THE PATTERN AND PROCESS OF REDEVELOPMENT: AN EMPIRICAL APPLICATION OF A REDEVELOPMENT SIMULATION MODEL TO KITCHENER, ONTARIO

By

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ABSTRACT

This thesis is an attempt to develop a more comprehensive understanding of the pattern and process of redevelopment through modelling. Conceptually, redevelopment is viewed as a process consisting of a series of individual events related in space and time. The location of redevelopment is influenced by both the relative ability of sites to attract it, as determined by their physical and locational attributes, and chance factors. Based on this conceptual framework, a stochastic simulation model of redevelopment is developed. It is applied to the core area of Kitchener, Ontario and produces a ten-year forecast (1980 - 1989) of the spatio-temporal pattern of redevelopment therein.

Analysis of the model output indicates that, as of 1980, the sites with the highest redevelopment potential are concentrated in the eastern core. If past trends continue, redevelopment in the early 1980's will occur primarily on the eastern core periphery. However, by the latter half of the decade, the location of redevelopment will have shifted to western core sites, ignoring those in between.

The contribution of this research to the geographic literature is three-fold. Its detailed analysis of redevelopment is a significant supplement to the few existing studies of such an important urban phenomenon. The applicability of the logit model as an alternative functional form in regression analysis under certain conditions is revealed. Finally, the ability of the model to operationalize change and to incorporate a spatio-temporal shift in redevelopment location demonstrates the utility of the simulation approach in dynamic urban modelling.

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CHAPTER ONE

INTRODUCTION

The city is a dynamic and complex system. Its multitude of interacting elements and structural relations are in constant flux, continually adjusting and adapting to changing pressures exerted on them by a gradually evolving society. The processes of adjustment incorporate many different forms and occur at various rates. Their diversity and undeniable impact on the city have stimulated the interest and curiosity of scores of urban geographers, economists, and sociologists. Their inherent complexity, however, has thwarted efforts to gain a comprehensive understanding of them in their entirety. Most urban scholars attempt to isolate one of the many adjustment processes and concentrate their efforts on it alone.

One such process is that of urban land use change. Urban land use change involves the continual accomodation of fixed urban capital and urban activities to the supply and demand conditions, respectively, imposed by each on the other. For present purposes fixed urban capital shall be restricted to buildings whereas urban activities include commercial, industrial, institutional, and residential land uses. There must be a measure of correspondence between these two related elements of urban structure because buildings provide the physical space in which the urban population engages in their various activities (Bourne, 1967). Through time buildings must be adjusted to accomodate the changing space and location demands of urban activities and urban activities must adapt to the space supplied by buildings. Thus a mutual adjustment process is the mechanism whereby a tendency toward a balance between urban space supply and demand is maintained.

A city-wide equilibrium is never attained so the process of adjustment continues perpetually. Constant maladjustment in the location, quantity, or quality of space (henceforth floorspace as buildings are of prime concern) stems from certain innate characteristics of both buildings and urban activities and their consequent tendency and capacity for change. Although urban activities are relatively mobile and can counteract the fixity of buildings, the rate of change of the fluid and malleable floorspace demands of urban activities can never be matched by the rate of adjustment of durable buildngs. Therefore, it is the adaptation of urban floorspace supply, as provided by buildings, to the floorspace demand of urban activities (rather than vice versa) that is of interest in this thesis because it involves a greater potential for disequilibrium at any given point in time or space. Identified with this facet of urban land use change are significant urban problems and inefficiencies.

Despite being only one of many urban adjustment processes, urban land use change is a very complex spatial phenomenon. Bourne (1976b) identifies four separate but interrelated components of it in an empirical investigation of Toronto. One of the dominant components was labelled 'Renewal'. According to Bourne's classification, 'Renewal' consists of the growth of the urban core including the expansion and replication of core land uses as well as the replacement or rejuvenation of the elements of the existing core area. It is on one sub-component of urban core growth, the replacement of existing buildings or the redevelopment process, that this thesis will focus.

1.1 The Concept of Redevelopment

In the literature, the term redevelopment is used to refer to two related concepts: 1) any re-use of urban land subsequent to the initial rural-urban conversion, and 2) the actual demolition and replacement of existing buildings

(Bourne, 1967). The former concept implicitly incorporates land use succession. Even though some urban economists equate the terms redevelopment and succession (Clapp, 1977; Heilbrun, 1976; Ratcliff, 1961), the latter term usually refers only to the relocation or migration of activities. Earlier it was mentionned that this facet of urban land use change is not of interest here. In this thesis, therefore, redevelopment is only used in the context of the physical demolition of existing buildings and the replacement thereof by the erection of new buildings.

From the perspective of an individual site or plot of land, redevelopment is an event discrete in both time and space. The demolition and replacement of a building on a given site takes place at one point in time and then does not usually reoccur for several decades at least. Since sites are separate spatial entities, defined as such by the legal right of land ownership, the replacement of a building on one site is spatially distinct from a similar action on another. It is because of the building situated on it that a site is referred to as developed. When an existing building is demolished and a new one constructed, the site is said to have been redeveloped.

From the perspective of the entire city, redevelopment is a spatio-temporal process. It exhibits a discernible pattern in space that evolves through time. The process consists of a spatially and temporally linked series of individual redevelopment events. The rejuvenation of the entire urban building inventory is the sum total of the replacement of individual buildings at various unique locations at many different times.

Theoretically, the redevelopment process is continuous in both space and time. Redevelopment differs from development in that it involves the replacement of existing buildings rather than the construction of new buildings during the initial rural-urban conversion. Both redevelopment and development, however, can be considered complementary segments of the urban growth process. As such they form a spatial continuum from redevelopment in the core to development on the periphery (Bourne, 1967). The proportion of redevelopment to development is relatively high in the city center decreasing gradually away from it with declining building ages and increasing amounts of available, unused urban land.

In a temporal context, the redevelopment process continually replaces old, deteriorated, obsolete buildings at the end of their of their physical or economic lifespans with new ones. Once all buildings constructed in a given time period have been replaced those built in the following period undergo the same treatment. Eventually all existing buildings will have been replaced and the cycle recommences.

In reality, the redevelopment process is spatially and temporally discontinuous. Differential deterioration and obsolescence rates of buildings, differing locational advantages of sites and many other diverse factors impede its steady progress. Despite the lack of spatio-temporal continuity, the redevelopment process exerts a significant influence on both urban morphology and the urban economy.

1.2 The Urban Impact and Significance of Redevelopment

The impact of redevelopment on the city is substantial and cannot be denied. It is "the mechanism by which cities are rebuilt" (Bourne, 1976b, p. 183). The efficiency, vitality, and future form of the city depend on the regenerative capacity of the redevelopment process.

Because they are complementary components of urban structure, the supply of floorspace provided by buildings and the demand for it by activities must match each other to some extent. The degree of fit between them reflects the efficiency of the urban economy because a lack of fit produces unused or underutilized buildings and contributes to activities being forced into unprofitable operation levels or poor locations; all of which are inefficient. Thus the process by which floorspace supply and demand are reconciled partially determines how well the urban economy functions.

According to Smith (1975), replacement investment is very important to the maintenance of urban living standards. During times of economic growth, not only must losses to natural hazards and to natural aging and obsolescence processes be covered, but upgrading of the urban inventory must take place for urban living standards to even remain stable. Since redevelopment represents a major percentage of replacement investment, it is crucial to the sustenance of urban opportunities.

The vitality of the city can in some ways be measured by the very existence of redevelopment. The visual impact of a new building is obvious. In addition to the aesthetic gain there is the symbolic significance of the replacement of the old with the new. The city is perceived as being vibrant and alive.

Besides these aesthetic and symbolic benefits, investment in redevelopment generates both direct and indirect economic benefits. In terms of employment, for example, the numbers employed by the construction industry swell during the demolition and construction stages. The wages received circulate through the urban economy and stimulate it. Future employment for the city's residents is promised in the activities that the new building will house. And since redevelopment usually involves an increased intensity of land usage (Bourne, 1967), it also means a real increase in the level of urban employment. Furthermore, whether the firms destined to occupy the new building are new to the city or are previous residents, the fact that they plan to locate there reflects their satisfaction with the current socioeconomic environment of that city.

Of course the effects of redevelopment are not all of a beneficial nature. Redevelopment generates externalities that are a real cost to urban dwellers and businesses (Alexander, 1974). Undesireable products of the construction activity include noise and air pollution, congestion, and an increased demand on existing transportation and utilities networks. Furthermore, the removal of buildings may put displaced activities out of business unless they are able to relocate in close proximity to their previous location. It may also cause the erosion of the social character of an area by removing a part of the milieu that made it unique. Nevertheless, redevelopment relentlessly reshapes urban structure.

Bourne (1967) claims redevelopment is the major way in which the existing elements of urban form are altered. Although the actual number of buildings replaced per year is relatively small, the average amount of investment, in dollar terms, represented by a new building is phenomenal. Figures in the million and multi-million dollar range are not uncommon. A building represents a great time investment as well. The initial investment decision, the site selection process, financial arrangements, and demolition and construction activities are very time consuming and in aggregate may require two to five years or more.

Because of the amount of money and time invested in it, redevelopment indicates commitment. Commitment on the part of the development agent, whether it be a land development firm, a financial institution, or a private individual to the future of the city. Buildings have an inherent permanence. They are characterized by immoblity and durability (Shafer, 1975). A building is vulnerable to the characteristics of the physical and socioeconomic environment surrounding it for a long period of time, and it is costly and time consuming to replace. By engaging in redevelopment the development agent indicates that it has analyzed the socioeconomic future of the city and has expectations of a profitable future there. This is probably the greatest significance of redevelopment to the city. It expresses and reflects long term patterns and trends. Redevelopment not only signifies the current health of the city, it also is indicative of the future status of it.

1.3 Thesis Rationale

Ironically, despite being the subject of widespread concern of planners and politicians because of its urban impact and significance, relatively little academic attention has been paid to the redevelopment process, especially by urban geographers (Bourne, 1978; Ledent, 1976). It is not that they have ignored urban dynamics altogether. It is just that traditionally only the migration of activities and populations or land use pattern changes have been considered as urban change (Bourne, 1969). Change in the inventory of buildings has been largely disregarded. Bourne attempted to remedy this oversight with his classical study of the nature and pattern of redevelopment in Toronto (1967) and his series of papers thereafter (1978; 1976a; 1976b; 1974; 1971; 1970; 1969). Despite his efforts little published work has followed. Lewis et al. (1974) developed a decision-based simulation model of redevelopment and Alexander (1974) applied a redevelopment forecasting model to the Covent Gardens area in London. In a theoretical paper, Clapp (1977) examined how redevelopment decisions are affected by uncertainty and risk. Some of the recent theoretical models of urban growth and land use, while not specifically focusing on redevelopment, have at least recognized the re-use of urban land and the non-malleability of floorspace (Breuckner and von Rabenau 1981; Breuckner, 1980; Anas, 1978; Muth, 1973). Real estate economists have acknowledged the replacement of buildings but their treatment of it is cursory and aspatial (Balchin and Kieve, 1977; Shafer, 1975; Smith, 1975; Cooper, 1974; Dorau and Hinman, 1969).

One can only speculate as to the reasons for the paucity of redevelopment research. Bourne (1971) suggests the answer lies in the complexity of the urban real estate market and the lack of disaggregate data. Admittedly both these factors can serve to intimidate anyone attempting to begin research. They do not, however, provide justification for ignoring the redevelopment process in light of its enormous influence on the city.

Buildings shape and constrain the activity patterns of every urban resident and function. They are an integral component of the urban system. Their demolition and replacement is "an ancient and basic process by which the urban structure ... moves to adjust itself to the everchanging needs of the community" (Ratcliff, 1949, p. 427). Redevelopment is the process on which the future growth and form of the city is largely dependent. It is indicative of future long term patterns and trends and represents "a summation of a complex array of factors acting to alter the spatial structure of the city" (Bourne, 1969, p. 184). Urban geographers would possess keener insight into the nature of the dynamics of urban spatial structure if they obtained a better, more complete understanding of the redevelopment process. Such knowledge would also aid urban planners for if they aim to manipulate existing processes in order to reach certain predetermined goals, the better the understanding of the processes involved, the more successful they will be (Cowan, 1969). For these reasons the research reported here was carried out.

1.4 Thesis Purpose, Scope and Objectives

The aim of the thesis is to develop a model of the redevelopment process. The purpose of the modelling effort is to: 1) develop a fuller, more comprehensive understanding of the nature and pattern of the redevelopment process by integrating several currently disparate concepts, and 2) test that understanding by facilitating the prediction or forecasting of future spatio-temporal patterns of redevelopment in an empirical application.

The difficulty of forecasting patterns of redevelopment, stemming from the discontinuity of the process in both space and time, has been noted by Alexander (1974). It is felt, however; that by making certain simplifying assumptions and by limiting the time span over which the forecast is made, future redevelopment patterns that are acceptable in terms of what is known and understood about it can be identified. Thus the forecast period will be only ten years. Furthermore, it is assumed that during those ten years there will be no parametric shifts in social and economic structural relations, i.e., there will be no change in societal values,, technological levels, or decision rules which would alter the 'laws' governing the redevelopment process (Kibel, 1972). The latter condition makes the forecast a projection in the sense of Harris (1965) in that it is a prediction which assumes a continuation of present influences.

One basic restriction put on the term redevelopment is that it is used to refer only to building demolition and replacement by private development agents. Henceforth, the terms urban renewal and revitalization are reserved for building conversion and replacement in which public (government or quasi-government agencies) or institutional (churches, school boards and other non-profit organizations) agents are actively involved. Admittedly there is often a fine line between redevelopment and urban renewal because public agents are necessarily involved in aa adjustments to urban form. Perhaps for this reason the two terms have been used interchangeably in the past (for example Woodbury, 1953). For definition purposes, a building will be considered a product of urban renewal if there is any financial involvement by a public or institutional agent, short of floorspace leasing arrangements.

The reason for differentiation between redevelopment and urban renewal is ease of prediction. In order to forecast anything there has to be some regulatory force or rationale that to some extent controls future outcomes. The 'guiding hand' in the land development industry, as in many other economic activities, is the profit motive. The profit motive, for all intents and purposes, makes private development agents behave rationally to the extent that their future actions can, to a certain degree, be predicted. On the other hand, public and institutional agents are not regulated in the same manner. The behaviour of public agents is influenced by such considerations as the public interest and politics. This can and does lead to unpredictable actions. Institutional agents are definitionally non-profit oriented. In fact, they may attach some non-economic sentimental, religious, or historic value to a building and actively resist redevelopment even if it is economically justified. The demolition and replacement of buildings by non-private agents is, therefore, excluded from this analysis; not a significant omission as the prime instigators of building replacement are private development agents (Bourne, 1976a).

It was mentionned earlier that redevelopment can be examined as an event and a process. To do so involves studying it at both disaggregate and aggregate spatial levels. Unfortunately there are two problems with working at a disaggregate scale in this context. They are the availability of data and the sheer quantity of it. This may sound contradictory but it is not. In most cases, detailed data for many of the characteristics of individual sites and buildings thereon do not exist or are not available for inspection. If data do exist, it is usually for only one period in time. Studying urban processes requires change data or data recorded at many different time points. Incidently, this is also a problem when working at a more aggregate spatial scale. Because of these defficiencies the use of surrogate measures for which data are available is necessitated. If the data are collected for several variables for each individual site, even for a relatively small area of a medium-sized city, the resulting data matix is quite large. Time constraints on data collection and manipulation then become a sizeable problem. To some extent, a personal knowledge of the study area can alleviate these aforementionned problems.

For the above reasons, the core area of Kitchener, Ontario was chosen for the study area. Kitchener is a medium-sized city with a population of 136,000 as of 1979. The city is large enough to attract a significant amount of redevelopment while possessing a core area that is small enough, in terms of the scope of the thesis, to be studied at the individual site level. Attention is focused solely on the core area for the above data considerations and because theory and empirical investigation indicate a very large percentage of all redevelopment in the city occurs therein. The specific boundaries of the study area will be defined later.

There will be no differentiation between the types of land use activities involved in redevelopment in the study. Since Kitchener experiences a significant but certainly not an overly abundant number of redevelopment events each year in its core area, the data matrix of past redevelopment is rendered inadequate if redevelopment involving only one building type were included. Any forecast of the amount or location of redevelopment will not make any reference to the type of building being replaced or built. Neither will there be any reference to the scale of construction. The type and scale of the new building are not particularly interesting subjects to forecast because they are both determined to a large degree by the land use controls in effect at any given location. These qualifications are not especially constraining because redevelopment usually involves an increased land use intensity and occurs primarily in the city center. The result is a certain similarity between newly constructed buildings. They are similar in that they are revenue-generating real estate and they exhibit a relatively narrow range of difference in the size of the investment required. Typically these buildings are office towers, commercial premises, or highrise apartments. The trend toward multiple use buildings which house a combination of office, commercial, and residential activities serves to make new buidings even more homogeneous (Witherspoon, 1976).

The principal objectives of the thesis, then, are the following:

1) To outline in detail the significant elements of the redevelopment process, paying special attention to the factors influencing the location of redevelopment events and the spatio-temporal links between them;

2) To analyze and evaluate previous attempts to model redevelopment or to incorporate floorspace supply and demand, and to determine a modelling approach that appears promising and productive in terms of the special nature of the redevelopment process;

3) To outline a conceptual model of redevelopment that will provide the theoretical base on which an operational model can be built;

4) To create an operational model of redevelopment that produces a forecast of likely spatio-temporal patterns of redevelopment.

The second and third chapters review the existing redevelopment literature, both theoretical and empirical, summarizing what is known about redevelopment and identifying strengths and weaknesses of selected attempts to model it. An introduction to Kitchener, its core area, and past redevelopment therein is provided in Chapter 4. Chapter 5 presents the conceptual model of redevelopment and describes the structure and operation of the simulation model. The sixth chapter contains the analysis of the output of the model, i.e., forecasted patterns of redevelopment in Kitchener's core area. A summary of the research together with the conclusions that can be drawn from it are the concern of the seventh and final chapter.

CHAPTER TWO

SYNOPSIS OF REDEVELOPMENT

2.1 Introduction

Models are selective approximations of reality (Chorley and Haggett, 1968). Modelling, therefore, is a subjective task and requires informed judgement on the part of the modeller. Bracken (1978) maintains it is as important to decide what elements to exclude from a model as to decide which ones to include. Thus the initial modelling step is to describe and summarize the pertinent features and relationships of the phenomenon of interest. Such a synopsis of redevelopment is presented below.

The chapter is organized in the following manner. Initially the evolution of urban floorspace supply and demand is described providing the background rationale for redevelopment. Then the factors determining when the redevelopment of a site is feasible are examined. Subsequently the factors that influence the redevelopment potential of a site relative to all other sites at any given point in time are reviewed. Attention is then switched to two concepts that spatially and temporally link the series of redevelopment events in a spatio-temporal process. An examination of the factors underlying the temporal variation in the number of redevelopment events in a city completes the chapter.

2.2 Urban Real Estate Market Dynamics

The demand for urban floorspace by urban activities and the supply of it as provided by the urban building inventory are constantly changing. The changes experienced, however, are divergent rather than convergent. In other words, the supply of floorspace becomes increasingly unsuitable for the new demands put on it by urban activities. An adaptation process is required to remedy the maladjustment. Urban floorspace as contained in the building inventory must be continually adjusted in response to changing urban socioeconomic needs. Many demand changes can be accomodated within existing buildings. Eventually, however, the disequilibrium becomes severe enough at a given location that redevelopment is required.

Real estate maladjustment results from a combination of three factors: 1) the fluidity and malleability of floorspace demand and its propensity for change; 2) the relative rigidity of floorspace supply and its inability to accomodate change; and 3) the constant decline through time in the suitability of buildings to house any activity. While the factors causing demand changes are of little interest here, those relating to supply changes are, and are expanded on below.

Immobility and durability are two characteristics of buildings that distinguish them from many other economic goods and prevent them being easily moulded to the varying demands put on them (Shafer, 1975). Immobility or fixity precludes buildings from being moved from one location to another as an activity's location demands shift. Durability or longevity refers to the long physical lifespan of a building. Once erected it is difficult and very costly to replace the building if it no longer satifies the demands put on it.

The suitability of a building to house any urban activity constantly declines with the aging of it. Aging refers to the natural process of physical deterioration through time. Although its rate can be partially controlled by proper maintenance operations, the aging process can never be reversed. At some point in time after its construction a building becomes physically used up and must be replaced.

The durability, immobility, and aging of buildings necessitate the implementation of a disjointed sequence of adjustments to buildings so some semblance of correspondence between floorspace supply and demand is maintained. Such adjustments are collectively called the adaptation process.

The adaptation process takes place in a temporal sequence of stages (Bourne, 1969). Each stage corresponds to a level of maladjustment. Initially an equilibrium exists in that the building is inhabited by the 'highest and best use' for which it was built. Shafer (1975, p.61) defines the 'highest and best use' as "the use that returns to the [building's] owner the maximum money return in comparison to alternative uses". Eventually the original activity is replaced by another, less suitable for the building. A slight structural modification may be required. As time passes, activities successively replace each other, the building ages, and the disequilibrium increases to the point that a partial conversion of the building is required. Once the disequilibrium becomes great enough the building experiences the most drastic adjustment, redevelopment.

2.3 Redevelopment Timing Factors

A building is an investment vehicle and the replacement of it can be perceived as a normal investment decision (Newell, 1977). The return on an investment has to be competitive with investment alternatives. Assuming the only two alternatives available to the development agent are to leave the existing building standing or to replace it, the agent must base its decision on a comparison of the net return from a new building from the time of redevelopment forward and the net return from the continued operation of the existing building (Ratcliff, 1949). That is, assuming that development agents are profit maximizers, a site will be redeveloped at that point in time when it is economically feasible to do so. The timing of redevelopment, therefore, depends on a set of cost-return relationships.

The profit realized from redevelopment varies with its cost relative to the return from the new building after redevelopment (Bourne, 1967). The costs of replacement include those associated with demolishing the existing building, constructing the new building, and the future income foregone by eliminating the existing building. Therefore, the redevelopment of a given site is economically feasible when:

$$V_n - B_n > V_o + D_o \qquad (1)$$

Clapp, 1977, p.73

where V_n is the present value of the site and the new building, B_n is the cost of constructing the new building, V_o is the present value of the site and the existing building, and D_o is the cost of demolishing the existing building. The demolition and replacement of an existing building will occur, _ceteris paribus_, when "the value of the cleared land ... exceeds the remaining value of the original property, land and building" (Ratcliff, 1949, p.403). The above condition for redevelopment may be fulfilled either because physical deterioration or functional obsolescence reduces the value of V_o, or because land values appreciate increasing the value of V_n, or by a combination of both changes (Heilbrun, 1974).

Theoretically, it is relatively easy to determine when the redevelopment of a given site will occur. It is known that a profit is realized from redevelopment when a certain cost-return relationship exists. One needs only to examine the changes in the relevant costs and returns through time and calculate when inequality (1) first holds. There are, however, many factors in reality that introduce much more complexity and make the prediction of the timing of redevelopment very difficult. These factors relate to: 1) the ease of determining if and when inequality (1) holds, 2) actions and circumstances which can alter the anticipated changes in the values of the quantities in inequality (1) through time, and 3) contingencies that thwart redevelopment despite the economic feasibility of it.

Certain characteristics of the real estate market and of buildings themselves introduce uncertainty to the redevelopment timing decision. Uncertainty refers to both the lack of definite knowledge of the magnitude of the costs and returns involved in redevelopment and their dynamics and the lack of assurance that the estimated redevelopment time is a profitable one. Uncertainty in turn introduces risk because if redevelopment occurs before inequality (1) holds a capital loss will be incurred (Clapp, 1977).

In terms of the real estate market, infrequent transactions, the absence of a central institution, and imperfect knowledge of the true market state all serve to make current prices and values of land and buildings difficult to estimate (Balchin and Kieve, 1977;Newell, 1977;Alexander, 1974;Ratcliff, 1949). The heterogeneity of buildings and sites has the same effect (Case, 1974). Because of the durability of buildings, future prices and values must be taken into consideration as well and there is no way of acccurately estimating them (Clapp, 1977; Smith, 1975). Uncertainty, therefore, hampers the accurate determination of the timing of redevelopment.

Circumstances and actions which cause existing building and site values to fluctuate alter the time at which inequality (1) can be expected to hold (Balchin and Kieve, 1977). Overcrowding and the lack of maintenance and repairs are profitable policies for building owners in that they reduce current costs and the resultant depreciation may be tax deductible (Ratcliff, 1961). The savings realized increases the value of the existing building and prevent redevelopment from being economically feasible even though the building becomes physically blighted. Extensive conversion of the building produces an identical effect in that the return from the building, and, therefore, its value rises. The declining demand for floorspace in the city center, because of pollution and congestion, can reduce land values and thereby also extend the building's economic life (Smith, 1975). Conversely, improvements in the urban infrastructure, or anything that causes land values to rise or the value of the building to fall, will encourage the economic justification of redevelopment.

And even if the development agent accurately estimates the costs and returns of redevelopment and the economic feasibility exists, the demolition and replacement of the building may not take place. Such things as a non-monetary interest in the building and the unwillingness to sell the site to a development agent may forestall redevelopment (Balchin and Kieve, 1977). Planning restrictions, legalities in the form of leases or multiple ownership, the lack of access to finance capital, and lower returns from real estate in relation to other investment alternatives may all act to prevent redevelopment (Balchin and Kieve, 1977; Newell, 1977; Alexander, 1974; Bourne, 1967; Turvey, 1957).

For the above reasons, then, the timing of the redevelopment of a given site is subject to random variation. In addition to depending on the basic cost-return relationship, it is affected by chance factors too numerous to describe in detail. Hence the spatio-temporal pattern of redevelopment is characterized to certain extent by random variation resulting in spatio-temporal discontinuities.

An alternative method of analyzing redevelopment is to examine the characteristics of each site and building in an attempt to determine the relative attractiveness of each site as a location for redevelopment at a given point in time. Identifying and evaluating the location factors that influence a site's relative redevelopment potential is arguably a more rewarding approach than is calculating the entire range of present and future costs and returns of redevelopment. It must be remembered that despite the perspective from which one studies the spatio-temporal pattern of redevelopment, the influence exerted by the chance factors remains.

2.4 Redevelopment Location Factors

The distribution of redevelopment among the multitude of sites comprising the urban area is a function of the relative potential of individual sites to attract new investment (Bourne, 1967). Redevelopment location factors, therefore, are those physical and locational characteristics of the site and building that determine their respective values and site clearance costs. Anything that increases the re-use value of the site, decreases the value of the existing building, or decreases site clearance costs increases the potential of the site for redevelopment, i.e., increases the relative likelihood that inequality (1) holds; and vice versa.

The physical characteristics of the site, exclusive of the building thereon, include essentially size or area, shape, and topography. These attributes influence the value of the site for re-use. For example, a minimum threshold size is required before a building can be profitably constructed on a site (Bourne, 1976b). Assuming increasing returns to scale in construction, the larger the site the higher the re-use value. Land ownership is usually so fragmented in the urban core that sites of a size greater than that for which increasing returns to scale no longer hold are rare. Conversely, if the shape of a site is extremely irregular or the topography especially unsuitable for the construction of the type of building proposed, then construction costs may exceed acceptable levels and the value for re-use would be relatively low. This would appear to be an unusual situation though because a building had already been erected on the site. If either of these two characteristics had not prevented initial development, then it is unlikely they would preclude redevelopment.

The relevant physical characteristics of the existing building consist of its level of physical deterioration and functional obsolescence and of its scale. They determine to a large extent the value of the site and building in their present use and the cost of site clearance. The greater the building's deterioration and obsolescence, the higher the maintenance costs and the lower the return from tenancy; and, therefore, the greater the potential for redevelopment. On the other hand, the relative cost of demolition varies with the scale of the building relative to the size of the site; the greater the relative scale, the lower the redevelopment potential.

The locational characteristics of a site are extremely important determinants of its redevelopment potential. Unlike the physical characteristics of sites and buildings, the locational attributes of each site are unique because of the exclusiveness of location. The spatial position of an individual site relative to all other entities in the urban area cannot be replicated by any other site. Thus although two sites may not be differentiable according to their size, shape or building characteristics, they can always be distinguished from each other in terms of their relative location. As a result, a site's locational attributes primarily influence the re-use value of the site alone. In general, a site's relative location can be identified in terms of accessibility and proximity. The accessibility of a site is usually measured with reference to the entire metropolitan population and to the urban functions and activities concentrated in the city center. A site's proximity refers to its nearness to urban amenities such as parks and to disamenities such as blighted buildings Bourne, 1971; 1967). The more accessible and the more proximal to urban amenities, the higher the site's redevelopment potential.

The land use controls that apply to a site determine the range of options available to the development agent with regard to its redevelopment. In many cases both the type and intensity of site usage are restricted by them. They influence the re-use value and, therefore, the redevelopment potential of the site by controlling the possible future uses of the site (Balchin and Kieve, 1977; Newell, 1977). If the most profitable re-use of the site is not allowed, in terms of either the type or the scale of the building, then redevelopment will not occur despite the site's apparent attractiveness to it exhibited by its physical and locational characteristics. Thus the more restrictive the land use controls, the lesser the possibility that a profitable re-use is allowed, and the lower the site's redevelopment potential.

The attractiveness of a site to redevelopment is thus primarily affected by the following location factors: 1) the size of the site; 2) the level of physical deterioration and functional obsolescence of the building; 3) the scale of the building relative to the site's size; 4) the relative accessibility and proximity of the site; and 5) the planning restrictions that apply to the site.

2.5 Spatial and Temporal Links

To this point redevelopment has been treated as a discrete event. It has been examined in both an aspatial temporal context (redevelopment timing factors) and in an atemporal spatial context (redevelopment location factors). It is now appropriate to analyze the concepts and factors that link the seemingly independent redevelopment events in time and space in a process that rejuvenates urban built form.

In terms of the entire city, redevelopment is highly spatially localized in that it is concentrated in the urban core. This is intuitively obvious because the great majority of the city's oldest buildings are found therein. Bourne (1967), however, reports that even at a very disaggregated spatial scale a strong tendency exists for agglomeration and clustering. Such locational inertia of redevelopment has two causes. Firstly, the location requirements of many urban core activities are similar. The combination of accessibility and proximity that is attractive to redevelopment exists on a spatial scale both larger than an individual site and smaller than the entire core area. The result is the existence of nodes of relatively high redevelopment potential, each consisting of a number of individual sites. Secondly, previous investment decisions often generate opportunities for further redevelopment (Bourne, 1967). If the redevelopment of a site has just occurred in a given core sub-area, it usually indicates that planning decision guidelines for that sub-area have been set and that community resistance, if it existed previously, has been broken. This acts as a 'triggering mechanism' for the future redevelopment of proximal sites (Bourne, 1967). For the above two reasons redevelopment can be perceived as a series of spatially related events.

Although neither von Boventer (1978) nor Johnston (1976) discussed it in this context, the 'contagion' or 'bandwagon' effect can help explain the temporal relationship between redevelopment events. Because of the relatively constant rate of physical deterioration buildings of similar ages are, in general, replaced around the same time. However, the redevelopment timing decision is rife with uncertainty and risk. The term contagion effect refers to the fact that peoples' attitudes, expectations, and behaviour are influenced by those of others in similar circumstances. Thus a development agent, in the absence of a definite knowledge of the profitable redevelopment time, may decide to proceed with redevelopment because another agent faced with similar constraints is doing the same or is thinking of doing so. The decision is made easier and carries with it somewhat less uncertainty and risk because someone else has decided similarly. The behavioural similarity extends as well to the situation in which one development agent decides against redevelopment at a certain time. The contagion effect infers redevelopment is a self-supporting expansionary or contractionary temporal process (von Boventer, 1978). How the actual quantity of redevelopment varies through time depends on a combination of the contagion effect and the factors that shape and constrain the ability of development agents to respond to changes in urban floorspace demand.

2.6 The Level of Redevelopment

It has been argued in this chapter that the redevelopment process consists of a spatio-temporally related series of building replacements. One important aspect of the process that has yet to be discussed is the determination of the level of redevelopment in the urban core and the temporal variation therein. The level of redevelopment is hereby defined as the quantity or number of redevelopment events initiated in a given time period.

The set of factors influencing the level of redevelopment is perhaps the most complex of any discussed to this point. Because of the nature of the real estate market local, regional, and national factors come into play. Urban floorspace demand changes with national as well as local or regional population growth, employment levels, per capita income, and household and business expenditures. Alternatively, the supply of floorspace varies with the national and local availability of construction materials, labour, and finance capital (McMahan, 1976). Thus national, regional, and local economic trends influence the level of redevelopment in a city's core area.

Because of the magnitude of the investment required for redevelopment the availability of finance capital is perhaps the single most important determinant of the redevelopment level. Access to capital resources for investment alternatives depends on their relative rate of return. During periods of economic growth the demand for non-real estate investment increases. Real estate becomes a less attractive investment vehicle as higher returns are realized on short-term financial instruments and business plant investment. In times of recession the demand for business capital decreases thereby making it available for investment in real estate. Thus the availability of redevelopment finance capital follows a cyclical trend opposite in phase to the business cycle (McMahan, 1976; Smith, 1975).

