the independent variables are highly correlated.[5] Johnston (1960) has also noted: "If multicollinearity is serious, in the sense that estimated parameters have an unsatisfactory low degree of precision, we are in the statistical position of not being able to make bricks without straw".[6]

---

[1] P. A. V. B. Swamy, "Efficient Inference in a Random Coefficient Regression Model", Econometrica, 38 (March, 1970), 2, p. 311.

[2] L. R. Klein, A Textbook of Econometrics (Evanston: Row, Peterson and Co., 1953), 216-18.

[3] J. Johnston, op. cit., p. 207.

[4] C. F. Christ, Econometric Models and Methods (New York: John Wiley and Sons, Inc., 1966), p. 389.

[5] T. Haavelmo, "Remarks on Frish's Confluence Analysis and Its Use in Econometrics", in T. Koopmans (ed.), Statistical Inference in Dynamic Economic Model (New York: John Wiley and Sons, Inc., 1950), chapter V, p. 260.

[6] J. Johnston, op. cit., p. 207.

Finally, the comments by Christ (1966) may be added to the above:

> There is a strong temptation to use equations whose independent variables are not highly correlated, even when this means excluding from an equation a theoretically plausible variable just because that variable is highly correlated with the other included independent variables. Presumably, there is some critical subjective rate of exhange, so to speak, between the two "goods," low correlation among explanatory variables, and inclusion of an explanatory variable if we have some confidence in its relevance... This rate of exchange of course will depend on the purpose at hand, and perhaps even on the tastes of the decision maker.[1]

The results of the regression analysis as shown in Table 7 may now be examined. One aspect of the results is related to the question of the negative and the positive effects of the independent variables on the attractiveness of destination sub-area j relative to a given origin i as revealed by the partial regression coefficients (Col. 2). The analysis supports seven of the thirteen assumptions, compared with nine in the simple correlation case. The seven variables verified as X_2, X_3, X_5, X_8, X_9, X_{10}, and X_{13}.

It may be mentioned that for six of the thirteen variables, the directions of relationship are reversed when their respective partial regression coefficients and simple correlation coefficients are compared. The six variables concerned are X_3, X_4, X_7, X_8, X_{11} and X_{12}.

Another important aspect of the results of the regression analysis is the relative importance and the statistical significance of the independent variables. On the basis of the standard regression coefficients (col. 4), the most important variables in a declining order are

---

[1] C. F. Christ, op. cit. p. 389.

TABLE 7

RESULTS OF THE REGRESSION ANALYSIS

Independent Variable	Regression Coefficient	Standard Error	Standard Regression Coefficient	Computed t-value
X_{1j}	-0.14780	0.13280	-0.14803	-1.11299
X_{2j}	0.24784	0.08464	0.45833	2.92812*
X_{3j}	-0.15780	0.32161	-0.13844	-0.49064
X_{4j}	0.04816	0.26932	0.04784	0.17883
X_{5j}	-0.11280	0.32331	-0.09518	-0.34888
X_{6j}	0.89141	1.60919	0.10107	0.55395
X_{7j}	1.78297	0.71088	0.41213	2.50811*
X_{8j}	-1.31894	2.91046	-0.07848	-0.45317
X_{9j}	-1.41794	0.67383	-0.36980	-2.10431*
X_{10j}	-0.46069	0.18387	-0.40089	-2.50553*
X_{11j}	-0.00686	0.09206	-0.01354	-0.07452
X_{12j}	-0.56371	0.43545	-0.13401	-1.29453
D_j	-0.01346	0.00660	-0.32667	-2.04000*

Note: constant term a = 8.51969,
multiple correlation coefficient = .66,
multiple coefficient of determination = .436,
standard error of the estimate = 1.25324,
No.of observations = 50,
total number of variables = 14,
degrees of freedom for t test = 36,
critical t value at the .05 level = 2.03,
*: significant at the .05 level.

Source: Author's Analysis.

a) measure of manufacturing concentration (X_2),

b) absolute change in industrial mill rate over the past six years (X_7),[1]

c) road distance to the nearest major highway (X_{10})

d) cost of one million gallons of industrial water consumption (X_9), and

e) average distance moved by plants located to j (X_{13}).

Using the t-statistic (col. 5), these five variables are found to be statistically significant at the .05 level.

In general, the five variables demonstrate the importance of industrial development (measured by level of concentration), property and business taxes, proximity to highway and proximity to origin in the plant site selection of a migrant firm.

The remaining eight variables, in their declining order of relative importance, are X_1, X_3, X_{12}, X_6, X_5, X_8, X_4 and X_{11}.

All of the thirteen variables yield a multiple correlation coefficient of .66 which is significant at the .05 level. Nevertheless, the percentage of the total variance explained is relatively low. This may be due partly to the fact that the space constraint factor has not been taken into consideration and partly to chance factors. The simulation procedure allows the space constraint factor and the chance elements to be handled in an explicit manner.

The thirteen variables are used in estimating the element $\hat{a}_j$. The regression coefficients derived from the regression analysis allow these thirteen variables to be weighted according to their true effects in the simulation model.

---

[1] Contrary to the assumption, the regression coefficient for this variable is negative.

Thus, for any given origin i, the element $\hat{a}_j$ is finally estimated as a linear function of the thirteen independent variables, that is,

$$\hat{a}_j = a + b_1 X_1 + b_2 X_2 + \ldots + b_{13} X_{13},$$

where a = 8.51969. It should be recalled that in this estimate, X_{13} is the distance variable between j and the origin i under consideration although the estimate of the parameter b corresponding to this variable is based on the average distance moved by plants located to destination j from all origins.

It is conceivable that the element $\hat{a}_j$ as defined can be negative. However, this situation very rarely occurs in the present study. This is due to the large positive value of the constant term a and the small values of the (negative) regression coefficients. However, where the problem of negative $\hat{a}_j$ arises, it is easily handled by equating $\hat{a}_j$ to zero; this means that the sub-area j concerned has no attractiveness to the origin i under consideration.

The Probabilities

The elements p_j are the probabilities assigned to individual j destinations for a given origin i. Each p_j expresses the probability that any type of industrial plant migrating from i will go to j. Since it is assumed that p_j depends upon the element $\hat{a}_j$, that is, the attractiveness of j given i, p_j is derived as:

$$p_j = \hat{a}_j \Big/ \sum_{j=1}^{n} \hat{a}_j$$

where there are n destinations and since p_j is non-negative, $\sum_j p_j = 1$.

It is conceivable that there are other procedures for estimating probabilities. For example, probabilities can be estimated strictly on the basis of frequencies without any reference to other variables. In the context of this study, such frequencies would be given by observed plant migrations. Thus, for any given origin i, the probability p_j can be estimated as:

$$p_j = F_j / \sum_j F_j,$$

where F_j is the frequencies of plant migration from origin i to destination j. This procedure is not used in the present study because of the concern for testing the adequacy of certain geographic hypotheses in predicting intra-urban plant site selection as already discussed in chapter III. These hypotheses are assumed to at least reflect some aspects of location theory.

It must be added that the problem of few plant migrations which are observed from each origin prevents any reliable estimate of probabilities based on such migration data. Nevertheless, the origin and the destination of each migrant plant observed for the present study are listed in Appendix E to allow an interested reader to work out such probabilities if desired. If the probabilities based on migration data are compared with those based on the attributes of destinations and the distance variable for any given origin i, the former will show many zero values while the latter will contain no or very few zeros.

The Constraints

The element u_k in the simulation model is the SIU measure of the space requirement level of a particular migrant plant (k). It is assumed in the model that u_k depends upon the characteristics of each individual plant. The procedure used in estimating u_k, therefore is to 1) use two characteristics to summarize plant characteristics, and 2) use these summary characteristics in a classificatory basis for obtaining the space requirement of any given plant k.

The two summary characteristics used are the standard industrial classification (SIC)- see Appendix F - and the total number of employees (EMTOT).[1]

To a large degree, the distribution of the observed migrant plants according to each of the two summary characteristics is related to the composition of manufacturing plants in the study area. With regard to SIC, for example, there is a significant correlation (.79) between the distribution of observed migrant plants in the period 1962-65 and the distribution of plants in the study area in 1964. These distributions are based on the SIC at the two digit level. The distribution of plants in the study area is based on a random sample drawn from the list of establishments in the 1964-65 edition of the Scott's Ontario Directory of Industry. This list contains over 4,500 names of firms.

---

[1] In a series of two-way analyses of variance, the classification of 200 plants, migrated in the period 1962-65, according to the SIC characteristic was found to be significantly different from the classification of the same plants according to any of the following characteristics: the total number of employees (EMTOT), the proportion of total employees that are production workers (PPW), the proportion of production workers that are male (PPWM), and country of control (COC). The classification according to EMTOT was found not to be significantly different from the classification according to PPW, PPWM or COC. The significance level of .05 was used in these analyses.

The similarity in the distribution of the observed migrant plants and the sample plants on the EMTOT characteristic is also striking as illustrated in Table 8. In both cases, the proportions of total plants decline as the number of employees increases. However, in the case of migrant plants, the proportions are higher for large plants, employing 100 or more persons, than in the case of the randomly sampled plants.

The element u_k is determined for any given plant k on the basis of its classification as defined by the SIC and EMTOT characteristics.

The SIU measure of u_k assigned to each classified group (Table 9) is obtained as the average amount of space occupied by observed plants belonging to that group. The information used is based on the space utilization at the new destinations of migrant plants in the study area in recent years.[1]

As illustrated in table 9, there are ten SIC groups compared with four EMTOT groups. Because of few observations in some of the major SIC groups, it is necessary to combine such groups with other groups. Thus, for example, SIC major groups 22 and 23 are combined into the same group, 24 and 25 into another group, etc. Some consideration is given to similarities in product types in arriving at these combinations. The four EMTOT groups are defined on the basis of arbitrarily assigned ranges of employees. Nevertheless, it is assumed that the chosen ranges make some realistic distinction between small, medium and large plants. Altogether, there are forty classified groups of plants as determined by ten SIC and four EMTOT groups.

The estimate of element u_j against which u_k is compared in the simulation procedure may now be discussed. The element u_j is the SIU measure of the

---

[1] Sources of information include field survey of migrant plants, Metro Toronto Assessment Department, and Metro Toronto Industrial Commission District News Letters.

TABLE 8

PERCENTAGE PROPORTIONS OF OBSERVED MIGRANT PLANTS AND RANDOMLY SAMPLED PLANTS ACCORDING TO SIZE OF EMPLOYMENT

Number of Employees	Proportion	
	Observed Relocated Plants	Random Sample Plants
1 - 49	67.01	70.80
50 - 99	15.46	20.35
100 -199	9.28	5.31
over 199	8.25	5.54
Total frequencies	200	400

source of information: Scott's Ontario Directory of Industry.

TABLE 9

SIU MEASURE OF u_k ACCORDING TO CLASSIFIED GROUPS

SIC	EMTOT			
	1 - 49	50 - 99	100 - 199	Over 199
20	6.6	11.0	14.0	20.0
22, 23	3.0	4.4	8.0	12.9
24, 25	5.0	8.0	10.2	13.4
26, 27	2.0	8.2	12.6	18.4
28, 30, 31	4.4	9.4	14.0	18.0
32, 33	3.2	6.0	11.2	15.4
34	3.4	4.2	10.0	16.0
35	5.4	6.0	7.1	9.6
36, 37, 38	2.2	6.4	14.2	19.0
39	1.2	5.0	8.0	12.3

Source of information: Metro Toronto Assessment Department; Metro Toronto Industrial Commission District News Letters; and Field Survey.

amount of vacant industrial space at a destination sub-area j at a given point in time. It is being assumed that this element acts as a constraint in the sense that a plant cannot be located to j if u_j is less than u_k.

The measurement of industrial vacancy in an area such as Metro Toronto is a very formidable task. For example, some Municipal governments in this area have spent many years and a large sum of money attempting to measure and classify industrial space uses in their respective local areas, so far, only the City of Toronto has successfully stored such information in an accessible and usable form. In the present study, the amount of vacant industrial space estimated to be available to migrant firms at each destination sub-area j in the test period 1966-67 is based upon seven items of data.

a) floor area equivalence of vacant serviced industrial land as determined from air photos and related land use maps.[1] The floor area equivalence is determined by considering the the ratio of land area to industrial floor area permitted at the individual destination sub-areas.[2]

b) industrial floor space vacated during the period 1966-67. Such vacation is the result of either migration or the final closing down of a plant's operation. Since it is impossible to obtain the relevant figures for all plants which vacated their floor areas, a general basis for estimate is obtained by computing from available information the average floor space use of a plant given its classification on a two dimensional basis as defined by the ten SIC and the four EMTOT groups discussed above. This general basis is shown in Table 10.

---

[1] Lockwood survey Corporation Ltd., Aerial Photograph of Metropolitan Toronto, scale: 1 inch to 2,640 feet (Toronto: April, 1965); and Municipality of Metropolitan Toronto, Existing Land Use, 1966, Plate 1, scale: 1 inch to 5,000 feet (December, 1967).

[2] Scarbourough Planning Board, Industrial Planning (April, 1966); Municipality of the Township of Scarborough, By-Law No. 12096, February 3, 1969, Schedule B; Borough of Etobicoke, Comprehensive Zoning By-Law, including ammendments up to 1966; The City of Toronto, Zoning System: A Representative List of Permissible Uses: Commercial and Industrial Districts; Borough of East York, Consolidation of Zoning By-Law, No. 6752, as ammended up to 1968 (May, 1968), Sections 9 and 10; and Town of Leaside By-Law No. 1916 (December, 1966), Section 8.1.2.

TABLE 10

AVERAGE ESTIMATE OF FLOOR SPACE AREA[a] VACATED BY MANUFACTURING PLANTS GIVEN THE SIC AND THE EMTOT CHARACTERISTICS

SIC	EMTOT			
	1 - 49	50 - 99	100 - 199	Over 199
20	20,000	50,000	70,000	100,000
22,23	9,000	10,000	30,000	55,000
24,25	15,000	30,000	67,000	90,000
26,27	10,000	20,000	62,000	84,000
28,30,31	6,000	10,000	25,000	50,000
32,34	10,000	20,000	65,000	95,000
34	13,000	17,000	47,000	65,000
35	10,000	19,000	35,000	60,000
36,37,38	6,000	10,000	23,000	45,000
39	2,000	13,000	25,000	45,000

a: area in square feet

Source of Data: Metro Toronto Assessment Department; Metro Toronto Industrial Commission District News Letters; and Field Survey of Migrant Plants.

c) vacant industrial floor space available in the beginning of 1966. This is an important source of industrial space vacancy in the City of Toronto which also is the only municipality that kept a complete record of this information.[1]

d) industrial floor space added by existing firms in the period 1966-67.[2]

---

[1] City of Toronto Planning Department, <u>Single Line Listings</u>, City of Toronto (1966).

[2] Including warehousing; the data are based upon the records of factory building permits for each municipality kept by the Metro Toronto Real Estate Board. Where figures kept are recorded only for values of buildings, the floor area equivalence is obtained by applying conversion ratios of 1) $5.00 per square foot to factories with values of $100,000 or higher; and 2) $5.70 per square foot to factory buildings of less than $100,000. These conversion ratios are based upon available observations.

e) industrial floor space occupied by newly established firms in the period 1966-67,[1]

f) industrial floor spaces added to the existing industrial buildings by developers or construction companies in the period 1966-67,[2]

g) floor space created in new industrial buildings constructed by developers or construction companies in the period 1966-67.[3]

The seven items of data listed above are used to estimate the vacant industrial space in each destination j for the period 1966-67. However, since item a is assumed to include items f and g, it is necessary to use only the first five items of the data in estimating u_j. Assuming that these data are in square feet measure, u_j is estimated as

$$u_j = (a + b + c - d - e)/5{,}000,$$

where 5,000 square feet are equivalent to one standard industrial unit.

Summary.

This chapter illustrates how the four sets of elements of the simulation model are estimated. It shows that the element $\hat{a}_j$, relative to any given origin i, is derived as a linear function of the thirteen variables explicitly considered in the study. The probability p_j is based on the element $\hat{a}_j$. The elements u_k and u_j of the model are also measured. The simulation runs and the evaluation of the model are discussed in the next chapter.

---

[1] *Ibid.*

[2] *Ibid.*

[3] *Ibid.*

CHAPTER V

RUNNING AND EVALUATING THE SIMULATION MODEL

In this chapter, the simulation model is operated for Metro Toronto relative to the period 1966-67 and evaluated by comparing its outcome with empirical data. It is to be recalled that the parameters of the model are estimated from data for the period 1964-65.

Altogether, 119 plants observed to migrate during the test period, i.e., 1966-67, are used in the simulation. These plants are exogenous to the model. A simulation run is complete when all the 119 plants have been successfully located by the model.

Running the Model

The simulation procedure was described in chapter III of the thesis.[1] This discussion could be extended to include data inputs and computational characteristics which are presented in Appendix G. The computer program is listed in Appendix H.

Three important questions pertaining to the application of the model to Metro Toronto are discussed below. First, there is the question of the number of simulation runs. Because of its stochastic nature, a simulation run should be repeated several times relative to the same time period before making empirical verification. Nevertheless, no standard number of runs has been suggested. Colenutt,

---

[1] *Supra.*, pp. 66-68.

for example, performs 100 simulation runs of his model of bill-board diffusion.[1] Hagerstrand performs three runs in his simulation of adopters with each run going through five generations.[2]

There is, thus, no standard procedure for determining the a desired number of simulation runs. The advent of high-speed computers, however, has made possible almost an infinite number of runs. In the present study, 100 simulation runs are performed, that is to say, the complete assignment of all 119 plants under consideration was simulated 100 times. This number of runs is perhaps necessary to level out the fluctuations arising from individual simulation runs.

The second question pertains to measures of outcome of the simulation runs. In this regard, the outcome is measured by two variables: 1) the number of plants received by a destination sub-area; and 2) the standard industrial units (i.e., the SIU measure) corresponding to these plants. Given the fact that individual plants may vary in their space requirements, the latter variable provides an additional way of measuring the outcome of the model so that this fact can be better evaluated with regard to the performance of the model. For example, if on one run, two large plants are assigned by the model to an area where two small plants had been observed to be located, it is the SIU measure, and not the frequency measure that would reveal this shortcoming in the

---

[1] R. J. Colenutt, "Linear Diffusion in an Urban Setting: An Example", Geographical Analysis, I (1969), 1, 106-14.

[2] Torsten Hagerstrand, "A Monte Carlo Approach to Diffusion", op.cit., 368-84.

performance of the model. Since a plant's space requirement level is assumed to reflect its characteristics, the use of the SIU measure indirectly allows the model to be evaluated as to whether or not such characteristics are adequately reflected in the simulation.

The third question concerns model output. A wide variety of output is possible in the type of simulation model under consideration. For example, it is possible to 1) output for each simulation run the number of plants located from each origin and the distribution of such plants according to destination sub-areas, 2) obtain a summary of the total number of plants received by each destination j on each run of the simulation, and 3) obtain an average estimate of the number of plants received by a destination sub-area j over all 100 simulation runs. The same series of outputs is possible with regard to the SIU measure.

However, a summary output of type 3 would be most useful for making a valid evaluation of the model. The distribution of migrant plants from each origin i will be difficult to test statistically since, in most cases, only one plant is observed to migrate from an origin. The maximum number of migrant plants from an origin is sixteen. For this reason, the output of the model is not considered on the basis of distribution of migrant plants from each origin. Similarly, a simulation by simulation output of the model, i.e., a summary output of type 2, will have a limited use for statistical comparison for three reasons: a) individual simulation outputs may be subject to considerable fluctuations by the very nature of the chance process involved in the simulation; b) the small aggregate number of plants being predicted; and c) the fact that each simulation run does not represent a time sequence but a repetition of the process. It thus appears that an average measure of outcome of the 100 simulation runs on the sub-area j basis is a useful output to consider. In this way, the fluctuations of the individual simulation runs will be evened out.

On the basis of these arguments, the main outcome of the simulation model is the estimated average outcome of the 100 simulation runs performed. This outcome is formally designated as the expected pattern. This is the pattern expected according to the assumptions of the simulation model.[1] Symbolically, the expected pattern may be denoted as $e_j = (\sum_{k=1}^{n} e_{jk})/n$, where e_j is the average outcome for destination j, e_{jk} is the predicted outcome for destination j on the kth simulation run, and n is the number of simulation runs.

The empirical counterpart of the expected pattern is the observed pattern. This is the pattern empirically observed for the study area in relation to the test period 19[illegible]-67.

The residuals are the deviations of the expected from the observed pattern. Each of the patterns mentioned above, as well as the pattern of residuals, is measured by the two measures of outcome already discussed. These are the frequency of plants at j (f_j), and

---

[1] Supra, pp. 60-65.

the corresponding SIU measure. Figures 5 and 6 show the observed pattern on these two measures, figures 7 and 8 show the expected pattern, and figures 9 and 10 show the residuals encountered using the same measures of outcome. The comparison of these patterns in an attempt to evaluate the model is discussed below.

Evaluation of the Model

The simulation model is evaluated on the basis of the outcome of the 100 simulation runs performed as indicated above. This evaluation is based on the comparison of the expected and the observed patterns.

Approach to Evaluation

In evaluating any model, a fundamental question is the degree to which the outcome agrees with empirical data. A researcher may be interested in one or more of such aspects of outcome as the course of growth,[1] the overall pattern of spatial arrangements,[2] the pattern of spread over space,[3] and frequency distribution per defined

---

[1] Torsten Hagerstrand, "A Monte Carlo Approach to Diffusion," op. cit.; and Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," Econometrica, XXV (1957), 501-22.

[2] Torsten Hagerstrand, Ibid.

[3] E. Casetti and R. K. Semple, "Concerning the Testing of Spatial Diffusion Hypotheses," Geographical Analysis, I (July, 1969), 254-59; J.C. Hudson, "Diffusion in a Central Place System," Geographical Analysis, I (1969), 1, 45-58; and Robert J. Colenutt, "Linear Diffusion in an Urban Setting: An Example," op. cit.