The ability of development agents to pursue the implementation of their redevelopment plans is shaped by the cyclical availability of capital financing. Because of the contagion effect the number of development agents responding to increasingly favourable or unfavourable real estate investment conditions is initially small, increasing as time passes. Thus the level of redevelopment exhibits a cyclical trend consisting of what Case (1974) refers to as 'feast and famine' conditions. The redevelopment level cycle and the finance capital cycle are not necessarily in phase; reflecting the influence of time lags caused by the contagion effect and the neccessity of having to plan ahead for redevelopment.

2.7 Synthesis

This chapter began by briefly outlining the role of redevelopment in the evolution of urban structure. The fluidity and malleability of urban floorspace demand combined with the relative rigidity of floorspace supply, and the constant aging of buildings, produce a disequilibrium in the real estate market. An adaptation process consisting of both the relocation of urban activities and the structural modification of existing buildings attempts in vain to reduce the growing maladjustment. Once the disequilibrium at a given location becomes great enough the only recourse is redevelopment.

Redevelopment will not occur unless it is economically feasible. The economic feasibility depends on a balance between the value of the cleared site and the value of the site with the existing building. The balance is tipped in favour of redevelopment when physical deterioration and functional obsolescence reduce the value of the existing building to such a point that it is just exceeded by the appreciating value of the land on which the building stands.

Theoretically, determining when redevelopment is economically feasible is relatively easy. In reality, uncertainty resulting from an imperfect knowledge of the future and anything that changes present or future land or building values makes the evaluation of the arrival of economic feasibility difficult. Other factors relating to the availabiltiy of the site for redevelopment also contribute to the difficulty of predicting when the redevelopment of a given site will occur.

Each urban site possesses a certain potential for redevelopment relative to all other sites therein depending on its locational and physical characteristics - site accessibility and proximity, site size, and building deterioration, obsolescence, and scale. The availability of the site for redevelopment in terms of local land use controls also influences and modifies relative redevelopment potential.

Redevelopment events are spatially related in that they exhibit a highly localized pattern, appearing in small clusters in the urban core. They are temporally linked by the influence one development agent's expectations and behaviour have on those of others. The demolition and replacement of an individual building is but a single element of the spatio-temporal process of redevelopment.

Finally, the level of redevelopment varies cyclically responding primarily to the changing availability of finance capital for real estate investment, a product of the business cycle.

The contents of this review of the nature of redevelopment as an event and a process will be used later to develop a conceptual model of redevelopment on which the ultimate operational model will be based. Prior to doing so, an introduction to urban modelling and a survey of previous attempts to model redevelopment will be presented. Such an excercise enables one to become acquainted with the many modelling considerations involved and allows the evaluation of the relative merits of various modelling approaches and techniques previously employed in similar circumstances.

CHAPTER THREE

MODELLING REDEVELOPMENT: A REVIEW

3.1 The Nature of Modelling

When designing a model, the modeller has to make many crucial decisions with respect to the identification of the essential components, variables, and functional relationships of the relevant phenomenon and to the design of the model structure itself.

Assuming that he has isolated the important elements and interactions to be included, the modeller must then decide on, among other things, the level of spatial aggregation, how time is to be treated, and the combination of alternative solution methods and techniques to be used (Ledent, 1976; Zeigler, 1976). In terms of spatial scale, the modeller chooses the basic areal unit at which the model operates. With regard to the handling of time, the model can be either static or dynamic. The choice of solution methods and techniques, perhaps the most important structural design decision, consists primarily of choosing between employing an analytical or a simulation approach and deciding whether the model will be deterministic or stochastic.

The model desigh strategy is based on both the purpose of the model and the nature of the phenomenon of interest. To reiterate the essential purpose of the proposed model is to forecast future spatio-temporal patterns of redevelopment empirically. The characteristic features of redevelopment were summarized in the preceeding chapter. On the basis of that review, present design decisions will take into account that redevelopment is a complex, dynamic urban process comprised of individual site redevelopment events. And although they can be conceptually linked in both space and time, the series of redevelopment events are characterized by spatio-temporal discontinuity. The resultant spatio- temporal pattern of the redevelopment process is a product of the physical and locational characteristics of individual sites and buildings in relation to those of all others, but also of a multitude of chance factors or unknown, unspecified causes.

3.2 Critique of Selected Urban Models

Despite the relatively short history of urban modelling there has developed a rather large related body of literature. A very broad range of urban phenomena has been examined. As well, many different types of models based on the various combinations of methods used to operationalize them have been employed. It is generally agreed, though, that urban modellers have paid more attention to urban population and functional activities, such as retail or residential location and spatial interaction, than to the urban building inventory (Batty, 1976; Colenutt, 1972).

There exists an abundance of urban modelling reviews in the literature, organized either by the phenomenon modelled (see Webber, 1979; Goldberg, 1977; Ledent, 1976; Chorley and Haggett, 1968) or by the structure of the models (see Bennett, 1978; Batty, 1977). There is no reason then for a comprehensive survey here. A partial review is worthwhile in that it can provide insight into how redevelopment can be successfully modelled. In light of the accumulated knowledge of redevelopment one can evaluate the strengths and weaknesses of different modelling techniques. Additionally, certain interesting aspects of existing redevelopment models can be highlighted. The survey is arranged by solution method. The first half contrasts the analytical and simulation approaches. The differences between deterministic and stochastic models are outlined in the second section. Not only will the differences between the approaches be analyzed, but examples of the application of each will be provided. The examples will be restricted to models of urban growth, land use, and land use change, focusing specifically on those that incorporate change in the urban building inventory.

3.2.1 The Analytical Approach

The analytical modelling approach is the use of formal mathematical analysis to arrive at explicit equations (Batty, 1976). It has been adopted by those involved in the recently developed field known as the new urban economics or NUE (for indication of the research in this field see Papageorgiou, 1976). In fact, analytical modelling and NUE are so closely intertwined that a critique of one can be readily applied to the other.

NUE is concerned with the study of the growth, composition and spatial form of urban areas and the analysis of related problems such as congestion, pollution and discrimination (Goldstein and Moses, 1973). The theoretical von Thunen-type analytical models that dominate the field have recently been subjected to much criticism. It is felt the unrealistic and restrictive assumptions that make the model mathematically tractable render them unable to deal with several essential aspects of urban structure (Richardson, 1977; 1976; Goldstein and Moses, 1973). The assumption of unidimensionality, monocentricity and exclusive zoning, among others, make the analytical models exclude an explicit consideration of time, trivialize space in that the second and third dimensions are ignored, and unable to include the competition between residential and non-residential uses. The failure to adequately deal with both space and time produces a certain lack of forecasting ability causing Richardson (1976, p.17) to write that the "kind of prediction possible with NUE models . . . is too general to be of practical help". Another short-coming of the analytical models especially relevant to their potential for modelling redevelopment is the demand for floorspace is treated simply as the demand for land; thereby ignoring the durability and immobility of buildings and the dynamic adaptation process therein (Richardson, 1977).

In defense of the analytical approach, the above criticisms mainly apply to the first and second generation models (Anas and Dendrinos, 1976). The more recent third generation models overcome some of the weaknesses of their predecessors. Pines (1976), for example, attempts to deal with the durability of buildings by introducing the assumption that the costs of adjustments to buildings are infinite. And Anas (1978) not only explicitly deals with the durable nature of buildings, the adjustment costs of building conversion and replacement and the fact that investment decisions are based on future expectations; he also makes the model dynamic through the use of recursive equations. However, the assumptions, such as perfect durability and decision-maker myopia, introduced to account for the aforementionned considerations are still far from realistic.

Another set of analytical models that recognize building durability are the vintage models of urban housing (see Muth, 1976; 1973; Evans, 1975). These models focus specifically on changes in the residential building inventory over time with increasing incomes and construction costs, physical deterioration, and urban growth. Breuckner (1981; 1980a; 1980b; 1978) by himself and with von Rabenau (1981) has extended these early vintage models by incorporating housing demolition and redevelopment and by allowing developers to have a choice in the lifespan of their buildings. More importantly, he eliminates their aspatiality by successfully integrating the vintage models of housing with a spatial model of urban growth. This has enabled Breuckner's model, unlike any other analytical one, to generate urban growth patterns. The model's output is interesting in that it demonstrates the spatial discontinuity of the redevelopment process. Its ultimate significance is that it facilitates the empirical testing of analytical models, something which had previously been impossible.

Excepting the most recent efforts, the analytical approach possesses several drawbacks as a method of modelling the redevelopment process. Its atemporality and aspatiality, not to mention the mathematical complexity, do not make it conducive to the purpose of the present model. The recent developments outlined immediately above indicate that it does hold promise for empirical application in the near future.

3.2.2 The Simulation Approach

The alternative to the analytical method is simulation. A simulation is an analogy or replication of the behaviour of a complex phenomenon (Bracken, 1978). It is actually a way of using a model in that the model represents the phenomenon or process and simulation imitates it (Ackoff, 1962). The model itself is constructed in such a manner that it artificially depicts certain significant features of the phenomenon in reality (Morrill, 1965a). The purpose of the simulation is to emulate the operation of the process and follow its evolution (Chojnicki, 1970). As opposed to producing explicit equations, simulation arrives at a number of potential histories of the process.

The simulation method is especially applicable to the wide range of urban processes that involve spatial patterns which are a product of individual decisions and develop over time (Chojnicki, 1970; Morrill, 1965b). It facilitates the employment of a disaggregate approach by allowing the summation of individual events into an aggregate process. The dynamic aspect of the process can be captured via recursion. That is, the simulation consists of a sequence of steps in which the results on one step become the starting point for the next (Harris, 1965). In this way, the time dimension that is such an essential component of a process can be explicitly accounted for. Bracken (1978) suggests simulation possesses special relevance when the analytical method is prevented or made difficult by such things as a large number of variables, non-linearity,and probabalistic or random effects. Furthermore, two dimensional space, locational interdependence, and real estate heterogenity can be better handled by simulation models than analytical models (Richardson, 1977). Simulation, therefore, appears to suit the requirements for the modelling of the redevelopment process very well.

The simulation approach is not immune to criticism. Besides the charge that simulation produces more expensive and less comprehensible models than the analytical approach, the main argument against its use is that it lacks any kind of theoretical structure (Ingram, 1979; 1975; Goldstein and Moses, 1973). It should be pointed out, though, that even if the method lacks a theoretical basis, simulation models may not. By carefully analyzing the phenomenon of interest before constructing the model, the modeller can formulate a conception of it and design the model accordingly. He, therefore, proposes his theory of the phenomenon in the structure of the model itself.

The attempts to simulate entire urban economies or major portions of them are the reason why the critics of simulation claim that it produces relatively incomprehensible and expensive models. Because of their notoriety, they have received the most attention of all urban simulation models. They include such ambitious efforts as the Massacheusetts Institute of Technology Econometric Simulation Model (Engel et al., 1972), the National Bureau of Economic Research Urban Simulation Model (Kain, 1975) and the San Francisco Community Renewal Program (Robinson, Wolfe and Barringer, 1965). Besides their large scale, an interesting aspect of these models is that they recognize the durability and heterogeneity of buildings and the importance of the adjustments therein to the urban economy. They are so comprehensive, however, that their actual application has been hampered by the costs and difficulties of data acquistion. They also lack any consideration of nonresidential buildings.

One of the few models found to date that deals specifically with nonresidential and residential redevelopment in the urban core is that of Lewis et al. (1975). The Manchester Decision-Based Urban Simulation Model (MANDEBUS) is a theoretical model that was developed for the simple reason that "there seemed to be no reasonably adequate model of central area change" (p.396).

As its name implies, the model is decision based. At the end of a lease, the tenant decides to renew it or relocate. Similarly, the landlord decides whether to relet or demolish and redevelop. The landlord bases his decision on expected rents for various land uses, probabilities of letting, and costs of redevelopment. Change in the market is not only accomplished by supply and demand decisions, but also by the aging process. The model's basis in decision-making is further reflected by the fact that the landlord can influence the aging process by his maintenance decisions. The output of the model includes the number of buildings used by each activity demolished and replaced each year, the number of units by activity available for tenancy each year, and the rent per unit by activity and building quality.

The significance of MANDEBUS is that it is one of only a few published studies to concentrate solely on redevelopment modelling. Its most interesting feature is that it is decision-based. Since decision-making underlies redevelopment it seems useful to structure a model on it. For example, the incorporation of expectations of the future and variable building aging rates is accomplished relatively easily.

The model's primary fault is that the urban core is seen as a single zone thereby introducing aspatiality. Thus it is unable to recognize the spatial pattern of the redevelopment process or the locational influences thereon. Another weakness is that influences on the level of redevelopment that are exogenous to the urban core, let alone to the city itself, are not considered. And although redevelopment can be modelled in a theoretical context on a decision-making basis, it would be extremely difficult to do so empirically. The data required are just not available. The model, therefore, remains artificial and untested in that it has not been applied to an actual city (Lewis et al., 1975). Personal communication with the modelling project director indicates that if it could be done again, a different approach would be used (Lewis, 1980).

3.2.3 Deterministic versus Stochastic Modelling

To this point urban models have been differentiated primarily on the basis of whether they involved the analytical or the simulation approach. A second important distinction can be made in terms of whether they are deterministic or stochastic. The implicit assumption of deterministic models is that the behaviour of a process can be perfectly predicted if a set of initial conditions and relationships are known (Harvey, 1967). Stochastic or probabalistic models, on the other hand, assume the existence of incomplete knowledge and uncertainty in terms of the agents in the process and in terms of the modeller himself (Morrill, 1965b). To accommodate this, they include a random variable in their structure. Thus processes that seem to be probabalistic and subject to possibly random fluctuations and disturbances are prime candidates for stochastic modelling.

Because of the innate characteristics of their solution method, analytical models are usually deterministic whereas simulation models are predominantly stochastic. There are exceptions of course. For example, Breuckner (1981a) has developed a stochastic version of his vintage model of urban growth in which building lifespan is assumed to be random. For the most part, though, mathematical tractability is jeopardized by the inclusion of random or probabilistic elements, thereby necessitating that analytical models be deterministic. For this and other reasons stated earlier, analytical models are no longer of interest here.

Stochastic models can basically be divided into two groups depending on whether they involve Markov chain or Monte Carlo methods.

Markov chain models involve the use of a probability transition matrix to predict future states or describe past changes (Lee, 1974). They have been used in the urban context primarily to model land use succession (see Bourne, 1978; Lee, 1974; Cowan, 1969; Drewett, 1969). However Bourne (1971; 1967) also used the Markov chain method to model redevelopment in Toronto. His model consisted of two parts: an aggregate area model and a disaggregate site model. The area model allocated redevelopment activity to sub-areas of the city on the basis of a set of location factors summarized in a series of regression equations. The site model with its probability transition matrix converted the output of the area model into changes in the location of activities (implicitly redevelopment) within each of the urban sub-areas according to the probabilities.

Bourne's model is noteworthy because again it is one of only a few published attempts to model redevelopment. It deserves recognition for the fact that it is an empirical application rather than being purely theoretical. Furthermore, Bourne recognized that redevelopment can only be effectively modelled if a combination of aggregate and disaggregate spatial levels are utilized. However, he did not concern himself with predicting where redevelopment would occur on an individual site basis. In fact Bourne was more interested in the type of activity a new building would house than in the essential questions of when and where building demolition and replacement would take place. Hence, although he correctly perceived that he could "describe and measure the potential for change from conditions apparent before redevelopment occurs" (1971, p.185), he failed to pay close attention to, i.e., examine on a small enough spatial scale, the evolution of the spatio-temporal pattern of redevelopment. Furthermore the basic premise of the Markov Chain method is that the present state of the process is a function of the immediate past state, not of all past states (Drewett, 1969). It is felt this assumption precludes the method from being an appropriate one by which redevelopment is modelled. The redevelopment of a site is planned many years before it actually takes place. The present or future state of the redevelopment process, therefore, is not a function of only the immediate past state but of states two, three or five years earlier, as well as anticipated current and future states. Bourne's effort, as would any that employed the Markov chain method to model redevelopment suffers from this contradiction. By the process of elimination, only the Monte Carlo method remains as a fruitful technique by which redevelopment can be stochastically modelled.

3.2.4 Monte Carlo Simulation

The Monte Carlo technique is analogous with the throwing of the dice in any game in that it involves a random sampling from a known probability distribution. As opposed to obtaining it from the dice, the value of a random variable is taken from random number tables or generated by some arithmetical procedure (pseudo-random). The link with reality takes place when a set of actual values, having the statistical properties of the random variable, is substituted for the random variable (Hammersley and Handscombe, 1964).

There is general agreement that a random element is a very characteristic feature of certain urban processes. It follows that a model which imitates a real world process should include that chance factor (Hagerstrand, 1967). Thus the Monte Carlo technique is virtually synonymous with urban simulation modelling. The procedures of Monte Carlo simulation will be described in detail later. At this point it is useful to introduce two models of this type. The structures of the models, rather than the phenomenon being modelled, are of primary interest in terms of the potential for their application to redevelopment modelling.

The first of the two models to be analyzed was developed at the University of North Carolina in the early 1960's and reported by Chapin and Weiss (1962), Donnelley, Chapin and Weiss (1964) and Chapin (1965). It was designed to simulate the rural-urban land conversion process.

The simulation procedure was the following. Initially a grid is imposed over the land area. A value is assigned to each grid square based on its score on an attractiveness index. The attractiveness index is developed by determining the factors important in land development using multiple linear regression. Each square's value is then modified by density constraints that guide the pattern of growth. The Monte Carlo technique is subsequently used to determine in turn whether a development unit is to be assigned to an individual square. The number of units available for allocation is determined exogenously. Time is accounted for by recursively applying the entire procedure in the following manner. Once all development units for a given time period are assigned, the attractiveness index values of all sites are adjusted to accommodate the changes brought about by the development in the preceding time period. The entire procedure is repeated for as many time periods as desired. In this way, the spatial pattern of land development in terms of location and density is developed.

One significant aspect of this model is that space and time are explicitly dealt with. The spatial evolution of the process can easily be followed because the model operates on a spatially disaggregate level and is recursive. The dynamic nature of the model is enhanced by the fact that changes in previous time periods influence the process in the present. Another interesting point is that the location of land development depands primarily on the characteristics of each grid square modified to a certain extent by a chance element. Furthermore, through time, the relative attractiveness of each grid square changes. Thus the importance of certain location factors and the temporal changes therein to the spatial pattern of the process is recognized, and yet they do not entirely determine how the pattern evolves.

The weaknesses of the model stem not from the use of Monte Carlo simulation but from certain other model design decisions. The imposition of a grid to form the model's basic spatial units is too artificial to satisfactorily imitate reality. It does not allow the model to account for land ownership patterns and the influence that will have on the land development process. The complexity of the attractiveness index requires excessive data manipulation. The modellers were only interested in residential land uses and ignored not only the existence of the nonresidential sector but also the influence the pattern of nonresidential development has on that of residential development. Nevertheless, as one of the first attempts in geography to model urban growth, it was a notable achievement.

The second of the two Monte Carlo simulation models being evaluated here is due to Morrill (1965a). Also dealing with land use change on the urban periphery, the model simulates the location, size and density of land development on the outskirts of Seattle using probability functions based on previously observed frequencies.

Parcels of land, according to legal title, are selected randomly, one at a time. A value of the "probability" for development of the parcel is assigned based on its accessibility to existing major developments, its quality in terms of view, lake frontage and so on, and its proximity to noncompatible land uses or blighted areas.

The probability value is converted to a range of discrete numbers and the Monte Carlo technique invoked. If the land parcel is picked for development, the new activity at that location is determined by using probabilities of land uses occurring in the existing zoning category and the Monte Carlo technique. The scale of development corresponded roughly to the area of the land parcel. And finally, the density of development is calculated by assigning different probabilities to different numbers of development units per acre and again employing the Monte Carlo technique. Morrill also realized that the succession of uses on a single land parcel based on building quality, the distance to a shopping center, and opportunity costs could have been incorporated in his model. As well, he mentionned the entire procedure could have been repeated over and over but like the land use succession idea, he did not include it in his published account.

Morrill's model improved upon that of Chapin, Weiss and Donnelley in some ways, and in others was more crude. Whereas the latter imposed a grid to determine the basic spatial units, the former used actual land parcels. It should be noted, though, that Morrill attributed some of the major differences between the simulated and actual development pattern to the fact that he did not differentiate between institutionally and privately owned land. Morrill's effort also included both the nonresidential and residential sectors and distinguished between development units by land use while Chapin, Weiss and Donnelley did neither. On the other hand, unlike his counterparts, Morrill did not have the use of a computer and was forced to perform the simulation completely by hand - a tedious and time consuming chore. He was, therefore, prevented from producing numerous runs or trials of the model; a distinct disadvantage in that the general solution of a Monte Carlo simulation is a distillation of many unique solutions represented by each repetition.

The two models just reviewed, could not be used as they exist for the purposes of this thesis. They are both designed to simulate land development, not redevelopment, and thus do not take into account building characteristics. Furthermore, certain of their respective design elements, as pointed out above, are not acceptable here and can be improved upon. One shortcoming they share is that land units are considered for development in isolation instead of in relation to all other units. Hence the models are implying that urban land use decisions are made irrespective of the entire range of opportunites in existence. This and other flaws would necessitate substantial changes in either of the models if they were to be deemed acceptable for present purposes.

The important point is that Monte Carlo simulation appears to be the most promising approach for modelling redevelopment. It satisfactorily imitated the land development process and pattern in the two aforementionned empirical models; and land development and redevelopment are in many ways quite similar. Space and time can be explicitly accounted for; a necessary condition when modelling a spatio-temporal process. Furthermore, it naturally includes the random or chance factor that arises from uncertainty and individual and real estate variability; elements that are inherent in redevelopment.

Before closing this review there remains one additional model that should be introduced if only because it is the only other existing model of redevelopment that has yet to be mentionned here. It is left until last because it is not a mathematical model and, thus, did not fit in with any of the other models in this chapter. It is interesting for its unique approach.

For the Covent Garden area of London, England, Alexander (1974) attempted to predict when and where wholesale (block by block) and piecemeal (site by site) redevelopment would take place by using a very subjective exercise. His data consisted of property ownership, the distribution of lease lengths, and the age of buildings.

The procedure employed was the following. Initially sites potentially available for redevelopment are identified using lease lengths as a guide. The ages of the buildings on available sites are then examined. All buildings over a certain age were designated for redevelopment whereas only a varying percentage of younger buildings would experience the same. Likely sites for redevelopment are picked on the basis of their relative location and past growth trends. In light of planning restrictions, site location, and apparent potential, new land uses are allocated to redeveloped sites. The timing of redevelopment is dependent on the length of the lease currently in effect. A detailed prediction is made for a period of fifteen years and a generalized one for thirty years.

Alexander's model, in relation to the ones presented earlier, indicates the wide range of approaches that can be taken to model urban land use change. It is felt, though, that it suffers from being too subjective and deterministic. It does demonstrate, along with the efforts of Lewis et al. (1975) and Bourne (1971 ;1967) that a satisfactory model of redevelopment does not exist. Any further research along that line is certainly justified.

3.3 Synthesis

This chapter commenced with an examination of the various decisions a modeller has to make with respect to model structural design. It was pointed out that, in this case, those design decisions should be based on the fact that redevelopment is a spatio-temporal process subject to random or chance variations. A review of models of urban land use change arranged by solution method and technique was then presented. The restrictive assumptions, mathematical complexity, and deterministic nature of analytical models rendered them unacceptable for use in this thesis, although recent efforts have reduced their inflexibility. The simulation approach was subsequently shown to be especially applicable to the predictive modelling of urban processes because the spatial and temporal aspects of the process could be imitated. Among the urban simulation models reviewed was a decision-based model of redevelopment. Since it was strictly theoretical and aspatial it possessed little relevance to this thesis other than it was one of a very few existing redevelopment models.

The differentiation between models was shifted to that of deterministic versus stochastic. As opposed to the rigidity of the deterministic approach, stochastic models incorporate a random variable. They were judged to be a suitable set of models to employ when the process being modelled is subject to random variations. Redevelopment is such a process. It was further argued that the Monte Carlo technique, when combined with the simulation approach, is a very promising tool with which to model redevelopment. Two Monte Carlo simulation models of land development were closely analyzed and evaluated in terms of their applicability in whole or in part to the modelling effort proposed here. It was concluded there were certain aspects that could be improved upon. They include, among others, the method by which the potential for the occurrence of the phenomenon at each location is calculated and the way in which it is decided where the phenomenon will take place. And finally, a non-mathematical redevelopment model was introduced, not so much for its structure as for a demonstration of the extent of the need for a generally applicable, objective model of redevelopment.

Such a model has been developed and it is the substantive basis of this thesis. Because it is an empirical model and because it deals with an urban economic process there is good reason to briefly introduce the geographic features and the socioeconomic history of the city to which the model will be applied, prior to describing its structure and operation. This is the subject matter of the next chapter.

CHAPTER FOUR

THE STUDY AREA

4.1 Kitchener's Economic Development and Growth

Kitchener is a medium-sized south-western Ontario city with a 1979 population of 136,000. Situated adjacent to the MacDonald-Cartier Freeway (Highway 401), halfway between London and Toronto, on a rolling till plain in the Region of Waterloo (inset Map 4.1) it lies at the heart of one of the fastest growing metropolitan areas in Canada (Table 4.1). A highly industrialized city, Kitchener has a relatively diversified manufacturing base (Bunting, 1972; King, 1966). Bordered on the north and south by the cities of Waterloo (51,000) and Cambridge (74,400) respectively, it is the physical, economic, financial, and administrative center of a prosperous agricultural hinterland. Its position of regional dominance, however, has not always existed.

Prior to the turn of the century, Galt (now Cambridge, together with Preston and Hespeler) was the

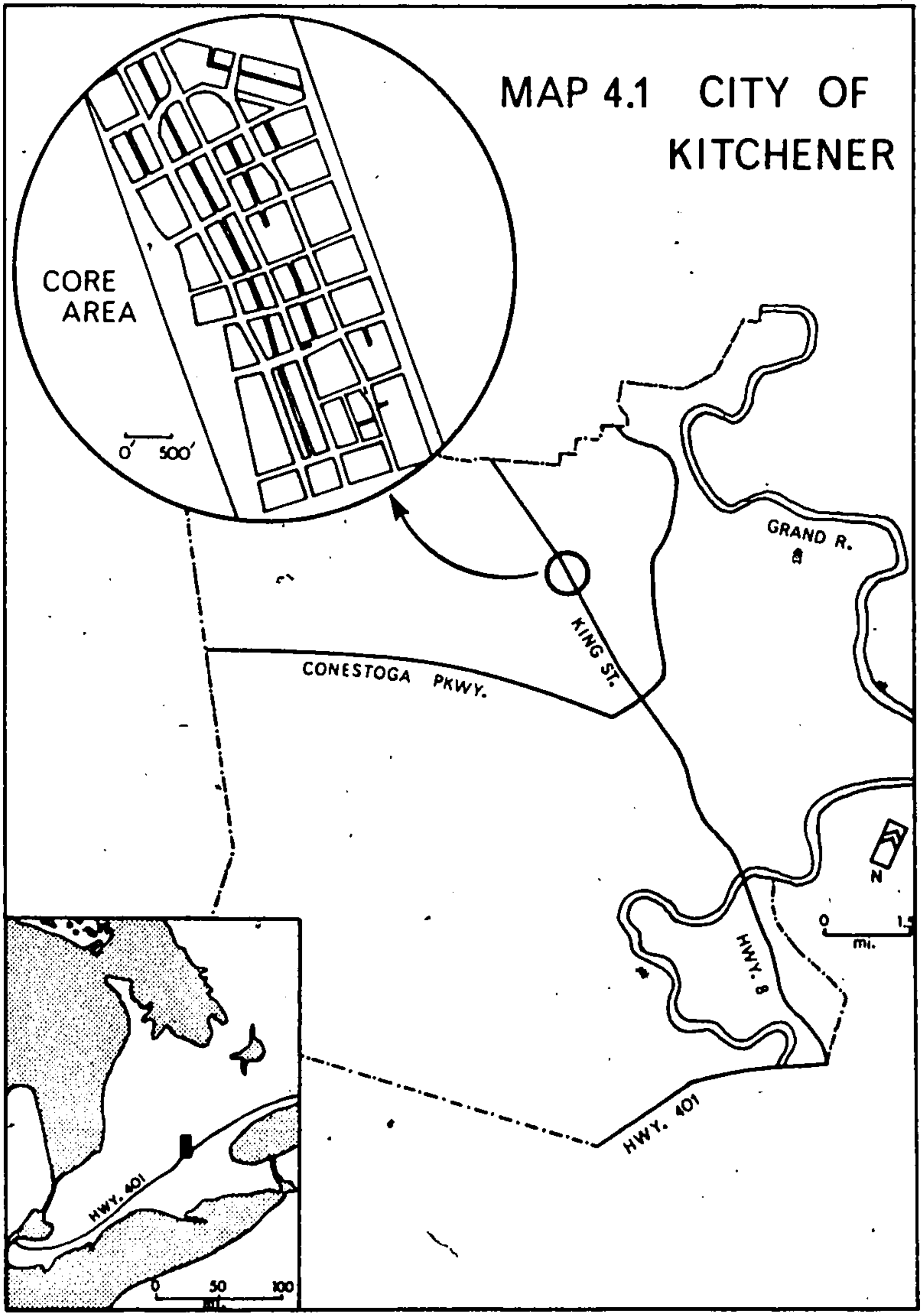

MAP 4.1 CITY OF KITCHENER
CORE AREA
0' 500'
GRAND R.
KING ST.
CONESTOGA PKWY.
HWY. 8
HWY. 401
N
0 1.5
mi.
HWY. 401
0 50 100
mi.

Table 4.1 Population Growth of the Fifteen Largest CMA, 1961 - 1971

CMA	1961-1971 % Change	1971	1961
Kitchener	46.48	226 846	154 864
Calgary	44.53	403 319	279 062
Edmonton	37.76	495 702	359 821
Toronto	36.92	2 628 043	1 919 409
Ottawa	31.83	602 510	457 038
Vancouver	30.91	1 082 352	826 798
Quebec	26.76	480 502	379 067
London	26.18	286 011	226 669
Victoria	25.70	195 800	155 763
Hamilton	24.30	498 523	401 071
Montreal	23.81	2 743 208	2 215 627
Windsor	19.07	258 643	217 215
St. Catherines	17.70	303 429	257 796
Halifax	15.15	222 637	193 353
Winnipeg	13.37	540 262	476 543

Source: Ray, D.(1976) Canadian Urban Trends, Vol. 1, Table A1.3, Population Growth, Employment Growth, and Age of Housing, Urban Areas, 1961-1971 dominant urban center of an area extending from Brantford to Stratford to Guelph, including Berlin (Berlin was renamed Kitchener in 1916). In fact, it was the general consensus in the early half of the nineteenth century that of the cluster of three settlements in Waterloo Township, Berlin, Waterloo and Bridgeport by name, the latter would become the largest and Berlin would perpetually be the smallest (Uttley, 1975). The reason underlying such a belief was Berlin's lack of access to water; a distinct disadvantage in terms of economic development potential at a time when water was the chief source of energy for industrial purposes. The initiative, innovativeness, and drive of its entrepreneurs together with the enlightened policies adopted by local politicians allowed Berlin to overcome its initial disadvantages and eventually outgrow not only Bridgeport and Waterloo, but Galt as well (Jeffrey, 1968).

Joseph Schneider is generally recognized as the founder of Kitchener (Berlin). A Mennonite from Pennsylvania, Schneider purchased the 448 acre Lot 17 of the German Company Tract in 1807 (unless otherwise noted the following historical review is from Uttley, 1975). That expanse of land included most of what is downtown Kitchener today. After building a road from his homestead to the Preston-Dundas Road and erecting a sawmill (1816), he further stimulated settlement by leasing some of his land (at the corner of King and Queen Streets) to Phineas Varnum, an innkeeper and blacksmith. With the influx of European German craftsmen in the 1830's, the developing village prospered but was still smaller than its neighbouring communities.

The prospects for Berlin brightened when in succession it was awarded the County seat (1854) and a railroad (1856) after intense political struggles with Galt and Waterloo. The adoption of a factory policy by town council in 1874 spurred rapid industrial growth. It granted a five year tax exemption to all new manufactories and a bonus equal to the annual rental of the building if the establishment employed seventy-five or more. Steam power was readily accepted by local businessmen thereby erasing the waterpower advantage held by other towns (Jeffrey, 1968). Berlin was a pioneer in the municipal ownership of utilities and was able to draw industries by the fact that it owned a waterworks (1898), gas company (1903), sewage disposal system (1891) and streetcar line (1907). The town was also the first urban center in Ontario, besides Niagara Falls, to receive electrification (October 11, 1910) because two of its citizens, Sir Adam Beck and D.B. Detweiler, were instrumental in establishing the Ontario Hydro Commission. Industrial power costs subsequently dropped by a little over 50%. All these factors worked to stimulate Berlin's economic development so that by 1912, when it became a city, it was not only the dominant urban center in the region but also a nationally and internationally known producer of buttons, furniture, luggage, and rubber, leather and felt products.