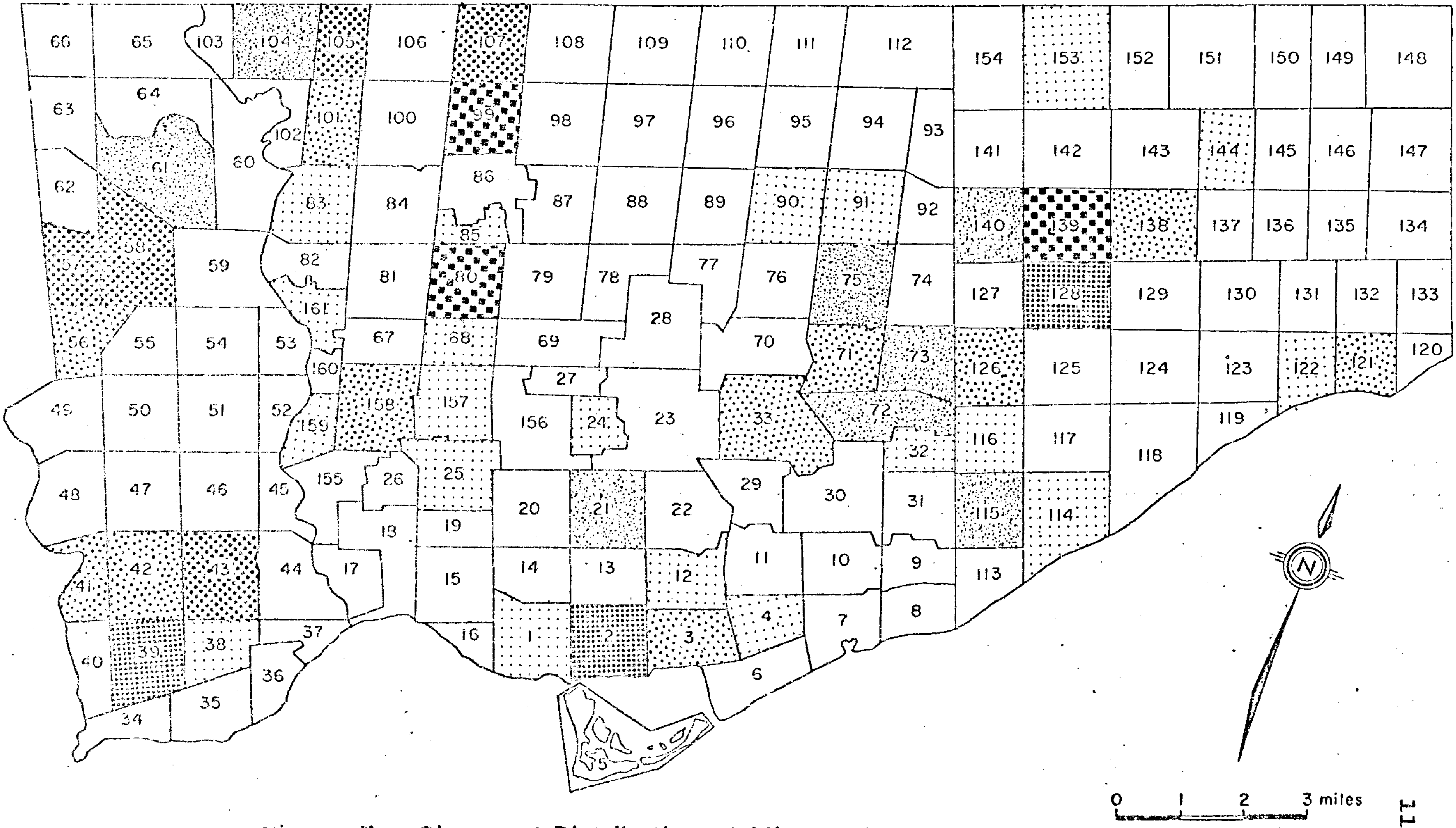


Figure 5: Observed Distribution of Migrant Plants, 1966-67

⬚ 1
▨ 2
▨ 3
▨ 4
▩ 5
▦ 6

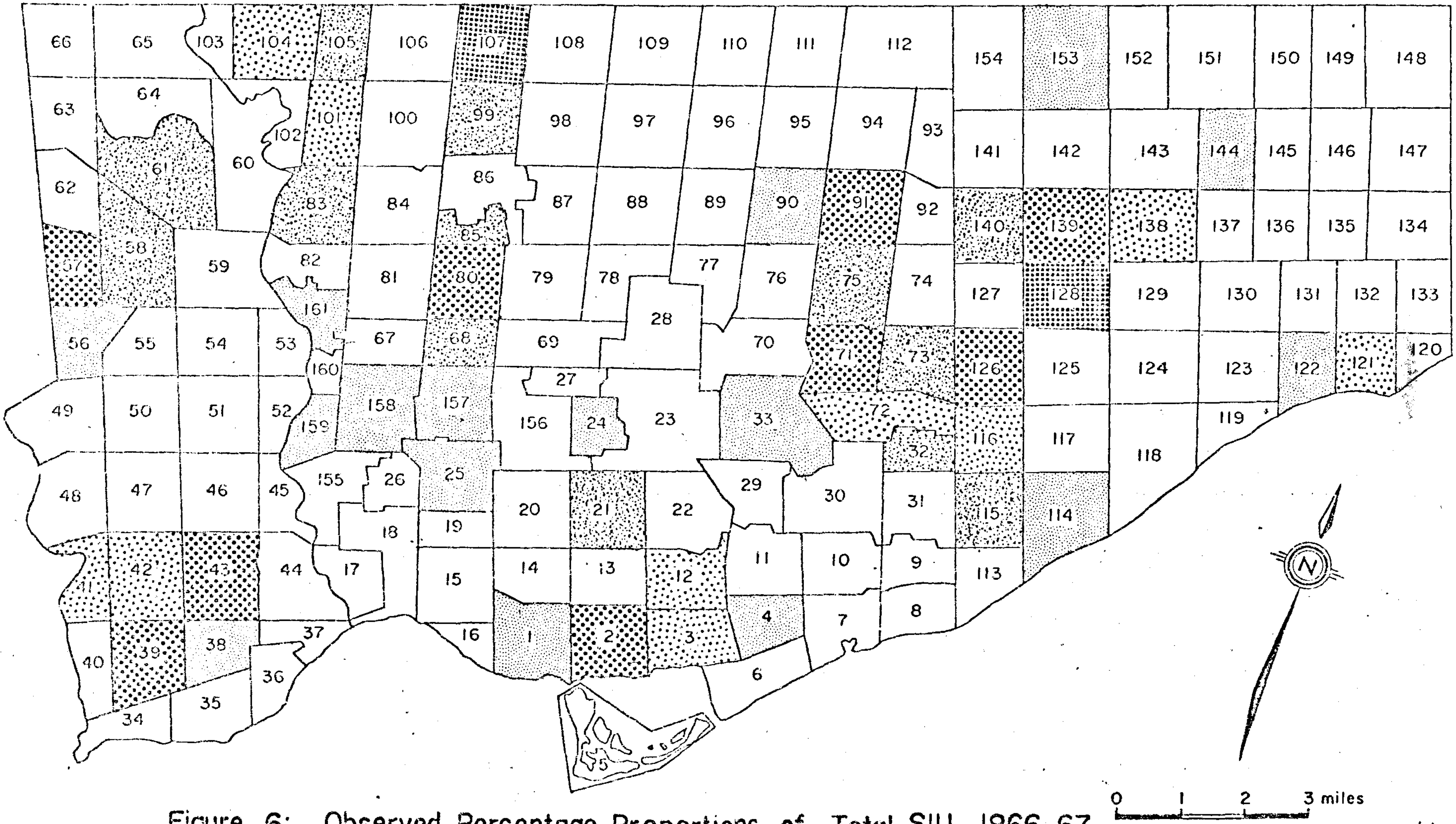


Figure 6: Observed Percentage Proportions of Total SIU, 1966-67

▨	1
▨	1 - 1·99
▨	2-2·99
▨	3-3·99
▨	4-4·99
▨	5-5·99

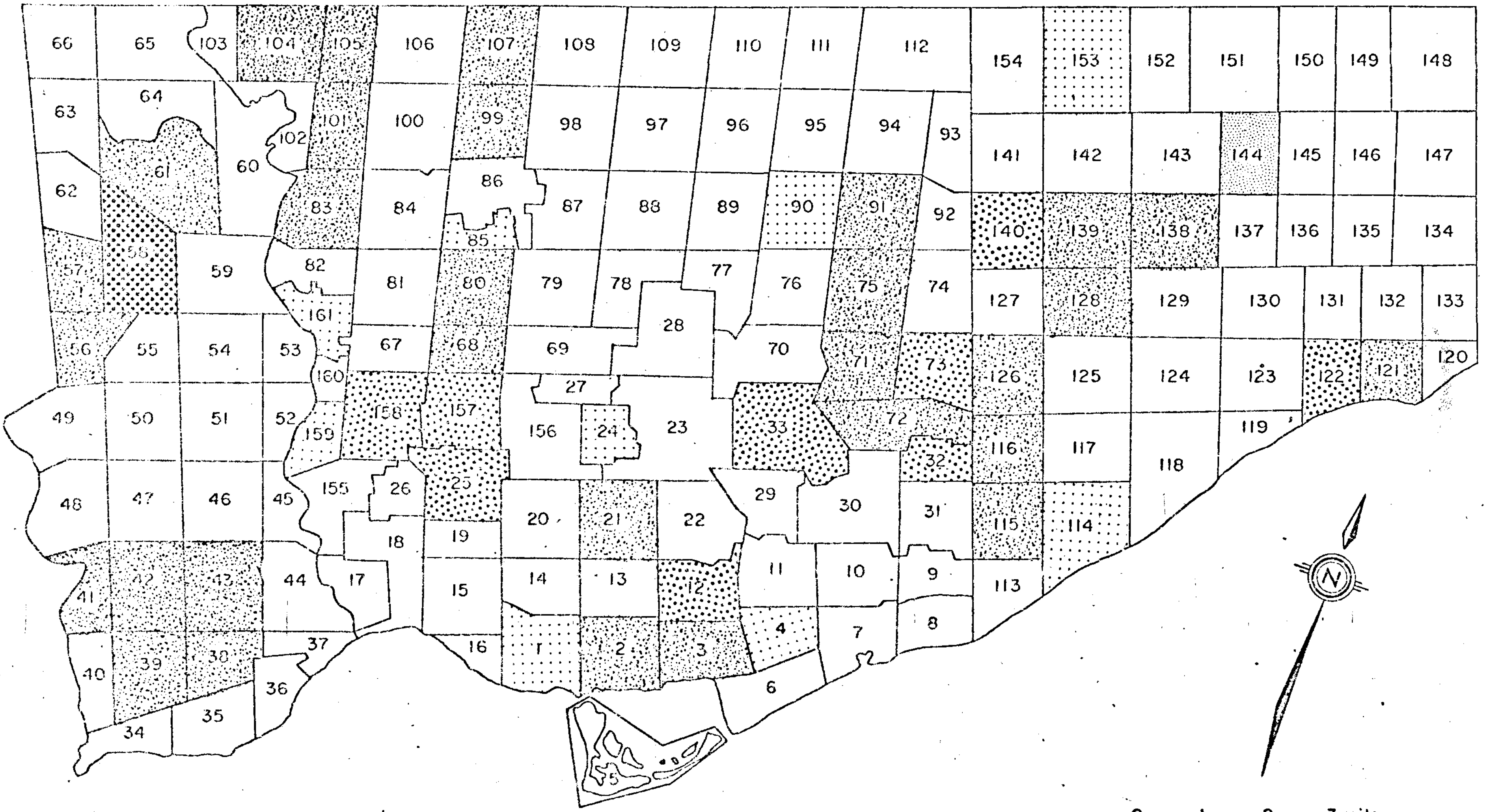


Figure 7: Expected Distribution of Migrant Plants, 1966-67

▨ 0 ▨ 1 ▨ 2 ▨ 3 ▨ 4

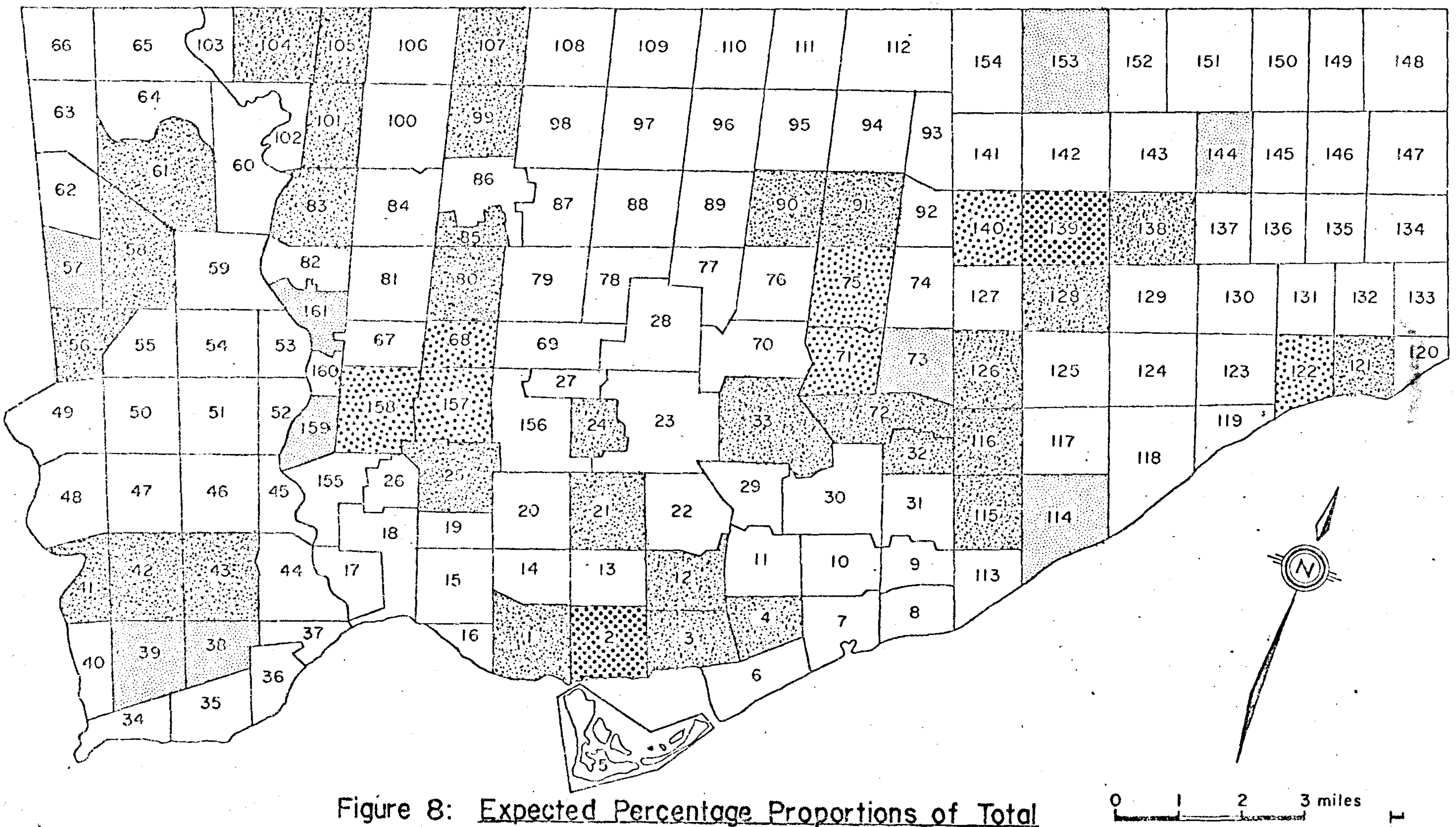


Figure 8: Expected Percentage Proportions of Total SIU, 1966-67

░ 1 ▒ 1-1·99 ▓ 2- 2·99 ▩ 3-3·99

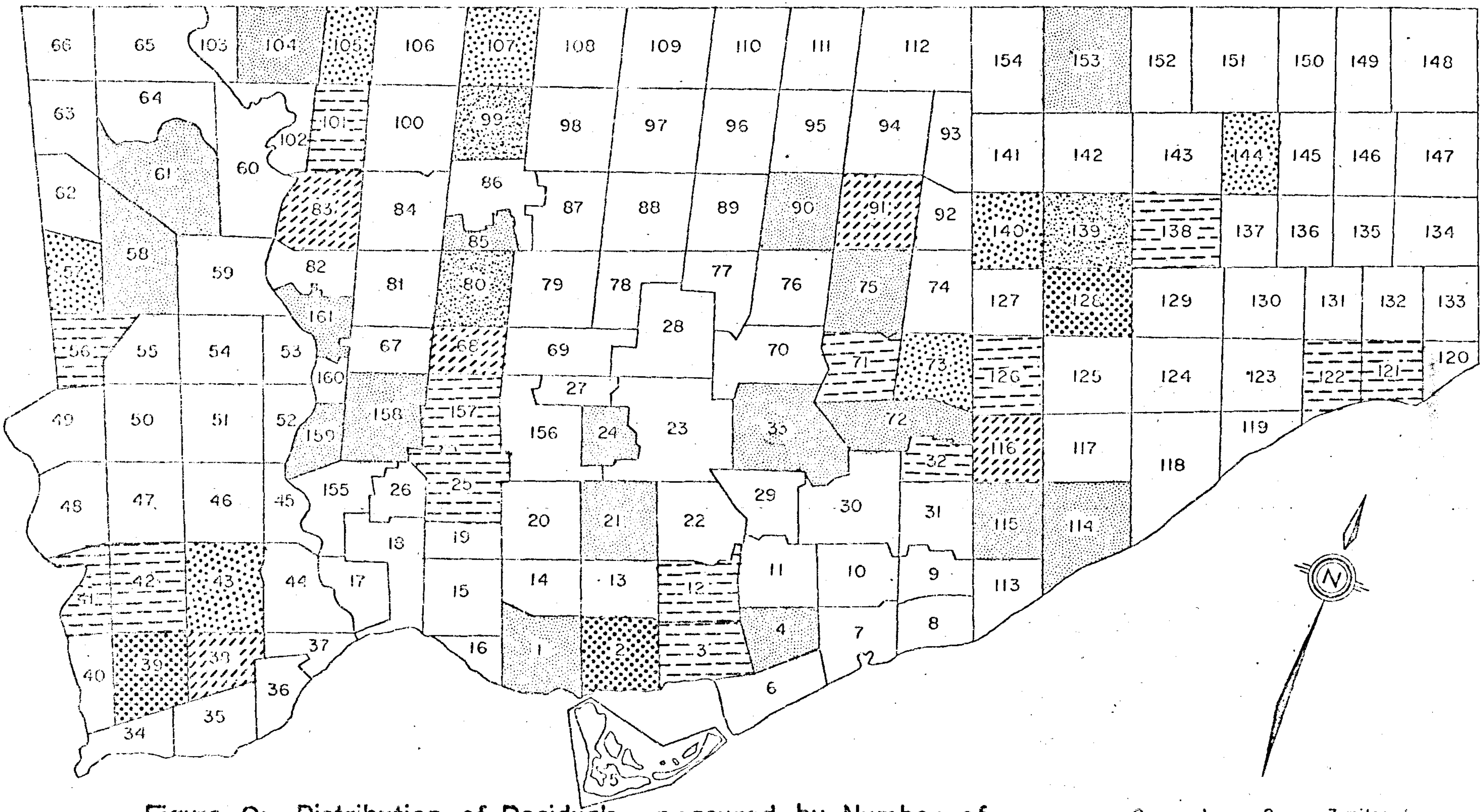


Figure 9: Distribution of Residuals, measured by Number of Plants, 1966-67

▤ -2 ▨ -1 ░ 0 ⠿ 1 ▒ 2 ▦ 3

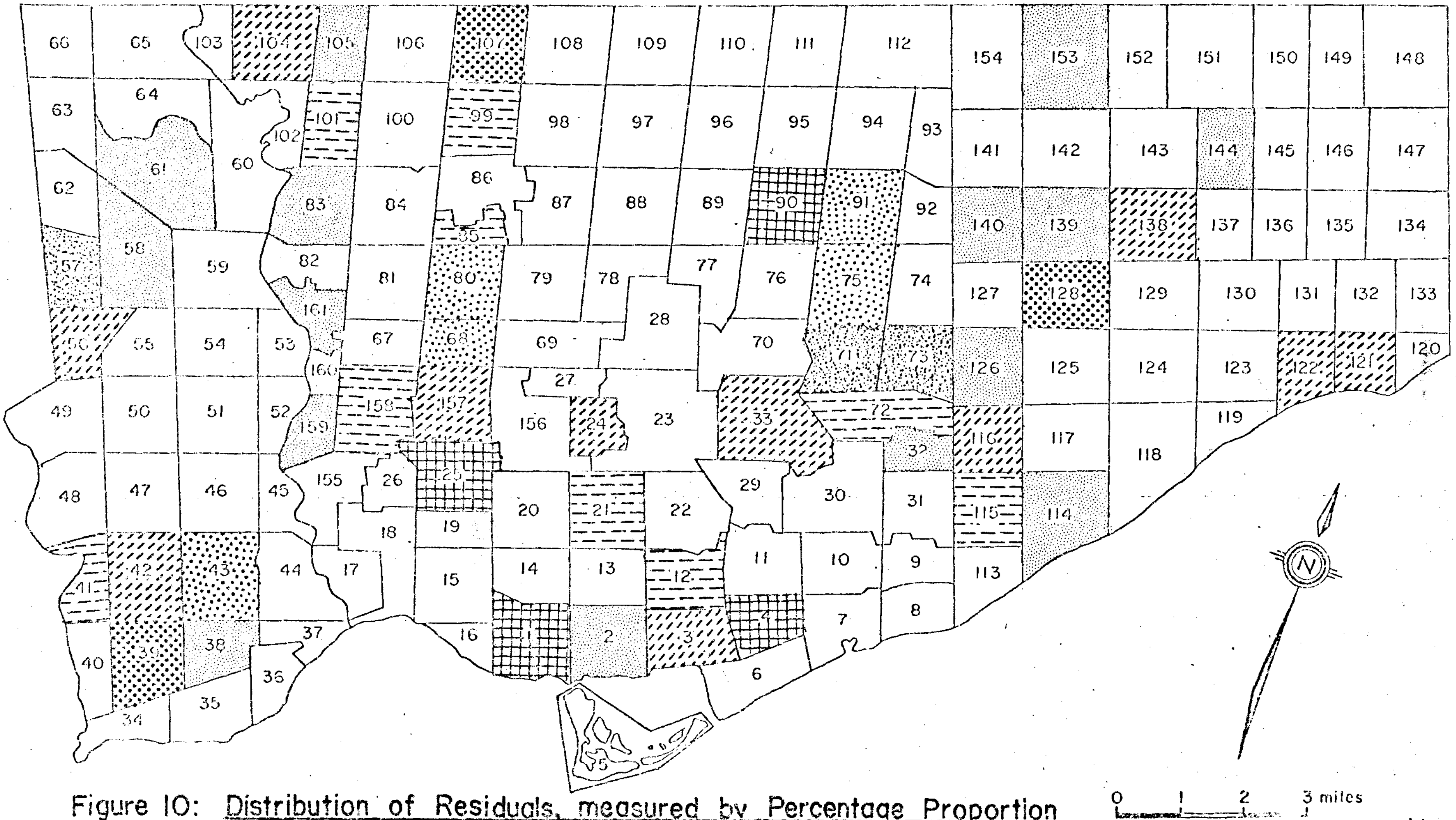


Figure 10: Distribution of Residuals, measured by Percentage Proportion of Total SIU, 1966-67

▤ 2 - 2·99 ▨ 1 - 1·99 ▦ <1 ░ <1 ▒ 1-1·99 ▒ 2-2·99 ▓ 3-3·99

negative positive

length of time or spatial unit.[1]

In this study, distribution per unit area is under consideration. This distribution is expressed by two measures (f_j and SIU) discussed already. The f_j is a frequency measure since it expresses the number of plants at a destination j. However, the SIU measure is not considered a frequency measure since different plants correspond to different SIU. This measure is converted into percentage proportions in evaluating the model. This is to say that the SIU for each destination sub-area is expressed as a percentage proportion of total SIU over all destination sub-areas.

Another question concerning the evaluation of the model is the method of comparison of the outcome with empirical data. Methods such as mapping, graphic presentation, descriptive analysis and statistical tests, or a combination of two or more of these methods may be used. In the present study, however, the emphasis is placed on statistical tests. In this regard, two statistical tests are performed. First, a chi-square goodness of fit test is performed between the observed and the expected distributions when each is measured by f_j and when each is measured by SIU. Second, a contiguity ratio is used to test for random

---

[1] For example, John D. Nystuen, "A Theory and Simulation of Intra-Urban Travel," in Studies in Geography, Part I: Economic and Cultural Topics, edited by D. F. Marble (Northwestern University: Department of Geography, 1967), 54-83.

arrangement of the residual values in the spatial setting. This test is also performed with respect to the f_j and the SIU measures.

The Chi-square Goodness of Fit Test

This test is suitable for evaluating a model where a frequency distribution is under consideration.[1] Nevertheless, the chi-square test does not get at the spatial patterns of distributions. This is to say that it is not concerned with the spatial arrangement of values. By using this test, therefore, one can only determine whether the difference between an observed and an expected distribution can be attributed to chance; it cannot be determined whether or not the residuals between such distributions are randomly arranged on the map. This limitation of the chi-square test must be borne in mind in the following discussion of the application of the test.

The chi-square goodness of fit test is based on the statistic χ^2, a measure based on the difference between an observed and an expected frequency distribution. The value of this statistic is obtained by summing over n categories the squared difference between the observed and the expected frequency divided by the corresponding expected frequency in each category, that is,

$$\chi^2 = \sum_{j=1}^{n} \frac{(f'_j - e_j)^2}{e_j}, \qquad (5:1)$$

---

[1] See, for example, Sidney Siegel, Non-parametric Statistics for the Behavioral Sciences (New York: McGraw Hill Book Co., 1956), 18-47.

where f'_j is observed frequency for the jth category; and e_j is expected frequency for the jth category; and n is the number of categories. When data are not given as frequencies, it is best to obtain the value of χ^2 as follows:

$$\chi^2 = N \sum_{j=1}^{n} \frac{(P'_j - P_j)^2}{P_j}, \qquad (5:2)$$

where P'_j is observed proportion for the jth category; P_j is expected proportion for the jth category; and N is the number of observations.[1] In the present study, N is fifty.

The chi-square goodness of fit test is best performed where none of the expected frequencies is less than five. To meet this requirement, the destination sub-areas are grouped into 17 categories (Table 11) on the basis of contiguity or proximity. Each category is thus treated as a class cell in the test. This grouping ensures that there are at least five expected frequencies in each category.

The null hypothesis (H_o) under consideration in the goodness of fit test may be stated as follows:

> Differences between the observed and the expected distributions (patterns) are not statistically significant.

The level of significance for the test is .05 and there are 16 degrees of freedom.

Formula 5:1 is used for the goodness of fit test between the observed and the expected patterns when each pattern is measured

---

[1] On this formula, see Helen M. Walker and Joseph Lev, Statistical Inference (New York: Holt, Rinehart and Winston, 1953), p. 94.

TABLE 11

CATEGORIES OF DESTINATION SUB-AREAS FOR GOODNESS OF FIT TEST

Category	Destination Sub-areas
1	1, 2, 3
2	4, 12, 21, 24
3	25, 157, 158, 159, 161
4	32, 33, 72
5	38, 39
6	41, 42, 43
7	56, 57
8	58, 61
9	68, 80,85
10	71, 73
11	75, 90, 91
12	83, 101
13	99, 107
14	104, 105
15	114, 115, 116, 126
16	121, 122, 144, 153
17	128, 138, 139, 140

Note: see Figure 2 for the identification of these categories.

by f_j . Formula 5:2 is used when each is measured by SIU.

The results of the two tests are shown in Tables 12 and 13. On both tests, the null hypothesis is accepted since the critical value at the .05 level of significance is 26.296 and the χ^2 statistic computed for the f_j measure is 8.879, and for the SIU is 24.163. Judging from these results, the model performs reasonably well since there is no ground for rejecting the null hypothesis that the difference between the observed and the expected patterns is attributable to chance. This conclusion, however, does

TABLE 12

GOODNESS OF FIT TEST BETWEEN THE OBSERVED AND THE EXPECTED PATTERNS AS MEASURED NUMBER OF PLANTS (f_j)

Category	f'_j	e_j	$f'_j - e_j$	$(f'_j - e_j)^2$	$(f'_j - e_j)^2/e_j$
1	9	7	2	4	.571
2	6	7	-1	1	.143
3	6	8	-2	4	.500
4	6	7	-1	1	.143
5	7	6	1	1	.167
6	8	9	-1	1	.111
7	6	6	0	0	.000
8	7	7	0	0	.000
9	7	7	0	0	.000
10	5	6	-1	1	.167
11	5	7	-2	4	.571
12	3	6	-3	9	1.500
13	9	6	3	9	1.500
14	7	6	1	1	.167
15	7	10	-3	9	.900
16	5	6	-1	1	.167
17	16	11	5	25	2.272

Note: f'_j = observed number of plants for the jth category,
e_j = expected number of plants for the jth category,
χ^2 = 8.879 (total of column 6),
$\chi^2_{.05}$ = 26.296; degrees of freedom = 16.

Source: Author's Analysis.

TABLE 13

GOODNESS OF FIT TEST BETWEEN THE OBSERVED AND THE EXPECTED PATTERNS AS MEASURED BY SIU

Category	P'_j	P_j	$P'_j - P_j$	$(P'_j - P_j)^2$	$(P'_j - P_j)^2 / P_j$
1	5.763	6.028	-0.265	0.070	0.011
2	5.085	5.358	-0.273	0.074	0.013
3	5.131	5.337	-0.206	0.042	0.007
4	6.511	6.898	-0.387	0.149	0.021
5	5.763	5.374	0.398	0.151	0.028
6	7.062	7.281	-0.219	0.048	0.006
7	4.915	5.304	-0.388	0.151	0.028
8	5.822	5.906	-0.083	0.006	0.001
9	5.932	5.691	0.241	0.058	0.010
10	5.650	5.112	0.537	0.289	0.056
11	4.407	5.037	-0.629	0.396	0.078
12	5.452	4.751	0.700	0.491	0.103
13	4.223	4.507	-0.284	0.080	0.017
14	4.209	4.577	-0.368	0.135	0.029
15	8.390	7.961	0.429	0.184	0.023
16	4.802	4.553	0.248	0.061	0.013
17	10.875	10.316	0.558	0.312	0.030

Note: P'_j = observed percentage proportion of total SIU for the jth category,

P_j = expected percentage proportion of total SIU for the jth category,

χ^2 = 24.163 (total of column 6 multiplied by N which is the number of observations for this study),

$\chi^2_{.05}$ = 26.296, degrees of freedom = 16.

Source: Author's Analysis.

not get at the problem of the spatial arrangement of the residuals which are the differences between the observed and the expected patterns on the areal unit basis. These residuals are now considered below.

The Residuals

Residuals are deviations encountered in comparing the outcome of a model with empirical data. Residuals of the type $f'_j - e_j$ may take positive or negative values. Where the observed frequency (f'_j) for a sub-area j is greater than the corresponding expected frequency (e_j), the residual is positive, i.e., the sub-area concerned is underpredicted by the model. Where f'_j is less than e_j, the residual is negative, indicating overprediction.

The way residuals are distributed on a sub-area unit basis may enable new independent variables to be identified, especially where the residuals are systematically distributed. Such systematic distributions may occur where concentrations of positive or negative residuals are observed in particular areas. Where no systematic patterns are identifiable, the areal arrangement of the residuals may be described as random.

One measure which can be used in evaluating such a random arrangement is the "contiguity ratio". Certain other testing procedures for a random distribution, such as the Poisson, the nearest neighbor and the quadrat analyses, cannot be applied to the problem under consideration since these analyses are concerned with frequency distribution or point patterns rather than spatial arrangement of values.[1]

The contiguity ratio is based on the difference between the observed and the expected sums of join values divided by the standard deviation of join values, where a join value is the product of values of two contiguous areal units. The expected sum and the variance of the join values for a random

---

[1] For a summary of the applications of these analyses in geographic studies, see Leslie J. King, *op. cit.*, pp. 41-52 and 89-109.

arrangement are known.[1] Symbolically, the contiguity ratio (R), i.e., the standard normal variate is defined as

$$R = (A-E)/S;$$

where A is the observed sum of join values, E is the expected sum of join values and S is the standard deviation of join values. "For a test of the randomness hypothesis, the contiguity ratio is treated as a normal variate with zero mean and unit standard deviation".[2] At the .05 level of significance, this ratio must not be less than -2 or greater than 2 for the hypothesis of random arrangement to be accepted. The application of contiguity measures in geographic research has been discussed by Dacey[3] and Anderson[4] and a further discussion of the contiguity ratio can be found in their studies.

The contiguity ratio is used in this study to test the hypothesis that the residual values encountered (Figures 9 and 10) are randomly arranged. Using the standard values of these residuals, a contiguity ratio of .4808 was obtained with respect [illegible].

[illegible]

---

[1] David Anderson, Three Computer Programs For Contiguity Measures, Technical Report No. 5 of ONR Task No. 389-140, Contract NONR 1228(33) (Department of Geography, Northwestern University, 1965), p. 2.

[2] *Ibid.*, p. 2.

[3] M. F. Dacey, A Review on Measures of Contiguity for Two and K-Color Maps, Technical Report No. 2 of ONR Task No. 389-140, Contract NONR 1228(33) (Department of Geography, Northwestern University, 1965).

[4] Anderson, *op. cit.*

to the f_j or the SIU measure.[1] The results of the tests are shown below:

Number of Areal Units = 50

Observed Value of R = .0449

Expected Value of R = -.0118

Variance of R = .0125

Standard Deviation of R = .1118

R (standard normal variate) = .4808

Since the contiguity ratio R falls within the 5 per cent confidence limit, that is, the critical values of -2 and 2, the spatial arrangement of the residual values can be described as random. This suggests that, perhaps, no new variables can be identified to improve the model significantly. An examination of the residuals as shown in Figures 9 and 10 seems to confirm this suggestion since no particular systematic pattern of distribution can be identified. It may, therefore, be said that the residuals could have been produced by chance.

On the basis of the goodness of fit and the contiguity ratio tests, it can be concluded that the model has performed reasonably well. However, one question which arises is whether or not the space requirement constraint has improved the explanatory power of the model since, as noted earlier, the regression model on the basis of which the probabilities are defined, explains only 44 per cent of the total variance. The contribution of the space

---

[1] More precisely, the contiguity ratios for the f_j and the SIU measures are .48076 and .48084 respectively. The corresponding observed values of R are .04493 and .04494.

requirement constraint factor is difficult to measure because of the way the model is operated and evaluated. Nevertheless, the results of the simulation runs are so encouraging that it can be assumed that this constraint factor has significantly improved the performance of the model.

Summary

In this chapter, the simulation model has been operated for Metro Toronto and the average outcome of the 100 simulation runs performed has been compared with empirical data. This comparison is based on the f_j and the SIU measures of outcome. Two tests are performed in making the comparison. First, a chi-square goodness of fit test is performed between the observed and the expected patterns with respect to each of these two measures. The chi-square test is used to test the null hypothesis that the difference between the two patterns is not statistically significant. On both the f_j and the SIU measures of outcome, the null hypothesis is accepted at the level of significance of .05.

Second, a contiguity ratio test is performed to verify the hypothesis of random arrangement in the spatial distribution of the residuals encountered in the study. Again with respect to both measures of outcome, the spatial arrangement is shown to be random, indicating, perhaps, that no new variables can be identified to explain the distribution of the residuals. An examination of the residual maps tends to suggest that this may be so since the residuals do not show any systematic form of spatial arrangement.

In conclusion, the foregoing tests show that the outcome of the model approximates reality. On the basis of this evidence, the model has performed reasonably well. Thus, in general, the assumptions of the model are verified although, in certain specific cases, the assumptions are not supported.

CONCLUSION

Intra-urban industrial migration, as distinct from the general field of industrial location and development, is deficient in theoretical models. This study is an attempt to develop and test a simple, and at least theoretically consistent, simulation model for site selection by migrant firms in an urban area. The model is based on three assumptions. It is assumed that 1) the probability that any type of industrial plant migrating from any origin will go to destination j depends on the attributes of destination j, which largely reflect the opportunities for earning external economies; 2) the probability that any type of industrial plant migrating from a particular origin i will go to destination j depends on the distance between i and j; and 3) the influence of plant characteristics on site selection for location is reflected through the space requirement levels of individual plants. These space requirement levels pose a constraint in the location process in the sense that a plant cannot be located in an area where the space available is less than is required by the plant.

In general, the simulation model provides a fair verification of the underlying assumptions. The outcome of the model is found not to be significantly different from empirical observations at the significance level of .05. Also, the spatial arrangement of the residuals encountered can be described as random. As a major contribution of this study, the model is seen as a complement not only to a general model of intra-urban migration, but to a yet more general model of urban location and growth processes.

The review of location theories suggests certain aggregate factors which can be used in assessing the attractiveness of a location to migrating industries. These factors include, for example, accessibility to major transportation facilities and labour force, costs and availability of industrial land, water and hydro; porperty tax; and level of industrial development. These factors largely represent the opportunities for earning external economies. Distance between a destination and an origin is also an important factor. In addition, the characteristics of a plant, particularly industry type and size of employment, as they affect its space requirement level must be considered.

The other aspect of the review of the literature is concerned with approaches to modelling in the area of urban growth processes. This aspect emphasizes the particular relevance of the Monte Carlo simulation technique to the process of site selection. In this regard, the iterative, the stochastic and the deterministic properties of this method are considered to be compatible with the nature of urban locational processes as is the case with the process of plant site selection under consideration in this study.

The present study also illustrates interesting approaches to certain measurement problems which have been, or may be, encountered in the analysis of plant location or migration. Three of these problems are identified in the present study.

First, there is the problem of jointly measuring industrial floor space and industrial land by a common denominator. This study introduces the concept of the "standard industrial unit (SIU)" which expresses all types of industrial space in floor area equivalence. Any piece of industrial land is thus expressed in SIU after due account has been taken of the ratio of floor area to industrial land prevailing or permissible in that site. For this study, a standard industrial unit is equal to 5,000 square feet.

Second, there are problems associated with handling the influence of plant characteristics on site selection. In this study, such problems are handled by using two summary characteristics to determine a plant's space requirement level. This requirement is then compared against the vacant industrial space available at a selected destination sub-area at any point in time under consideration. Where the vacant space is less than is required by the plant, migration to that destination cannot be effected.

The two summary characteristics used are the standard industrial classification (SIC) and the total number of employees (EMTOT). These characteristics are assumed to reflect many other characteristics of plants such as the proportion of employees that are production workers or male workers and the country of control. A plant's space requirement level is determined on the basis of the SIU empirically assigned to the classified group to which that plant belongs. There are forty classified groups for the present study. These groups are defined by ten SIC and four EMTOT groups.

Third, the use of surrogates in research is often important where detailed measurement of particular factors is not feasible because of time, monetary and other practical considerations. Manufacturing linkages, one of the attributes of a destination sub-area considered in this study, constitute one example. This factor is expressed by two surrogates: 1) a measure of manufacturing concentration based upon the frequencies of randomly selected sample plants observed to locate in a defined destination sub-area; and 2) a measure of product diversification, based on the number of different product types manufactured by the observed sample plants as determined by the four digit SIC classification. It is assumed that these two measures would reflect the level of industrial development in a defined location and, indirectly, the potential of that location for urbanization economies in the form of inter-industry input-output relations. It is highly interesting that one of these measures, manufacturing concentration, is found to be the most significant variable determining plant site selection. This judgement is based on the result of the multiple regression analysis used to derive empirical weights for the variables explicitly assumed in the model. Product diversification is found not to be significant in the empirical analysis.

Planning Implications

The variables analysed in this study may be discussed under the heading of planning implications. Altogether, thirteen variables are explicitly considered.

These thirteen variables account for 44% of the variance in the frequencies of plants observed to migrate to destination sub-areas. It must be borne in mind, however, that the influence of plant characteristics is excluded from consideration in the regression analysis used to investigate these thirteen variables. The simulation model allows us to consider the influence of plant characteristics.

Five of the thirteen variables are found to be statistically significant judging from a t-test performed on their corresponding regression coefficients. In a declining order of relative importance (based on the standard regression coefficients), the five variables include

1) measure of manufacturing concentration (positive),
2) absolute change in industrial mill rate over the past six years (positive),
3) road distance to the nearest major highway (negative),
4) cost of one million gallons of industrial water consumption (negative), and
5) distance between i and j (negative).

Absolute change in industrial mill rate should be particularly noted in view of the significance of this variable, and its positive relationship to the attractiveness of a destination sub-area which is contrary to the assumption held earlier in the study. These five variables may be quite important to the problem of urban industrial planning and, as such, deserve to be given further attention in future studies.

The fact that the remaining eight variables are not found to be statistically significant does not mean that they are unimportant to urban industrial location. For one thing, the statistical significance of the five variables above depends upon the effects of the eight variables being held statistically constant. Moreover, it should be stressed that the conclusions regarding the thirteen variables are based on a limited number of observations since only migrated plants are used. These conclusions are, therefore, tentative pending a further analysis of these variables in the general context of urban industrial location embracing newly-established and migrated plants. Such a general analysis may offer a new insight concerning the relationships of such factors as the Toronto International Airport and the cost variables associated with industrial land.

Future Research

The present study may be extended in a number of ways. Three of these are suggested below.

1. The model can be tested for the same study area relative to other time periods. In the light of such tests, the validity of the simulation model can be evaluated further.

2. The model can be used as a basis for predicting choice of plant sites for a given time period for which empirical data are not available. In this connection, however, changes in the attributes of potential destinations, and in their potential industrial vacancy should have to be predicted or projected. Appropriate techniques for making such projections constitute a major research topic.

3. The present study is a partial analysis of the problem of intra-urban plant migration since the migrant plants and their

respective origins are given. Only the choice of plant sites is predicted. The development of a model to predict origins from where migration takes place is a research challenge. Such a model and the one developed in the present study can be combined into a generalized model of intra-urban plant migration.

One important limitation in conducting the types of research suggested above has to do with availability of data. As illustrated by the present study, there are three aspects of this limitation.

1. Certain data are non-public or difficult to obtain, for example, municipal assessment records are non-public records. Yet, these records contain vital data relating to space utilization of individual firms. It can be suggested that such records can be collected from individual firms directly. However, it has to be remembered that this is a tedious, often unrewarding procedure. Most firms have definite regulations as to the amount and types of information that can be disclosed, even for research use. Data pertaining to certain aspects of industrial linkages such as the volume, the type, or the value of products bought and sold, and the names of the firms involved in the transactions may be difficult to obtain. This difficulty adds to the problem of obtaining sufficient capital to conduct such an investigation.

2. Most types of data cannot be collected from a single source. For this study, information on industrial water rate, hydro rate, and land use regulations is obtained from the several municipalities in the study area. The source of certain data was often unknown until four or more departments were contacted.