As Table 4.2 indicates, Kitchener continued to widen the population gap between itself and the other Waterloo County urban centers as time passed. Its phenomenal demographic and economic growth were slowed by the onset of the Great Depression in the 1930's and the outbreak of World War II. Entering the 1950's as the sixteenth largest Canadian city, Kitchener's population growth rate once again exploded and continued relatively steadily throughout the following two decades as one of the highest of the largest cities of Canada (Table 4.3). During the period 1951 - 1976, Kitchener reported not less than the sixth highest population growth rate by five year increments, and over that entire time boasted the third highest total percentage increase (189.02%), ranking only behind Calgary (264.11%) and St. Catharines (224.74%), respectively. And during the five year period, 1971 - 1976, in which Canadian urban growth rates in general began to decline (25% of the 20 largest Canadian cities suffered real population losses), its population growth rate (17.95%) was second only to that of Mississauga (60.20%). However, despite recording an

Table 4.2 Population Growth of Selected Urban Areas in Waterloo County, 1901-1951

	Kitchener	Galt	Waterloo	Preston	Hespeler
1951	44 867	19 207	11 991	7 619	3 862
	(25.83)*	(25.16)	(32.86)	(13.65)	(26.29)
1941	35 657	15 346	9 025	6 704	3 058
	(15.80)	(9.57)	(11.49)	(6.75)	(11.11)
1931	30 793	14 006	8 095	6 280	2 752
	(41.92)	(5.98)	(37.60)	(15.80)	(-0.90)
1921	21 763	13 216	5 883	5 423	2 777
	(43.22)	(28.32)	(34.96)	(39.66)	(17.27)
1911	15 196	10 299	4 359	3 883	2 368
	(55.90)	(30.93)	(23.24)	(68.24)	(-3.62)
1901	9 747	7 866	3 537	2 308	2 457

Source: DBS, 1961 Census of Canada, Vol. 1(1), Population, Table 6, Population by Census Subdivisions, 1901-1961

* - (Percentage Change)

Table 4.3 Population Growth of the Twenty Largest Canadian Cities, 1951-1976

	Calgary 1	St. Catherines 2	Kitchener 3	Edmonton 4	Oshawa 5
1976	469 917	123 351	131 870	461 361	107 023
	(16.51)	(12.42)	(17.95)	(5.30)	(16.85)
1971	403 319	109 722	111 804	438 152	91 857
	(22.00)	(13.00)	(19.89)	(16.24)	(17.30)
1966	330 575	97 101	93 255	376 925	78 082
	(32.42)	(14.95)	(25.20)	(34.12)	(25.10)
1961	249 641	84 472	74 485	281 027	62 415
	(37.33)	(112.73)	(25.05)	(24.35)	(23.81)
1956	181 780	39 708	59 562	226 002	50 412
	(40.85)	(4.54)	(32.75)	(41.58)	(21.34)
1951	129 060	37 984	44 867	159 631	41 545

	London 6	Saskatoon 7	Winnipeg 8	Regina 9	Metro. Toronto+ 10
1976	240 392	133 750	560 874	149 593	2 124 291
	(7.69)	(5.77)	(4.79)	(7.26)	(1.83)
1971	223 222	126 449	535 233	139 469	2 086 017
	(14.82)	(9.11)	(6.47)	(6.36)	(10.86)
1966	194 416	115 892	502 694	131 127	1 881 691
	(14.65)	(21.32)	(5.97)	(16.93)	(16.20)
1961	169 569	95 526	474 374	112 141	1 618 787
	(66.75)	(31.11)	(85.96)	(24.94)	(27.63)
1956	101 693	72 858	255 093	89 755	1 268 376
	(6.66)	(36.78)	(8.22)	(25.85)	(22.20)
1951	95 343	53 268	235 710	71 319	1 037 920

Table 4.3 Population Growth of the Twenty Largest Canadian Cities, 1951-1976, Continued

	Thunder Bay* 11□	Windsor 12	Ottawa 13	Hamilton 14	Halifax 15
1976	111 476	196 526	304 462	312 003	117 882
	(2.83)	(-3.33)	(0.73)	(0.92)	(-3.40)
1971	108 411	203 300	302 241)	309 173	122 035
	(10.88)	(5.59)	(3.96)	(3.71)	(40.61)
1966	97 770	192 544	290 741	298 121	86 792
	(9.13)	(68.36)	(8.40)	(8.81)	(-6.18)
1961	91 625	114 367	268 206	273 991	92 511
	(18.07)	(-6.24)	(20.72)	(14.34)	(-0.85)
1956	77 600	121 980	222 179	239 625	93 301
	(17.38)	(1.61)	(9.97)	(15.03)	(9.01)
1951	66 108	120 049	202 045	208 321	85 589

	Vancouver 16	Quebec 17	Montreal 18	Laval	Mississauga
1976	410 188	177 082	1 080 546	246 243	250 017
	(-3.77)	(-4.84)	(-11.02)	(8.00)	(60.20)
1971	426 256	186 088	1 214 352	228 010	156 070
	(3.87)	(11.44)	(-0.65)	(16.28)	
1966	410 375	166 984	1 222 255	196 088	
	(6.72)	(-2.90)	(2.62)	(57.20)	
1961	384 522	171 979	1 191 062	124 741	
	(5.11)	(0.75)	(7.36)		
1956	365 844	170 703	1 109 439		
	(6.09)	(4.08)	(8.61)		
1951	344 833	164 016	1 024 520		

Table 4.3 Population Growth of the Twenty Largest Canadian Cities, 1951-1976, Continued

Source: DBS, 1961 Census of Canada, Vol. 1(1), Population, Table 6, Population by Census Subdivisions, 1901-1961

Stats. Canada, 1971 Census of Canada, Vol. 1(1), Population, Table 7, Population for Incorporated Cities, Towns and Villages, 1966 and 1971

Stats. Canada, 1976 Census of Canada, Vol. 8, Supplementary Bulletins: Geographic and Demographic - Population, Land Area and Population Density for Census Divisions and Subdivisions, 1976

□ - Indicates 1951-1976 Growth Rate Ranking

+ - Includes: City of Toronto; Boroughs of Scarborough, Etobicoke, York, East York, and North York

* - Includes: Fort William and Port Arthur

Table 4.4 Population Growth, Kitchener, 1971-1979

Year	Population	% Change	Year	Population	% Change
1979	136 091		1975	130228	
		(0.59)			(3.22)
1978	135 288		1974	126 162	
		(1.10)			(3.00)
1977	133 815		1973	122 481	
		(1.47)			(2.51)
1976	131 870		1972	119 483	
		(1.26)			(2.06)
1975	130 228		1971	117 075	

Source: Region of Waterloo Planning Department, "Population - Regional Municipality of Waterloo", mimeograph annual growth rate of 2% - 3% in the first half of the 1970's, the city has experienced as little as 0.59% population growth in the latter half (Table 4.4).

Kitchener's recent economic performance as measured by the number of dollars invested in construction per person (deemed appropriate considering the subject matter of this study) has been good relative to other large Canadian cities despite its lagging population growth (Table 4.5). Every year since 1975, except in 1978, the value of construction investment per person equalled or exceeded the median and the average value for 1975 - 1979 ($574 /person) was the third highest of all recorded Eastern Canadian cities.

From this brief historical analysis of Kitchener's population and economic growth it can be reasonably argued that, although it is not an extremely large city by national standards, it has a vitality that rivals and in some cases exceeds that of cities much larger than itself. Its dynamic yet relatively stable economy makes Kitchener an appropriate city in which to study the dynamic process of redevelopment.

4.2 The Core of Kitchener: Delimitation and Development

The delimitation of the areal extent of the urban core, or central business district (CBD), was the sole

Table 4.5 Building Permit Value / Population*, Twenty Largest Canadian Cities, 1975-1979

City	1979 ($)	1978 ($)	1977 ($)	1976 ($)	1975 ($)	Average ($)
Calgary	2347	2240	1711	953	833	1617
Edmonton	1685	1568	1307	1046	657	1253
Saskatoon	1915	1171	1218	963	956	1245
Regina	1195	965	1212	1135	1009	1103
Mississauga	1069	985	1051	1332	917	1071
Vancouver	891	563	570	592	371	597
Windsor	1024	756	518	339	288	585
Kitchener	673	442	545	658	552	574
Laval	586	489	545	660	500	556
Thunder Bay	531	617	643	489	419	540
Oshawa	353	534	576	727	457	529
Halifax	324	560	633	391	676	517
Ottawa	337	486	500	545	625	499
Metro. Toronto+	464	508	462	398	551	477
Quebec	552	548	408	577	273	472
Winnipeg	464	693	417	433	272	456
London	391	486	488	407	438	442
St. Catherines	404	316	292	406	368	357
Hamilton	248	270	357	335	475	337
Montreal	196	184	304	374	266	265

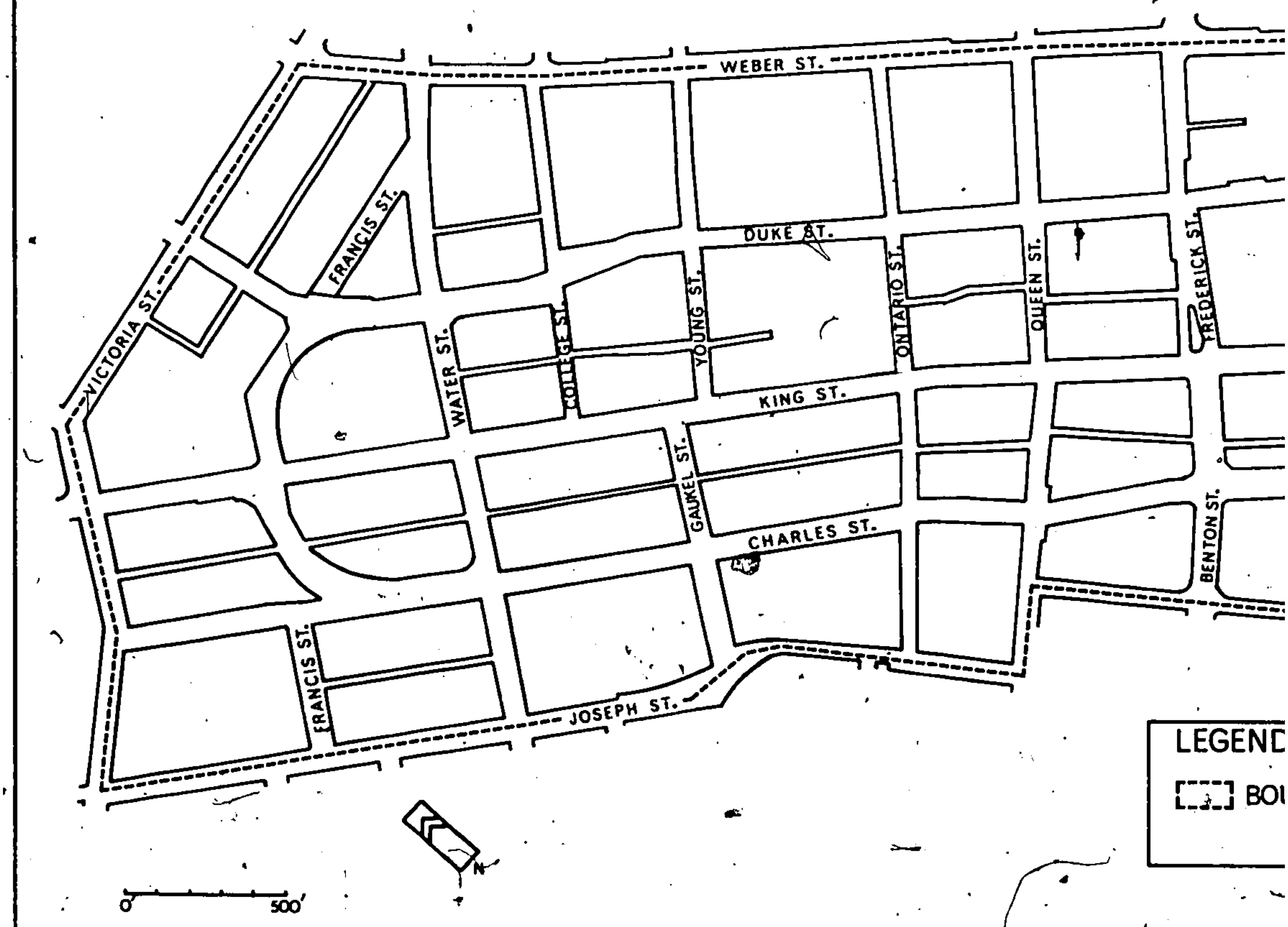
Source: Stats. Canada, <u>Building Permits</u>, Annual Summary, Table 10, Building Permits Issued in Metrpolitan Areas, by Municipality

* - 1976 Population Statistics Used Throughout

\+ - Includes: City of Toronto; Boroughs of Scarborough, Etobicoke, York, East York, and North York concern of many early geographical studies of the internal structure of cities. Murphy and Vance (1954), for example, developed two indices based on the height of buildings and the intensity of land use specifically for that purpose. Methods based on retail sales attraction, diurnal population density variations, land value variations, and building function were considered by Boyce and Horwood (1959) as aids for delimiting a city's CBD. While urban geographers have turned their attention to more sophisticated urban problems, an undisputed, easily employable delimitation technique has not yet been found. The identification of appropriate core boundaries for a study such as this one, therefore, remains somewhat problematic.

In the case of Kitchener there has been no consensus among urban consultants, the municipal government, or the federal government as to what land area its CBD consists of (refer to Map 4.2). In 1955, the Dominion Bureau of Statistics outlined the city's central census tract by Weber Street, Victoria Street, Joseph-Church Streets, and Cedar Street. The Kitchener Planning Department, using a standard of 48% legitimate CBD use (the ability of the land use to attract people to the core area), identified an area broadly defined by Duke Street, Francis Street, Charles Street and Eby Street as the city's core (1967; 1964). An economic analysis of Kitchener's CBD by an urban consulting firm

MAP 4.2 THE STUDY AREA



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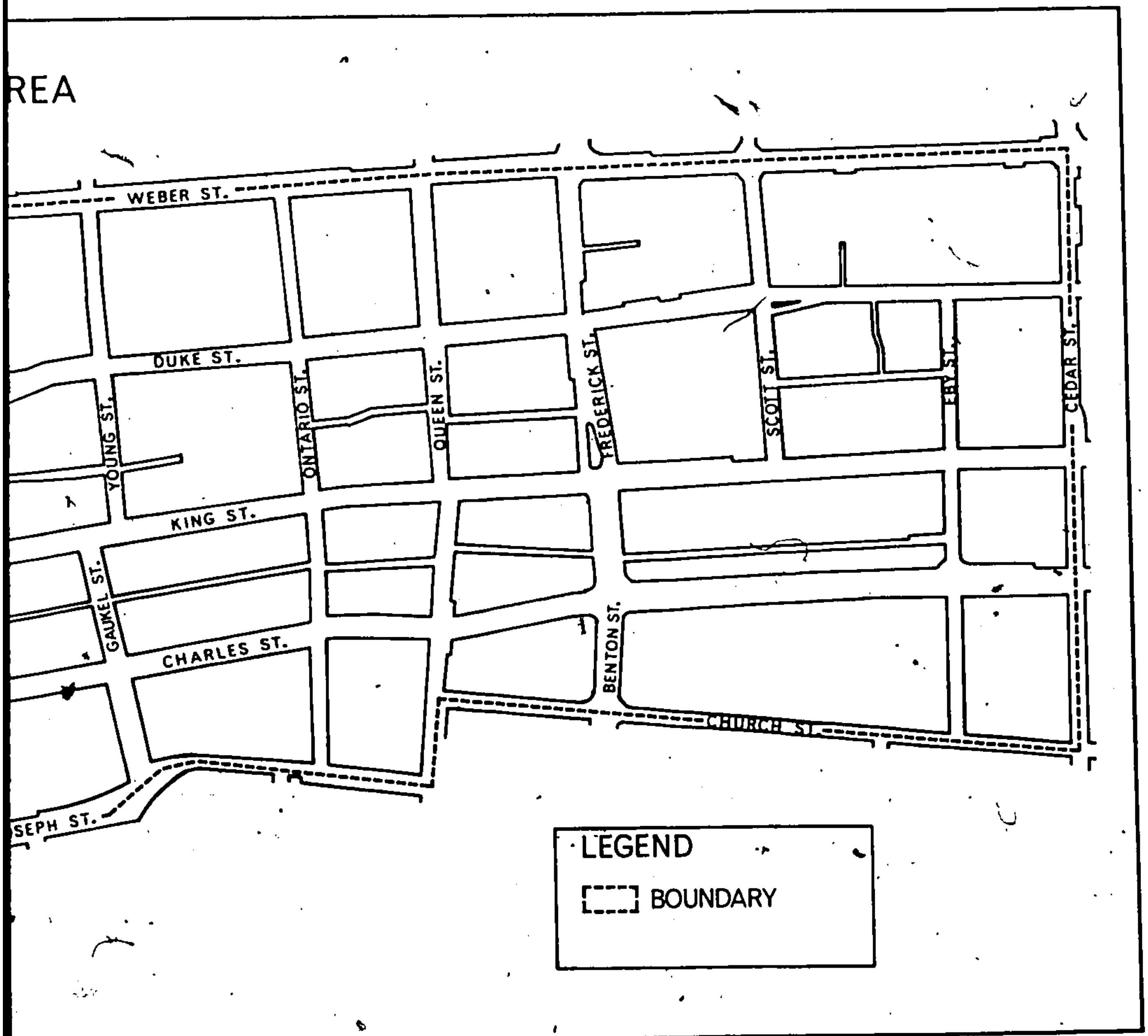

REA
WEBER ST.
DUKE ST.
YOUNG ST.
ONTARIO ST.
QUEEN ST.
FREDERICK ST.
SCOTT ST.
EBY ST.
CEDAR ST.
KING ST.
GAUKEL ST.
CHARLES ST.
BENTON ST.
CHURCH ST.
SEPH ST.
LEGEND
BOUNDARY

2 of 2

(Larry Smith and Company, 1964) used yet another set of boundaries. In light of this lack of agreement the decision was made to adopt the census tract boundaries for the study area since they represent a compromise between the Kitchener Planning Department's position and that of the urban consultants. Thus the study area is bounded by Weber Street on the north, on the west by Victoria Street, by Joseph and Church Streets on the south, and on the east by Cedar Street.

Originally a densely forested series of sandy hills and swampy depressions, Kitchener's core area is now the largest commercial center of the entire region, although its dominance is being challenged by at least one regional level shopping mall (KPD, 1967). As mentionned earlier, the initial commercial development consisted of an inn and blacksmith shop at the southwest corner of King and Queen Streets. Since then King Street has always been the undisputed commercial artery in the city, and the corner of King and Queen Streets the prime land value intersection (Simpson , 1968).

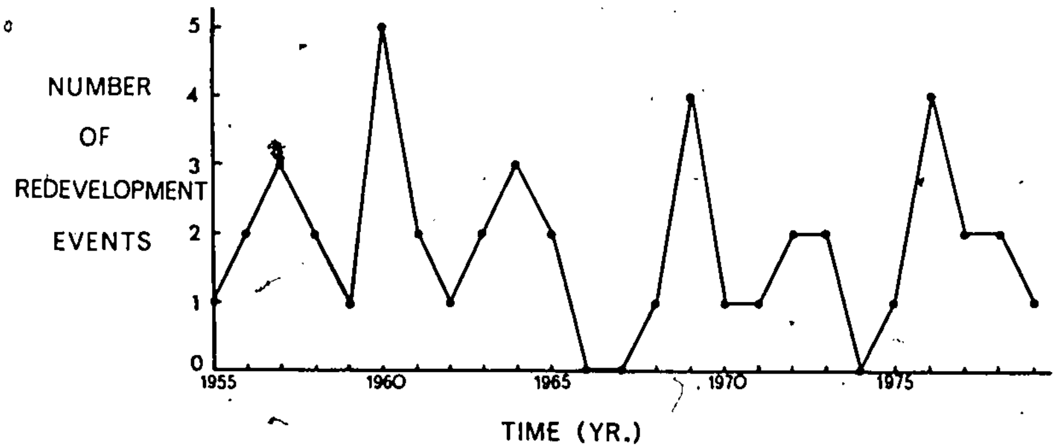
In the early stages of the city's development commercial land uses were dispersed along King Street, intermixed with residential uses and avoiding swampy areas (this review of the historical development of Kitchener's core area is from Simpson, 1968). By 1911 businesses and residences were still interspersed but commercial uses were beginning to dominate. Twenty years later, most residential use on the main artery had been eliminated with the conversion of single family dwellings to commercial use. Industries began moving off of King Street about the same time and some office buildings began appearing. During the depression and war years little change took place other than the replacement of less intensive uses by more intensive ones. In the early 1950's, with federal rent controls lifted, construction activity increased. Soon afterward the CBD approached its current areal limits and virtually no horizontal expansion occurred since then. However, the pressure for more intensive land use and technological changes in floor space demand require that many of the existing buildings within the core area be replaced.

4.3 Past Redevelopment in Kitchener's Core

Because of the spatial discontinuity of the urban growth process and the lack of historical records of land use it is often difficult to determine whether a building constructed in the past was the first one erected on the site or if it replaced a previously existing one. Thus this survey of past redevelopment in the core area of Kitchener covers only the 25 year period, 1955 - 1979. The data were obtained from the city's Engineering Department building permit records and annual reports. It was assumed that by 1955 all core sites had previously been built upon, even though possibly vacant at that time. In the building permit records all new building units were entered in red. In some cases though it referred to the conversion of an existing building rather than the building's replacement. Demolition records were, therefore, checked to corroborate the evidence in the building permit records. It was also assumed that all new buildings within the study area boundaries represented redevelopment whether they replaced buildings that had simply aged and obsolesced or buildings that had been destroyed by natural hazards, such as fire. Of the 45 redevelopment events that were initiated between 1955 and 1979 inclusive, only four are known to have resulted directly or indirectly from fires.

As expected from the review of redevelopment in Chapter 2, the level of redevelopment varies cyclically through time (Figure 4.1). A high of five was recorded in 1960; the years 1966, 1967 and 1974 were marked by the absence of any redevelopment. The cyclical trend appears to exhibit some regularity. This point will be investigated in more detail in the following chapter.

Figure 4.1 Number of Redevelopment Events per Year, Kitchener's Core Area, 1955-1979



Source: City of Kitchener Engineering Department, Building Permit Records, 1955-1979

The estimated construction value of individual redevelopment projects varies widely (Table 4.6). Of the 21 events for which price data are available, 8 are valued in excess of one million dollars, 7 between one hundred thousand and one million dollars, and 6 under one hundred thousand dollars. The most expensive project is in the eight million dollar range whereas the least expensive is slightly less than twenty-five thousand dollars.

In general, redevelopment from 1955 - 1979 is linearly dispersed along King Street (Map 4.3). In fact, a little over 55% (25 of 45) of all redevelopment during that quarter century occurred thereon. Off King Street redevelopment was predominant in the northern half of the core as only three of twenty cases took place in the southern half. The dominance of King Street is also reflected by the marked absence of redevelopment in the corner blocks of the core area; the points furthest from King Street.

Redevelopment from 1955 - 1964 lacks any distinguishing spatial pattern other than occurring adjacent to traffic artery intersections (64%); although over the entire twenty-five year period just under half of all redevelopment was similarly situated. However, beginning in the late 1960's and continuing through the 1970's

Table 4.6 Location and Value of Redevelopment, Kitchener's Core Area, 1955-1979

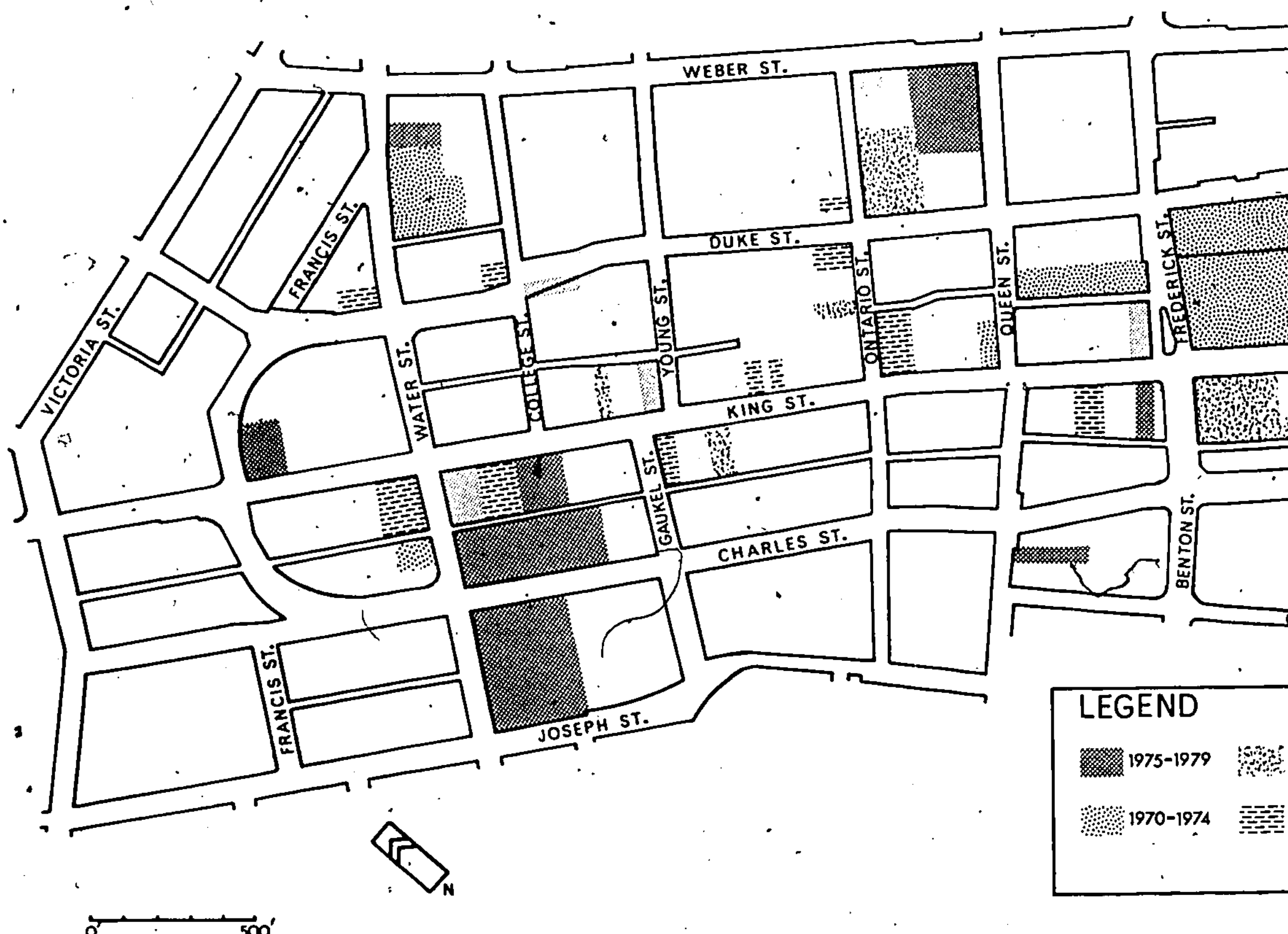
Year Building Permit Issued	Street Address	Estimated Value of Construction (1971 Dollars)
1955	194-204 King St. E.	-
1956	143 Duke St. W.	-
	31 Water St. S.	-
1957	166-174 King St. W.	-
	33-39 Scott St.	-
	21 Weber St. W.	-
1958	155 Duke St. E.	-
	70 King St. E.	-
1959	277-281 King St. W.	-
1960	150 Duke St. W.	-
	92-96 King St. W.	-
	102-104 King St. W.	-
	259-269 King St. W.	-
	60-62 Ontario St. N.	-
1961	29-39 King St. E.	-
	183-185 King St. W.	-
1962	64-68 King St. W.	-
1963	305 King St . W.	-
	104 Ontario St. N.	-
1964	329-339 King St. E.	-
	13-15 Scott St.	-
	30 Water St. N.	-
1965	157-159 King St. E.	-
	153-157 King St. W.	62 000
1968	42 Ontario St. N.	78 000
1969	30 Duke St. W.	4 252 000
	99-127 King St. E.	1 913 000
	200 King St. W.	48 000
	71-75 Weber St. E.	37 000
1970	53 Water St. N.	1 875 000
1971	18-24 Water St. S.	100 000

Table 4.6 Location and Value of Redevelopment, Kitchener's Core Area, 1955-1979, Continued

1972	22 Frederick St.	1 749 000
	25 Frederick St.	2 529 000
1973	49 Frederick St.	2 069 000
	2-8 King St. W.	546 000
1975	67 King St. E.	515 000
1976	235 King St. E.	2 297 000
	400 King St. W.	393 000
	91 Queen St. S.	64 000
	77 Water St. N.	-
1977	265 King St. E.	485 000
	50 Queen St. N.	3 594 000
1978	342 King St. E.	24 000
	231-255 King St. W.	8 349 000
1979	301 King St. E.	261 000

Source: City of Kitchener Engineering Department, Building Permit Records and Annual Reports 1955 - 1979

MAP 4.3 THE LOCATION OF REDEVELOPMENT, 1955-1979



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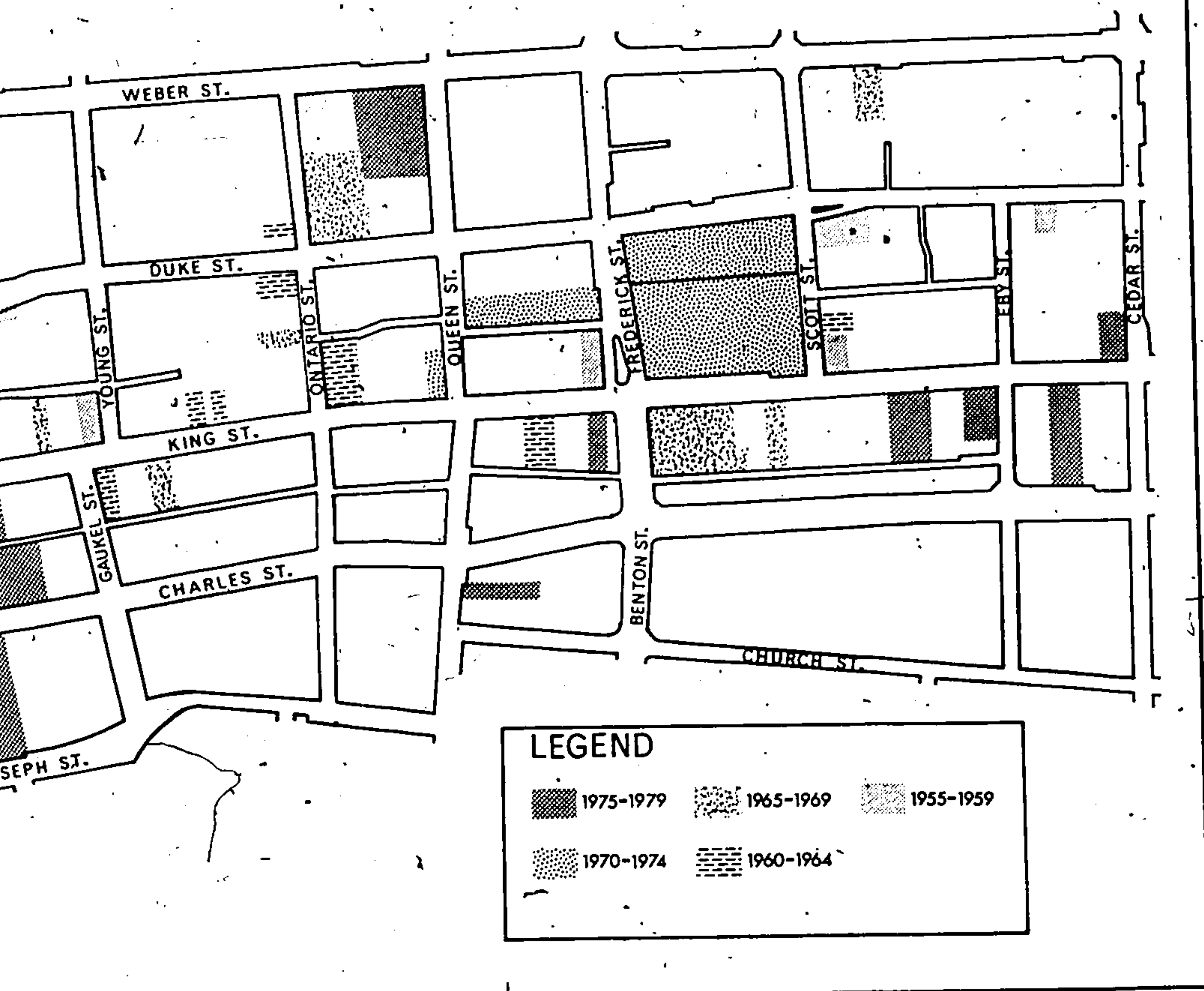
OF REDEVELOPMENT, 1955-1979



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redevelopment shifted toward the eastern half of the CBD (east of Ontario Steet). During the 1970's, 69% (11 of 16) of all redeveloped sites were located in the core's east end. Another notable recent trend is the increasing occurrence of redevelopment on the core periphery. In the period 1975 - 1979 redevelopment took place farther north, south, east and west in the core than in the previous twenty years.