3. Certain data are available for areal units too large for research use. The Metro Toronto Planning Board data on vacant industrial land and on acreage of industrial development, for example, are tabulated for sixteen planning districts. Other data are tabulated according to municipalities.

The limitation associated with the data problems above makes necessary the use of secondary sources in estimating some of the aggregate measures used in the study. Examples of such sources are illustrated in the measurement of manufacturing linkages and vacant industrial spaces.

The data problems encountered in this study suggest the need for a comprehensive collection of data for the purpose of industrial location and other types of urban research in the Metro Toronto area. It is, perhaps, not irrelevant to suggest here that a location data bank would be of great utility. Presumably, such data bank should be undertaken by a University Department to facilitate its use for research.

APPENDIX A

FIELD SURVEY QUESTIONNAIRE

Manufacturing Migration in Metropolitan Toronto

Part A

Answer the following questions in the spaces provided

1. Name of Firm ______________________________

2. Types of product produced ______________________________
____
____

3. Address of present location ______________________________

4. Area of site occupied at your present location ____________ (acres)
total floor space ____________ (sq. feet)
total parking space ____________ (acres)

5. Address of previous location ______________________________

6. Area of site occupied at your previous location ____________ (acres)
total floor space ____________ (sq. feet)
total parking space ____________ (acres)

7. Date of relocation to present site ______________________________

8. Length of time between acquisition of your present site and actual occupation of the site ________ (years), ________ (months), ____ (weeks)

9. Method of acquisition of your present site (rent, lease, or purchase)
____

10. Is relocation due to expropriation of your old site? ____ (yes or no)

11. If not, what is the major reason for your relocation?
____

12. Name two other important reasons for your relocation
I) ______________________________
II) ______________________________

APPENDIX A (contd.)

13. How many other industrial sites were considered before selecting your present site? ______________________

14. Was any serious investigation conducted before your final selection? ____________(yes or no)

15. Do you intend to relocate in the nearest future? ______(yes or no)

16. If yes, give the major reason ______________________

17. Within how many miles radius do you draw 75 per cent of your permanent employees? ____________

Part B

Mark with x the squares corresponding to any of the following reasons favouring the choice of your present site.

1. closeness to residences of employees
2. closeness to parent firm in Metro Toronto
3. closeness to the Toronto International Airport
4. closeness to the Toronto Harbour
5. closeness to manufacturing firms in your previous location
6. migration of former neighbouring manufacturing firms to this area
7. attraction of firms existing in this area
8. good contact with retailing firms
9. advertising value of the site
10. availability of serviced industrial land
11. availability of industrial floor space
12. favourable cost of land per acre
13. favourable hydro and water rate
14. favourable taxation rate
15. availability of special industrial facility, for example, __________ __________ __________
16. access to a major highway
17. closeness to market areas served from the previous location
18. central location in Metro Toronto
19. better access to suburban market
20. better access to southern Ontario market
21. pleasant climate
22. attractive natural surroundings
23. personal preference
24. prestige reason
25. advise of a frienly firm
26. read of site from a newspaper
27. decision of your research department
28. local regulations not too restrictive

APPENDIX A (contd.)

Mention any other reasons not listed above which are important to the choice of your present site.

Part C

From the reasons listed above, choose the most important five and list their numbers in a declining order of importance in the square spaces provided below.

1st.

2nd.

3rd.

4th.

5th.

APPENDIX B

SURVEY OF MIGRANT PLANTS

The survey of migrant plants whose purpose and methodology were explained in chapter IV of this thesis may be discussed under three general headings: 1) factors motivating firms to migrate; 2) reasons for choice of location sites; and 3) other elements which do not fit into 1 or 2. Before discussing these various aspects of the survey, certain general observations may be explained. It was pointed out in chapter IV that 85 firms responded to the questionnaires out of a total of 200 firms interviewed. However, not all the 85 respondent firms answered every single question in the questionnaire, for example, 80 of the firms state a primary reason for migration, and 60 state secondary reasons. This then explains the reason why the total number of firms indicated at the foot of each summary table does not equal 85.

Factors Motivating Firms to Migrate

Eighty of the 85 respondent firms state a primary reason for migration. Of these eighty firms, 72.5 per cent (Table 1) mention the need for more space as the primary reason for their migration. This need for additional space is related to expansion of production, larger premises, future expansion, and the like. Cost-related reasons, such as high rent, high taxes, and high production costs, rank as the second major reason for migration. These reasons are cited by 6.25 per cent of the firms. The other reasons listed in the Table assume more or less equal importance.

TABLE 1

PERCENTAGE PROPORTIONS OF RESPONDENT FIRMS ACCORDING TO THE PRIMARY REASONS FOR MIGRATION

Reason	Proportion
Need for additional space	72.50
Cost-related reasons	7.50
Lease expired	6.25
Outmoded facilities	2.50
Destruction of property by fire	2.50
Expropriation	2.50
Property sold to free capital	2.50
Change of ownership	1.25
Consolidation of operation	1.25
Desire to work at home	1.25

No. of respondent firms = 80.
Source: survey of migrant firms (questionnaire, Appendix A).

The secondary reasons for migration cited by the respondent firms are more varied than the primary reasons (Table 2). Cost-related reasons, cited by 46.67 per cent of the firms, constitute the most important of the secondary reasons, compared with 13.33 per cent with regard to parking problems, cited mostly by downtown manufacturers. The need for better location, increasing property values, the need to be closer to customers, and the need to expand are the other secondary reasons, respectively ranking in the third, the fourth, the fifth and the sixth positions as shown in Table 2. The other reasons listed in the Table are less frequently cited.

TABLE 2

PERCENTAGE PROPORTIONS OF RESPONDENT MANUFACTURING FIRMS ACCORDING TO THE SECONDARY REASONS FOR MIGRATION

Reason	Proportion
Cost-related reasons	46.67
Parking problems	13.33
Need for better location	10.00
Real estate value	8.33
Need for closeness to customers	6.67
Need for expansion	3.33
Need for female employees	1.67
Corporate policy to own property	1.67
Uneasy relationship with landlord	1.67
High risk of fire	1.67
Prestige	1.67
Expiration of lease	1.67
To qualify for government inspection	1.67

No. of respondent firms = 60.
Source: survey of migrant firms (questionnaire, Appendix A).

All of the reasons for migration discussed above are hardly startling. The same reasons are often discussed in most empirical studies, for example, Kerr and Spelt (1957, 1961, 1965)[1], Logan (1964)[2], and

---

[1] Donald Kerr and Jacob Spelt, "Manufacturing in Downtown Toronto," <u>Geographical Bulletin</u>, X (1957), 4-20; <u>Industry and Warehousing in the City of Toronto</u> (City of Toronto Planning Board, April, 1961), 10-11; and <u>Industrial Prospects in the City of Toronto</u> (City of Toronto Planning Board, June, 1965), 21-32.

[2] M. I. Logan, "Suburban Manufacturing: A Case Study," <u>The Australian Geographer</u>, IX (September, 1964), 4, 223-34.

Hoover and Vernon (1962).[1] Nevertheless, the distinction between primary and secondary reasons as made in this study should be noted.

Reasons for Choice of Destinations

It is to be recalled that destinations, as defined in this study, include all of the sub-areas where it is possible for a plant to be located. To some of the migrant plants, the same areal units are both the origins and the destinations since such plants migrate within the same areal units. The reasons for the choice of destinations as discussed here should, therefore, be seen in the context of manufacturing areas as a whole, that is in the context of comparative utility.

Parts B and C of the questionnaire (Appendix A) used in the field survey deal with the reasons for the choice of location sites. These reasons can be grouped into four categories as shown in Table 3.

Category 1 is related to opportunities for realizing external economies (part B, 1-16). This category includes a wide range of factors such as industrial linkages, urban facilities as reflected by availability or cost, etc. Category 2 (part B, 17-20) is related to market factors, that is, accessibility to the Metro Toronto market and the rest of southern Ontario. Category 3 (part B, 21-22) includes physical environmental factors. Category 4 (part B, 23-28) includes miscellaneous factors such as prestige location and other personal considerations.

---

[1] E. M. Hoover and Raymond Vernon, op. cit., 21-57.

TABLE 3

PERCENTAGE PROPORTIONS OF RESPONDENT FIRMS ACCORDING TO CATEGORIES OF REASONS FOR THE CHOICE OF LOCATION SITES

Category[a]	Overall	Major Reasons				
		first	second	third	fourth	fifth
1	53.09	69.87	61.71	59.72	58.73	39.58
2	22.86	20.48	21.05	25.00	26.98	20.83
3	4.97	1.21	1.32	1.39	0.00	12.50
4	19.09	8.83	15.79	13.89	14.29	27.08
Total frequencies:	503	83	76	72	63	48

a: 1. opportunities for earning external economies
2. accessibility to market
3. physical environment
4. other reasons

source: survey of migrant firms (questionnaire, Appendix A).

Table 3 summarizes the proportional distribution of the overall frequencies of times factors in each category are cited and the proportional distribution of the respondent firms under each of the first to the fifth major reasons. A strict comparison of the relative importance of the categories of reasons as revealed by the Table is rendered difficult because of the unequal number of reasons included under each category. The summary should, therefore, be interpreted as broad tendencies. The overwhelming importance of external economies is obvious. In the overall distribution of the frequencies and under each of the first to the fifth major reasons, this category of reasons ranks in the first position.

Market availability ranks in the second position when the overall and the first to the fourth major reasons are considered. It ranks in the third position as the fifth major reason for site selection. Miscellaneous reasons rank in the third position in the overall and in the first to the fourth major reasons. They rank in the second position under the fifth major reason. Physical environmental factors are the least important reasons for site selection. However, this statement should be qualified by the fact that the number of reasons included under this category is very small.

In summary, this aspect of the survey illustrates the overwhelming importance of the desire to earn external economies in selecting a location site when all or many of the factors revealing this desire are combined as single factor. Indirectly, some of these factors may be regarded as crude proxies for other factors; for example, closeness to a major highway or the Toronto International Airport reflect regional access. It thus appears that the comparative utility of a location site is largely determined by opportunities for external economies at that site.

Other Elements in the Field Survey

Four other elements in site selection process are investigated in this survey. These are time lag between decisions to migrate and actual migration, methods of acquiring location sites, the degree to which alternate sites are investigated before making the final selection; and the nature of the investigation.

The time lag between decisions to migrate and actual migration is found to vary considerably (Table 4): 45.5 per cent of the plants were located within the first thirteen weeks after sites were acquired, compared with 14 to 26 weeks for 12.99 per cent of the plants, 27 to 39 weeks for 7.79 per cent, 40 to 52 weeks for 16.88 per cent and over 52 weeks for 16.88 per cent.

With regard to methods of acquiring location sites, three methods are specified. These include purchase, lease and rent. The majority of the respondent firms (59 per cent) purchase their sites (Table 5). Renting is the least popular method of acquiring location sites. Only nine per cent of the respondent firms rent their floor spaces. More interesting is the fact that all of these firms located their plants within the first thirteen weeks of acquiring their floor spaces. Perhaps, this suggests that renting may speed up migration because renters may be satisfied with using less than ideal space. Leasing is a moderately popular method of acquiring a location space. One third of the respondent firms lease their property.

The degree to which alternate sites are investigated in terms of the number of location sites considered besides the final selection is also enquired in the survey. An overwhelming majority of the respondent firms considered other sites (Table 6). Only twelve per cent did not consider other sites. The number of other industrial sites considered by the remaining firms ranges from one to more than ten.

Although many of the respondent firms state the fact that they investigated more than one site before making their final selection, it does not appear that such an investigation is based on any scientific

TABLE 4

PERCENTAGE PROPORTIONS OF RESPONDENT MANUFACTURING FIRMS ACCORDING TO THE TIME LAG BETWEEN ACQUISITION OF SITES AND ACTUAL MIGRATION

Time Lag in Weeks	Proportion
1 - 13	45.45
14 - 26	12.98
27 - 39	7.79
40 - 52	16.88
over 52	16.88

No. of respondent firms : 77
source: survey of migrant firms (questionnaire, Appendix A).

TABLE 5

PERCENTAGE PROPORTIONS OF RESPONDENT MANUFACTURING FIRMS ACCORDING TO METHOD OF ACQUISITION OF SITES

Method	Proportion
Purchase	59.26
Lease	32.10
Rent	8.64

No. of respondent firms: 81.
source: as for Table 4.

TABLE 6

PERCENTAGE PROPORTIONS OF RESPONDENT MANUFACTURING FIRMS ACCORDING TO THE NUMBER OF OTHER INDUSTRIAL SITES INVESTIGATED

Number of other Industrial Sites	Proportion
0	12.35
1	3.70
2	12.35
3	14.81
4	4.94
5	11.11
6	13.58
7	3.70
8	0.00
9	0.00
10	3.70
over 10	19.75

No. of respondent firms: 81
source: based on questionnaire, Appendix A.

analysis. For example, only five per cent of the respondent firms state that the decision of their research departments was involved in choosing their sites.

Summary

The basic findings of the survey can now be summarized. The reasons for migration, as given by the respondent firms, are quite varied. In general, the primary reasons for migration are the need for more space; cost-related reasons such as high rent, high taxes, and high costs of production; expiration of lease; and outmoded facilities.

The reasons stated as secondary include cost-related reasons, parking problems, need for better location, increasing property value and the need to be closer to customers.

The reasons for choosing particular location sites are overwhelmingly due to opportunities for realizing external economies. These include a variety of urban and industrial facilities, industrial linkages and the like. The findings from the survey concerning reasons for migration as well as reasons for choosing particular location sites are largely confirmed by empirical studies on the subject.

On the other elements of the site selection process, certain facts are established. First, the time lag between decisions to migrate and actual migration is found to vary considerably, ranging from less than thirteen weeks to more than 52 weeks. Second, the method of acquiring a location site is specified to be either purchase, or lease, or rent. More than half of the respondent firms purchase their property, compared with one third with respect to leasing and one third with respect to renting. The majority of the respondent firms state that more than one site was investigated before they selected their final sites. However, such investigations are not generally based on any intensive analysis judging from the fact that only five per cent of the respondent firms state that their research departments were involved in their decisions.

APPENDIX C: LIST OF VARIABLES USED IN THE MULTIPLE REGRESSION MODEL, 1964-65

Sub-area	Variables													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2.155	5.154	4.752	0.274	0.907	2.167	2.233	2.023	1.900	1.492	3.225	2.794	1.332	3
2	1.437	15.119	4.752	2.747	0.907	2.167	2.233	2.023	1.900	0.504	3.225	2.564	0.711	5
3	3.187	5.154	4.752	2.747	0.907	2.167	2.233	2.023	1.900	0.480	3.225	2.456	0.428	4
4	2.227	4.123	4.277	2.197	0.802	2.167	2.233	2.023	1.900	0.814	0.000	2.743	1.227	5
11	7.032	0.343	4.277	2.197	0.802	2.167	2.233	2.023	1.900	1.702	0.000	2.867	1.911	1
14	2.812	0.687	4.277	2.197	0.802	2.167	2.233	2.023	1,900	2.721	0.000	3.918	0.729	1
15	2.008	2.404	4.277	2.197	0.802	2.167	2.233	2.023	1.900	2.144	3.225	3.256	0.366	1
21	1.406	1.374	3.564	2.747	1.232	2.167	2.233	2.023	1.900	3.547	0.000	3.665	0.500	1
23	2.344	1.030	2.375	1.373	0.907	2.167	2.233	2.023	1.900	4.956	0.000	3.049	1.216	1
28	0.000	0.000	2.375	1.373	0.907	2.167	2.233	2.023	1.900	2.441	0.000	2.422	0.652	1
31	0.000	0.000	2.851	5.494	3.449	1.997	2.394	1.811	2.445	3.032	0.000	2.285	0.575	1
32	3.164	2.748	2.851	5.494	3.449	1.997	2.394	1.811	2.445	1.899	0.000	1.820	1.165	1
33	2.250	1.718	2.851	5.494	3.449	1.614	2.884	2.023	1.903	1.979	0.000	2.890	2.004	3
37	0.000	0.000	1.187	0.549	0.718	1.778	1.620	1.979	2.059	1.182	3.225	2.189	5.166	1
38	2.380	4.467	0.997	0.274	0.420	1.778	1.620	2.465	2.059	2.452	3.225	1.856	2.727	1
39	1.839	4.467	0.997	0.274	0.420	1.778	1.620	1.979	2.059	1.553	3.225	1.540	0.776	4
41	0.000	0.000	0.950	1.373	2.464	1.778	1.620	1.979	2.059	0.937	3.225	1.319	0.316	1
42	2.209	2.404	1.425	1.923	1.750	1.778	1.620	1.979	2.059	1.226	3.225	1.498	1.835	2
43	2.461	6.873	1.805	1.923	1.750	1.778	1.620	1.979	2.059	2.500	3.225	2.086	1.627	1
44	2.109	0.687	1.187	1.373	1.916	1.778	1.620	1.979	2.059	2.220	3.225	2.376	1.241	1
46	0.000	0.000	1.187	1.373	1.916	1.778	1.620	1.979	2.059	2.367	3.225	2.156	0.985	1
56	4.992	0.687	0.997	2.197	4.057	1.778	1.620	1.979	2.059	0.740	3.225	1.059	2.611	2
57	3.750	1.030	0.807	1.098	2.299	1.778	1.620	1.979	2.059	1.479	3.225	0.975	1.703	1
58	1.581	2.748	1.045	0.824	1.261	1.778	1.620	1.979	2.059	1.247	3.225	1.235	0.213	1
61	1.406	2.748	1.045	0.824	1.261	1.778	1.620	1.979	2.059	1.553	3.225	1.156	2.931	3
68	2.068	5.841	2.946	3.846	2.194	1.971	2.045	1.979	1.911	1.793	3.225	3.106	1.351	4
71	3.516	0.687	2.470	3.296	2.249	1.971	1.506	1.979	1.911	1.202	0.000	2.379	1.827	2
73	2.250	1.718	2.470	3.296	2.249	1.971	1.506	1.979	1.911	0.573	0.000	2.315	1.540	2
74	0.000	0.000	2.375	4.120	3.043	1.971	1.506	1.979	1.911	1.405	3.225	2.164	2.426	1
75	1.406	0.343	2.470	3.296	2.249	1.971	1.506	1.979	1.911	1.683	3.225	2.171	2.922	1
80	2.410	4.811	2.946	1.923	1.032	1.971	2.045	1.979	1.911	0.990	3.225	2.631	2.518	2
82	4.219	0.343	1.662	1.373	1.326	1.971	2.045	1.979	1.911	0.517	3.225	1.959	1.305	1
83	2.812	1.030	1.662	2.747	2.847	1.971	2.045	1.979	1.911	1.282	3.225	1.841	2.119	1

APPENDIX C contd.

Sub-area	Variables													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
99	2.344	1.030	1.662	1.373	1.326	1.971	2.045	1.979	1.911	3.095	3.225	1.698	3.515	2
104	1.151	3.780	0.950	1.648	3.043	1.971	2.045	1.979	1.911	2.191	3.225	0.973	3.515	5
105	0.937	1.030	0.997	1.923	3.449	1.971	2.045	1.979	1.911	1.258	3.225	1.057	2.930	3
107	2.812	0.343	1.045	2.197	3.832	1.971	2.045	1.979	1.911	3.920	3.225	1.313	3.415	2
114	2.812	0.687	0.950	1.373	2.464	2.151	2.074	2.035	2.019	4.585	0.000	1.782	0.504	1
115	2.109	0.687	1.187	1.373	1.916	2.151	2.074	2.035	2.019	4.351	0.000	2.169	0.213	1
116	2.511	4.811	1.710	4.395	4.928	2.151	2.074	2.035	2.019	3.550	0.000	2.182	2.570	1
117	0.000	0.000	1.710	4.395	4.928	2.151	2.074	2.035	2.019	5.770	0.000	1.953	6.214	1
121	4.219	0.687	0.474	0.549	1.916	2.151	2.074	2.035	2.019	1.812	0.000	0.485	5.664	2
127	1.875	2.062	0.950	0.549	0.907	2.151	2.074	2.035	2.019	1.776	3.225	1.895	2.803	4
128	0.000	0.000	0.950	0.549	0.907	2.151	2.074	2.035	2.019	1.947	3.225	1.653	1.871	6
137	0.000	0.000	0.617	0.824	2.249	2.151	2.074	2.035	2.019	0.591	0.000	0.763	4.226	1
138	2.344	1.030	0.664	0.274	0.638	2.151	2.074	2.035	2.019	1.109	3.225	0.907	2.291	3
139	1.406	0.687	0.950	1.923	3.658	2.151	2.074	2.035	2.019	0.844	3.225	1.197	3.425	6
140	0.000	0.000	0.950	1.373	2.464	2.151	2.074	2.035	2.019	0.628	3.225	1.423	3.265	1
156	2.344	1.030	1.662	0.824	0.772	2.022	2.669	1.867	2.163	2.220	0.000	3.786	0.764	1
158	1.757	1.374	1.662	0.000	3.808	2.022	2.669	1.867	2.163	3.717	0.000	2.912	1.832	3

Source of data: municipal and private agencies, industrial directories and census materials.

List of Variables (note: variables 1 to 13 are expressed in percentage proportions):

1 measure of manufacturing diversification,
2 measure of manufacturing concentration,
3 cost of serviced industrial land per acre,
4 absolute change in the cost of serviced industrial land per acre over the past six years,
5 relative change in the cost of serviced industrial land per acre over the past six years,
6 industrial mill rate,
7 absolute change in industrial mill rate over the past six years,
8 industrial hydro rate,
9 cost of one million gallons of industrial water consumption,
10 road distance to the nearest major highway,
11 access to the Toronto International Airport,
12 labour force potential,
13 average distance (air) moved by plants received at destination j, and
14 number of plants relocated into destination j.

APPENDIX D: TRANSGENERATED VARIABLES AND MEASURE OF INDUSTRIAL VACANT SPACE FOR SUB-AREAS, 1966-67

Sub-area	Variables												SIU measure of u_j
	1	2	3	4	5	6	7	8	9	10	11	12	
1	2.445	3.960	4.406	2.306	0.847	2.133	2.216	2.038	1.905	1.494	3.448	2.959	139.5
2	1.283	13.200	4.406	2.306	0.847	2.133	2.216	2.038	1.905	0.505	3.448	2.683	306.2
3	3.248	4.620	4.406	2.306	0.847	2.133	2.216	2.038	1.905	0.481	3.448	2.573	207.2
4	2.934	2.640	4.406	2.229	1.235	2.133	2.216	2.038	1.905	0.815	0.000	2.866	157.7
12	0.000	0.000	4.006	2.076	0.838	2.133	2.216	2.038	1.905	1.555	0.000	3.355	137.2
21	1.711	1.980	3.205	1.729	0.876	2.133	2.216	2.038	1.905	3.408	0.000	3.839	221.6
24	1.466	0.330	2.804	2.306	1.413	1.965	1.781	1.768	2.313	3.934	0.000	3.386	15.3
25	1.955	0.990	3.606	4.614	2.422	2.133	2.216	2.038	1.905	3.764	0.000	3.367	120.8
32	2.934	2.970	2.804	3.459	2.311	1.893	1.804	1.824	2.452	1.902	0.000	1.925	98.4
33	1.833	2.640	2.804	3.459	2.311	1.703	1.628	2.038	1.908	1.982	0.000	3.044	186.9
38	2.595	4.290	1.962	3.345	3.562	1.896	2.050	1.994	2.064	2.456	3.448	1.951	136.2
39	1.999	3.630	1.202	1.153	1.695	1.896	2.050	1.994	2.064	1.555	3.448	1.623	609.9
41	0.000	0.000	1.402	2.306	3.391	1.896	2.050	1.994	2.064	0.939	3.448	1.390	384.6
42	1.833	2.640	1.402	0.576	0.652	1.896	2.050	1.994	2.064	1.228	3.448	1.578	454.2
43	2.161	6.269	1.602	1.037	1.074	1.896	2.050	1.994	2.064	2.504	3.448	2.194	367.5
56	5.133	0.660	1.122	1.729	3.100	1.896	2.050	1.994	2.064	0.741	3.448	1.115	494.4
57	3.228	1.650	0.801	0.807	1.798	1.896	2.050	1.994	2.064	1.481	3.448	1.025	600.5
58	1.733	3.630	1.281	1.499	2.160	1.896	2.050	1.994	2.064	1.249	3.448	1.301	556.8
61	1.792	2.970	1.281	1.499	2.160	1.896	2.050	1.994	2.064	1.555	3.448	1.218	279.4
68	2.095	4.620	2.684	2.190	1.401	1.959	2.023	1.994	1.916	1.796	3.448	3.267	125.7
71	3.667	0.660	2.804	3.459	2.311	1.959	1.803	1.994	1.916	1.204	0.000	2.510	298.2
72	3.667	0.660	2.404	2.306	1.695	1.959	1.803	1.994	1.916	1.136	0.000	2.563	283.1
73	2.200	1.980	2.804	3.459	2.311	1.959	1.803	1.994	1.916	0.574	0.000	2.442	244.8
75	1.466	0.330	2.804	3.459	2.311	1.959	1.803	1.994	1.916	1.685	3.448	2.294	293.1
80	2.031	4.290	2.684	1.384	0.834	1.959	2.023	1.994	1.916	0.992	3.448	2.774	493.1
83	4.401	0.990	1.602	1.729	1.956	1.959	2.023	1.994	1.916	1.284	3.448	1.941	42.1
85	0.000	0.000	2.804	4.614	3.391	1.959	2.023	1.994	1.916	1.444	3.448	2.537	26.0
90	0.000	0.000	2.003	2.883	2.826	1.959	2.023	1.994	1.916	0.778	3.448	2.126	25.2
91	1.466	0.660	2.003	2.883	2.826	1.959	2.023	1.994	1.916	0.852	3.448	1.768	80.3
99	2.567	1.320	1.602	1.153	1.210	1.959	2.023	1.994	1.916	3.100	3.448	1.792	605.7
101	2.514	2.310	1.241	0.576	0.743	1.959	2.023	1.994	1.916	1.136	3.448	1.424	449.4
104	1.692	4.290	1.402	2.422	3.632	1.959	2.023	1.994	1.916	2.194	3.448	1.025	499.4
105	1.099	1.320	0.840	0.807	1.695	1.959	2.023	1.994	1.916	1.260	3.448	1.115	566.1

APPENDIX D contd.

Sub-areas	Variables												SIU measure of u_j
	1	2	3	4	5	6	7	8	9	10	11	12	
107	2.934	0.660	1.361	2.306	3.532	1.959	2.023	1.994	1.916	3.926	3.448	1.386	552.0
114	2.934	0.660	1.081	1.384	2.422	2.091	1.949	2.050	2.024	4.593	0.000	1.878	56.3
115	1.466	0.330	1.241	1.268	1.827	2.091	1.949	2.050	2.024	4.358	0.000	2.282	149.6
116	2.475	5.280	1.803	2.883	3.260	2.091	1.949	2.050	2.024	3.556	0.000	2.306	112.2
121	3.911	0.990	0.601	0.807	2.579	2.091	1.949	2.050	2.024	1.815	0.000	0.511	196.4
122	0.000	0.000	0.601	0.807	2.579	2.091	1.949	2.050	2.024	2.371	0.000	0.682	45.0
126	2.934	2.640	1.803	2.883	3.260	2.091	1.949	2.050	2.024	3.161	0.000	2.168	150.9
128	2.445	1.980	1.202	1.384	2.119	2.091	1.949	2.050	2.024	1.950	3.448	1.748	426.1
138	1.466	0.330	0.601	0.231	0.605	2.091	1.949	2.050	2.024	1.110	3.448	0.959	299.6
139	1.466	1.980	1.161	1.845	3.229	2.091	1.949	2.050	2.024	0.846	3.448	1.267	495.9
140	1.466	0.330	1.122	1.499	2.562	2.091	1.949	2.050	2.024	0.629	3.448	1.507	248.5
144	0.000	0.000	0.801	0.807	1.798	2.091	1.949	2.050	2.024	2.501	0.000	0.581	80.0
153	0.000	0.000	0.801	0.807	1.798	2.091	1.949	2.050	2.024	3.816	0.000	0.709	50.0
157	3.667	0.660	1.803	1.499	1.431	2.010	2.137	1.881	2.168	2.934	0.000	3.231	157.5
158	2.200	1.320	1.803	1.499	1.431	2.010	2.137	1.881	2.168	3.722	0.000	2.319	321.6
159	1.466	0.330	1.803	1.499	1.431	2.010	2.137	1.881	2.168	3.853	0.000	1.959	39.6
161	0.000	0.000	1.803	1.499	1.431	1.909	1.541	1.994	1.850	1.852	3.448	1.511	5.5

Source of data: as for Appendix C

Note:- Names of variables are indicated in Appendix C. Variable 13, which is not shown in this Appendix, is air distance from sub-area j to an origin sub-area (i) under consideration.

APPENDIX E

ORIGINS AND DESTINATIONS OF OBSERVED MIGRANT PLANTS

1964-65

Origin Sub-area	No. of Plants	Destination Sub-area
1	1	61
2	11	1, 2 (two), 3 (two), 4, 14, 42, 71, 75, 128
3	10	1, 2, 3, 11, 104, 116, 121, 139 (two), 158
4	5	33, 68, 74, 137, 140
7	1	128
10	2	4, 31
12	2	3, 23
13	3	21, 68, 158
14	2	2, 4
15	2	43,44
19	1	15
20	1	121
21	3	4 (two), 105
22	1	127
23	2	28, 139
25	2	33, 156
26	1	99
27	1	2
37	1	39
38	3	39,46, 107
39	1	56
42	2	39, 41
43	5	1, 39, 42, 104 (two)
46	1	61
53	1	57
58	1	58
61	1	127
68	5	38, 68, 82, 107, 158
69	1	104
72	2	80, 139
73	1	128
80	5	56, 61, 68, 105, 139
88	1	139

APPENDIX E contd.

Origin Sub-area	No. of Plants	Distination Sub-area
104	1	117
113	1	128
114	3	32, 73, 127
115	5	73, 114, 115, 138 (two)
116	4	37, 99, 127, 138
126	3	71, 128 (two)
155	2	80, 105
156	1	83
157	1	33
158	1	104

1966-67

1	7	12, 38, 39, 43, 80, 126, 128
2	16	2 (four), 25, 33, 39, 43, 72, 80, 83, 90, 115, 116, 128, 140
3	15	1, 3, 42 (two), 72, 75 (two), 99 (two), 101, 115, 122, 128 (two), 158
4	2	71, 85
12	2	33, 139
13	2	75, 107
14	1	2
15	1	157
19	3	3, 73, 105
21	5	21 (two), 80, 107, 114
22	2	4, 139
25	1	159
29	1	139
31	1	144
32	3	107, 138, 139
33	1	140
34	1	21
35	1	39
38	4	39 (three), 61
39	2	43, 43
42	2	41, 58
43	1	41

APPENDIX E contd.

Origin Sub-area	No. of Plants	Destination Sub-area
56	1	56
57	1	57
58	3	57 (two), 99
59	1	56
61	5	58, 61, 80 (two), 104
68	2	68, 161
71	1	73
72	2	32, 139
73	1	2
75	2	58, 115
80	4	91, 99 (two), 126
83	3	57, 104, 105
97	1	61
99	1	73
101	2	101, 105
104	1	104
113	1	121
116	3	72, 121, 138
126	3	128, 140, 153
139	1	128
157	2	24, 102
158	2	58, 157
159	1	71
161	1	105

APPENDIX F

STANDARD INDUSTRIAL CODE

DIVISION D - MANUFACTURING

SIC	Major Group
19	Ordnance and accessories
20	Food and kindred products
21	Tobacco manufacture
22	Textile mill products
23	Apparel and other finished products made from fabrics and similar materials
24	Lumber and wood products, except furniture
25	Furniture and fixtures
26	Paper and allied products
27	Printing, publishing and allied industries
28	Chemicals and allied products
29	Petroleum refining and related industries
30	Rubber and miscellaneous plastics products
31	Leather and leather products
32	Stone, clay and glass products
33	Primary metal industries
34	Fabricated metal products, except ordnance, machinery and transportation equipment

APPENDIX F (contd.)