Conclusions pertaining to the location of future redevelopment in Kitchener's CBD that can be drawn from these two trends vary. If the location of redevelopment is influenced by that of previous redevelopment, then one might expect to observe a continuation of the majority of redevelopment in the eastern core. On the other hand, one has not yet accounted for the distribution of sites with relatively high redevelopment potential. If such sites in the core's eastern half become nearly all used up by redevelopment relative to those in the western end, then redevelopment may shift to the western end in the near future. With regard to increasingly peripheral redevelopment, one might expect to see the continuation of the replacement of slightly newer buildings or larger, more accessible peripheral sites than exist in the center of the core. This would lead to a rejuvenated ring around an increasingly deteriorated and obsolesced central core.

Alternatively, the conditions necessary for the redevelopment of the innermost sites may be rapidly approaching and building replacement may switch back to the heart of the CBD.

To attempt to determine the future spatio-temporal behaviour of the redevelopment process in Kitchener from such a summary review of past redevelopment is not justified. However, likely patterns of redevelopment in terms of what is known about the process can be generated by an operational simulation model, whose basis consists of past redevelopment trends. In the next chapter a conceptual model of redevelopment is outlined and the construction and operation of an empirically -based simulation model is described.

CHAPTER FIVE

AN EMPIRICAL REDEVELOPMENT SIMULATION MODEL

5.1 Introduction

The model of redevelopment presented in this chapter is, in the terminology of Alves and Morrill (1975), a conditional predictive model. It is predictive in that the inputs are characteristics of the current state of an urban process and the outputs are attributes of an expected future urban process. The prediction or forecast of the future state of the redevelopment process is an 'explorative' one because it "begins with the assured basis of present knowledge and is oriented toward the future" (Chojnicki, 1970, p.215). The simulation approach is particularly appropriate for the explorative forecasting of a dynamic process because it facilitates the operationalization of change.

The model is conditionally predictive in that the output depends on the input conditions or the rules of the model itself. Therefore, stochastic modelling in itself "does not necessarily imply grave uncertainty as to the outcome" (Harris, 1965, p.94). A certain amount of variability in the output can be expected because of the randomness allowed. Nevertheless, the simulation of the process is guided by the structure of the model itself, and though each run produces individually varying output, a succession of runs leads to a convergence of outcomes (Cowan, 1969).

This chapter is organized as follows. First, a conceptual model or "a concise, systematically organized statement" (Lehman, 1977, p.28) of the redevelopment process is introduced. Subsequently the organization of the data set required for the simulation model is outlined. A discussion of the techniques utilized in the development of the redevelopment attractiveness index and the redevelopment level forecast, the two basic elements of the simulation model, follows. The chapter is completed with a detailed description of the structure and the operation of the simulation model in its entirety.

5.2 A Conceptual Model of Redevelopment

At any given point in time each and every site in the urban core exhibits a varying potential for redevelopment relative to all other sites therein based on certain physical and locational characteristics of both the individual site and the building thereon. The relevant attributes relate to the value of the site alone in the highest and best re-use and to the value of the site and existing building in the present use.

Through time, the relative redevelopment potential of an individual site is constantly altered reflecting continual changes in the physical and locational attributes of the site and building relative to those of all the others.

However, the relative potential for redevelopment of a given site and the changes therein do not exclusively determine when that site will be redeveloped relative to all the other sites. That is, the location of redevelopment in the urban core does not depend solely on the relative ability of individual sites to attract it. It is also influenced by a chance or random factor arising from uncertainty and incomplete knowledge on the part of the development agent, the variability and heterogeneity of real estate, legal restrictions pertaining to the individual sites themselves, and other unspecified causes.

The level of redevelopment in the urban core varies primarily with the availability of finance capital which in turn varies with the health and vitality of the national and local economies. In general, it will follow a cyclical trend reflecting the influence of the business cycle on investment opportunities and the response of development agents to the changing investment climate.

5.3 Organization of the Data Set

The construction and operation of the simulation model required the collection of a wide variety of data. Data were needed for three purposes: 1) the creation of the redevelopment attractiveness index; 2) the development of the redevelopment level forecast; and 3) the operation of the model itself. The bulk of the data collection effort was associated with obtaining the data for the attractiveness index. Therefore it will be described in detail below. The remaining data will be introduced where appropriate.

The derivation of the attractiveness index required data measuring: 1) the physical and locational characteristics of the individual sites of interest in the study area as of the end of 1979; and 2) those same characteristics of each site redeveloped between 1965 and 1979, inclusive, prior to the occurrence of redevelopment. The fifteen year period 1965-1979 was chosen for two reasons. It was presumed that the redevelopment occurring within those fifteen years just exceeded the minimum amount necessary to positively identify the relationships between the occurrence of redevelopment and various site attributes. It was also felt those same relationships were then current enough that it could be safely assumed they would not change significantly over the ten year forecast period. A binary variable recorded as 1 if redevelopment had taken place on the site within the allotted time or 0 if the opposite were true completed data matrix [A]. It should be noted that a site could be included twice; once with the relevant characteristics measured prior to redevelopment and once measured at the end of 1979.

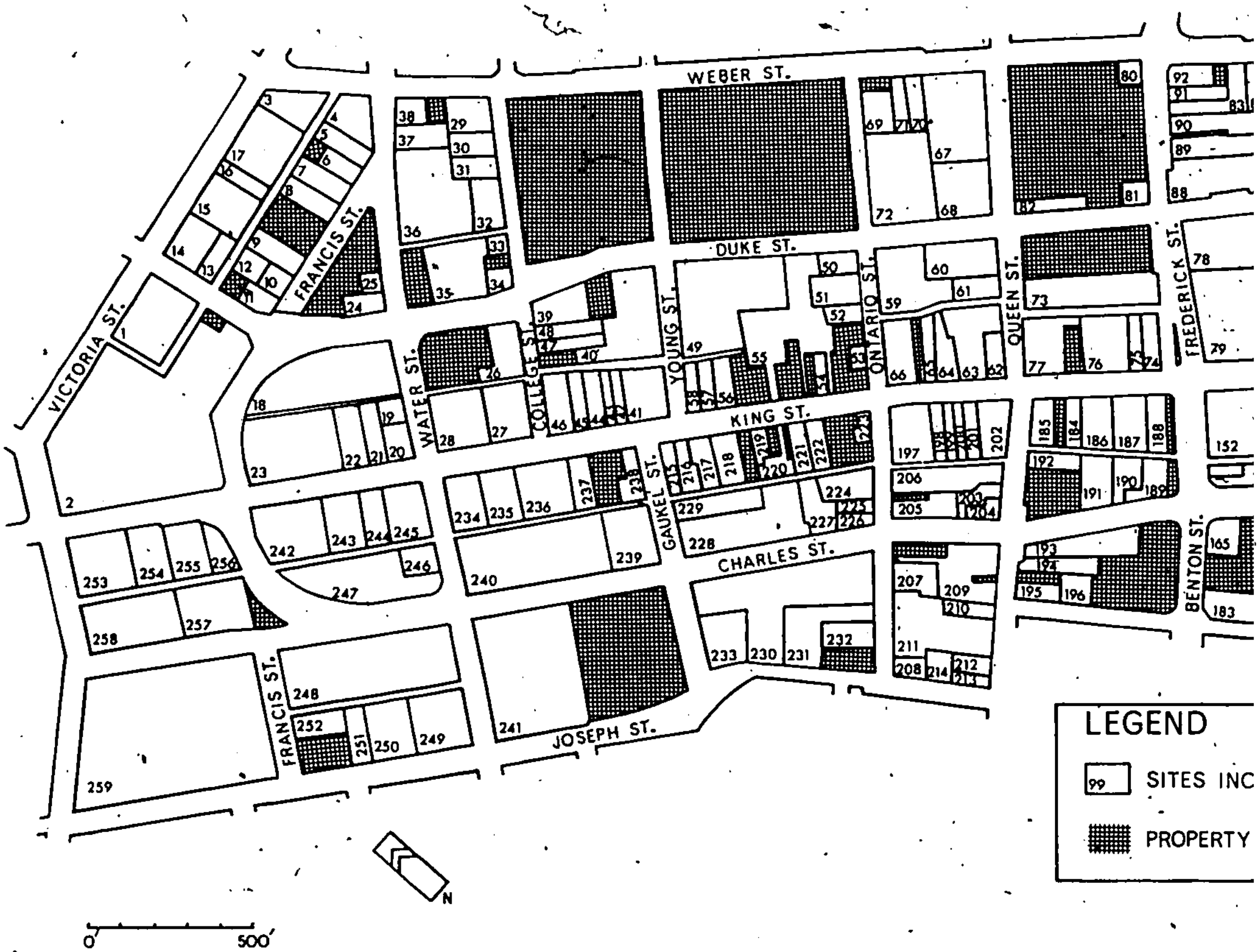
5.3.1 The Spatial Units

As both the creation of the attractiveness index and the operation of the model required individual site data the first data collection task was to discern the pattern of land ownership in the study area, i.e., record the dimensions of every parcel of land as of the end of 1979 (henceforth a parcel of land is referred to as a property when land ownership is involved and as a site in reference to a location for redevelopment). This was primarily accomplished with the aid of the 1979 property assessment records. Often being incomplete in their description of property, the information acquired from the assessment records was supplemented with a map of property ownership in the mid-1960's (City of Kitchener, 1967, Plate 2) and the personal knowledge of the researcher of the study area.

Once the record of land ownership was completed all contiguous or abutting properties (abutment greater than or equal to 30 feet) owned by one party (whether a private individual or a company) or a group of parties related in some manner (in the case of individuals, when they shared a surname, i.e., kinship; in the case of two or more companies, when they shared at least one principal; in the case of an individual and a company, when the individual was a principal in the company) were joined and counted as one site. In this way site assembly that might not have been obvious by simply observing property boundaries as recorded in the assessment rolls was uncovered. The grouping of properties owned by apparently unrelated paties was not carried out because of insufficient grounds on which to base a grouping procedure. Just over 500 sites remained when the grouping of the properties was completed.

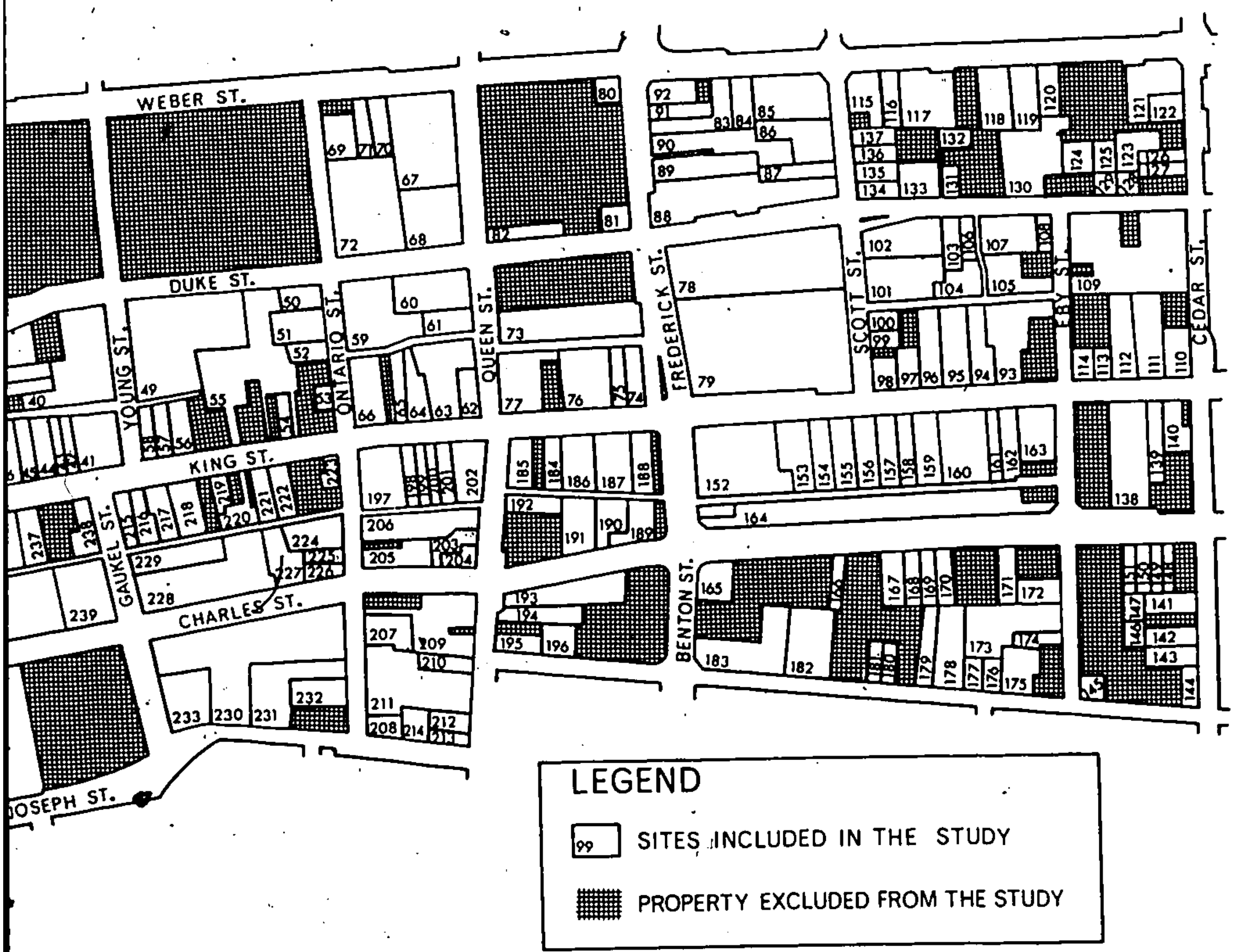
The next step involved selecting the sites that were to be included in the study. It was mentionned in Chapter 1 that the involvement of public agents in the re-use of urban land was to be ignored. In the case of public institutions and the federal government it was assumed their behaviour is not influenced by the profit motive and, therefore, is relatively more difficult to predict than that of private agents. For this reason all sites owned by churches, schools, or other public (non-government) institutions, and by the federal government were excluded from further analysis. Fewer than twenty sites were affected although some, such as the holdings of the Roman Catholic church bounded by Weber, Young, Duke, and Ontario Streets were relatively large. Sites owned by the municipal government were included, however, because it was felt that the actions of local officials in the past indicated a willingness to support the redevelopment proposals of private agents even if they included the purchase of city owned land (more will be said about this matter later). Additionally, all sites possessing an area of less than 3,900 square feet (.09 acres) were excluded from consideration as it was assumed their small size precluded their redevelopment. All redevelopment since 1965 has occurred on sites of at least that size or larger. The assembly of several small sites for redevelopment during the time period covered by the forecast is a possibility that is ignored because no reasonable method of modelling site assembly could be discovered. One further site on the southwest corner of Benton and King Streets was not included because it was zoned as parkland. The 259 sites included in the data set are shown on Map 5.1.

MAP 5.1 LAND OWNERSHIP PATTERN



1 of

HIP PATTERN



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A perusal of Table 4.6 indicates there were twenty-three redevelopment events in the study area between 1965 and 1979. The location of each is identified on Map 4.3. An examination of pre-redevelopment property boundaries revealed that four of the redeveloped sites consisted of two or more properties. In three of the four cases the properties involved were contiguous so they were treated as one site in the data collection process. The exception was the King Centre redevelopment on King Street West. It involved three properties separated by a public laneway and a major traffic artery (Charles Street). The development agent obtained air rights from the city so the three properties could be linked by one building. Because of the uniqueness of the situation data was collected for all three properties and entered into the data set separately; thereby raising the number of redeveloped sites to twenty-five. In order to avoid this problem in the simulation, and in conjunction with the aforementionned site assembly problem, it was assumed all future redevelopment will involve only one site at a time regardless of the size of the site.

Another problem, alluded to earlier, regarded whether the replacement of Kitchener's city hall in 1972 and farmer's market in 1973 should be considered urban renewal or redevelopment in terms of the respective definitions assigned in Chapter 1. Whether the proposal for their replacement was initiated by the private development agent (Oxlea Investments Limited) or by the city's planning department and urban renewal committee has never been decisively proven. It is known the city sold the land to Oxlea and has leased the parking garage erected thereon since then (Pasternak, 1975). It was concluded that the replacement of the two buildings would be considered redevelopment and would be included in the data set.

One further problem in determining the number of sites redeveloped between 1965 and 1979 was how to treat the erection of a new building on a vacant site or parking lot since no existing building was demolished at that time. Technically, building replacement did not take place. It was mentionned in Chapter 4, however, that the assumption was made that all sites in the study area had been built on by 1955. The fact that a building did not exist on the site immediately prior to the construction of a new building was considered to be the result of an extended lag period between demolition and replacement; even to the point of including a temporary land use in between. In this way the problem was eliminated.

5.3.2 The Variables

The site attributes that influence the economic feasibility of redevelopment and, therefore, determine the relative redevelopment potential of each site were reviewed in Chapter 2. From that review it can be hypothesized that site accessibility, site proximity, site size, building deterioration, and building obsolescence vary directly with site redevelopment potential whereas building scale and land use control restrictiveness vary inversely with it. In order to test these hypothesized relationships data measuring each redevelopment location factor on each site had to be collected. Since most of the factors cannot be measured directly one or more surrogate variables had to be found before the testing could be undertaken.

The choice of variables to be utilized was restricted to a large degree by data availability, or rather the lack of it. For example, the physical deterioration and functional obsolescence of buildings would ideally be determined by a building condition (internal and external) survey of all buildings in the study area. The last such survey performed in Kitchener took place in the mid-1960's so the data collected for it were not appropriate for current use. Since this researcher did not have the time or expertise to carry out an adequate building condition survey it was assumed buildings of a similar age had deteriorated and obsolesced to a similar degree. Historical building permit records were checked to determine the age of all buildings in the study area. Again, data availability problems arose because building permit records only extended back to 1927. The solution arrived at was to assign a uniform construction date to all buildings erected before 1927 for which an exact age was not known. The year 1915 was chosen for this purpose because the great majority of old buildings date from at least the turn of the century and 1915 is approximately midway between 1900 and 1927. Thus as of the end of 1979 all undated pre-1927 buildings were considered to be sixty five years old. It is felt the imprecision of such a measure is insignificant. Once buildings attain that age five or ten years do not make much difference in terms of their level of deterioration or obsolescence. Data availability, therefore, greatly influenced the substitute variables that were selected in lieu of the actual location factors and the manner in which the data for each variable were collected and recorded. The rest of the variables and the method by which they were calculated are recounted below. Variable acronyms are in brackets.

Site size (SS) was obtained by using the site dimensions (length and width) from the land ownership records compiled for the purpose of delimiting the sites to be included in the study.

The relative scale of the building on a site was recorded as the ratio of the total floorspace of the building to the total area of the site (FAR). Total building floorspace was calculated by measuring the dimensions of each building from a map and multiplying that area by the number of floors in the building; the latter determined from a map of building heights (in terms of floors) provided in a City of Kitchener Planning Department study (1967, Plate 11) and from visual observation.

The accessibility of a site was measured in three different ways. The first was the straight-line distance from the geographic center of the site to the prime land value intersection of Kitchener, generally acknowledged to be the intersection of King and Queen Streets (DCC). The second was the straight-line distance from the major traffic artery (King Street) to the closest site boundary of each site (DK). The reason for using the closest site boundary instead of the geographic center was so that all sites bordering King Street would be assigned the same value; as opposed to having the value vary with the size and the shape of the site. The third accessibility measure was the total average annual daily traffic volume on all vehicular traffic arteries bordering the site (TV). It was felt this variable would indicate the amount of exposure to the urban population the site received. Since such traffic volume data existed only at intersections an average value was assigned to all sites situated between each pair of intersections. In the case of some relatively infrequently used streets such data did not exist and had to be estimated.

Obtaining a surrogate variable for the proximity of a site to urban amenities or disamenities proved to be unnecessary in Kitchnerer's case because none are clearly recognizable. There are no slums or extremely blighted sub-areas within the city center. The one park that does exist near the core, Victoria Park, does not appear to have affected the location of redevelopment in the past. Therefore, proximal location was included only in terms of the average distance of each site to sites that had been redeveloped in the previous five years (ARD). To obtain data for this variable a grid was placed over the study area (centered on King and Queen Streets) and a pair of location coordinates were assigned to each site (based on its geographic center). The location coordinates of all sites redeveloped in the years 1975 - 1979 were then identified.

The straight-line distances between each site and each redeveloped site were summed and the total divided by the number of redeveloped sites. In this way the possible influence of the locational inertia of redevelopment on a site's redevelopment potential was measured.

The eighth and final variable was one which indicated the restrictiveness of the land use controls applying to a site (ZONE). Zoning sheets allowed the zoning category corresponding to each site to be recorded. The zoning categories were ranked from the least restrictive (1) to the most restrictive (9) based on the number and type of activities allowed thereon. They ranged from the least restrictive Downtown Commercial (C4) to the most restrictive Restricted Residential (R2).

The site characteristic data matrix [A] (Appendix 5.1) was completed by collecting for all redeveloped sites data of a similar nature as close to the year of redevelopment as possible. Refinements to the raw data included the following. The variable TV was logarithmically transformed. The building age variable was represented by three dummy variables since the exact ages for many buildings were not available. The first dummy took on the value 1 if the building was 0-15 years old and 0 if not (BA1); the second assumed the value of 1 for building ages

16-53 and 0 if not (BA2); and the third referred to the 54 year and older age group (BA3). All three dummy variables registered 0 if no building existed on the site. The building age data recorded in years was retained for another use in the simulation. Finally it should be added that the site size variable was categorized into four levels - 1) less than 6,530 square feet; 2) 6,530 - 19,999 square feet; 3) 20,000 - 44,000 square feet; 4) more than 44,000 square feet - according to the observed clustering of the values in the range of the variable in order to increase its level of explanation.

5.4 The Redevelopment Attractiveness Index

The assumption underlying the creation of the attractiveness index is that redevelopment location factors do not change substantially through time. Thus a comparative examination of the characteristics of sites redeveloped in the past, prior to redevelopment, and non-redeveloped sites should reveal the location criteria of future redevelopment and their relative importance. One statistical technique employed by geographers to investigate the statistical relationship between variables is multiple regression analysis. If a statistically significant regression equation relating the various location factors to the occurrence of redevelopment can be found, then it can be used as a composite attractiveness index to measure the redevelopment potential of individual sites.

5.4.1 Multiple Regression Analysis: The Binary Dependent Variable Case

This specific application of regression analysis is unusual because it involves a discrete dichotomous or binary dependent variable. The redevelopment of a site, the dependent variable, is an event. It either occurs or it does not. Interest, therefore, lies not in the value or numerical size of the dependent variable but rather in analyzing the underlying probability of the event and in determining how the independent variables influence that probability (Hanushek and Jackson, 1977). Of course the probabilities are never observed; only the occurrence or non-occurrence of the event is. Quantitatively, the dependent variable Y can only take on the value 1 if the event occurs or 0 if it does not. But the expected or estimated value of the dependent variable $\hat{Y}$ can be interpreted as the probability that $Y_i = 1$ given the levels of the independent variables X_n at the ith observation (Neter and Wasserman, 1974).

The existence of a dichotomous dependent variable causes at least two problems with using the classical linear regression model and the standard parameter estimation method known as ordinary least squares (OLS). First, the assumption of homoscedasticity, one of the seven basic assumptions of the classical linear regression model, is violated. Homoscedasticity refers to the constant variance of the error term (e_i) over the ranges of the independent variables. When the dependent variable is binary the error variance is unequal varying with the values of the independent variables (Wrigley, 1976). This results in the OLS parameter estimators not being the best possible. That is, they no longer have the smallest variance of any linear unbiased estimator - a statistically desirable property. Secondly, although the estimated value of the dependent variable can be usefully and reasonably interpreted as the probability of an event occurring, the actual predicted values can range from positive to negative infinity depending on the levels of the independent variables. Since probabilities are only defined over 0 to 1 the predicted values may fall outside the meaningful range of probability and, therefore, be inconsistent with the interpretation given them. These two problems require that some modifications to the classical linear regression model or to the OLS method of estimation, or both, must be made. Thus when modelling with a discrete dependent variable special consideration must be given to both the functional form of the regression model that is specified and the parameter estimation method that is employed (Hanushek and Jackson, 1977).

A possible solution to the problem of heteroscedasticity is to use weighted least squares estimation instead (Neter and Wasserman, 1974; Wrigley, 1973). This method introduces weights that are the inverse of the known error variances (Wrigley, 1976). The problem with using that method is individual observations must be grouped into sets with a constant probability of the occurrence of the event within each set. With multiple regression analysis it is rarely possible to achieve such a grouping (Cox, 1970).

Two options exist for the solution of the improper range problem. Quite simply the range of the estimated value of the dependent variable can be arbitrarily restricted. For eample, if it falls above 1 or below 0 it can be assigned the value of 1 or 0, respectively. The OLS method can then be used to estimate the parameters of this linear probability model. This solution, however, results in parameter estimates that are significantly biased below their true values when several of the observations have values drawn from their respective ranges where the probabilities take on some extreme value (Wrigley, 1976). That solution, therefore, is not acceptable.

The alternative is to completely respecify the functional form of the regression model so the predicted values of the dependent variable fall within the desired range. In the case of modelling with a discrete binary dependent variable the two alternative forms are the logit and probit models. Associated with the logistic and cumulative normal distributions, respectively, the logit and probit models produce estimated values so similar that "they are virtually equivalent for empirical purposes" (Domencinch and McFadden, 1973, p.58). Because the logit model is better known in geography and because it is a little less complicated, it was chosen for further investigation (for examples of the use of logit models in geography, see Wrigley, 1976; 1975; 1973).

5.4.2 The Logit Model and Maximum Likelihood Estimation

When the estimated value of the dependent variable is interpreted as a probability a non-linear functional relationship (that when graphed produces an S-shaped or logistic curve) between the dependent and independent variables is suggested and is more intuitively appealing than a straight-line relationship. In such cases the classical linear regression model is replaced by the non-linear logit model of the form:

$$P_i = \frac{e^{\alpha + \sum_{n=1}^{p} \beta_n X_{in}}}{1 + e^{\alpha + \sum_{n=1}^{p} \beta_n X_{in}}} \qquad (1)$$

where P_i is the probability of the occurrence of an event given the values of the independent variables at the ith observation, X_{in} is the nth independent variable at the ith observation, $n = 1,\ldots,p$, α is the constant term, β_n is the coefficient of the nth independent variable, and e is the base of the natural logarithms. Deriving the linear form of the model requires a minor transformation:

$$\frac{P_i}{1 - P_i} = e^{\alpha + \sum_{n=1}^{p} \beta_n X_{in}} \qquad (2)$$

$$\log_e \frac{P_i}{1 - P_i} = \alpha + \sum_{n=1}^{p} \beta_n X_{in} \qquad (3)$$

The term logit is due to Berkson (1944). The ratio (P_i / 1 - P_i) defines the odds of an event occurring at i. When the logarithm is taken it becomes the log-odds or logit.

Whether the linear or non-linear form of the logit model is adopted depends on the parameter estimation method to be used. Either weighted least squares or maximum likelihood estimation is appropriate (Wrigley, 1976; Theil, 1971). When there are many repeat observations the linear logit model and weighted least squares can be utilized. However, when few repeat observations exist, as in many cases of multivariate analysis, the same grouping problem noted earlier arises. Maximum likelihood estimation with the non-linear logit model is the alternative.

Maximum likelihood estimation was developed by Fischer in 1936. It avoids the grouping problem by treating each observation separately. In simple terms the method involves choosing a and b_n as estimates of α and β in such a way that, if they were actually α and β., the given observations would have the greatest probability of occurrence (Ashton, 1972, p.24). In other words, the parameters α and β are estimated by accepting as estimates the values of α and β that maximize the likelihood function. The likelihood of a set of observations from a discrete distribution is their joint probability of occurrence and is derived from observing the pattern of occurrences and non-occurrences in the data set.

Maximum likelihood estimators are statistically desireable because under broad conditions they are consistent (as the sample size becomes larger the probability distribution converges on the true parameter values), asymptotically efficient (smallest asymptotic variance among all asymptotic unbiased estimators), and asymptotically normal (Hanushek and Jackson, 1977).

The non-linear logit model, therefore, will be used as the structural base of the attractiveness index in the simulation model. The only adjustment to be made is that the estimated value of the dependent variable will be interpreted as the potential for redevelopment, not the probability of redevelopment. The parameters that specify the relationships between the occurrence of redevelopment on a site and the site's physical and locational attributes will be estimated using the method of maximum likelihood. The attractiveness index will have the form:

$$\hat{P}_i = \frac{1}{1 + e^{-(a + \sum_{n=1}^{p} b_n X_{in})}} \qquad (4)$$

where $\hat{P}_i$ is the estimated redevelopment potential of site i, X_{in} is the nth attribute of site i, b_n is the estimated coefficient of the nth attribute, and a is the estimated constant term. Before the results of the regression analysis are reported and the specific form of the index presented, two of the common problems associated with its (regression analysis) use, despite the functional form of the regression model and the parameter estimation method employed, will be briefly addressed. They are the violation of the assumptions of the independence of the observations and of the independent variables.

5.4.3 Multiple Regression Analysis: Two Problems

The former problem, spatial autocorrelation, "exists when the value of a variable at one observation is not independent of the value of adjacent observations" (Johnston, 1978, p.253). It causes statistical estimates of regression parameters to be biased. In the last decade geographers have increasingly recognized that to a great extent geographical applications of regression analysis necessarily involve spatial autocorrelation. Some now believe regression techniques must no longer be used in geographical research (Gould, 1970). Others have spent time developing measures of spatial autocorrelation so a researcher will know the extent to which the problem exists (Cliff and Ord, 1973). In the case of non-linear regression, however, the same measures cannot be used and Wrigley (1976) maintains much work remains to be done in this area. Therefore Johnston's (1978) view that regression analysis can still be validly utilized if the problem is recognized and the results qualified in light of the problem is adopted here.

The latter problem, multicollinearity, occurs when there is a high degree of linear dependence between two or more of the independent variables. The result is that the estimated regression coefficients tend to have a large sampling variability and, therefore, only imprecise information about the true coefficients may be gained (Neter and Wasserman, 1974). That does not mean a good fit of the data cannot be obtained though. It is just that when multicollinearity exists it is possible for many different models to provide the same good fit. One must avoid interpreting any one set of coefficients as reflecting the inherent effects of the particular independent variables on the dependent variable; rather they are partial effects given whatever other correlated independent variables are included in the model.

Various remedial measures can be used to eliminate or reduce multicollinearity. They include dropping one or several of the independent variables, increasing the sample size, or estimating the coefficients for different variables from different sets of data (Neter and Wasserman, 1974). Often, however, these alternatives are not possible or desireable; the regression analysis must then proceed with multicollinearity. Poole and O'Farrell (1971, p.55) claim that "if the purpose of the regression analysis is only to predict the value of Y corresponding to a set of X values, then multicollinearity is not a serious problem". Since this is the express aim of employing regression anlaysis in this thesis any multicollinearity of the independent variables will be noted but will not be deemed a significant problem.

5.4.4 Logistic Regression Analysis: Results and Interpretation

The initial regression analysis was performed on data matrix [A] consisting of 284 observations (259 non-redeveloped and 25 redeveloped sites) measured on the 10 independent variables and 1 dependent variable described earlier. The SHAZAM Version 3.0 Logit Analysis Program (White, 1978) was used. The method of maximum likelihood was employed so significance testing of the 'goodness of fit' of the resultant logit model involved both a likelihood ratio statistic and a pseudo R^2 statistic. The likelihood ratio λ is the ratio of the value of the likelihood function assuming a constant probability divided by the value of the function when the probabilities are assumed to depend on the independent variables (Nerlove and Press, 1973). For large samples, the quantity $-2 \log \lambda$ is distributed as χ^2 (Chi Square) with as many degrees of freedom as independent variables. The alternative test statistic, pseudo R^2, is a variation of the usual R^2 statistic; the variation required because maximum likelihood rather than least squares estimation was used. It can be interpreted in exactly the same way as R^2. The statistic for testing the significance of each of the individual regression coefficients is the t-ratio.