35	Machinery, except electrical
36	Electrical machinery, equipment and supplies
37	Transportation equipment
38	Professional, scientific, and controlling instruments: photographic & Optical goods, watches and clocks
39	Miscellaneous manufacturing industries

APPENDIX G

THE SIMULATION MODEL: DATA INPUTS AND COMPUTATIONAL CHARACTERISTICS

Data Inputs

Data inputs into the simulation model are of three categories. For convenience, the computer program notations (Appendix H) are used in describing these data inputs

1. Program control parameters. These parameters provide the general controls for the simulation program and they are the first set of data to be read into the program. These control parameters include:

a) NO = the number of origin sub-area i. There are 46 such sub-areas for the time period under consideration in this study. It should be recalled that these sub-areas are determined from observations.

b) ND = number of destination sub-area j. There are 50 of these for the time period under consideration. They are those manufacturing areas where it is possible for a manufacturing plant to be located in the study area as explained in chapter I of this thesis.

c) NP = the number of plants to be located by the model. There are 119 of these plants for the period under consideration.

d) NS = the number of simulation runs. For the test under consideration, NS = 100.

2. Matrix A(I, J) which contains the elements $\hat{a}_j$ relative to each given origin sub-area i. This means that the elements of each ith row of this matrix are measures of attractiveness of the destination sub-areas

(j columns) to a particular origin sub-area i. As mentioned earlier, the elements $\hat{a}_j$ for any given origin are estimated as a linear function of the thirteen variables as expressed by the multiple regression model discussed in chapter IV.

3. A set of vectors including:

a) Vector I(K) containing the origins for the 119 plants to be located.

b) Vector UP(K) containing the elements u_k. These elements are the standard industrial units assigned to the 119 plants to be located.

c) Vector TU(J) containing the elements u_j, that is, the standard industrial units assigned to the 50 destination sub-areas at the beginning of each simulation run. This assignment represents the total vacant industrial space, measured in SIU, estimated to be available to migrating plants at each destination sub-area j over the test period (1966-67) - see Appendix D.

Computational Characteristics.

Four steps in the computational characteristics of the model may be described for a particular simulation run. These steps are described below.

1. Random sampling of a plant k for location. The 119 plants to be located by the model are numbered consecutively from 1 to 119, each number corresponding to each plant. A random number is generated to select any of these plants and the plant selected is the one having the generated random number unless the random number was generated earlier in the particular simulation run being performed. Whenever a generated random number is greater than 119 or has been generated earlier in a particular simulation run, a new random number is generated and this procedure may be repeated

as many times as are necessary to successfully sample a plant k for location.

2. Computations for sampling destination sub-area j to receive the selected plant k. These computations include a) assignment of probabilities to the destination sub-areas j on the basis of their attractiveness relative to the origin i under consideration. Each probability p_j is thus computed as $p_j = \hat{a}_j / \sum_{j=1}^{n} \hat{a}_j$, where there are n j destinations; b) the assignment of random numbers to each destination sub-area in proportion to its probability. This means that in the sampling procedure, the destination sub-areas do not have equal chances of being selected since they vary in their probabilities on the basis of which the random numbers are assigned. To sample a sub-area j, a random number is generated and it is the sub-area j having the generated random number that is sampled. However, before the selected plant k is finally located, the model would compare the space required by the plant (u_k) against the vacant industrial space at the sampled sub-area (u_j). The location can be effected at this point provided that u_j is greater than, or equal to, u_k. Otherwise, another sub-area j is sampled by generating another random number.

3. Adjustment computations following the successful location of a plant k. These computations include simple substractions or additions, for example,

a) removing the located plant from among those remaining to migrate. In this regard, the probability of sampling the located plant is zero, and

b) substracting u_k from u_j to take into account the vacant industrial plant remaining at the receiving sub-area j.

APPENDIX H: THE COMPUTER PROGRAM

```
*STOREDATA   WS   UA    EMAT     48
*ONEWORDINTEGERS
*LIST SOURCE PROGRAM
C   THE COMPUTER PROGRAM FOR SIMULATING PLANT SITE RELOCATION
C   THE PROGRAM IS WRITTEN FOR IBM 1130
       SUBROUTINE VECT(K,NP,ND)
C   THIS SUBROUTINE IS USED TO DETERMINE PROBABILITIES ASSIGNED
C   TO J DESTINATIONS FOR ANY GIVEN ORIGIN I
C   CP(J) = VECTOR CONTAINING SETS OF RANDOM NUMBERS ASSIGNED
C   TO DESTINATIONS FOR ANY GIVEN ORIGIN I
C   ALL OTHER ELEMENTS APPEARING IN THIS SUBROUTINE ARE
C   DEFINED IN THE MAIN PROGRAM
C
       COMMON E(50), I(120), CP(50)
       SUM = 0.0
       DO 10 J = 1, ND
       SUM = SUM+E(J)
    10 CONTINUE
       CP(1) = E(1)/SUM
       L=ND-1
       DO 30 J= 2,L
       CP(J)=CP(J-1)+E(J)/SUM
    30 CONTINUE
       CP(ND) = 1.0001
       RETURN
       END

*STORE       WS   UA    VECT
*IOCS(CARD,1132PRINTER,DISK)
*ONEWORDINTEGERS
*LIST SOURCE PROGRAM
C   PROGRAM TO SIMULATE PLANT SITE RELOCATION - MAIN PROGRAM
C   DATA INPUTS
C   NO = NUMBER OF ORIGIN SUB-AREAS = 46
C   ND = NUMBER OF DESTINATION SUB-AREAS = 50
C   NP = NUMBER OF PLANTS TO BE RELOCATED = 119
C   NS = NUMBER OF SIMULATION RUNS DESIRED = 100
C   UP(K) = STD UNITS OF PLANT K
C   I(K) = ORIGIN OF PLANT K
C   TU(J) = TOTAL STANDARD UNITS AVAILABLE AT J
C   UPA(J) = TOTAL STANDARD UNITS ALLOCATED TO J
C   LND(J) = IDENTIFICATION NUMBER OF DESTINATION SUB-AREA J
```

APPENDIX H contd.

```
C  E(I,J) = MATRIX OF ATTRACTIVENESS OF J GIVEN I
C  IX OR IZ = INPUT PARAMETER FOR RANDU
C OTHER PARAMETERS OF THE SIMULATION PROGRAM
C  NPS(K) = SEQUENCE NUMBER OF PLANT K
C  RTU(J) = TOTAL REMAINING STD. UNITS AVAILABLE AT J
C  YFL = RANDOM NUMBER GENERATED BY RANDU
C  NRE = NUMBER OF PLANTS REMAINING TO BE RELOCATED AFTER
C  EACH SUCCESSFUL RELOCATION
C  UPAS(K,J)= STD. INDUSTRIAL UNITS ALLOCATED TO J ON THE
C  KTH SIMUATION RUN
C  JSUM(K,J) = NUMBER OF PLANTS RELOCATED TO J ON THE KTH
C  SIMULATION RUN
C
      DIMENSION L(120),UP(120),TU(50),UPA(50),
     1RTU(50),LND(50),NSRR(100),UPAS(100, 50), NEWJ(50),
     2JSUM(100, 50),NPS(120)
      COMMON E(50),I(120),CP(50)
      DEFINE FILE 1(46,100,U,IR)
      IX = 10001
      IZ = 30001
      NSS = 0
      NN = 0
      NSR = 0
      NM = 0
C  READ IN CONTROL PARAMETERS
      READ(2,5) NO,ND,NP,NS
    5 FORMAT(4I3)
C  READ IN DATA
      READ(2,10) (UP(K),K=1,NP)
   10 FORMAT(6X,F4.1)
      READ(2,12) (I(K),K=1,NP)
   12 FORMAT(25I3)
      READ(2,15) (LND(J),J=1,ND)
   15 FORMAT(25I3)
      READ(2,16) (TU(J),J=1,ND)
   16 FORMAT(16F5.1)
      IR=1
      DO 444 KK=1,NO
      READ(2,30) (E(J),J=1,ND)
   30 FORMAT(8F10.5)
      WRITE(1'IR) E
  444 CONTINUE
C
C  START SIMULATION
      DO 111 IJK=1,NS
      NRE=NP
      DO 18 J=1,ND
      RTU(J) = TU(J)
   18 CONTINUE
      NN=NN+1
```

```
      NM = NM+1
      NSR =NSR+1
      NSS = NSS+1
      NSRR(IJK) = NSS
C
C     SET ALL L(K) INITIALLY TO 1 AND ASSIGN SEQUENCE NUMBERS TO
C     PLANTS
      L(1) = 1
      NPS(1) = 1
      DO 32 K = 2,NP
      L(K) = 1
      NPS(K) = NPS(K-1) + L(K)
   32 CONTINUE
C     SET UPA(J) TO ZERO AND NEWJ(J) TO ZERO
      DO 33 J=1,ND
      UPA(J) = 0.
      NEWJ(J) = 0
   33 CONTINUE
C     SELECT PLANT K FOR RELOCATION
      PN=NP
  360 CALL RANDU(IX,IY,YFL)
      IX=IY
C     GENERATE ANOTHER RANDOM NUMBER IF YFL IS ZERO
      IF(YFL) 360, 360, 361
C     GENERATE ANOTHER RANDOM NUMBER IF YFL IS GREATER THAN PN, PN=NP
  361 IF(YFL-PN) 362, 362, 360
C     SELECT PLANT K, THAT IS PLANT HAVING GENERATED YFL
  362 DO 363 K = 1, NP
      PSN = NPS(K)
      IF(YFL-PSN) 364, 364, 363
  363 CONTINUE
C     GENERATE ANOTHER RANDOM NUMBER IF PLANT K IS ALREADY RELOCATED,
C     THAT IS, IF L(K) = 0
  364 IF(L(K)) 360, 360, 365
  365 IR = I(K)
      READ(1'IR) E
C     CALL SUBROUTINE VECT TO ASSIGN PROBABILITIES TO J FOR THE
C     GIVEN ORIGIN I
      CALL VECT(K,NP,ND)
C     SELECT J BY GENERATING RANDOM NUMBER YFL AND COMPARING WITH
C     CP(J)
   40 CALL RANDU(IZ,IY,YFL)
      IZ = IY
C     SELECT ANOTHER RANDOM NUMBER IF GENERATED YFL =0
      IF(YFL) 40, 40, 390
  390 DO 50 J=1,ND
      IF(YFL-CP(J)) 55, 55, 50
   50 CONTINUE
C     IF RTU(J) IS LESS THAN UP(K) SELECT ANOTHER J
   55 IF(RTU(J)-UP(K)) 40, 391,391
  391 CONTINUE
```

```
C  INCREASE UPA(J), NEWJ(J) AND DECREASE NRE, RTU(J) AND L(K)
      UPA(J) = UPA(J)+UP(K)
      NEWJ(J) = NEWJ(J) + L(K)
      NRE = NRE - 1
      RTU(J) = RTU(J)-UP(K)
      L(K) = L(K)-1
C  CHECK IF PLANTS REMAIN TO BE RELOCATED
      IF(NRE) 80, 80, 392
 392  GO TO 360
  80  DO 90 J = 1, ND
      UPAS(NM,J) = UPA(J)
      JSUM(NM,J) = NEWJ(J)
  90  CONTINUE
C END OF A SIMULATION RUN
C START A NEW SIMULATION RUN
 111  CONTINUE
C
C END OF ALL SIMULATION RUNS
C OUTPUT OF INDIVIDUAL SIMULATION RUNS MAY BE PRINTED AT THIS
C POINT IF DESIRED
C
C COMPUTE THE AVERAGE OUTCOME OF ALL SIMULATION RUNS AND PRINT
C THE RESULTS
      DO 112 K = 1, ND
      NPR=0
      TUR=0
      DO 113 IJK = 1, NS
      NPR = NPR+JSUM(IJK,K)
      TUR = TUR+UPAS(IJK,K)
 113  CONTINUE
      SSN = NS
      RNP = NPR
      AVEP = RNP/SSN
      AVEU = TUR/SSN
      WRITE(3,117)
 117  FORMAT(3X,'DESTN',1X,'AVE PLANT',1X,'AVE UNIT')
      WRITE(3,114) LND(K),AVEP,AVEU
 114  FORMAT(3X,I5,2F10.2)
 112  CONTINUE
      CALL EXIT
      END
// XEQ
```

BIBLIOGRAPHY

Books

Alonso, William. *Location and Land Use: Toward a General Theory of Land Rent*. Cambridge, Mass.: Harvard University Press, 1964.

Artle, Roland. *The Structure of the Stockholm Economy*. New York: Cornell University Press, 1965.

Chinitz, Benjamin. *Freight and the Metropolis*. Cambridge: Havard University Press, 1960.

Chorley, R. J. and Haggett, Peter (eds.). *Frontiers in Geographical Teaching*. London; England: Methuen and Company Ltd., 1965.

Christ, C. F. *Econometric Models and Methods*. New York: John Wiley and Sons, Inc., 1966.

Christaller, Walter. *Central Places in Southern Germany*, Translated by C. Baskin. Englewood Cliffs: Prentice Hall, 1966.

Draper, N. R. and Smith, H. *Applied Regression Analysis*. New York: John Wiley and Sons Inc., 1966.

Estall, R. C. and Buchanan, R. O. *Industrial Activity and Economic Geography*. London: Hutchinson University Library, 1961.

Forrester, Jay W. *Urban Dynamics*. Cambridge, Massachusetts: The M. I. T. Press, 1969.

Freund, John E. *Modern Elementary Statistics*. 3rd edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1967.

Friedrich, Carl J. (ed.). *Alfred Weber's Theory of the Location of Industries*. Chicago: University of Chicago Press, 1929.

Garrison, W. L. *et. al*. *Studies of Highway Development and Geographic Change*. Seattle: University of Washington Press, 1959.

Greenhut, M. L. *Plant Location in Theory and Practise: The Economy of Space*. Chapel Hill: The University of North Carolina Press, 1956.

Hagerstrand, Torsten. *Innovation Diffusion as a Spatial Process*. Translated and Edited by Alan Pred. Chicago: University of Chicago Press, 1967.

Haig, Robert M. *Major Economic Factors in Metropolitan Growth and Arrangement*. New York: Committee on Regional Plan of New York and its Environs, 1927.

Hammersley, J. M. and Handscomb, D. C. Monte Carlo Methods. London: Methuen and Co. Ltd., 1965.

Hoover, E. M. Location Theory and the Shoe and Leather Industries. Cambridge; Masachusetts: HavardUniversity Press, 1937. 1st reprint, 1968.

_______. The Location of Economic Activity. New York: McGraw Hill Book Company Inc., 1948. paper back edition, 1963.

_______. and Vernon, Raymond. Anatomy of a Metropolis. New York: Garden City, Double Day Anchor, 1962.

Isard, Walter. Location and Space Economy. New York: The M. I. T. and John Wiley and Sons, Inc., 1956.

_______. General Theory: Social, Political, Economic and Regional. Cambridge, Massachustetts: The M. I. T. Press, 1969.

_______, et.al. Methods of Regional Analysis. New York: The M. I. T. and John Wiley and Sons, Inc., 1960.

Johnston, J. Econometric Methods. New York: McGraw Hill Book Co., 1960.

Karaska, G. J. and Bramhall, D. F. Locational Analysis for Manufacturing: A Selection of Readings. Cambridge, Massachusetts: The M. I. T. Press, 1969.

Kemeny, J. G., et.al. Finite Mathematical Structures. New York: Prentice Hall Inc., 1959.

Kendall, Maurice G. and Stuart, Allan. The Advanced Theory of Statistics. Vol. 2. 4th impr. New York: Harner Publishing Co., 1969.

King, Leslie J. Statistical Analysis in Geography. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1969.

Kitagawa, E. M. and Bogue, D. J. Suburbanization of Manufacturing Activity within Standard Metropolitan Areas. Oxford: Scripps Foundation for Research in Population Problems and the Population Research Training Centre, 1955.

Klein, L. R. A Textbook of Econometrics. Evanston: Row Peterson and Co., 1953.

Koopmans, T. (ed.). Statistical Inference in Dynamic Economic Model. New York: John Wiley and Sons, Ltd., 1950.

Losch, August. The Economics of Location. New Haven: Yale University Press, 1954.

Pred, Alan R. Behavior and Location. Part I. Lund Series in Geography, 1967.

Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw Hill Book Co., Inc., 1956.

Simon, Herbert A. Models of Man. New York: John Wiley and Sons, Inc., 1957.

Spiegel, Murray R. Theory and Problems of Statistics. Schaum's Outline Series. New York: McGraw Hill Book Co., 1961.

Von Thunen, Johann Henrich. Von Thunen's Isolated State. Edited by Peter Hall. Translated by Carla M. Wartenberg. London: Pergamon Press Ltd., 1966.

Walker, Helen M. and Lev, Joseph. Statistical Inference. New York: Holt, Rinehart and Winston, 1953.