The selection of the variables to be included in the final form of the attractiveness index was performed by running a number of regression analyses with different combinations of the original variables. After each analysis was completed the λ, R^2, and t-ratio statistics were analyzed to evaluate the change in them caused by dropping the various variables. The seven variables found to be significantly related (at the .05 significance level) to the occurrence of redevelopment were (t-ratios): 1) DCC - distance to the city center (3.97); 2) ARD - average distance to other redevelopment (-4.58); 3) TV - traffic volume (2.60); 4) SS - site size (2.19); and BA1, BA2, and BA3 - the three building age dummies (-0.99,-2.52, and -2.37, respectively). Despite several transformations of the other three variables the absolute value of their t-ratios did not become large enough to statistically conclude their respective coefficients were significantly different from zero. And although the t-ratio of BA1 did not indicate statistical significance either, it was accpted because those of the other two age dummies did.

The final accepted form of the logit model and, hence, the attractiveness index was:

$$\hat{P}_i = \frac{1}{1+e^{-(-10.96+24.02DCC_i-46.28ARD_i+4.15\log TV_i+.77SS_i-9.91BA1_i-2.08BA2_i-1.63BA3_i)}} \quad (7)$$

where $\hat{P}_i$ is the estimated redevelopment potential of site i, DCC_i is the distance to the city center from site i, ARD_i is the average distance to other redevelopment from site i, TV_i is the traffic volume at site i, SS_i is the size of site i, and $BA1_i$, $BA2_i$, and $BA3_i$ are the dummy variables referring to the age of the building on site i.

According to the pseudo R^2 statistic the model explained approximately half (49.80%) of the variation in the dependent variable. Considering the complexity of the redevelopment process and the number of uncontrollable factors involved that amount of explanation is acceptable. The likelihood ratio statistic also indicated the model was a good fit of the data as its value 71.87 with 7 degrees of freedom far exceeded the critical value 20.28 at the .005 significance level.

Because of the multicollinearity between the variables DCC and ARD ($r=.877$), the specific relationship between the occurrence of redevelopment and each of the independent variables was not revealed by the respective regression coefficients. Some general relationships, both expected and unexpected, between the independent variables and the dependent variable and between the various independent variables themselves were identified though.

As hypothesized, site proximity varied with the dependent variable. However, since proximity itself varies inversely with distance, the sign of the regression coefficent of the variable ARD is negative. In other words, the closer a site is to other redeveloped sites, the greater that site's redevelopment potential. This spatial clustering or locational inertia of redevelopment was suggested in the literature and there appears to be evidence of it in the core in Kitchener. Traffic volume and site size varied directly with redevelopment potential. The higher the traffic volume or the larger the site, the higher the redevelopment potential. The relative size of the regression coefficients of the building age dummies together with their signs (all negative) suggested the older the building, the greater the attractiveness to redevelopment.

The unexpected relationship that emerged related to the DCC variable that was included as a measure of accessibility. According to traditional geographic theory the most accessible urban locations are those nearest the center of the city. Accessible locations are associated with high land values because of their relatively lower transportation costs. If land valus are high one would anticipate relatively high redevelopment potential. Thus one would expect distance measures of accessibility to vary indirectly with redevelopment potential since accessibility itself varies inversely with distance. On the contrary, the DCC variable was positively related to the dependent variable. That is, the farther the site from the city center, the greater its redevelopment potential. This relationship does not extend to the urban fringe. It only applies as far as the periphery of the core because that was the spatial extent of data collection. A tentative conclusion that is suggested is that the peripheral core sites are actually more accessible than those of the inner core.

The fact that the regression coefficient signs of the DCC and ARD variables are opposite is interesting as well. If they had been the same, both negative, they would be identifying the clustering of redevelopment in the central core; a spatial pattern suggested by theory. Their opposite signs combined with the negative DCC coefficient suggests an unexpected pattern of past redevelopment; that of clustering on the core periphery. The continuation of such a pattern for an extended period of time would have undesireable consequences for the socioeconomic health of the inner core area of Kitchener.

5.5 The Redevelopment Level Forecast

The second substantive component of the simulation model is the forecast of the level of redevelopment over the ten year prediction period. There are several ways to develop such a forecast; some very complex and some rather simple.

One approach involves the relationship of construction activity with the health of the national and local economies. Based on future trends in the business cycle, a forecast of the building or construction cycle can be made. The problem with this particular approach is that it is extremely difficult to identify the specific link between the performance of the national or local economies and the level of redevelopment in a particular city. Furthermore, it is also an onerous task to forecast the behaviour of the business cycle for any length of time.

An alternative approach is to assume there will be no substantive change in national and local economic conditions in the future from those in the past. The redevelopment level, therefore, will continue to vary from year to year according to the trend established in the past. A forecast of the variation in the level of redevelopment can then be derived by analyzing the historical trend, determining its regularities, and extrapolating it.

There have been numerous statistical techniques developed by econometricians and others to analyze such time series data. They range from the sophisticated Box-Jenkins approach and the autoregressive integrated moving average (ARIMA) models (Box and Jenkins, 1976) to the conventional regression analysis. One technique, Fourier analysis, is specifically used for identifying cyclical tends. It involves fitting a combination of trigonometric functions to time series data (Bloomfield, 1976).

It was decided, however, that the degree of precision in trend identification afforded by the aforementionned statistical techniques, when compared to the amount of time and expertise required to properly use them, did not warrant their utilization. Furthermore, the amount of variation in the number of redevelopment events initiated from year to year in Kitchener's core area is rather minimal. The average for the past twenty five years is 1.8 sites per year. The maximum was five in 1960; the minimum zero in 1966, 1967, and 1974. Thus even if the average value were selected for each year of the forecast the maximum error would be underestimation by three or overestimation by two. Over the entire forecast the cumulative error would be negligible. However, a rather simple yet effective technique was devised to provide a more satisfactory estimation of the past redevelopment trend.

The procedure employed was the following. Initially the number of sites redeveloped annually in the study area for the years 1955 - 1979, inclusive, as recorded by the City of Kitchener Engineering Department, were plotted on a graph (Fig. 5.1). The points on the graph were joined and the curve was examined closly by eye for any indication of regularity in its frequency or amplitude. It was noticed that indeed the curve exhibited a cyclical trend with an average wavelength of approximately four years. Hence varying repetitive series of four numbers were plotted against the observed curve in an attempt to replicate the trend as much as possible.

A 'goodness of fit' measure between the actual and the various fitted time series of numbers was calculated by summing the difference between them for each of the twenty-five years (Table 5.1). Of the six fitted series, the two with the smallest sums were series C (1,3,1,2,...) and E (1,4,2,0,...); they both underestimated by two. A

Figure 5.1 Observed Versus Fitted Redevelopment Trends

Series A - 1,2,3,2, . . .

Series B - 1,4,1,2, . . .

Series C - 1,3,1,2, . . .

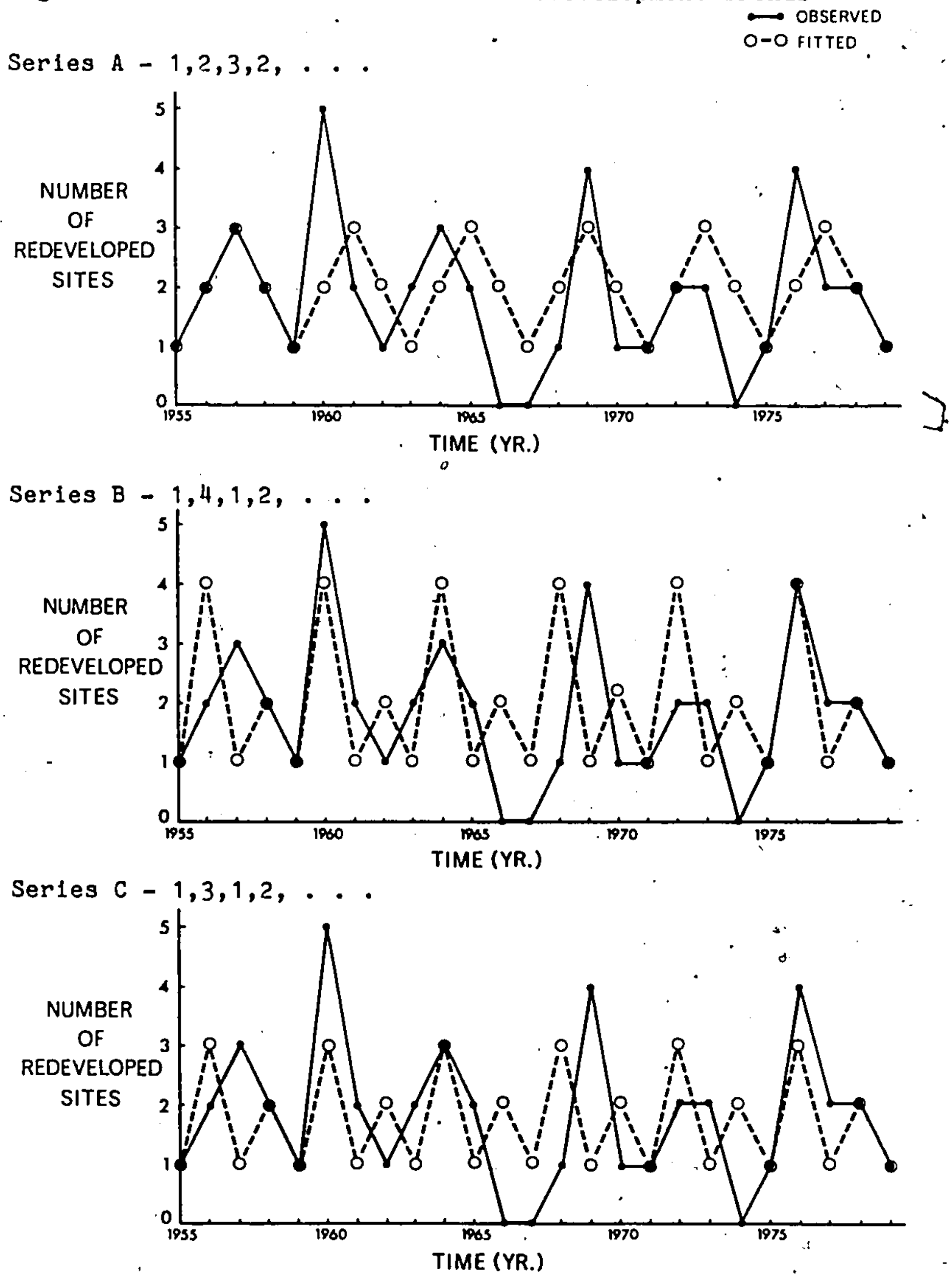
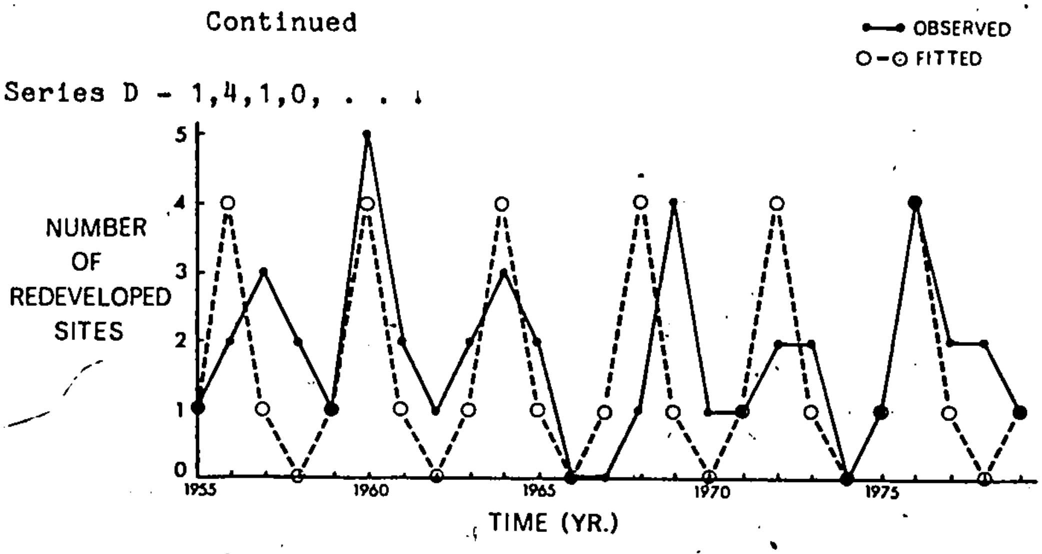
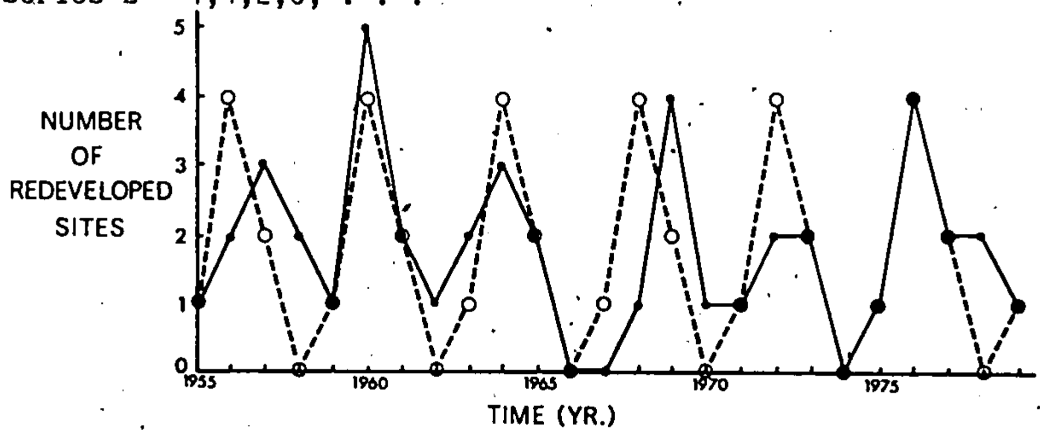


Figure 5.1 Observed Versus Fitted Redevelopment Trends, Continued

Series D - 1,4,1,0, . . .



Series E - 1,4,2,0, . . .



Series F - 1,3,2,0, . . .

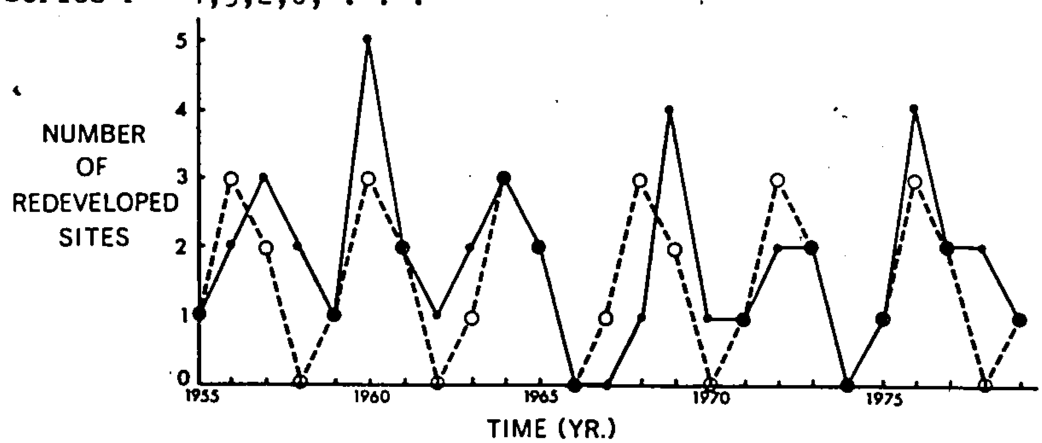


Table 5.1 Statistical Comparison of the Observed and Fitted Redevelopment Trends

Year	Obs. Level (O)	Series A (A)	Series A (O-A)*	Series A $(O-A)^2$	Series B (B)	Series B (O-B)*	Series B $(O-B)^2$
1955	1	1	0	0	1	0	0
1956	2	2	0	0	4	-2	4
1957	3	3	0	0	1	2	4
1958	2	2	0	0	2	0	0
1959	1	1	0	0	1	0	0
1960	5	2	3	9	4	1	1
1961	2	3	-1	1	1	1	1
1962	1	2	-1	1	2	-1	1
1963	2	1	1	1	1	1	1
1964	3	2	1	1	4	-1	1
1965	2	3	-1	1	1	1	1
1966	0	2	-2	4	2	-2	4
1967	0	1	-1	1	1	-1	1
1968	1	2	-1	1	4	-3	9
1969	4	3	1	1	1	3	9
1970	1	2	-1	1	2	-1	1
1971	1	1	0	0	1	0	0
1972	2	2	0	0	4	-2	4
1973	2	3	-1	1	1	1	1
1974	0	2	-2	4	2	-2	4
1975	1	1	0	0	1	0	0
1976	4	2	2	4	4	0	0
1977	2	3	-1	1	1	1	1
1978	2	2	0	0	2	0	0
1979	1	1	0	0	1	0	0
	45	49	-4	32	49	-4	49

* - Negative value indicates overestimation; and vice versa

Table 5.1 Statistical Comparison of the Observed and Fitted Redevelopment Trends, Continued

Year	Obs. Level (O)	Series C (C)	(O-C)*	$(O-C)^2$	Series D (D)	(O-D)*	$(O-D)^2$
1955	1	1	0	0	1	0	0
1956	2	3	-1	1	4	-2	4
1957	3	1	2	4	1	2	4
1958	2	2	0	0	0	2	4
1959	1	1	0	0	1	0	0
1960	5	3	2	4	4	1	1
1961	2	1	1	1	1	1	1
1962	1	2	-1	1	0	1	1
1963	2	1	1	1	1	1	1
1964	3	3	0	0	4	-1	1
1965	2	1	1	1	1	1	1
1966	0	2	-2	4	0	0	0
1967	0	1	-1	1	1	-1	1
1968	1	3	-2	4	4	-3	9
1969	4	1	3	9	1	3	9
1970	1	2	-1	1	0	1	1
1971	1	1	0	0	1	0	0
1972	2	3	-1	1	4	-2	4
1973	2	1	1	1	1	1	1
1974	0	2	-2	4	0	0	0
1975	1	1	0	0	1	0	0
1976	4	3	1	1	4	0	0
1977	2	1	1	1	1	1	1
1978	2	2	0	0	0	2	4
1979	1	1	0	0	1	0	0
	45	43	2	40	37	8	48

* - Negative value indicates overestimation; and vice versa

Table 5.1 Statistical Comparison of the Observed and Fitted Redevelopment Trends, Continued

Year	Obs. Level (O)	(E)	Series E (O-E)*	$(O-E)^2$	(F)	Series F (O-F)*	$(O-F)^2$
1955	1	1	0	0	1	0	0
1956	2	4	-2	4	3	-1	1
1957	3	2	1	1	2	1	1
1958	2	0	2	4	0	2	4
1959	1	1	0	0	1	0	0
1960	5	4	1	1	3	2	4
1961	2	2	0	0	2	0	0
1962	1	0	1	1	0	1	1
1963	2	1	1	1	1	1	1
1964	3	4	-1	1	3	0	0
1965	2	2	0	0	2	0	0
1966	0	0	0	0	0	0	0
1967	0	1	-1	1	1	-1	1
1968	1	4	-3	9	3	-2	4
1969	4	2	2	4	2	2	4
1970	1	0	1	1	0	1	1
1971	1	1	0	0	1	0	0
1972	2	4	-2	4	3	-1	1
1973	2	2	0	0	2	0	0
1974	0	0	0	0	0	0	0
1975	1	1	0	0	1	0	0
1976	4	4	0	0	3	1	1
1977	2	2	0	0	2	0	0
1978	2	0	2	4	0	2	4
1979	1	1	0	0	1	0	0
	45	43	2	36	37	8	28

* - Negative value indicates overestimation; and vice versa

second 'goodness of fit' measure was then calculated to determine which of those two provided the better fit. It consisted of the squared differences of each year summed over the entire period and guaged the absolute difference (both over- and underestimation) between the observed and fitted curves. Series E scored the lower total of the two on the second measure. And although outperformed on the second measure by both series F (1,3,2,0,....) and A (1,2,3,2,...), it was felt series E provided the best overall fit. In addition to its relative performance on the two goodness of fit measures, it also boasted (together with series F) the greatest number of coincidental values (approximately 50%) with the actual series. Extrapolating that trend into the future the forecast of the level of redevelopment in the study area is: four in 1980; two in 1981; zero in 1982; one in 1983; four in 1984; and so on to 1989.

5.6 The Simulation Model: Structure and Operation

The simulation model of redevelopment is a computer program (Appendix 5.2) written in FORTRAN IV. It is a sequential procedure consisting of six basic steps: 1) data input; 2) redevelopment attractiveness index calculation; 3) site redevelopment selection; 4) data output; 5) 'accounting procedures'; and 6) repetition of the entire sequence as many times as desired. For the sake of computing efficiency parts of some of the steps are not in exactly the same order as listed above.

Before a detailed description of the model is presented it should be noted that one completion of the entire procedure is considered to be one time period equivalent to one year. Although the model could have been designed to operate for any given number of time periods, the limit was set at ten (one decade). It was felt ten years was long enough for the evolution of an obvious spatial pattern of redevelopment and yet short enough for the socioeconomic, and the resultant redevelopment, trends on which the attractiveness index and the level forecast are based not to drastically change. The model furnishes a forecast of the number and location of sites redeveloped in the core of Kitchener each year for the ten year period 1980 - 1989.

The intial task of the model is to declare the number and order of the data arrays required for the execution of the program. It then instructs the computer to access or locate those arrays in its memory bank. The primary data matrix [B] is a mutation of matrix [A] introduced earlier. It consists of 259 observations (non-redeveloped sites) measured on 7 variables (comprising the attractiveness index). Matrix [B] is necessary for the repeated calculation of the estimated redevelopment potential of each site. In order to facilitate data collection each site was assigned an identification number, 1 through 259. The sites were numbered in a spatially ordered fashion beginning at the north-east corner of Victoria and King Streets and continuing clockwise around the study area. In order that the manner in which the indentification numbers were assigned did not affect the results of the simulation, the observations' order was arbitrarily scrambled before being entered into the computer. Throughout the model measures were taken to ensure that site identification remained correct. Other data arrays required for the operation of the model are: 1) the ten redevelopment level forecast values; 2) the X and Y location coordinates of each of the 259 non-redeveloped sites; 3) the building age in years of each site; and 4) the x and Y coordinates of previously redeveloped sites (Appendix 5.3). After all the data arrays are located a number of quantities used elsewhere in the program are initialized.

The following step is the calculation of the estimated redevelopment potential of each site from the attractiveness index (logit model), the form of which was reported earlier. The range of the index values is originally 0-1, inclusive, but it is transformed to 0-100, inclusive. Any transformed index values between .500 and .999, inclusive, are increased to 1.00; any less than .500 are considered to be 0.00. All sites with estimated potential values of zero are ignored for the duration of that time period. The maximum index value and the sum of the values are both calculated and recorded for later use.

A matrix of consecutive numbers [IR] consisting of a variable number of rows corresponding to the number of sites with non-zero index values and a variable number of columns matching the maximum index value for the given time period is then created. Each row relates to one observation or site and is comprised of a series of consecutive numbers, the number of which corresponds to the index value of the given site. The remaining elements of the row, up to the maximum index value of all observations, are assigned zeroes. For example, if a given site's index value is 23 and the maximum value is 89, there would be 23 consecutive numbers in that row, beginning in the first column, and 66 zeroes. The value of the first element in each row is one greater than the last non-zero value in the previous row. The sequence begins at one and ends at a value equal to the sum of all the index values. This matrix [IR] is the probability distribution by which the pseudo-random numbers generated by an arithmetic procedure within the computer are transformed into values that have some empirical meaning.

Prior to the generation of the pseudo-random numbers a check is made to determine how many, if any, sites are forecasted for redevelopment in the given time period. If no redevelopment is forecast for that year the computer is instructed to ignore all following operations until the output stage. Otherwise the Monte Carlo technique is invoked.

The Monte Carlo technique involves the generation of a pseudo- random number whose value lies between zero and one, inclusive. It, in turn, is multiplied by the sum of the index values so that it falls within the range of values created by the attractiveness index. Matrix IR is then checked to determine in which row the pseudo-random number falls. The site that corresponds to the row which contains the element whose value matches the pseudo-random number is the site that is selected for redevelopment.

In this way the chance a site is selected for redevelopment in a given time period varies with its redevelopment potential relative to that of all other sites. The randomizing factor is, therefore, subject to certain restrictions. A site with an index value higher than another site has a greater chance of being selected for redevelopment than the second site. However, the possibility of a site possessing relatively little redevelopment potential being picked still exists. Thus the index value is relative rather than absolute. A value of 90 does not represent a 90% chance of being selected for redevelopment in a given time period. It merely indicates the site has twice the chance or twice the potential of a site scoring 45.

Returning to the model procedure, the location coordinates of the redeveloped site and the year of redevelopment are recorded for later use. The building age variable value is changed to zero and the site's dummy variables' values are adjusted accordingly. The subroutine is repeated as many times as the redevelopment level forecast specifies. On subsequent passes through the subroutine a check is made to ensure that the same site is not redeveloped more than once in one time period.

At this point the computer is instructed to output the results from the previous operations. However, the format of the output will be described following the presentation of the rest of the model.

Once all redevelopment forecasted for the given time period has been produced by the model, one time period has effectively passed. The time variable is incremented by one. The only remaining task before the activities of the subsequent time period are embarked upon is to account for the changes in the data values contained in matrix B that resulted from the redevelopment activity and the passing of time. The changes with respect to the age of the buildings on redeveloped sites have already been processed. Thus alterations must be made to the ages of all buildings arising from the passing of one year and to the average redevelopment distance of each site stemming from the redevelopment that occurred in the recently expired time period.

The adjustment to the building age variable consists of increasing each respective value by one, except for sites lacking a building (indicated by the value 999). The age of each building is compared to the limits of the three dummy variable categories and the required changes in the dummies made.

The average redevelopment distance of each site is recalculated by recording the location coordinates of all sites redeveloped in the previous five years, including the one just completed. All the distances from one site to each redeveloped site are calculated, summed, and an average value computed; the procedure is repeated for all sites included in the study. With that all accounting procedures are completed since site assembly and, therefore, site size changes are ignored, changes in the prime land value intersection and, therefore, changes in the distance to the city center are assumed not to occur, and traffic volumes are assumed to increase proportionally through time.

Subsequently the entire procedure is repeated beginning with initialization. Changes in the values included in matrix [B] produce changes in the redevelopment potential of each site. All sites including those selected for redevelopment in the previous time period are available for redevelopment once again. However, the newness of recently replaced buildings lowers the redevelopment potential of the site relative to the preceeding time period. The attractiveness of non-redeveloped sites may increase or decrease depending on the interplay of changes in building age and average redevelopment distance. If the number of time periods for which the operation of the model is desired has expired, the changes to the age variables and the ARD variable are ignored and the operation of the model ceases.

The model output is uncomplicated. For each of the ten time periods the attractiveness index values of each site are listed, the forecasted number of redeveloped sites is printed, the street address, identification number, and location coordinates of each redeveloped site are reported, and the year corresponding to the given time period is recorded. Matrix B , containing all the adjustments made to it over the simulated decade, concludes the model's output.

Since the randomizing factor within the model causes each run of it to produce a unique potential history of redevelopment in the core of Kitchener in the 1980's, 100 runs of the model were performed. It was felt that after 100 repetitions were analyzed a convergence on the probable outcome would occur. The actual output and the analysis of it are presented in the following chapter.

5.7 Synthesis

This chapter began by introducing the conceptual model of redevelopment that underlied the construction of the simulation model. The redevelopment potential of any site in the urban core depends on and varies with the site's physical and locational characteristics relative to those of all others therein. The ultimate redevelopment of a site reflects not only the influence of the aforementionned attributes but also the effect of a random or chance factor resulting from uncertainty and incomplete knowledge, among other things. The level of redevelopment in the urban core varies cyclically with the climate of investment opportunities.

The first aspect of the simulation model to be described was the organization of the primary data set; the data required for the creation of the attractiveness index. Initially the criteria used to determine the sites to be included in the study along with their respective boundaries were discussed. It was mentionned that as of the end of 1979 there were 259 sites that qualified for inclusion as non-redeveloped sites and 25 that could be considered as having been redeveloped since 1965. Redevelopment location factors and their relationship to the occurrence of redevelopment were hypothesized. The surrogate variables for which data were collected subject to availability were then briefly described.

The development of the attractiveness index employing regression analytical techniques was discussed at length. The applicability of the non-linear logit model and maximum likelihood estimation to the binary dependent variable case was outlined. The seven significant variables that comprised the attractiveness index and together explained almost half the variation in the occurrence of redevelopment were: 1) distance to the city center; 2) average redevelopment distance; 3) traffic volume; 4) site size; and 5) three building age dummies.

Subsequently, various methods by which a forecast of the level of redevelopment could be generated were briefly reviewed. It was decided an effective method would be to analyze the past trend by eye for any apparent regularities and extrapolate that trend into the future. After trying a number of variations, a repetitive series of four numbers, 1,4,2,0, seemed to fit the cyclical curve from the past reasonably well. Over the twenty-five year period 1955 - 1979 it underestimated the total number of redevelopment events by 4% (2 of 45) and provided exactly the same values as the actual curve 48% (12 of 25) of the time. That series of numbers, beginning with 4 in 1980, repeated two and one half times was accepted as the ten year forecast of the level of redevelopment.

The final section of the chapter examined the structure and operation of the simulation model. The half dozen basic steps of the model included data input, redevelopment attractiveness index calculation, site redevelopment selection, data output, accounting procedures, and repetition. Following a comprehensive description of the entire model it was mentionned that the model output consisted of 100 ten year forecasts of the number and location of redeveloped sites in the core of Kitchener beginning in the year 1980.

CHAPTER SIX

THE FORECASTED SPATIO - TEMPORAL PATTERN OF REDEVELOPMENT

6.1 Introduction

The redevelopment simulation model generated two arrays of data that will be presented and analyzed. The first, matrix [C], is the set of initial attractiveness index values (Table 6.1). These values define a redevelopment potential surface. As each site's index values are mapped, the spatial variation in redevelopment potential evolves. Since the initial attractiveness index values are the same over all 100 runs of the model, they provide equivalent starting conditions for each model repetition. Their distribution is different for each succeeding time period in the initial run and all subsequent runs because the values of some of the variables comprising the index change with the passing of time and the redevelopment locations selected. The redevelopment potential surface significantly influences which of the 259 sites is selected for redevelopment at any given point in the forecast.

Table 6.1 Initial Attractiveness Index Values (1980)

Site ID Number	Index Value (x 100)	Site ID Number	Index Value (x 100)	Site ID Number	Index Value (x 100)
1	2	26	1	51	0
2	11	27	3	52	0
3	2	28	6	53	0
4	3	29	2	54	0
5	0	30	0	55	15
6	0	31	0	56	2
7	0	32	0	57	1
8	0	33	0	58	1
9	0	34	1	59	0
10	0	35	2	60	2
11	0	36	0	61	1
12	0	37	0	62	0
13	0	38	2	63	4
14	1	39	1	64	1
15	1	40	11	65	0
16	0	41	2	66	1
17	1	42	1	67	0
18	4	43	0	68	7
19	0	44	2	69	0
20	2	45	1	70	2
21	1	46	3	71	2
22	1	47	0	72	0
23	2	48	0	73	0
24	1	49	5	74	7
25	0	50	1	75	1

Table 6.1 Initial Attractiveness Index Values (1980), Continued

Site ID Number	Index Value (x 100)	Site ID Number	Index Value (x 100)	Site Id Number	Index Value (x 100)
76	3	101	4	126	2
77	2	102	36	127	3
78	0	103	5	128	2
79	0	104	0	129	2
80	5	105	0	130	6
81	2	106	2	131	2
82	1	107	5	132	0
83	17	108	3	133	3
84	7	109	87	134	5
85	19	110	0	135	0
86	0	111	29	136	0
87	0	112	30	137	0
88	19	113	13	138	0
89	4	114	21	139	33
90	34	115	12	140	31
91	4	116	6	141	1
92	8	117	0	142	1
93	31	118	1	143	1
94	22	119	11	144	0
95	20	120	6	145	0
96	26	121	12	146	0
97	24	122	3	147	0
98	24	123	0	148	8
99	1	124	0	149	8
100	2	125	0	150	9

Table 6.1 Initial Attractiveness Index Values (1980), Continued

Site ID Number	Index Value (x 100)	Site ID Number	Index Value (x 100)	Site ID Number	Index Value (x 100)
151	9	176	0	201	1
152	0	177	0	202	2
153	15	178	0	203	1
154	0	179	0	204	4
155	15	180	0	205	10
156	25	181	0	206	2
157	16	182	0	207	0
158	17	183	8	208	1
159	29	184	0	209	6
160	0	185	1	210	1
161	15	186	1	211	6
162	76	187	1	212	1
163	0	188	0	213	2
164	84	189	18	214	1
165	14	190	14	215	1
166	5	191	11	216	2
167	14	192	0	217	2
168	8	193	26	218	0
169	8	194	0	219	1
170	9	195	1	220	2
171	19	196	0	221	1
172	0	197	2	222	1
173	4	198	0	223	21
174	0	199	0	224	1
175	0	200	0	225	0

Table 6.1 Initial Attractiveness Index Values (1980), Continued

Site ID Number	Index Value (x 100)	Site ID Number	Index Value (x 100)	Site ID Number	Index Value
226	1	238	2	249	1
227	1	239	3	250	0
228	4	240	0	251	0
229	0	241	0	252	0
230	23	242	2	253	1
231	2	243	4	254	2
232	0	244	1	255	0
233	1	245	4	256	8
234	3	246	0	257	1
235	1	247	13	258	1
236	0	248	19	259	2
237	2				

The second array compiled from data produced by the model is a 259 site X 8 time period matrix [D] (Table 6.2). The elements of [D] indicate the redevelopment selection frequency of each site per time period over the 100 runs of the model. There are only eight time periods included because the ten year redevelopment level forecast includes two time periods, 3 (1982) and 7 (1986), for which the value is zero. Each row of [D] shows the frequency distribution of redevelopment selection through time of an individual site; each column the spatial frequency distribution of a given time period.