Articles, Periodicals and Monographs

Alchian, Armen A. "Uncertainty, Evolution and Economic Theory," Journal of Political Economy, LVIII (June, 1950), 211-21.

Alonso, William. "A Reformulation of Classical Theory and Its Relation to Rent Theory," Regional Science Association: Papers and Proceedings, 19 (1967), 23-44.

Barloon, Marvin J. "The Interrelationship of the Changing Structure of American Transportation and Changes in Industrial Location," Land Economics, 41 (1965) 169-79.

Berry, B. J. L., et. al. Commercial Structure and Commercial Blight. Research Paper, 85. Chicago: University of Chicago, Department of Geography, 1963.

Blalock, Jr. H. M. "Correlated Independent Variables: The Problem of Multicollinearity," Social Forces, 42 (1963), 233-37.

Britton, John N. H. "A Geographical Approach to the Examination of Industrial Linkages," The Canadian Geographer, XIII (1969), 3, 185-98.

Brown, Lawrence A. Diffusion Processes and Location. Bibliographic Series, No. 4. Regional Science Research Institute, 1968.

Burton, Ian. "The Quantitative Revolution and Theoretical Geography," Spatial Analysis. edited by B. J. L. Berry and D. F. Marble. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968, 13-23.

Carrothers, Gerald A. P. "An Historical Review of the Gravity Potential Concepts of Human Interaction," *Journal of the American Institute of Planners*, XXII (1956), 94-102.

Casetti, E. and Semple, R. K. "Concerning the Testing of Spatial Diffusion Hypotheses," *Geographical Analysis*, I (1969), 3, 254-59.

Chapin, Jr. F. Stuart. "A Model for Simulating Residential Development," *Journal of the American Institute of Planners* (May, 1965), 2, 120-25.

Chinitz, Benjamin. "The Effect of Transportation Forms on Regional Economic Growth, *Traffic Quarterly*, 14 (1960), 129-42.

Cliff, A. D. "The Neighbourhood Effect in the Diffusion of Innovations," *Institute of British Geographers*, XLIV (May, 1968), 75-84.

Colenutt, Robert J. "Linear Diffusion in an Urban Setting: An Example," *Geographical Analysis*, I (1969), 1, 106-114.

Collins, Lyndhurst. "Market Potential and Economic Shadow: A Critique," *The Canadian Geographer*, XI (1967), 3, 180-82.

________. *Markov Chains and Geographical Applications.* A paper prepared for the International Geographical Union Commission on Quantitative Methods. September, 1970.

Donnelly, Thomas C., Chapin, Jr. F. Stuart and Weiss, Shirley F. *A Probabilistic Model for Residential Growth.* Institute for Research in Social Science: University of North Carolina (1964).

Fuchs, Victor R. "Statistical Explanations of the Relative Shift of Manufacturing Among Regions in the United States," *Regional Science Association: Papers and Proceedings*, VIII (1962), 105-126.

________. "The Determinants of the Redistribution of Manufacturing in the United States since 1929," *The Review of Economics and Statistics*, 44 (1962), 167-77.

Griliches, Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, XXV (1957), 501-22.

Hagerstrand, Torsten. "A Monte Carlo Approach to Diffusion," *Spatial Analysis.* edited by B. J. L. Berry and D. F. Marble. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1968, 368-84.

Harris, C. D. "Market as a Factor in the Localization of Industry in the United States," *Association of American Geographers: Annals*, XLIV (Dec., 1954), 315-55.

Ian Hamilton, F. E. "Models of Industrial Location," in *Socio-Economic Models in Geography.* edited by R. J. Chorley and Peter Haggett. London, England: Methuen and Co. Ltd., 1967.

Karaska, Gerald J. "Manufacturing Linkages in the Philadelphia Economy," *Geographical Analysis*, I (1969), 4, 354-69.

Keeble, D. E. "Industrial Migration from North-West London, 1940-64," *Urban Studies*, 2 (1965), 15-32.

________. "Industrial Decentralization and the Metropolis: the North-West London Case," *Institute of British Geographers*: *Transactions* 44 (1968), 1-54.

Kerr, Donald and Spelt, Jacob. "Manufacturing in Suburban Toronto," *Canadian Geographer*, XII (1958), 11-19.

________. "Manufacturing in Downtown Toronto," *Geographical Bulletin*, X (1967), 4-20.

Latham, Robert F. and Yeates, Maurice H., "Population Density Growth in Metropolitan Toronto," Geographical Analysis, 2 (April, 1970), 2, 177-85.

Linge, G. J. R. "The Diffusion of Manufacturing in Auckland, New Zealand," *Economic Geography*, XXXIX (1963), 23-39.

Logan, M. I. "Manufacturing Decentralization in the Sydney Metropolitan Area," *Economic Geography*, XL (1964), 151-62.

________. "Suburban Manufacturing: A Case Study," *The Australian Geographer*, IX (Sept., 1964), 4, 223-34.

Lowry, Ira S. "A Short Course in Model Design," *Journal of the American Institute of Planners* (May, 1965), 2, 158-165.

Manners, Gerald. "Decentralization in Metropolitan Boston," *Geography*, XLV (1960), 276-85.

McGovern, P. D. "Industrial Development in the Vancouver Area," *Economic Geography*, XXXVII (July, 1961), 3, 189-206.

Morrill, Richard L. "The Distribution of Migration Distances," *Regional Science Association*: *Papers and Proceedings* (1963), 11, 75-84.

________. and Pitts, Forrest. "Marriage, Migration and the Mean Information Field: A Study in Uniqueness and Generality," *Association of American Geographers*: Annals, LVII (1967), 401-22.

Moses, Leon and Williamson, Jr. Harold F. "The Location of Economic Activity in Cities," *American Economic Review*, 57 (1967), 211-221.

Muncy, Dorothy. *Space for Industry: An Analysis of Site and Location Requirements*, Technical Bulletin, No. 23. Urban Land Institute, July, 1954.

Nystuen, John D. "A Theory and Simulation of Intra-urban Travel," Quantitative Geography, Part I: Economic and Cultural Topics. edited by W. L. Garrison and D. F. Marble. Northwestern University, Department of Geography, 1967, 54-83.

Olsson, Gunnar and Cale, Stephen. "Spatial Theory and Human Behavior," a paper presented at the Meeting of the Regional Science Association, Cambridge, Massachusetts (Nov., 1967).

Parr, John.B. and Denike, Kenneth G. "Theoretical Problems in Central Place Analysis," Economic Geography, 46 (1970), 4, 568-586.

Pred, Allan R. "The Intrametropolitan Location of American Manufacturing," Association of American Geographers: Annals, LIV (June, 1964), 2, 165-80.

Putnam, Stephen H. " Intra-Urban Industrial Location Model: Design and Implementation," Regional Science Association: Papers and Proceedings, XIX (1967), 199-214.

Quandt, Richard E. "Statistical Discrimination among Alternative Hypotheses and some Economic Regularities," Journal of Regional Science, V (1964), 2, 1-23.

Reed, Harry. A Dual Approach to the Locational Aspects of Manufacturing in Kitchener. A Discussion Paper. Waterloo: University of Waterloo, Department of Geography and Planning, March, 1967.

Renner, George T. "Geography of Industrial Localization," Economic Geography, XXIII (1947), 167-89.

Robinson, Ira M., Wolfe, Harry B. and Barringer, R. L. "A Simulation Model for Renewal Programmings," Journal of the Institute of American Planners (May, 1965), 2. 126-33.

Rodgers, A. "Some Aspects of Industrial Diversification in the United States," Economic Geography, XXXIII (January, 1957), 16-30.

Ryan, Bryce and Gross, N. C. "The Diffusion of Hybrid Seed Corn in Two Iowa Communities," Rural Sociology, VIII (1943), 1, 15-24.

Seidman, David R. Report on the Activities Allocation Model. Penn Jersey Transportation Study, Nov. 1964.

Seyfried, W. R. "The Centrality of Urban Land Values," Land Economics (1963), 39, 275-85.

Smith, David M. and Lee, Tso-Hwa. A Programmed Model for Industrial Location Analysis. Department of Geography, Southern Illinois University, April, 1970.

Steger, Wilbur A. "The Pittsburgh Urban Renewal Simulation Model," *Journal of the American Institute of Planners* (May, 1965), 2, 144-50.

Stevens, Benjamin H., and Brackett, Carolyn A. *Industrial Location*. Bibliographic Series, No. 3. Regional Science Research Institute (1967).

Stouffer, S. A. "Intervening Opportunities: A Theory Relating Mobility and Distance, "*American Sociological Review*, 5 (Dec., 1940), 845-67.

Swamy, P. A. V. B. "Efficient Inference in a Random Coefficient Regression Model," *Econometrica*, 38 (March, 1970), 2, 311-323.

Thompson, John H. "A New Method for Measuring Manufacturing," *Association of American Geographers*: Annals, XLV (1955), 422-23.

Tiebout, C. M. "Location Theory, Empirical Evidence and Economic Evolution," *Regional Science Association*: *Papers and Proceedings*, III (1957), 74-86.

Vernon, Raymond. "Production and Distribution in the large Metropolis," *Annals of the American Academy of Political and Social Sciences*, 314 (1957), 15-29.

Wills, Marshall T. "A Study of Speculative Industrial Buildings (SIB) in the Eastern United States," *American Industrial Development Council*, I (January, 1966), 1, 27-54.

Wolpert, J. "The Decision Making in the Spatial Context," *Association of American Geographers*: *Annals*, LIV (1964), 537-58.

________. "Behavioral Aspects of the Decision to Migrate," *Regional Science Association*: *Papers and Proceedings*, XV (1965), 159-69.

________. "A Regional Simulation Model of Information Diffusion," *Public Opinion Quarterly*, XXX (1966), 1, 27-54.

Wrigley, Jr. Robert L. "Organized Industrial District," in *Readings in Urban Geography*. edited by Mayer and Kohn. Chicago: University of Chicago Press (1959), 475-95.

Yeates, M. "Some Factors Affecting the Spatial Distribution of Chicago Land Values, 1910-60," *Economic Geography* (1965), 41, 57-70.

Zelinsky, Wilbur. "A Method for Measuring Change in the Distribution of Manufacturing Activity: The United States, 1939-47, "*Economic Geography*, XXXIV (1958), 2, 95-126.

Government Agency-Sponsored Research

Anderson, David L. *Three Computer Programs For Contiguity Measures.* Technical Report No. 5 of ONR Task No. 389-140. Contract NONR 1228 (33). Department of Geography, Northwestern University, 1965.

Dacey, M. F. *A Review on Measures of Contiguity for Two and K - Color Maps.* Technical Report No. 2 of ONR Task No. 389-140. Contract NONR 1228 (33). Department of Geography, Northwestern University, 1965.

George, Roy E. *The Attraction of Quebec and Ontario for New Manufacturing Industries.* Social Science Research Council of Canada, August, 1966.

Hoyt, Homer. *The Structure and Growth of Residential Neighbourhoods in American Cities.* Washington: Government Printing Office, 1939.

Kerr, Donald and Spelt, Jacob. *Industry and Warehousing in the City of Toronto.* City of Toronto Planning Board, April, 1961.

________. *The Changing Face of Toronto.* Ottawa: Department of Mines and Technical Survey, 1965.

________. *Industrial Prospects in the City of Toronto.* City of Toronto Planning Board, June, 1965.

McGregor, John R. *Manufacturing Linkages Within the Kane County Area.* Geneva; Illinois: KaneCounty Planning Department, 1967.

Metro Toronto and Region Transportation Study. *Growth and Travel: Past and Present*, April, 1966; *Transportation for the Regional Study*, November, 1967; and *Choices for a Growing Region*, November, 1967.

Mills, J. C. *Industrial Location with Special Reference to the Atlantic Provinces.* Atlantic Provinces Research Board, 1967.

Noyes Development Corporation. *Investment and Plant Location in Canada.* Plant Location Study, 3, 1965.

Ray, D. M. *Regional Aspects of Foreign Ownership of Manufactuing in Canada.* University of Waterloo, 1967.

Ray, D. M., *et. al.* *The Socio-Economic Dimensions and Spatial Structure of Canadian Cities.* A C.M.H.C. Project. Waterloo: University of Waterloo, Summer, 1968.

________. *The Spatial Structure of the Canadian Economy.* A CCURR Project Waterloo: University of Waterloo, Summer, 1968.

Sinclair, A.M. *The Economic Base of the Halifax Metropolitan Area.* Halifax: Dalhousie University, 1961.

Government Documents

Canada. Dominion Bureau of Statistics. Census of Canada, 1966. Vol. 1. 1-16, March, 1968.

Canada. Dominion Bureau of Statistics. Census of Canada, 1966. Bulletin c-20, October, 1968.

Ontario. Department of Trade and Industry. Ontario Industrial Review, 1964, 1965, 1966, 1967.

Ontario. The Hydro Electric Power of Ontario. Annual Reports for the Years 1965 and 1966.

Metro Toronto. Goldenberg, Carl H. Report of the Royal Commission on Metropolitan Toronto. Toronto, June, 1965.

Metro Toronto. Metro Toronto Industrial Commission. District News Letters. 1962, 1963, 1964, 1965, 1966, 1967.

Metro Toronto. Municipal Assessment Department. Records of Commercial Mill Rates, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967.

Metro Toronto. Data Extracted from Municipal Assessment Records, 1964, 1965, 1966, 1967.

Metro Toronto. Metro Toronto Planning Board. Official Plan of the Metropolitan Toronto Planning Area: Supplement, 1965.

Metro Toronto. Metro Toronto Planning Board. Metropolitan Plan Review. Report No. 1: Existing Land Use, 1966, May, 1968.

Metro Toronto. Metro Toronto Real Estate Board. Records of Industrial Building Permits according to Municipalities, 1964, 1965, 1966, 1967.

East York. Borough of East York. Consolidation of Zoning By-Law. No. 6752, as ammended up to 1968, May, 1968.

Etobicoke. Borough of Etobicoke. Comprehensive Zoning By-Law, including ammendments up to 1966, 1967.

Leaside. Town of Leaside. By-Law No. 1916, December, 1966, Section 8:1:2.

Scarborough. Municipality of the Township of Scarborough. By-Law No. 12096. Schedule B, February 3, 1969.

Scarborough. Scarborough Planning Board. Industrial Planning, April, 1966.

Toronto. City of Toronto Planning Department. Single Line Listings, 1966.

Toronto. The City of Toronto. Zoning System: A Representative List of Permissible Uses - Commercial and Industrial Districts.

Theses

Bourne, Larry S. Private Redevelopment of the Central City of Toronto: spatial processes of structural change in the City of Toronto. Published Ph.D. Thesis. Chicago: University of Chicago, 1967.

Collins, Lyndhurst. Industrial Migration and Relocation: A Study of European Branch Plants with Special Reference to Metropolitan Toronto. M.A. Thesis. Toronto: University of Toronto, 1966.

_______. Markov Chains and Industrial Migration: Forecasting Aspects of Industrial Activity in Ontario. Ph.D. Thesis. Toronto: University of Toronto, 1970.

Kenyon, J. B. Industrial Localization and Metropolitan Growth: The Paterson-Passaic District. Published Ph.D. Thesis. Chicago: University of Chicago, 1960.

Liddle, David B. The Intrametropolitan Location of Manufacturing and the Industrial Land Market: A Case Study of the Toronto Region. M.A. Thesis. Toronto: University of Toronto, 1968.

Murdie, R.A. The Factoral Ecology of Metropolitan Toronto, 1951-61: an essay on the social geography of the city. Published Ph.D. Thesis. Chicago: University of Chicago, 1969.

Ray, D.M. Market Potential and Economic Shadow: a statistical analysis of manufacturing location in southern Ontario. Published Ph.D. Thesis. Chicago: University of Chicago, 1965.

Zolzman, David M. Waterway Industrial Sites: A Chicago Case Study. Published Ph.D. Thesis. Chicago: University of Chicago, 1966.

Other Sources

Financial Times of Canada. Industrial Location. Montreal, June, 1968.

Lockwood Survey Corporation Ltd. Aerial Photograph of Metropolitan Toronto. Scale: 1 inch to 2,640 feet, 1965.

Scott's Directory of Ontario Industry. Editions: 1958-59, 1960-61, 1962-63, 1964-65, 1966-67.

Teela Market Surveys Ltd. Records of Property Sale Transactions in Metro Toronto. Years: 1961, 1962, 1963, 1964, 1965, 1966, 1967.

University of Toronto. Department of Geography. Economic Atlas of Ontario, 1969.