The forecasted spatio-temporal pattern of redevelopment will be unveiled by analyzing [D] in terms of: 1) aggregate redevelopment selection per site over the entire forecast period; and 2) the temporal frequency distribution of site selection. The first analysis will provide a static picture of future redevelopment patterns whereas the second will furnish a dynamic scenario. Before performing these analyses, however, it is useful to examine the initial redevelopment potential surface that specifies the starting conditions for the subsequent operation of the simulation model.

Table 6.2 Site Redevelopment Selection Frequency, by Time Period (per 100 runs)

Site ID No.	Time Period 1	2	4	5	6	8	9	10
1					5		12	3
2	4	1		4	3	4	14	11
3				1		4	4	5
4	1				2	3	10	6
5								
6								
7								
8							1	
9							1	
10							1	
11		1	4	9	2			1
12								
13		5	2	9	2			
14		4	3	13	5		2	2
15		1	3	13	2	1	6	2
16		7	1	9	3		2	
17		5	1	10	4	5	13	7
18	1	4		7	4	2	9	8
19						6	4	3
20	2				1	1	11	4
21				1		2	6	5
22					3	6	11	4
23		1	2	6	4		16	6
24		4	2	7	2		3	
25		1	2	5	1			
26		4	1	3	2	1	1	
27	1	3		10				
28	2	1	1	8	6		1	
29		6	1	3	2		2	
30								
31								
32				1				
33								
34				4		1		
35		3	2	3	1			
36								
37								
38	1	6	2	5	3	1	1	
39		1	2	2				
40	2						4	1
41							2	
42						1	3	1
43							3	2
44	1			1			6	4
45								
46	3							1
47								
48								
49	1			3			1	
50								

Table 6.2 Site Redevelopment Selection Frequency, by Time Period (per 100 runs), Continued

Site ID No.	Time Period 1	2	4	5	6	8	9	10	Site ID No.	Time Period 1	2	4	5	6	8	9	10
51									76							1	
52									77								
53									78								2
54									79							2	2
55	1			2	3		1		80	3	1						
56				1					81	1				1			
57		1			1				82	3			1				
58								1	83	2		1					
59									84	2	1	2	1				
60	1								85	8	1	2	4	2			
61									86			1					
62									87								
63									88	8		1	4			1	
64	1								89			1					
65									90	4	1					5	2
66	2								91				2	1			
67	1								92						1	1	1
68	1						3		93	10			1	1	1	3	
69								1	94	4						3	2
70	1						1		95	3						6	
71	2						1	2	96	3						3	
72							3		97	3						2	2
73									98	7						3	
74	1						1		99						1		
75									100								

Table 6.2 Site Redevelopment Selection Frequency, by Time Period (per 100 runs), Continued

Site ID No.	1	2	4	5	6	8	9	10	Site ID No.	1	2	4	5	6	8	9	10
101	4					1			126		4	2	7	3		1	
102	14			2	1		1	1	127		4	1	6	4		3	1
103	1	1		1					128		4		4	1			1
104									129	5					2	5	4
105									130	2			1	1		6	
106				1					131						1	2	1
107	2	1				1			132								
108			1						133	2						2	
109	24	5	3	10	3	1	3		134							1	
110			1						135								1
111	7	3	1	5	1				136								
112	13	2	2	5	2	2	1	1	137			1					
113	4			3	1		1		138		1						
114	7	1		2	1		1		139	11	4	2	3	1		3	
115	4	4	3	11					140	9		3	3	3		3	
116	3	1	1	7					141		4		1				
117					1	1	1		142		3		2	1			1
118		3	1	1	1				143		5	1	3		1		
119	4	3	1	9	2		1	2	144				1	2		1	
120	4	2	1	1				2	145							1	
121	6	5	1	11	8		2	4	146				1				
122	2	6	2	6	5	1	4	1	147								
123									148	3					5	3	
124									149	1			1	2	2	7	2
125									150	1			1		5	6	

Table 6.2 Site Redevelopment Selection Frequency, by Time Period (per 100 runs), Continued

Site ID No.	Time Period 1	2	4	5	6	8	9	10	Site ID No.	Time Period 1	2	4	5	6	8	9	10
151	1			1		2	1	3	176								
152									177								
153	6	1	1						178								
154									179								
155	4								180								
156	9			1					181								
157	6				2				182								
158	4			2					183	1							
159	18		1	1					184								
160									185	1							
161	2						2		186							1	
162	18				1	3	5	5	187								
163									188	1							
164	22				1	2	7	6	189	3						2	
165	1						6		190	3							1
166	1	1		1			2		191	1						1	
167	6			1	1	1			192								
168	2			1					193	7						2	1
169	3	2		1					194								
170	1	3	4	1	1				195	2							
171	9	2	2	4	1		1		196								
172									197								
173	1								198								
174		1							199								
175									200								

Table 6.2 Site Redevelopment Selection Frequency, by Time Period (per 100 runs), Continued

Site ID No.	Time Period 1	2	4	5	6	8	9	10	Site ID No.	Time Period 1	2	4	5	6	8	9	10
201									226		1		1			1	
202									227								
203									228		2				1		
204	5								229								
205							2	2	230	5	1			1			
206									231	2		1			1	3	
207									232								
208			1	4					233	2						1	2
209	3	2		3	1				234	3	2		1	4		5	
210	1	2		1					235	1	3	1	1			1	1
211	2	1	1	3	2				236								
212		1							237		1		1			2	3
213	1			1					238							1	1
214		1							239	1			3				
215	1	1		1					240								
216		1		3					241								
217					2				242		1		8			3	
218						1	2	1	243	2	3	1	4	2		1	
219							2	1	244	1	3	1	6	2		8	1
220						1	1	3	245		3	1	6	4		7	3
221									246							2	
222	2							1	247	2	3	1	13	8	6	8	4
223	4				1	2	4	5	248	5	3	1	8	4	1	1	
224						1			249		3		10	3		3	1
225									250		1	1	3	1		2	

Table 6.2 Site Redevelopment Selection Frequency, by Time Period (per 100 runs), Continued

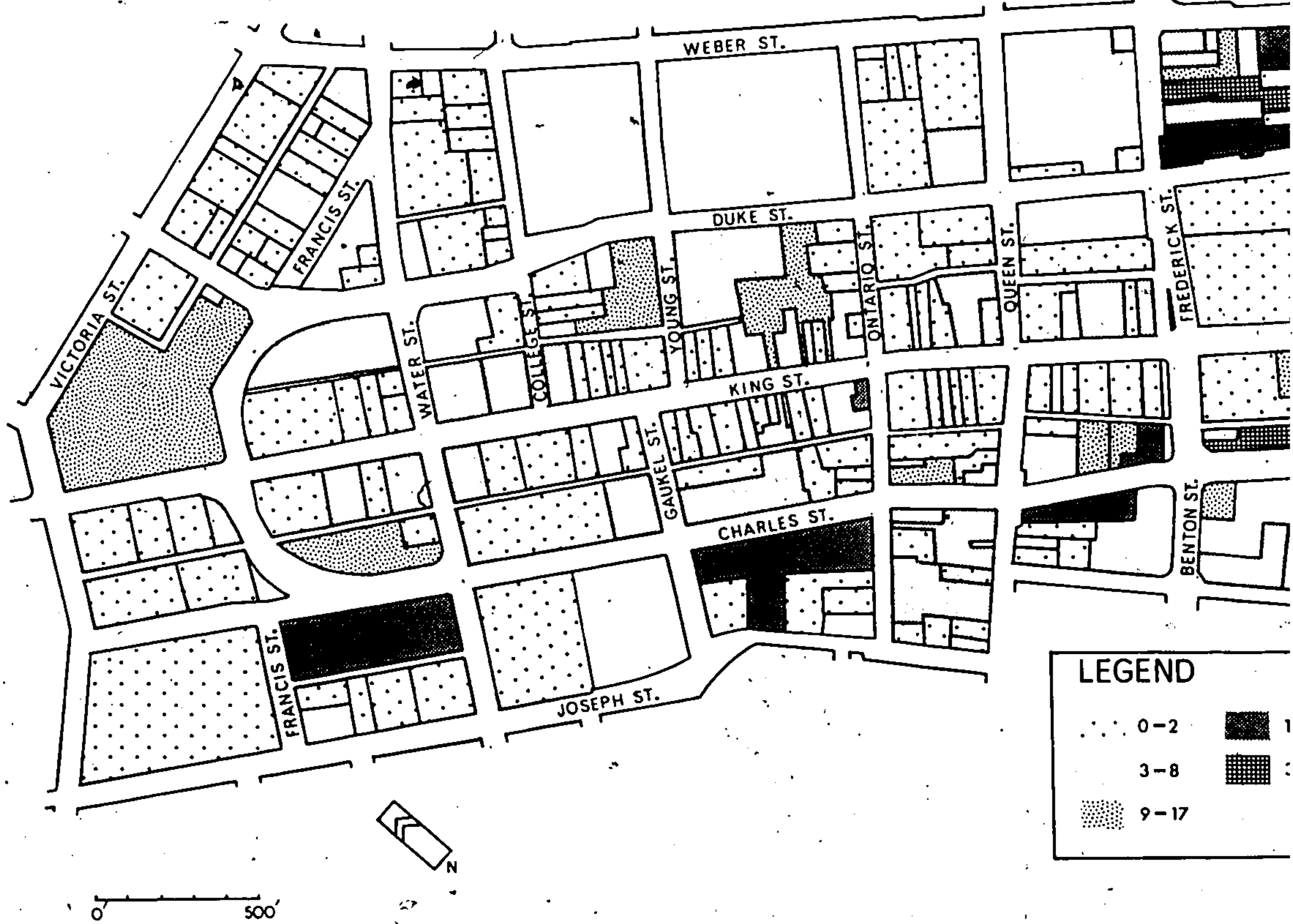
Site ID No.	Time Period 1	2	4	5	6	8	9	10	Site ID No.	Time Period 1	2	4	5	6	8	9	10
251		1	1	4	2		1	1	256		5	2	9	10	4	8	3
252									257		4	4	7	6	1	4	4
253		1		3	11	3	14	7	258		2	4	10	7	4	8	6
254				2	5	5	10	8	259		4	4	4	4	1	8	5
255		5	2	5	2	1	9	2									

6.2 Initial Spatial Variation of Redevelopment Potential

Of the 259 attractiveness index values associated with time period 1 (1980), 65% (169) were equal to or less than 2 and only 3% (9) equalled or exceeded 30 (Table 6.1). This distribution is expected since at any point in time only a small percentage of all sites are relatively attractive to redevelopment.

A visual inspection of the redevelopment potential surface (Map 6.1) provides an overview of the spatial variation of redevelopment attractiveness in the study area at the beginning of the forecast period. Since the index values affect to a great extent the selection of sites for redevelopment, sub-areas of the core with a concentration of relatively high index value sites have a greater likelihood of having sites within them selected than those that do not. An initial indication of the general location of redevelopment taking place early in the forecast period is, therefore, provided by the 1980 potential surface. However, the chance factor built into the simulation model can result in redevelopment locating in core sub-areas containing predominantly relatively low potential sites. If this happens to occur several times the shape of the potential surface may drastically change as average

MAP 6.1 ATTRACTIVENESS INDEX VALUES, 1980
(INITIAL REDEVELOPMENT POTENTIAL SURFACE)



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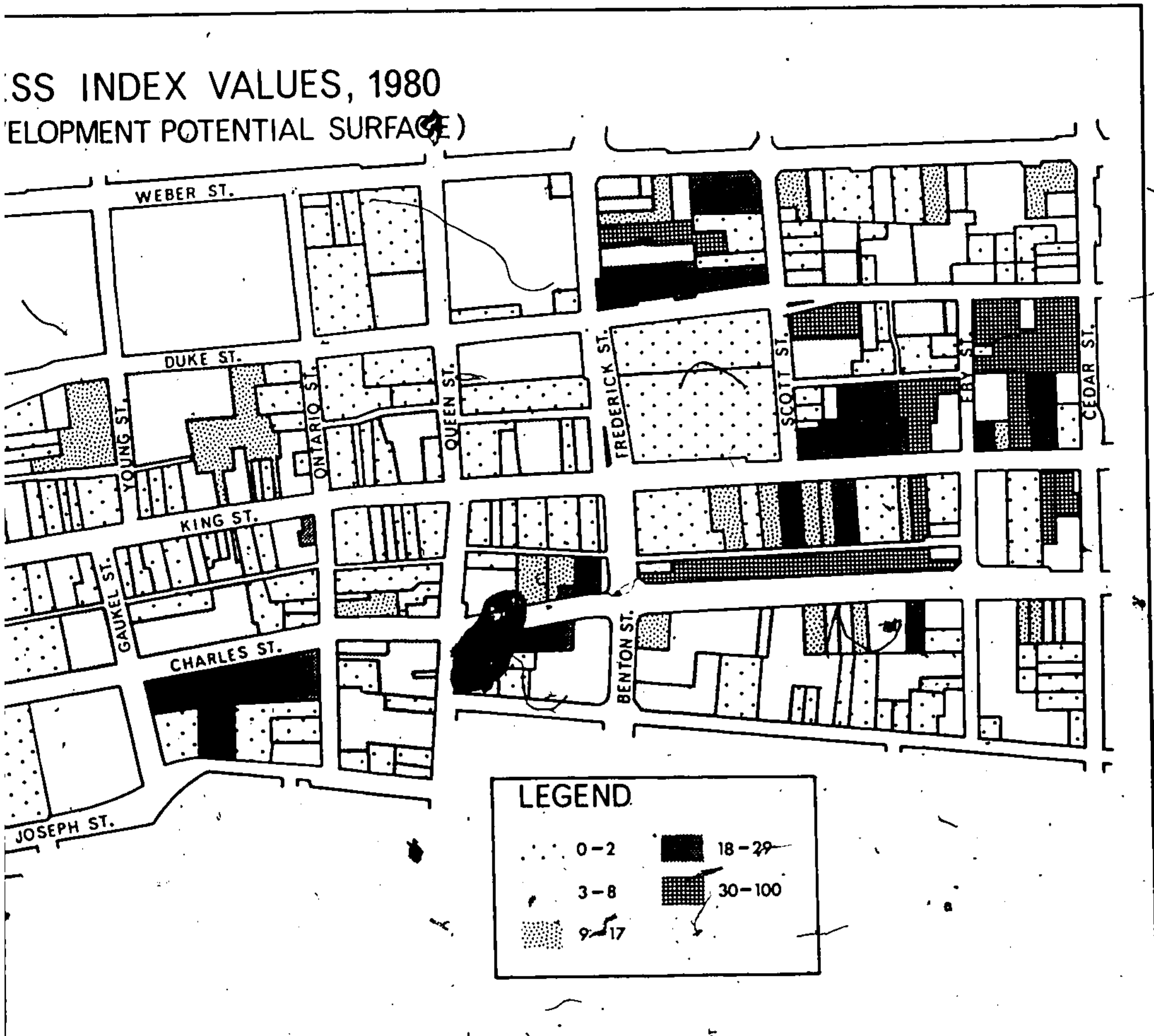

:SS INDEX VALUES, 1980
(ELOPMENT POTENTIAL SURFACE)
WEBER ST.
DUKE ST.
KING ST.
CHARLES ST.
JOSEPH ST.
YOUNG ST.
ONTARIO ST.
QUEEN ST.
FREDERICK ST.
SCOTT ST.
CEDAR ST.
GAUKEL ST.
BENTON ST.
LEGEND
0–2
3–8
9–17
18–29
30–100

2 of 2

redevelopment distances become significantly altered. Thus high likelihood areas of the core can shift during the forecast period. The initial potential surface suggests possible redevelopment locations in only the earliest one or two time periods.

Map 6.1 reveals that the relatively high index values are concentrated in the eastern core, especially along King Street between Cedar and Benton Streets. The high values along that section of the major commercial artery are interrupted only by low values corresponding to sites 79, 110, 152, 154, 160, 163, and 168. All of those sites have been redeveloped in the previous fifteen years. Other nodes of relatively high values are located along Charles Street between Queen and Cedar Streets, and on Weber Street and Duke Street between Frederick and Cedar Streets.

Conversely, relatively low index values are predominant in the western core (west of Ontario Street). The only sites therein with relatively high values are those that are relatively large. The exception is site 223 on the southwest corner of Ontario and King Streets. Sites with relatively low index values are also found on the southern and eastern boundaries of the eastern core. These are generally very small sites.

The general spatial pattern of the initial index values appears to be most influenced by the location of redevelopment from 1965 - 1979. It was noted in Chapter 4 (Map 4.3) that redevelopment in that fifteen year period primarily occurred in the eastern half of the study area. The other variables included in the attractiveness index do not seem to account for the east-west division. For example, the index value of site 259 was one of the lowest possible (2) even though it was the largest site included in the study, its building was one of the oldest in the core, and its traffic volume was among the highest of all sites. Although it was also one of the farthest sites from the city center the fact that it scored so lowly on the attractiveness index can be primarily explained by its relatively great distance from previously redeveloped sites.

6.3 Static Spatial Pattern of Forecasted Redevelopment

No model can perfectly forecast the behaviour of urban phenomena through time. The object of constructing a stochastic simulation model is to generate a spatial pattern enough like that of reality that "both could have been produced from the same process" (Morrill, 1965a, p.197). The difficulty of utilizing a stochastic model is that the chance factor can produce a wide range of variability between successive runs of the model. The results of a great number of model repetitions must be analyzed, therefore, to discover the solution which approximates reality. Thus the output generated by the simulation model is interpreted in the following way.

The results of each of the 100 runs of the model were cumulated into frequency distributions. It is assumed that after 100 repetitions the cumulative data represent the spatio-temporal pattern of redevelopment about which all 100 individual potential patterns are distributed. Thus the greater the site redevelopment selection frequency relative to other sites, the greater the relative likelihood that it will be redeveloped in reality; and vice versa.

The likelihood of each individual site being redeveloped any time during the entire forecast period was calculated by summing the elements of each row of [D]. Each sum represents the total number of redevelopment selections per site after 100 runs of the model (Table 6.3). By mapping these sums one obtains a static representation of the forecasted aggregate spatial pattern of redevelopment between 1980 and 1989 in the core of Kitchener (Map 6.2).

The total redevelopment selection frequencies range from a high of 49 for site 109 to a low of 0 for 71 sites. In fact, just over one half (145) of the 259 sites were

Table 6.3 Total Redevelopment Selection Frequency and Temporal Dominance Index Value, by Site

Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value
1	20	.644	26	12	-.185	51		
2	41	.469	27	14	-.317	52		
3	14	.730	28	19	-.135	53		
4	22	.667	29	14	-.254	54		
5			30			55	7	-.016
6			31			56	1	
7			32	1		57	2	
8	1		33			58	1	
9	1		34	5	.022	59		
10	1		35	9	-.358	60	1	
11	17	-.111	36			61		
12			37			62		
13	18	-.296	38	19	-.275	63		
14	29	-.050	39	5	-.333	64	1	
15	28	.151	40	7	.302	65		
16	22	-.222	41	2		66	2	
17	45	.333	42	5	.889	67	1	
18	35	.333	43	5	.867	68	4	
19	13	.726	44	12	.630	69	1	
20	19	.759	45			70	2	
21	14	.762	46	4		71	5	.156
22	24	.676	47			72	3	
23	35	.479	48			73		
24	18	-.111	49	5	-.111	74	2	
25	9	-.210	50			75		

Table 6.3 Total Redevelopment Selection Frequency and Temporal Dominance Index Value, by Site, Continued

Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value
76	1		101	5	-.689	126	17	-.203
77			102	19	-.649	127	19	.018
78	2		103	3		128	10	-.244
79	4		104			129	16	.250
80	4		105			130	10	.267
81	2		106	1		131	4	
82	4		107	4		132		
83	3		108	1		133	4	
84	6	-.593	109	49	-.546	134	1	
85	17	-.569	110	1		135	1	
86	1		111	17	-.595	136		
87			112	28	-.452	137	1	
88	14	-.571	113	9	-.383	138	1	
89	1		114	12	-.593	139	24	-.528
90	12	.093	115	22	-.424	140	21	-.365
91	3		116	12	-.407	141	5	-.644
92	3		117	3		142	7	-.206
93	16	-.444	118	6	-.444	143	10	-.400
94	9	.037	119	22	-.212	144	4	
95	9	.185	120	10	-.400	145	1	
96	6	-.111	121	37	-.135	146	1	
97	7	.079	122	27	-.103	147		
98	10	-.467	123			148	11	.192
99	1		124			149	15	.511
100			125			150	13	.692

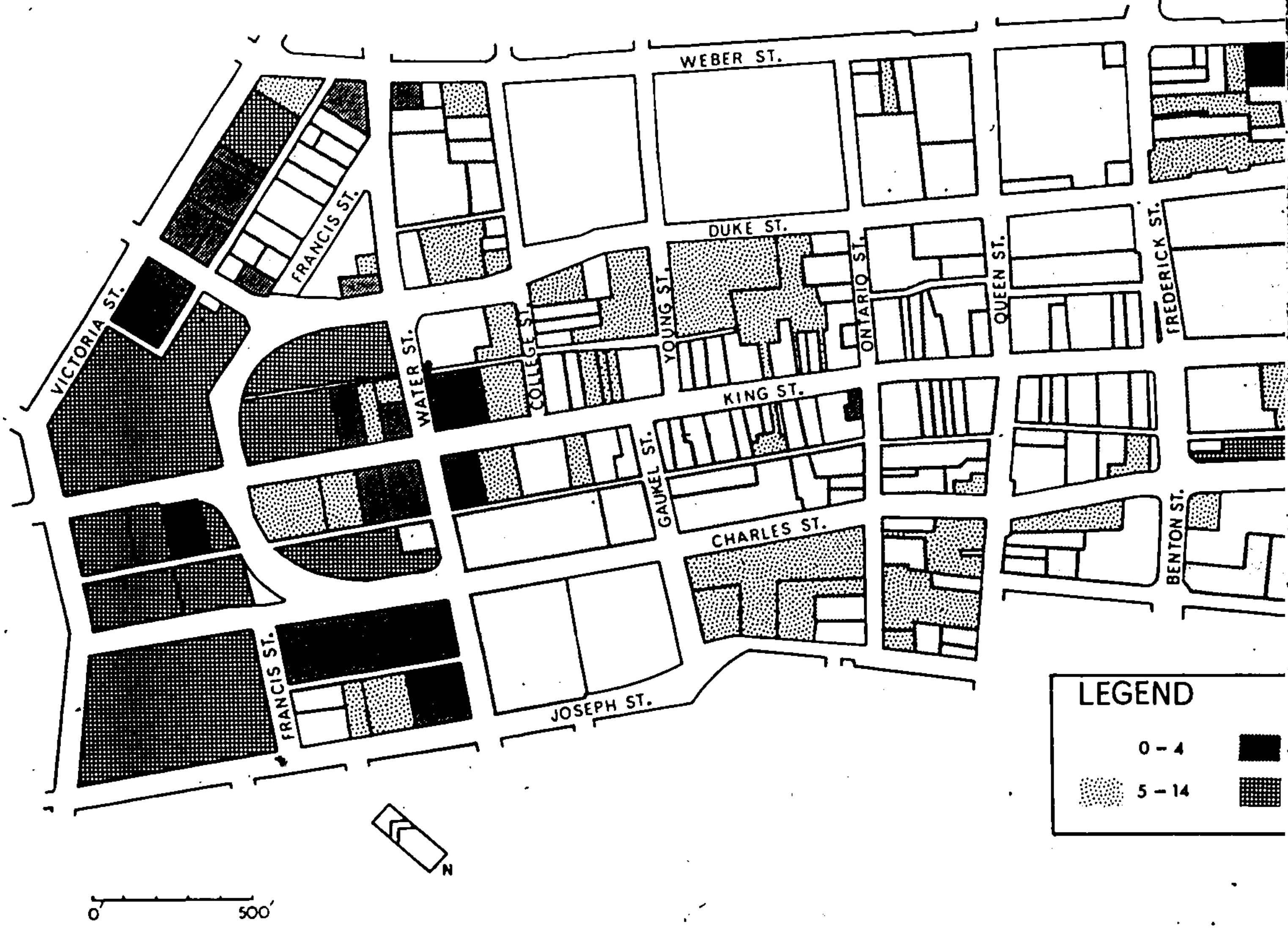
Table 6.3 Total Redevelopment Selection Frequency and Temporal Dominance Index Value, by Site, Continued

Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value
151	8	.472	176			201		
152			177			202		
153	8	-.889	178			203		
154			179			204	5	-1.00
155	4		180			205	4	
156	10	-.911	181			206		
157	8	-.722	182			207		
158	6	-.704	183	1		208	5	-.156
159	20	-.922	184			209	9	-.531
160			185	1		210	4	
161	4		186	1		211	9	-.358
162	32	-.229	187			212	1	
163			188	1		213	2	
164	38	-.246	189	5	-.289	214	1	
165	7	.524	190	4		215	3	
166	5	-.067	191	2		216	4	
167	9	-.605	192			217	2	
168	3		193	10	-.444	218	4	
169	6	-.778	194			219	3	
170	10	-.467	195	2		220	5	.867
171	19	-.567	196			221		
172			197			222	3	
173	1		198			223	16	.333
174	1		199			224	1	
175			200			225		

Table 6.3 Total Redevelopment Selection Frequency and Temporal Dominance Index Value, by Site, Continued

Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value	Site ID No.	Sel. Freq.	T. D. Index Value
226	3		238	2		249	20	.011
227			239	4		250	8	.028
228	3		240			251	10	.044
229			241			252		
230	7	-.810	242	12	.056	253	39	.504
231	7	.079	243	13	-.256	254	30	.630
232			244	22	.141	255	26	.179
233	5	.156	245	24	.231	256	41	.171
234	15	-.022	246	2		257	30	.104
235	8	-.250	247	45	.185	258	41	.274
236			248	23	-.295	259	30	.244
237	7	.524						

MAP 6.2 TOTAL REDEVELOPMENT SELECTION FREQUENCIES
(PER 100 MODEL RUNS)



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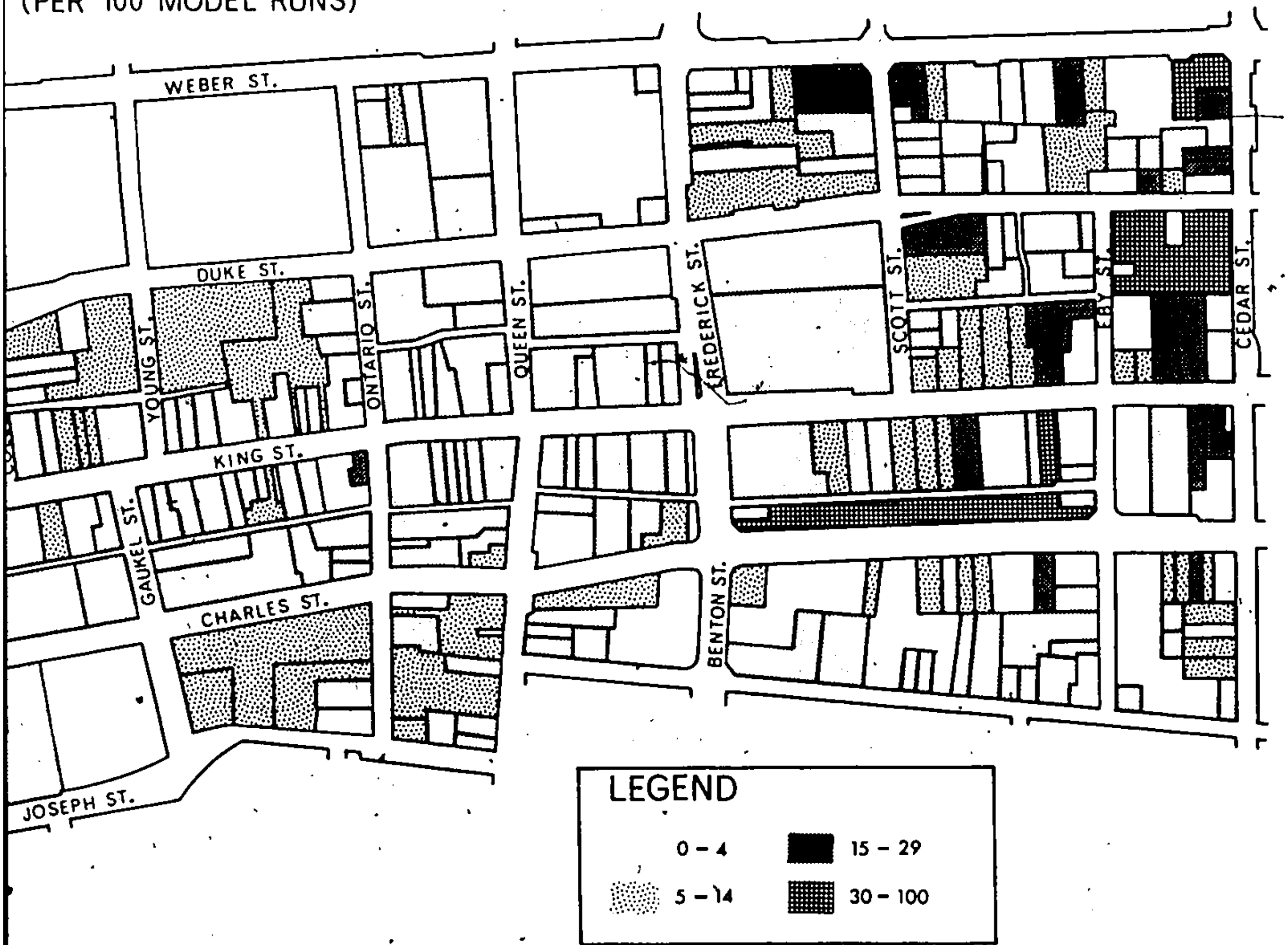
LOPMENT SELECTION FREQUENCIES
(PER 100 MODEL RUNS)



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selected in less than 5% (5) of the runs. On the other hand, the aggregate frequencies of the top 15% (39) of the sites fell between 19 and 49, inclusive (Table 6.4).

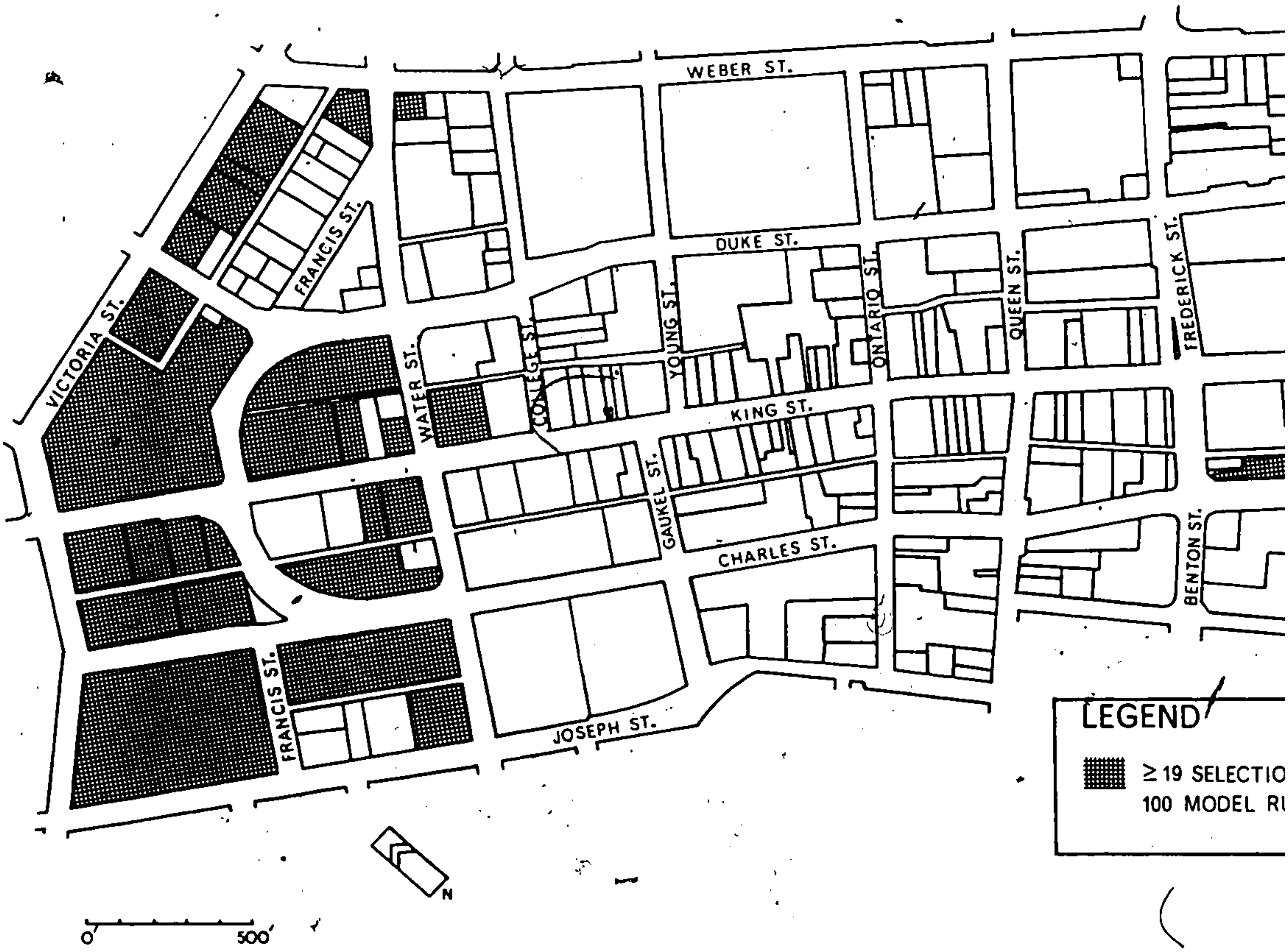
The most frequently selected sites vary widely in terms of their physical attributes. Although most are of a relatively large size, there are some, notably sites 38, 119, 127, and 171, that are among the smallest of those included in the study. Most have old buildings on them, many have no buildings thereon, and at least one (site 245) has a sixteen year old office building on it. They are somewhat more similar in terms of their locational characteristics though (Map 6.3). Virtually all of them are located on the fringe of the study area although they are polarized to the east and the west. The western core contains more of the high frequency sites than the east and a substantial portion of it is covered by those sites because of their large individual sizes.

The sites most infrequently selected for redevelopment (0-4 times) can be divided into three groups. The first group includes relatively small inner core sites, primarily along King Street, (north and south sides) between Gaukel and Benton-Frederick Streets (for example, sites 215-222, excluding site 220). The second group consists of relatively small peripheral sites on residential (low

Table 6.4 Most Frequently Selected Sites

Site ID No.	Street Address	Sel. Freq.	Site ID No.	Street Address	Sel. Freq.
109	- Cedar St. N.	49	22	320-328 King St. W.	24
17	87 Victoria St. N.	45	139	325 King St. E.	24
247	- Charles St. W.(B)	45	245	305 King St. W.	24
2	410 King St. W.	41	248	36-40 Water St. S.	23
256	399 King St. W.	41	4	80-86 Water St. N.	22
258	144 Charles St. W.	41	16	83 Victoria St. N.	22
253	445 King St. W.	39	115	59-61 Weber St. E.	22
164	- Charles St. E.(C)	38	119	87 Weber St. E.	22
121	103-109 Weber St. E.	37	244	319 King St. E.	22
18	24 Water St. N.	35	140	329-339 King St. E.	21
23	334-400 King St. W.	35	1	247 Duke St. W.	20
162	253 King St. E.	32	159	205 King St. E.	20
254	- King St. W.(B)	30	249	54 Water St. S.	20
257	30 Francis St. S.	30	20	300-310 King St. W.	19
259	36-50 Francis St. S.	30	28	276 King St. W.	19
14	240 Duke St. W.	29	38	79-87 Water St. N.	19
15	73 Victoria St. N.	28	102	33-39 Scott St.	19
112	312 King St. E.	28	127	50 Cedar St. N.	19
122	64-68 Cedar St. N.	27	171	67 Charles St. E.	19
255	417 King St. W.	26			

MAP 6.3 MOST FREQUENTLY SELECTED SITES



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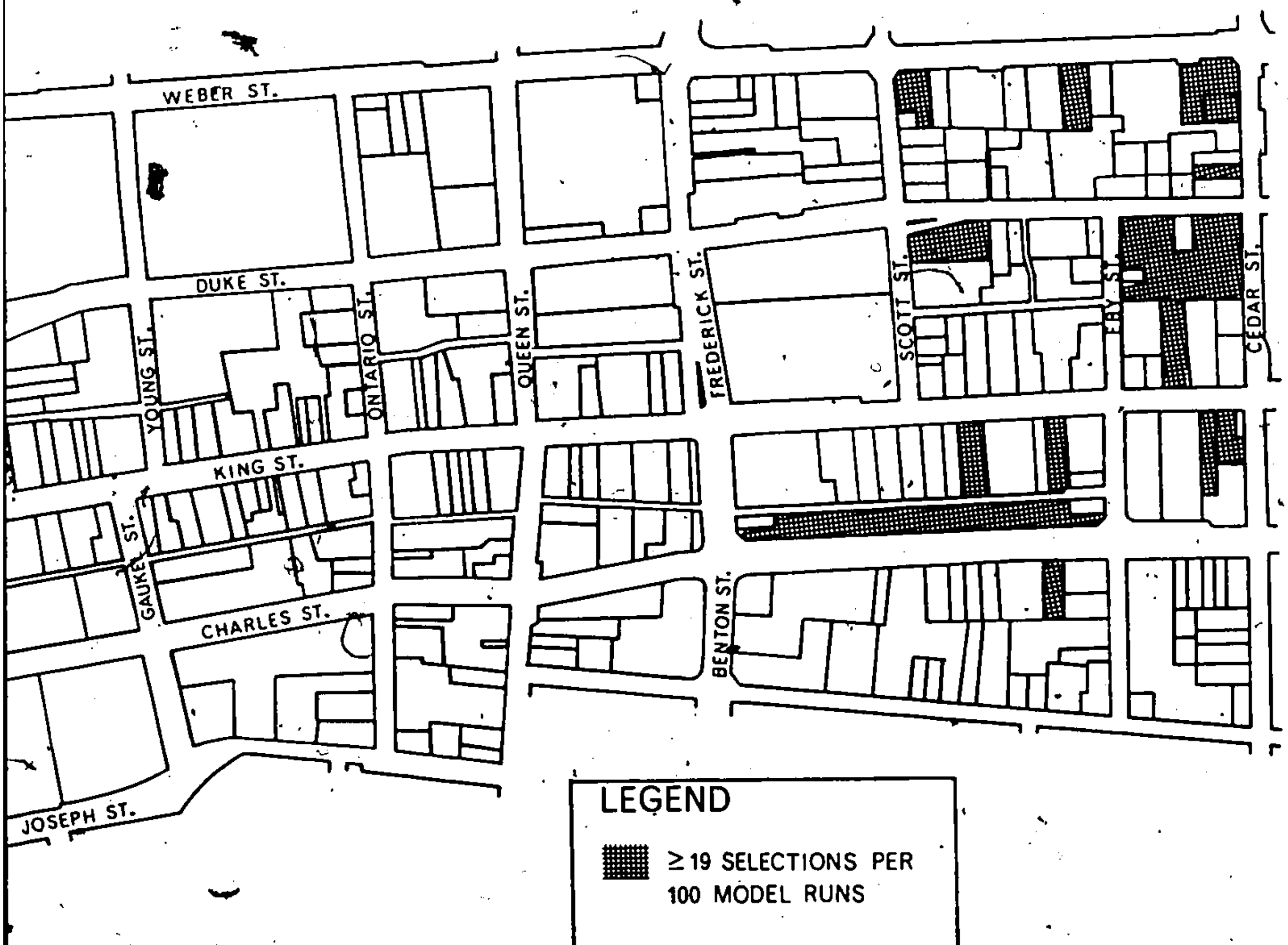
NTLY SELECTED SITES



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vehicular traffic volumes) streets or lanes (for example, sites 5-12, excluding site 11). The sites that have been redeveloped since 1965 make up the third group. These sites are relatively larger than those in the other two groups, they are located in the eastern and westerns ends of the core on major traffic arteries, and have new buildings (for example, sites 37, 67, 72, 138, and 160).

The general spatial pattern, therefore, is one of a concentration of sites with low frequencies in the central core surrounded by high frequency sites in the western and eastern peripheries. The frequencies in the western core (College to Victoria Streets) are relatively higher than those in the eastern core (Benton-Frederick Street to Cedar Street). This pattern was predicted during the examination of the signs of the variable coefficients in the attractiveness index regression equation. The positive sign of the DCC variable together with the negative sign of the ARD variable produced concentrations of forecasted redevelopment on the core periphery and an absence of it in the central core.

This predicted pattern of redevelopment is extremely interesting when compared with that suggested by the shape of the initial redevelopment potential surface. The analysis of the potential surface indicated the western core suffered an absence of sites with relatively high index values and suggested future redevelopment could be expected to be predominant in the eastern core, a pattern contradicted by that generated by the simulation model. The contradiction in itself illustrates the utility of simulation modelling in urban analysis. The initial attractiveness index values were static measures of redevelopment potential and were unable to provide insight into the dynamics of the redevelopment process. An examination of their spatial variation at one point in time, therefore, did not enable the analyst to foresee the comprehensive spatial product of changes in various elements of urban structure through time. Simulation, on the other hand, facilitates the operationalization of change thereby allowing the model to accomodate alterations in the redevelopment potential surface caused by changes in the levels of the location factors through time. Ultimately the simulation model was able to incorporate a spatio-temporal shift of relatively high index values to the western core caused by the changing conditions and to produce a more complete, realistic pattern of future redevelopment.

The static analysis of the model's output just completed, while revealing the aggregate pattern of redevelopment, failed to identify when or why the significant alteration in the redevelopment potential surface took place. A dynamic analysis that more fully illustrates the spatio- temporal pattern of forecasted redevelopment will be presented next.

6.4 Dynamic Spatial Pattern of Forecasted Redevelopment

The spatio-temporal pattern of redevelopment in the study area in the 1980's forecasted by the model can be determined by analyzing the temporal frequency distribution of each site (each row of [D]). If the distribution is negatively skewed, then site redevelopment selection took place in the early time periods; and vice versa. By mapping a measure of the skewness of the individual distributions one is able to ascertain the forecasted location pattern of redevelopment through time.

To facilitate this procedure a temporal dominance index was devised. It measures the degree of dominance of early or late redevelopment selections for each site and has the form:

$$d_i = \sum_{t=1}^{10} [n_{it} (t - \bar{t})] \; / \; [N_i (|(t - \bar{t})_{max}|)] \qquad (1)$$

where n_{it} is the number of redevelopment selections per site i in time period t, t = 1-10, $\bar{t}$ is the mean of the time periods, 5.5, N_i is the total number of redevelopment selections per site i over all time periods, and $|(t-\bar{t})_{max}|$ is the absolute value of the maximum difference between a given time period and the mean of the time periods, 4.5.

The temporal dominance index compares the actual distribution to a perfectly skewed one (positive or negative) and measures how closely they match each other. The values of the index range from positive to negative one inclusive, representing all last time period selections or all first time period selections, respectively.

There are several problems with using this index that must be recognized. The first problem regards unequal weighting of the index because of varying redevelopment selection frequencies among sites. Although the statistic includes a weighting factor to account for this, there is still a certain lack of comparability between the index value of a site selected thirty-five times and one picked twice. To circumvent this problem all sites selected less than five times were eliminated from this analysis; a total of 145. The problem is not entirely eliminated but its seriousness is substantially reduced. A related problem to be mentionned in passing is that the index possesses a discrete distribution at lower frequencies and a continuous one at higher frequencies. This problem is solved satisfactorily by excluding the lowest frequency sites.

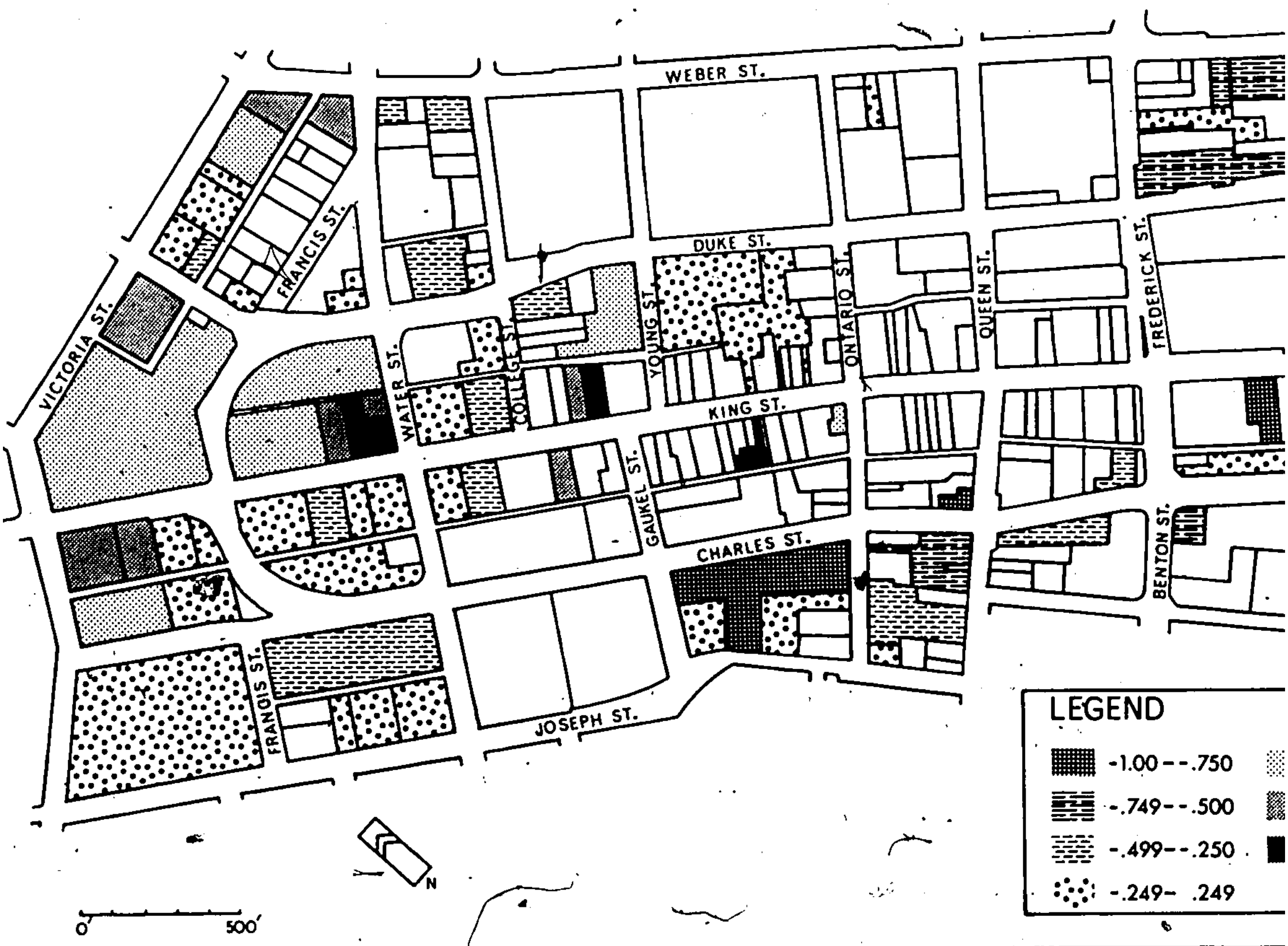
A third problem exists in terms of interpretability of the index. Extreme values are relatively easy to interpret. If the index value approaches negative one, then the redevelopment selection for that site occurred primarily in the early time periods; and vice versa. The problem arises when near zero values are encountered. Any distribution equivalent about the mean produces an index value approaching zero. Therefore a concentration of selections about the mean could result in an index value very close to zero. In that case the interpretation would be that the site is destined for redevelopment between the earliest and latest time periods. However a polarized or bimodal distribution in which site selection occurred nearly equally in both the very early and very late time periods will produce a near zero value as well. A possible interpretation would be that neither early nor late selections show a dominance but selection in the middle time periods is noticeably absent. A third possible distribution producing a similar index value is one in which the selections are spread evenly across all time periods. Again no dominance exists but at least some of the selections took place in the middle time periods. Thus there are three possible distributions that produce index values approaching zero and three different interpretations of such values. One solution would be to examine each of the distributions individually before making an interpretation. This was done and it was discovered that very few examples of polarity or concentration about the mean could be found. Most of the distributions producing near zero index values consisted of relatively equal frequencies across all eight time periods. It was decided to ignore the cases in which near zero index values existed and focus on those with extreme values.

A fourth and final problem arose, that being how to determine which values are significantly different from zero. An arbitrary decision was made to consider values greater than or equal to |.250| as being non-zero values. Thus although some small problems do remain the temporal dominance index will be used to indicate whether a site's redevelopment is forecasted in the early or late half of the forecast period. However, the index values will only be interpreted in a very general manner.

With the exclusion of all sites with index values approaching zero a total of 71 sites remain in this dynamic analysis; 27 with positive values and 41 with negative values (Table.6.3). The actual values range from .889 (site 42) to -1.00 (site 204).

The dynamic pattern of redevelopment in the study area as forecasted by the simulation model is shown on Map 6.4 Sites with relatively high negative values are

MAP 6.4 TEMPORAL DOMINANCE INDEX VALUES



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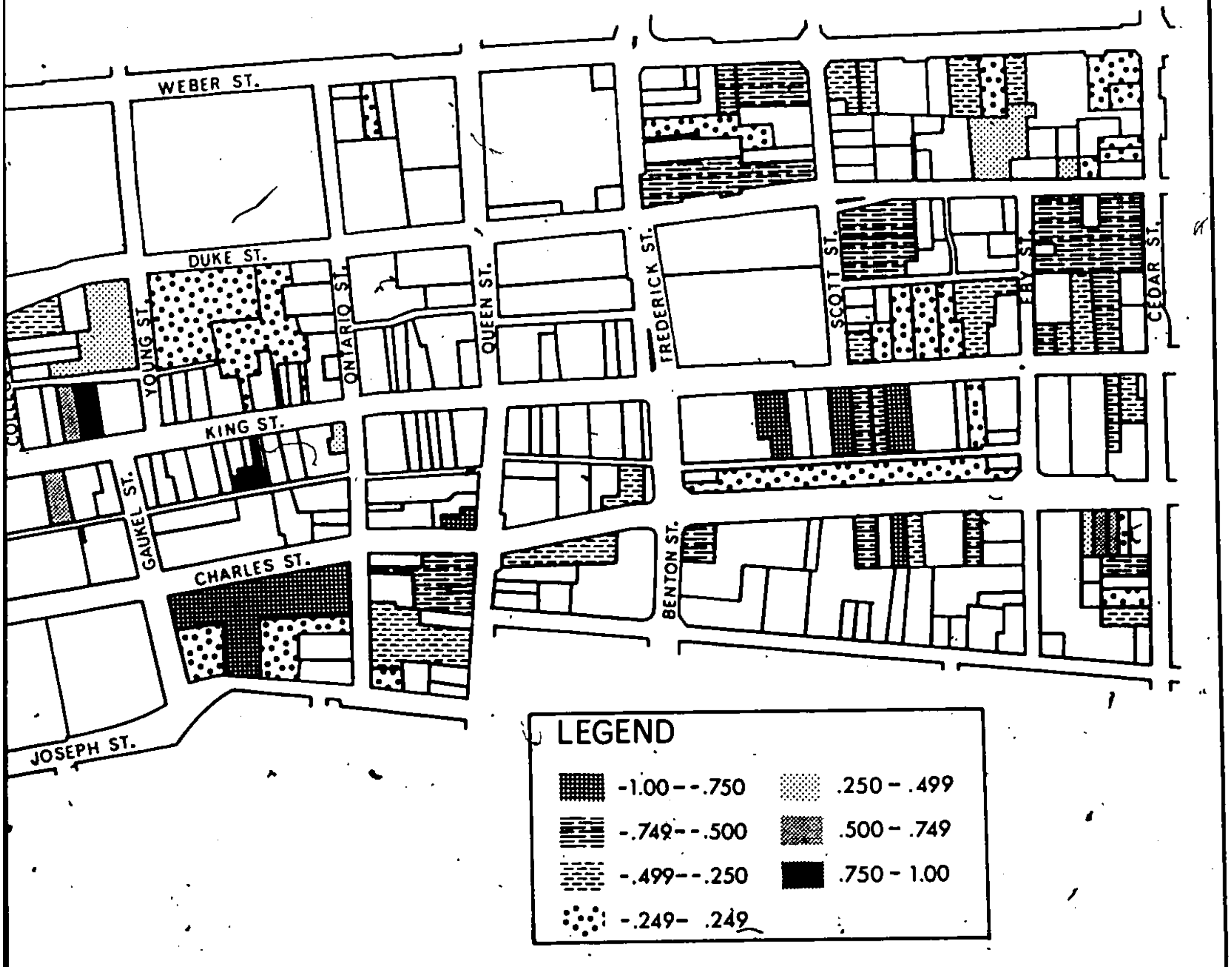
DOMINANCE INDEX VALUES



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concentrated in the eastern core, mainly along King Street, and to a lesser extent in the southern core. On the other hand, sites with relatively high positive values are predominantly found in the western core, again primarily along King Street. One additional point of interest is that sites with similar signs appear in clusters. There are only two cases in which sites with opposite signs abut each other. In both cases the contiguous sites face onto different streets. There are no examples of a site with a positive value bordered by two or more sites with negative values; or vice versa.

The spatial distribution of the temporal dominance index values indicates that, according to the simulation model, redevelopment in the study area will be located on eastern and south-central sites in the early 1980's. By the last half of the decade redevelopment will have shifted to sites in the western core. The shift will be spatially discontinuous in that the central cores sites will not be subjected to redevelopment. The exact timing of the shift cannot be determined from the analytical method used. Wherever it occurs, the redevelopment of abutting sites will take place within a few years of each other, if at all in the near future.

One question that remains to be answered is why the locational shift will take place at all? One possible explanation is that the chance factor in the model caused several low potential sites in the western core to be selected for redevelopment at the expense of high potential sites in the opposite end of the core. Such an occurrence, a distinct possibility in reality, might have been enough to equalize or shift the redevelopment potential surface in favour of western core sites. Redevelopment would then most likely shift to the western core from the east. This is an unlikely explanation, however, because the chance selection of low potential western sites would have had to have taken place in a large percentage of the 100 runs of the model. A more acceptable explanation involves the relative availability of redevelopable sites. After redevelopment has occurred for several years in one sub-area of the urban core the number of sites highly attractive to redevelopment begins to become limited. Sites elsewhere in the core that were previously unattractive become relatively more attractive and redevelopment subsequently migrates to another sub-area of the core. After being the location of much of the redevelopment in the early 1980's, the eastern core will suffer a lack of redevelopable sites. Redevelopment will then shift to equally or more attractive sites in the western core.

6.5 Synthesis

This chapter commenced with a description of the output generated by the redevelopment simulation model and the format by which it was organized. The output consisted of the initial attractiveness index values of each site and a 259 site X 8 time period matrix, the elements of which indicated the number of times a site was selected for redevelopment in each time period over the 100 runs of the model.

The initial index values showed that the vast majority of sites in the study area exhibited relatively little potential for redevelopment in 1980. It was mentionned that this corresponds with reality in that at any point in time relatively few sites possess that mix of physical and locational characteristics that make a site a prime candidate for redevelopment. By mapping the index values a redevelopment potential surface was derived. A visual inspection of that surface ascertained that, as a group, sites in the eastern core had relatively more potential for redevelopment than those in the west. The shape of the potential surface appeared to be most reflective of the spatial pattern of redevelopment in the 15 year period before 1980 rather than of any of the other site attributes that comprised the attractiveness index.

Subsequently, the aggregate redevelopment selection frequencies of each site were examined. They ranged from 49 downward with over half falling under 5. The sites selected most frequently varied widely in terms of their physical characteristics but were nearly all located on either the eastern or western core periphery. The sites with the least likelihood of redevelopment or that were m[illegible] infrequently picked were either relatively small central core sites on King Street, or relatively small peripheral sites on residential streets, or sites that had been redeveloped since 1965. The general spatial pattern of redevelopment during the 1980's, therefore, is one of concentration in the eastern and western core peripheral zones and a marked absence in the central core. The aggregate frequencies were relatively higher for western core sites than eastern ones.

The evolution of the spatial pattern of future redevelopment was determined by an analysis of the temporal frequency distribution of each site. In other words, the variation in the number of redevelopment selections per site over each of the ten time periods was examined to identify whether early or late selections were dominant. In this way a general indication of the timing of the redevelopment of each individual site was obtained. A temporal dominance index was introduced to measure the temporal variation. Several problems with using the index were discussed and some remedial measures undertaken so that it could be acceptably utilized. The actual index values ranged from .889 to -1.00. Positive values corresponded with a predominance of late selections and vice versa. Mapping the values showed that sites with relatively high negative values were concentrated in the eastern core, along King Street, and to a lesser degree in the south-central core. Those with relatively high positive values were predominantly located in the western core, again along King Street. It was also noted that sites with similar signs were located adjacent to each other. The spatio-temporal pattern of redevelopment in Kitchener's core in the 1980's as indicated by the spatial distribution of the temporal dominance index values is the following. Eastern and south-central core sites will be redeveloped in the early 1980's. The location of redevelopment will then shift to the western core and continue therein throughout the latter half of the decade. Central core sites will for the most part be ignored by any redevelopment during the entire forecast period. Finally it was suggested that the change in the location of redevelopment between the eastern and the western core would be caused by either the influence of chance factors or, more plausibly, by the relative lack of high potential sites in the eastern core after its most attractive sites had been redeveloped earlier.

CHAPTER SEVEN

SYNTHESIS AND CONCLUSIONS

In this thesis a stochastic simulation model of urban redevelopment was developed by employing and integrating a collection of diverse concepts uncovered in the urban geographic and economic literature. The model was predictive; the assumption of the continuation of recent past trends in the future allowed a ten year forecast of the spatio-temporal pattern of redevelopment to be made. Empirically applied to an arbitrarily bounded area identified as Kitchener's core, the model both operated and generated its many individually varying forecasts at the individual site level. The model output analysis, however, was performed at a more aggregate core sub-area spatial scale. The rationale for such an investigation into redevelopment lies in the significant impact and influence redevelopment has on the urban economy and urban morphology juxtaposed with the relative lack of academic attention paid to it. The modelling approach was adopted because models allow the incorporation of many diverse ideas and concepts, facilitate the systematic summarization of the phenomenon, and enable empirical application and experimentation.

7.1 Thesis Summary

Redevelopment was introduced as a sub-component of the urban land use change process. It was described as the ultimate adjustment to the ever increasing disequilibrium between urban floorspace supply and demand.

Depending on the level of spatial aggregation one adopts redevelopment can be viewed as an event or a process. The replacement of an existing building on a site with a new one by a private agent is an event. It is discrete in both time and space. From a city-wide point of view redevelopment is an urban process that exhibits the evolution of a distinct spatial pattern through time. It is a series of spatially and temporally related individual events.

As an event redevelopment can be studied from either the aspatial temporal or the atemporal spatial perspective. In the former case, the focus is on one individual site and the factors involved in regulating the timing of redevelopment thereon. In the latter, time is held constant and concern lies with all the sites and the factors that influence the relative attractiveness of each site as a location for redevelopment. The second approach was employed here with the relevant factors being various physical and locational site attributes.

Two concepts, locational inertia and the contagion effect, were introduced as the spatial and temporal links, respectively, between redevelopment events. Even at a very disaggregate spatial scale the agglomeration or clustering of redevelopment occurs because of the similarity of their resident activities' locational requirements and the clarification of planning policy and guidelines in the immediate neighbourhood of previous redevelopment events. The contagion effect relates redevelopment events in time in the sense that, in the face of uncertainty and risk, an agent's decision to redevelop a site is influenced by the attitudes, expectations, and behaviour of others in similar circumstances. Redevelopment, therefore, can be considered a self-supporting cyclical temporal process.

Although the elements of the redevelopment process can be conceptually linked in time and space, they are characterized by spatial and temporal discontinuity in reality. Uncertainty and the lack of perfect knowledge on the part of the development agent, the heterogeneity of real estate, and other factors produce a somewhat random variation in the location of redevelopment. The number of redevelopment events per time period, or the process level, varies cyclically due to, among other things, changes in the availability of finance capital.

Given the above characteristics of redevelopment, modelling techniques and approaches were analyzed and evaluated to ascertain the combination that appeared best suited to the mix of features peculiar to the phenomenon of interest. Monte Carlo simulation was judged to be the most rewarding approach for two primary reasons. It allowed both space and time to be specifically accounted for and it inherently incorporated a random or chance factor. Furthermore, it had somewhat successfully imitated the land development process.

Before the simulation model itself was described, the study area to which it was to be applied was delimited and previous redevelopment therein outlined.

The two basic components of the model were the attractiveness index and the redevelopment level forecast. The attractiveness index was created to provide a measure of the relative redevelopment potential of individual sites. It was developed using the non-linear logit model and maximum likelihood estimation. Multiple regression analysis determined a set of statistically significant relationships between the occurrence of redevelopment and four hypothesized location factors as measured by the following five surrogate variables: 1) distance to the city center; 2) average redevelopment distance; 3) traffic volume; 4) site size; and 5) building age. The redevelopment level forecast dictated the number of events in each year of the forecast period. It was formed by analyzing the trend in the fifteen years prior to the initial forecast year, determining its regularities by statistically comparing it to various fitted curves, and extrapolating the best fitting curve into the future.

In its entirety the redevelopment simulation model consisted of a half dozen steps. They were data input, attractiveness index calculation, site redevelopment selection, data output, accounting procedures, and sequence repetition. Each step was described in detail and there is no need to repeat those descriptions here. One of the most interesting aspects of the model was that changes in past time periods were accomodated and allowed to influence the operation of the process in succeeding time periods. Hence the model was able to incorporate in its forecasts the effects of the changing states of the urban system through time. The analysis of the model output demonstrated the value of such an ability. Because of the influence of the random factor on the individuals forecasts, 100 runs of the model were performed and the cumulative result analyzed.

The product of the application of the model to Kitchener's core area was subjected to three analyses.

First, the initial redevelopment potential surface was examined. The spatial variation of redevelopment attractiveness in the study area at the beginning of the forecast period revealed a concentration of relatively high potential sites in the eastern core. This initial index value pattern was attributed primarily to the influence of the location of redevelopment in the past. Secondly, the pattern of aggregate site redevelopment selections was scrutinized. According to this static analysis, future redevelopment will be concentrated in the eastern and western core peripheries and relatively absent in the central core. The selection frequencies of western sites were relatively higher than those in the east. A comparison of these first two patterns confirms the utility of the simulation approach. An examination of the initial potential values failed to uncover the physical manifestation of changes in the urban system. The influence of the aging of buildings and the location of previous redevelopment on the evolution of the spatial pattern of redevelopment was accounted for by the simulation model and was reflected in the generated forecast. The third method of analysis presented a more dynamic picture. An index was created to measure the dominance of early or late redevelopment selections. The pattern of these temporal dominance index values indicated that redevelopment early in the forecast period will be concentrated in the eastern core, mainly along King Street, and to a lesser extent in the southern core. By the latter half of the 1980's, it will have shifted primarily to sites in the western core, avoiding those in between. The locational shift through time was attributed to the eventual relative absence of redevelopable sites in the eastern core.

7.2 Theoretical and Methodological Advances

The delimitation of redevelopment into two components, event and process, and the conceptual linkage of events in time and space to form a process is not found elsewhere in the literature. It is very useful in developing and organizing one's knowledge and understanding of such a complex and dynamic phenomenon. It also serves to illustrate that redevelopment is guided by some systematic relationships even though its discontinuity in reality leads one to believe it is just a haphazard assembly of construction activity. For present purposes, the concept provided the framework which enabled the modeller to mesh two spatial scales in one model.

The model itself is to some degree unusual in that it is one of only a very few known attempts to model redevelopment. It is, however, the only redevelopment model to combine all the following characteristics: 1) operation at the individual site level; 2) incorporation of a random factor; 3) use of the logit model as the basis of the attractiveness index; and 4) empirical applicability. It is felt a comprehensive and acceptable model of redevelopment should possess each of the four listed attributes; all earlier redevelopment models lack one or more of them and are, therefore, incomplete. The model should be empirically applicable so that it can be tested and experimented with. The logit model is the superior functional form of the regression model in a binary dependent variable case, and it is relatively easy to work with. Inclusion of the random or chance factor is imperative when dealing with a complex urban phenomenon around which so much uncertainty and risk exist. And model operation at the most disaggregate spatial level of the process is beneficial in that the evolution of the spatial pattern can easily be followed.

The model also demonstrates the advantages of utilizing the simulation approach when modelling dynamic urban phenomenae. The passing of time was imitated by the repetition of the model sequence. Changes in the levels of certain of the location factors caused by the passing of time and the occurrence of redevelopment were accounted for. Thus the evolution of the spatial pattern of redevelopment effectively reflected all the changes in the system since the forecast began. Furthermore, simulation enabled the model to operate at the individual site level by facilitating the summation of individual events into an aggregate process.

And finally, although already mentionned above, the utility of the logit model in the discrete binary dependent variable case was brought to light. In a wide variety of geographic applications in which regression analysis is used to investigate the relationship between one or more independent variables and a phenomenon that either occurs or does not, the interpretation afforded and the range of values produced by the logit model are superior to those of the classical linear or the linear probability models.

7.3 Empirical Significance of the Results

The forecasted pattern of redevelopment generated by the simulation model presents a gloomy scenario for the future of the heart of the city of Kitchener. If past trends continue, then during the 1980's the city's core periphery will undergo regeneration but its central core will not. While the existing buildings on peripheral sites are replaced with new investment, the inner core buildings will continue to deteriorate. The maladjustment between floorspace supply and demand will continue to increase unabated. Economic activity will flee the central core for the healthier surroundings on the periphery. Unless the trend is reversed, the very heart of Kitchener will become physically and functionally blighted to the detriment of the entire core area and the city itself.

Of course no forecast of the future can assuredly be accurate. The redevelopment forecast in this thesis was primarily formulated to demonstrate how the simulation model could be empirically applied. It was more an academic exercise aimed at generating a pattern that was acceptable in terms of what is known and understood about redevelopment than a serious attempt to see into the future. It is felt the former objective has been achieved. The validity of the forecast is only as robust as the assumption on which it is based; that being the relationships governing the redevelopment process will remain unchanged over the forecast period. However, the fact that past trends indicate the very possibility of such a bleak and undesireable scenario occurring suggests the city's civic officials would be wise to take notice now, before it is too late.

7.4 Directions for Future Research

The need for more research into every facet of redevelopment is obvious since so little attention has been paid to it in the past. In terms of extending the work presented here, it would be useful to generalize the model by reformulating the relationships contained in the attractiveness index to make them less city specific. This would require a detailed analysis of the relationships between the occurrence of redevelopment and various location factors in many different cities. An extension of the model to include activity and building type and building scale in the forecast, and the application of the model to a large city possessing higher process levels would be wothwhile. Another interesting project would be to lengthen the forecast period and evaluate the result. Does the lack of redevelopable sites in certain core sub-areas cause distinct shifts in the location of redevelopment? The answer to this and many other questions have yet to be found. Their pursuit would surely be rewarding.

Appendix 5.1 Regressed Variables: All Sites

Site ID No.	DCC	ARD	DK	log TV	SS ft^2	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
1	.439	.472	.073	4.226	20910	3	1.196	001	5	0
2	.450	.482	.001	4.559	227690	4	.935	001	4	0
3	.380	.441	.168	4.406	16550	2	.076	001	8	0
4	.370	.417	.152	4.290	13500	2	.422	001	2	0
5	.368	.415	.144	2.000	8710	2	.413	001	2	0
6	.367	.414	.137	2.000	6530	2	.459	001	2	0
7	.375	.420	.128	2.000	10450	2	.344	001	2	0
8	.377	.421	.121	2.000	8710	2	.344	001	2	0
9	.386	.428	.097	2.000	10450	2	.120	001	2	0
10	.385	.424	.085	2.000	5230	1	.456	001	2	0
11	.393	.432	.078	3.625	7840	2	.491	001	2	0
12	.399	.436	.102	1.000	4360	1	.229	001	2	0
13	.415	.453	.099	3.625	6970	2	.373	001	5	0
14	.426	.463	.109	4.214	13500	2	.981	001	5	0
15	.415	.454	.121	4.084	20910	3	.220	001	5	0
16	.410	.447	.140	4.084	5230	1	.478	001	5	0
17	.409	.450	.144	4.084	26140	3	.792	010	5	0
18	.359	.403	.031	4.020	60110	4	.813	010	2	0
19	.322	.375	.017	3.778	4360	1	1.720	010	1	0
20	.320	.376	.001	4.177	7410	2	1.721	010	1	0
21	.332	.384	.001	3.956	6970	2	.933	010	1	0
22	.344	.392	.001	3.956	9580	2	.986	001	1	0
23	.372	.412	.001	4.131	36590	3	1.309	010	1	0
24	.341	.391	.076	4.026	9580	2	.438	010	2	0
25	.341	.389	.089	3.787	5660	1	.530	001	2	0
26	.263	.341	.031	3.849	15680	2	.869	001	1	0
27	.263	.340	.001	4.045	21780	3	1.000	010	1	0
28	.289	.356	.001	4.210	20910	3	3.000	010	1	0
29	.313	.377	.154	4.163	9150	2	.678	001	2	0
30	.305	.370	.142	2.954	8280	2	.363	001	2	0
31	.300	.366	.130	2.954	8280	2	.743	001	2	0
32	.286	.356	.107	2.954	18700	2	1.341	010	2	0
33	.277	.347	.095	2.954	3920	1	.893	001	2	0
34	.271	.346	.073	3.849	6970	2	.904	010	2	0
35	.295	.361	.073	3.790	20470	3	1.250	001	2	0
36	.315	.374	.107	3.787	41820	3	9.240	100	2	0
37	.334	.387	.170	3.787	8710	2	.434	100	2	0
38	.345	.395	.166	4.313	6100	1	.959	001	2	0
39	.238	.329	.054	3.849	10020	2	.362	001	2	0
40	.201	.309	.028	3.851	39640	3	.001	000	2	0

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft^2	cat.	FAR	BA 123	ZONE	RDVMT DUMMY
41	.192	.305	.001	4.055	17860	2	2.484	010	1	0
42	.209	.309	.001	4.020	5230	1	1.338	001	1	0
43	.213	.311	.001	4.020	3920	1	1.403	100	1	0
44	.221	.318	.001	4.020	6530	2	.620	001	1	0
45	.227	.318	.001	4.020	3920	1	.957	001	1	0
46	.237	.326	.001	4.056	10450	2	2.000	001	1	0
47	.231	.320	.045	2.954	5660	1	.574	001	2	0
48	.233	.321	.050	2.954	6100	1	1.311	010	2	0
49	.168	.295	.026	3.906	64470	4	1.573	001	2	0
50	.113	.272	.059	4.040	6530	2	.689	010	2	0
51	.107	.270	.043	3.587	10890	2	1.102	001	2	0
52	.098	.265	.038	3.587	3920	1	.600	100	1	0
53	.088	.262	.009	3.587	4360	1	1.813	001	1	0
54	.103	.267	.001	4.018	5230	1	2.000	010	1	0
55	.121	.275	.001	4.244	47040	4	.580	001	1	0
56	.155	.289	.001	4.018	6530	2	2.940	001	1	0
57	.162	.289	.001	4.018	5660	1	2.544	001	1	0
58	.169	.292	.001	4.055	4360	1	5.539	001	1	0
59	.077	.258	.038	4.111	30490	3	5.507	100	2	0
60	.074	.254	.054	4.254	16990	2	2.649	010	1	0
61	.055	.249	.038	3.949	15680	2	.880	001	2	0
62	.025	.244	.001	4.273	7410	2	.911	100	1	0
63	.038	.247	.001	4.273	22220	3	2.588	001	1	0
64	.045	.250	.001	3.993	8280	2	2.283	001	1	0
65	.050	.250	.001	3.993	4360	1	1.491	001	1	0
66	.065	.256	.001	4.137	15680	2	.599	010	1	0
67	.141	.275	.111	4.359	37900	3	4.550	100	3	0
68	.106	.263	.083	4.266	24830	3	1.226	010	3	0
69	.158	.286	.133	3.529	6100	1	1.492	001	3	0
70	.153	.281	.133	4.128	6100	1	.655	001	3	0
71	.158	.285	.133	4.128	4360	1	.562	001	3	0
72	.126	.274	.083	4.094	43560	3	3.157	100	1	0
73	.062	.241	.033	4.313	27010	3	3.360	100	1	0
74	.071	.234	.001	4.338	7410	2	1.552	010	1	0
75	.055	.233	.001	4.006	3920	1	2.870	001	1	0
76	.048	.235	.001	4.006	22650	3	2.563	001	1	0
77	.023	.239	.001	4.279	16120	2	2.792	001	1	0
78	.144	.252	.052	4.341	63160	4	1.752	100	1	0
79	.134	.242	.001	4.449	123710	4	2.313	100	1	0
80	.169	.283	.144	4.432	4360	1	.310	010	3	0

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft^2	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
81	.116	.255	.085	4.242	3920	1	2.487	010	1	0
82	.095	.253	.085	4.217	3920	1	.893	010	1	0
83	.177	.280	.123	4.383	16550	2	.411	001	3	0
84	.193	.288	.123	4.140	7840	2	.536	001	3	0
85	.210	.293	.128	4.186	24830	3	.431	001	3	0
86	.203	.284	.109	3.193	14810	2	.527	001	3	0
87	.187	.274	.099	3.193	10890	2	.689	001	3	0
88	.170	.270	.088	4.266	29620	3	.728	010	2	0
89	.161	.271	.102	4.016	13070	2	.593	001	2	0
90	.169	.275	.111	4.016	20470	3	.001	000	2	0
91	.176	.283	.135	4.016	7840	2	1.205	001	3	0
92	.182	.286	.144	4.383	5660	1	1.193	001	3	0
93	.253	.273	.001	4.055	14810	2	1.089	001	1	0
94	.231	.263	.001	4.055	16120	2	.690	010	1	0
95	.219	.259	.001	4.055	10020	2	2.000	010	1	0
96	.207	.255	.001	4.055	9580	2	1.253	001	1	0
97	.197	.252	.001	4.055	6530	2	1.685	001	1	0
98	.188	.249	.001	4.179	7840	2	2.000	010	1	0
99	.190	.252	.021	3.574	6100	1	1.107	010	1	0
100	.191	.254	.031	3.574	3920	1	1.161	001	1	0
101	.206	.266	.043	3.574	22650	3	.344	010	1	0
102	.214	.273	.080	3.941	11330	2	.001	000	3	0
103	.232	.277	.057	3.696	6970	2	.344	001	7	0
104	.250	.280	.043	.000	13500	2	.889	001	1	0
105	.232	.272	.045	.000	6970	2	.689	001	1	0
106	.242	.282	.062	3.696	5230	1	.478	001	7	0
107	.260	.291	.064	3.696	11760	2	.638	001	7	0
108	.276	.298	.064	3.738	4360	1	.688	001	7	0
109	.311	.316	.043	4.082	50100	4	.001	000	1	0
110	.375	.314	.001	4.267	8710	2	.207	100	1	0
111	.313	.307	.001	4.055	16120	2	1.520	001	1	0
112	.299	.298	.001	4.055	15250	2	.918	001	1	0
113	.287	.288	.001	4.055	5660	1	1.060	010	1	0
114	.280	.284	.001	4.074	4790	1	1.597	001	1	0
115	.244	.307	.130	4.196	12630	2	.594	001	3	0
116	.252	.307	.129	4.151	4790	1	.574	001	3	0
117	.268	.317	.125	4.151	17860	2	.722	100	3	0
118	.197	.332	.123	4.151	13500	2	.222	001	9	0
119	.309	.339	.123	4.151	8710	2	.448	001	9	0
120	.319	.343	.130	4.151	4360	1	.459	001	9	0

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft²	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
121	.350	.366	.123	4.338	10020	2	.719	010	9	0
122	.354	.366	.123	3.881	9150	2	.536	001	9	0
123	.331	.346	.102	1.000	7410	2	.425	001	7	0
124	.313	.331	.102	1.000	5230	1	.382	001	7	0
125	.321	.337	.102	1.000	5230	1	.402	001	7	0
126	.344	.352	.104	3.881	4790	1	.522	001	3	0
127	.339	.346	.097	3.881	4790	1	.522	001	7	0
128	.322	.332	.085	3.696	3920	1	.765	001	7	0
129	.310	.325	.085	3.696	4360	1	.573	001	7	0
130	.294	.321	.088	3.696	33110	3	.776	001	7	0
131	.245	.291	.088	3.696	6100	1	.410	001	7	0
132	.258	.304	.118	1.000	4360	1	.459	001	7	0
133	.235	.290	.085	3.696	7410	2	.675	001	7	0
134	.214	.280	.090	3.815	6970	2	.603	001	3	0
135	.219	.285	.099	3.193	6970	2	.502	001	3	0
136	.224	.290	.109	3.193	6970	2	.430	001	3	0
137	.230	.296	.121	3.193	6970	2	.516	001	3	0
138	.299	.293	.001	4.324	28750	3	.939	100	1	0
139	.310	.301	.001	4.055	6970	2	.588	001	1	0
140	.319	.309	.001	4.174	8710	2	.597	010	1	0
141	.325	.330	.085	3.354	7410	2	.304	001	9	0
142	.331	.338	.104	3.354	10450	2	.239	001	9	0
143	.335	.345	.114	3.354	10890	2	.230	001	9	0
144	.349	.360	.129	3.441	5660	1	.265	001	9	0
145	.307	.331	.129	3.000	4790	1	.626	001	9	0
146	.310	.323	.099	2.699	5230	1	.287	001	9	0
147	.309	.320	.085	2.699	4790	1	.261	001	9	0
148	.320	.322	.066	3.989	4360	1	.516	001	9	0
149	.313	.317	.066	3.989	4360	1	.516	001	9	0
150	.306	.312	.066	3.989	4360	1	.516	001	9	0
151	.300	.307	.066	3.989	4360	1	.516	001	9	0
152	.112	.235	.001	4.352	34850	3	3.257	100	1	0
153	.139	.239	.001	4.103	12200	2	1.660	001	1	0
154	.151	.241	.001	4.103	6970	2	1.227	100	1	0
155	.163	.242	.001	4.103	12630	2	.507	010	1	0
156	.175	.244	.001	4.103	11760	2	1.341	001	1	0
157	.182	.245	.001	4.055	6530	2	.586	010	1	0
158	.189	.247	.001	4.055	7840	2	.918	010	1	0
159	.201	.249	.001	4.055	10450	2	.651	001	2	0
160	.222	.253	.001	4.055	24830	3	4.007	100	1	0

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft²	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
161	.236	.258	.001	4.055	5230	1	.248	010	1	0
162	.243	.261	.001	4.055	10450	2	.001	000	1	0
163	.257	.267	.001	4.074	13500	2	1.300	100	1	0
164	.190	.251	.038	3.989	45300	4	.001	000	1	0
165	.126	.246	.066	4.239	6530	2	.919	001	2	0
166	.172	.255	.066	3.989	4790	1	.626	001	6	0
167	.201	.263	.064	3.989	6530	2	.536	001	6	0
168	.210	.265	.066	3.989	5660	1	.530	001	6	0
169	.216	.267	.066	3.989	5660	1	.530	001	6	0
170	.225	.270	.066	3.989	5230	1	.516	001	6	0
171	.253	.281	.064	3.989	6530	2	.322	001	6	0
172	.266	.290	.078	2.699	6530	2	.490	001	6	0
173	.255	.219	.088	2.699	26140	3	.390	001	6	0
174	.271	.301	.102	2.699	4790	1	.271	010	6	0
175	.272	.306	.109	2.699	10020	2	.299	001	6	0
176	.260	.300	.112	2.699	4360	1	.482	001	6	0
177	.254	.297	.112	2.699	4790	1	.731	001	6	0
178	.240	.287	.088	2.699	15240	2	.400	001	6	0
179	.228	.281	.088	2.699	8710	2	.344	001	6	0
180	.218	.281	.102	2.699	5660	1	.353	001	6	0
181	.177	.265	.085	2.699	21780	3	.691	001	6	0
182	.212	.279	.102	2.699	5660	1	.353	010	6	0
183	.159	.263	.085	3.908	25700	3	.442	001	2	0
184	.030	.234	.001	4.006	4790	1	1.973	001	1	0
185	.020	.237	.001	4.287	5660	1	2.583	001	1	0
186	.043	.233	.001	4.006	16120	2	1.973	010	1	0
187	.057	.231	.001	4.006	17860	2	1.937	010	1	0
188	.071	.229	.001	4.006	8710	2	1.837	100	1	0
189	.082	.236	.036	4.061	10890	2	.001	000	1	0
190	.071	.236	.033	4.061	9580	2	.001	000	1	0
191	.061	.237	.031	4.061	13350	2	.001	000	1	0
192	.041	.238	.028	3.966	4360	1	2.752	001	1	0
193	.089	.246	.069	4.061	20910	3	.001	000	1	0
194	.095	.250	.083	4.030	6530	2	1.832	100	1	0
195	.104	.257	.092	3.908	5660	1	.848	001	1	0
196	.109	.255	.092	2.699	4360	1	.917	001	1	0
197	.063	.255	.001	4.140	16550	2	2.592	001	1	0
198	.052	.250	.001	3.993	3920	1	5.357	010	1	0
199	.048	.249	.001	3.993	3920	1	3.125	001	1	0
200	.043	.248	.001	3.993	3920	1	3.125	001	1	0

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft^2	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
201	.038	.247	.001	3.993	7410	2	2.510	001	1	0
202	.024	.242	.001	4.281	17860	2	4.516	001	1	0
203	.057	.248	.038	3.966	9580	2	1.628	001	1	0
204	.068	.249	.050	4.298	7410	2	2.368	001	1	0
205	.079	.258	.045	4.164	10020	2	.001	000	1	0
206	.059	.251	.033	4.122	17420	2	1.910	001	1	0
207	.109	.269	.076	3.525	9580	2	1.425	001	2	0
208	.152	.291	.125	3.983	4360	1	1.101	001	2	0
209	.096	.260	.071	4.329	18730	2	1.839	001	2	0
210	.113	.268	.095	4.030	4360	1	.573	001	2	0
211	.130	.277	.090	4.198	40510	3	.318	001	2	0
212	.139	.281	.123	4.030	4790	1	.626	001	2	0
213	.148	.286	.133	4.230	5230	1	.860	001	2	0
214	.146	.285	.121	3.797	6530	2	.459	001	2	0
215	.187	.301	.001	4.088	4360	1	1.376	010	1	0
216	.178	.299	.001	4.018	6970	2	1.492	001	1	0
217	.168	.295	.001	4.018	9150	2	1.902	001	1	0
218	.159	.291	.001	4.018	9580	2	2.000	100	1	0
219	.146	.284	.001	4.018	4360	1	2.980	001	1	0
220	.137	.282	.001	4.018	17420	2	2.790	001	1	0
221	.123	.277	.001	4.018	6970	2	4.000	001	1	0
222	.114	.273	.001	4.018	8280	2	2.220	001	1	0
223	.085	.263	.001	4.395	6970	2	.001	000	1	0
224	.108	.269	.031	3.600	11760	2	.001	000	1	0
225	.109	.271	.043	3.600	6100	1	.607	001	2	0
226	.111	.272	.047	4.134	7410	2	1.032	010	1	0
227	.134	.281	.031	3.984	7840	2	1.212	001	1	0
228	.162	.293	.031	4.059	36150	3	1.258	001	1	0
229	.171	.297	.031	3.262	11330	2	1.688	001	1	0
230	.157	.293	.071	4.353	77100	4	.647	001	2	0
231	.159	.295	.095	3.983	20470	3	.777	010	2	0
232	.154	.292	.104	3.525	10020	2	.749	001	2	0
233	.196	.314	.090	3.981	17860	2	.280	010	2	0
234	.289	.356	.001	4.209	11330	2	1.787	010	1	0
235	.270	.344	.001	4.020	9150	2	1.421	010	1	0
236	.251	.333	.001	4.020	20910	3	3.121	100	1	0
237	.230	.322	.001	4.020	6530	2	2.593	001	1	0
238	.202	.309	.001	4.090	10020	2	1.280	010	1	0
239	.213	.315	.033	4.006	23520	3	.202	010	1	0
240	.264	.340	.033	4.147	58930	4	2.444	100	1	0

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft²	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
241	.286	.363	.073	4.273	87120	4	2.854	100	1	0
242	.382	.423	.001	4.195	26140	3	.199	010	1	0
243	.356	.403	.001	3.956	15680	2	.001	000	1	0
244	.341	.392	.001	3.956	10450	2	.718	001	1	0
245	.320	.377	.001	4.169	20910	3	5.261	010	1	0
246	.318	.378	.033	3.757	6530	2	2.757	100	1	0
247	.354	.405	.033	4.091	40950	3	.001	000	1	0
248	.356	.413	.073	4.102	72750	4	.001	000	2	0
249	.348	.411	.107	3.980	31360	3	.730	001	9	0
250	.370	.428	.107	3.703	12200	2	.582	001	9	0
251	.383	.438	.107	3.703	8710	2	.230	001	9	0
252	.388	.450	.107	2.301	6530	2	.345	001	9	0
253	.477	.510	.001	4.473	26750	3	.555	010	2	0
254	.453	.487	.001	4.172	13070	2	.001	000	2	0
255	.435	.470	.001	4.172	8710	2	.775	010	2	0
256	.420	.457	.001	4.332	6530	2	.001	000	2	0
257	.428	.467	.033	3.960	24830	3	.242	001	2	0
258	.473	.508	.033	4.239	36150	3	.606	010	2	0
259	.470	.511	.073	4.354	167710	4	2.656	001	5	0
260	.391	.403	.001	4.131	10020	2	.001	000	1	1
261	.315	.312	.107	3.787	41820	3	.866	001	2	1
262	.334	.361	.170	3.787	8710	2	.001	000	2	1
263	.224	.272	.001	4.020	3920	1	1.403	001	1	1
264	.099	.226	.038	3.587	3920	1	.001	000	2	1
265	.141	.219	.111	4.359	37900	3	.001	000	3	1
266	.176	.239	.083	4.094	43560	3	.001	000	2	1
267	.025	.176	.001	4.273	7410	2	.911	001	1	1
268	.062	.216	.033	4.313	27010	5	.001	000	2	1
269	.134	.264	.001	4.449	123710	4	.848	001	1	1
270	.144	.219	.052	4.341	63160	4	.475	001	1	1
271	.325	.338	.001	4.267	8710	2	1.085	001	1	1
272	.266	.300	.125	4.151	6970	2	.516	001	9	1
273	.299	.324	.001	4.324	28750	3	.366	010	1	1
274	.112	.212	.001	4.352	29620	3	1.545	010	1	1
275	.151	.287	.001	4.103	6970	2	.001	000	1	1
276	.222	.226	.001	4.055	24830	3	.001	000	1	1
277	.257	.277	.001	4.092	10450	2	.861	001	1	1
278	.071	.187	.001	4.006	8710	2	1.406	001	1	1
279	.095	.175	.083	4.030	6530	2	.001	000	1	1
280	.159	.166	.001	4.018	9580	2	.001	000	1	1

Appendix 5.1 Regressed Variables: All Sites, Continued

Site ID No.	DCC	ARD	DK	log TV	SS ft^2	SS cat.	FAR	BA 123	ZONE	RDVMT DUMMY
281	.251	.312	.001	4.020	20910	3	5.429	010	1	1
282	.264	.325	.033	4.147	58930	4	.023	010	2	1
283	.286	.349	.073	4.273	87120	4	.001	000	2	1
284	.318	.312	.033	4.055	6530	2	.827	001	2	1

Appendix 5.2 Redevelopment Simulation Computer Program

```
C      THIS PROGRAM SIMULATES REDEVELOPMENT BY CALCULATING
C      THE REDEVELOPMENT POTENTIAL OF EACH SITE AND
C      RANDOMLY SELECTING A FORECASTED NUMBER OF SITES
C      FOR EACH TIME PERIOD.
C
C
C
       DIMENSION D(259,8), DIST(13), E(259), MF(10),
     C IS(259), ISR(259), P(259), IPP(259),
     C QD(36), QX(36), QY(36), IR(259,100), IX(4),
     C XLCX(259), XLCY(259), ADRA(259), ADRB(259), ADRC(259),
     C ADRD(259), ADRE(259)
C
       DO 10 I=1,259
       READ(4,2) XLCX(I), XLCY(I), E(I)
     2 FORMAT(1X,3F6.0)
    10 CONTINUE
C
       DO 11 I=1,10
       READ(3,7) MF(I)
     7 FORMAT(I2,3X)
    11 CONTINUE
C
       DO 12 I=1,36
       READ(2,4) QD(I), QX(I), QY(I)
     4 FORMAT(3F5.0)
    12 CONTINUE
C
       DO 13 I=1,259
       READ(1,8) ADRA(I), ADRB(I), ADRC(I), ADRD(I), ADRE(I)
     8 FORMAT(5A4)
    13 CONTINUE
C
       READ(5,1)((D(I,J), J=1,8), I=1,259)
     1 FORMAT(I4,2F5.3,5X,F6.3,7X,F2.0,13X,I2,2I1,6X)
C
       IT=1
       ICONT=9
  1000 IPMAX=0
       IPSUM=0
       ICOUNT=0
C      IPPSUM(1)=0
       ITYR=IT+1979
       ITM=0
       ICHK=0
       NT=0
```

Appendix 5.2 Redevelopment Simulation Computer Program, Continued

```
C
      DO 20 I=1,259
      P(D(I,1))=(1.+2.718**(-1.*(-10.96+24.02*(D(I,2))-
     C46.28*(D(I,3))+4.15*(D(I,4))+.77*(D(I,5))-9.91*
     C(D(I,6))-2.08*(D(I,7))-1.63*(D(I,8))))))**(-1.)
C
      IF(P(D(I,1)).LT..005) GO TO 20
      ICOUNT=ICOUNT+1
      IPP(ICOUNT)=IFIX((P(D(I,1))*100.)+.5)
      IS(ICOUNT)=D(I,1)
      IPSUM=IPSUM+IPP(ICOUNT)
      IF(IPP(ICOUNT)-IPMAX) 20,22,22
   22 IPMAX=IPP(ICOUNT)
   20 CONTINUE
C
      DO 130 I=1,ICOUNT
      DO 140 J=1,(IPP(I))
      IF(I.NE.1.AND.J.NE.1) IR(I,J)=IR(I,(J-1))+1
      IF(I.EQ.1.AND.J.EQ.1) IR(I,J)=1
      IF(I.EQ.1.AND.J.NE.1) IR(I,J)=IR(I,(J-1))+1
      IF(I.NE.1.AND.J.EQ.1) IR(I,J)=IR((I-1),(IPP(I-1)))+1
  140 CONTINUE
  130 CONTINUE
C
      IF(MF(IT).EQ.0) GO TO 35
      DO 30 J=1,(MF(IT))
   31 IX(J)=(IFIX(RND(1)*(FLOAT(IPSUM))+.5))
      IF(IX(J).LT.1) GO TO 31
      DO 40 I=1,ICOUNT
      DO 50 K=1,IPP(I)
      IF(IX(J).EQ.IR(I,K)) GO TO 55
   50 CONTINUE
   40 CONTINUE
C
   55 ISR(J)=IS(I)
      IF(J.EQ.1) GO TO 56
      ICHK=ISR(J)
      NT=J-1
      DO 65 N=1,NT
      IF(ICHK.EQ.ISR(N)) GO TO 31
   65 CONTINUE
   56 ICONT=ICONT+1
C
      QD(ICONT)=FLOAT(ITYR)
      QY(ICONT)=XLCY(ISR(J))
      QX(ICONT)=XLCX(ISR(J))
      DO 32 I=1,259
      NA=0
      IF(D(I,1).NE.ISR(J)) GO TO 32
      NA=I
```

Appendix 5.2 Redevelopment Simulation Computer Program, Continued

```
      D(NA,6)=1.
      D(NA,7)=0.
      D(NA,8)=0.
   32 CONTINUE
      E(ISR(J))=0.
   30 CONTINUE
C
   35 WRITE(6,601) ITYR
  601 FORMAT(1H1,//,1X,'SUMMARY OF SIMULATION OF FORECASTED ',
     C'REDEVELOPMENT',/,1X,'IN KITCHENER IN',1X,1X,I5,///)
C
      WRITE(6,999)((D(I,J), J=1,8), I=1,10)
  999 FORMAT(1X,I3,2F5.3,F6.3,1X,F2.0,I2,2I1)
      WRITE(6,604)
  604 FORMAT(1X,//,1X,'SITES WITH ATTRACTIVENESS INDEX > 0:',/)
C
      DO 220 I=1,ICOUNT
      WRITE(6,605) IS(I), IPP(I)
  605 FORMAT(10X,I3,':',2X,I3)
  220 CONTINUE
C
      WRITE(6,606) IPSUM, IPMAX
  606 FORMAT(1X,//,1X,'THE SUM OF THE ATTRACTIVENESS INDICES:',
     C2X,I5,//,1X,'THE MAXIMUM ATTRACTIVENESS INDEX VALUE IS:',
     C2X,I3,//)
C
      WRITE(6,609) ITYR, MF(IT)
  609 FORMAT(1X,//,1X,'THE FORECASTED AMOUNT OF REDEVELOP',
     C'MENT IN',1X,I4,',',/,1X,'IN TERMS OF NUMBER OF SITES, ',
     C'IS',1X,F2.0,//)
C
      IF(MF(IT).EQ.0) GO TO 241
C
      DO 230 J=1,(MF(IT))
      WRITE(6,610) ADRA(ISR(J)), ADRB(ISR(J)), ADRC(ISR(J)),
     C ADRD(ISR(J)), ADRE(ISR(J)), ISR(J), XLCX(ISR(J)),
     C XLCY(ISR(J)), IX(J), P(ISR(J))
  610 FORMAT(1X,//,1X,'REDEVELOPMENT IS PREDICTED AT',1X,
     C5A4,2X,'- SITE',1X,I3,1X,'(',F5.0,',',F5.0,') -',
     C/,5X,'RESULTING FROM IX(J)=',I4,1X,'AND PROB.=',1X,F5.4)
  230 CONTINUE
C
  241 WRITE(6,613) IT, ITYR
  613 FORMAT(1X,//,1X,'END OF RECORD FOR TIME PERIOD',
     CI3,1X,'(',I4,')')
C
      IT=IT+1
      ITM=IT-1
      IF(IT.EQ.11) GO TO 500
```

Appendix 5.2 Redevelopment Simulation Computer Program,

```
C
      DO 80 I=1,259
      IF(E(I).EQ.999.) GO TO 80
      E(I)=E(I)+1.
      IF(E(I).LT.15.) GO TO 81
      IF(E(I).GT.15..AND.E(I).LE.53.) GO TO 82
      IF(E(I).GT.53.) GO TO 83
   81 DO 37 J=1,259
      IF(D(J,1).NE.FLOAT(I)) GO TO 37
      D(J,6)=1.
      D(J,7)=0.
      D(J,8)=0.
   37 CONTINUE
      GO TO 80
   82 DO 38 J=1,259
      IF(D(J,1).NE.FLOAT(I)) GO TO 38
      D(J,6)=0.
      D(J,7)=1.
      D(J,8)=0.
   38 CONTINUE
      GO TO 80
   83 DO 39 J=1,259
      IF(D(J,1).NE.FLOAT(I)) GO TO 39
      D(J,6)=0.
      D(J,7)=0.
      D(J,8)=1.
   39 CONTINUE
   80 CONTINUE
C
      DO 90 I=1,259
      DSUM=0.
      Y=0.
      ICNT=0
      DO 100 M=1,ICONT
      Y=(FLOAT(ITYR))-QD(M)
      IF(Y-5.)102,102,100
  102 ICNT=ICNT+1
      DIST(ICNT)=SQRT((XLCX(D(I,1))-QX(M))**2+(XLCY(D(I,1))
     C-QY(M))**2)
      DSUM=DSUM+DIST(ICNT)
  100 CONTINUE
      D(D(I,1),3)=((DSUM/(FLOAT(ICNT)))*12.5)/5280.
   90 CONTINUE
C
      GO TO 1000
  500 WRITE(6,700)((D(I,J), J=1,8), I=1,259)
  700 FORMAT(1X,I4,2F6.3,F7.3,2I2,2I1)
      STOP
      END
```

Appendix 5.3.1 Site Attributes, 1980

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
1	.439	.472	4.226	3	001
2	.450	.482	4.559	4	001
3	.380	.441	4.406	2	001
4	.370	.417	4.290	2	001
5	.368	.415	2.000	2	001
6	.367	.414	2.000	2	001
7	.375	.420	2.000	2	001
8	.377	.421	2.000	2	001
9	.386	.428	2.000	2	001
10	.385	.424	2.000	1	001
11	.393	.432	3.625	2	001
12	.399	.436	1.000	1	001
13	.415	.453	3.625	2	001
14	.426	.463	4.214	2	001
15	.415	.454	4.084	3	001
16	.410	.447	4.084	1	001
17	.409	.450	4.084	3	010
18	.359	.403	4.020	4	010
19	.322	.375	3.778	1	010
20	.320	.376	4.177	2	010
21	.332	.384	3.956	2	010
22	.344	.392	3.956	2	001
23	.372	.412	4.131	3	010
24	.341	.391	4.026	2	010
25	.341	.389	3.787	1	001
26	.263	.341	3.849	2	001
27	.263	.340	4.045	3	010
28	.289	.356	4.210	3	010
29	.313	.377	4.163	2	001
30	.305	.370	2.954	2	001
31	.300	.366	2.954	2	001
32	.286	.356	2.954	2	010
33	.277	.347	2.954	1	001
34	.271	.346	3.849	2	010
35	.295	.361	3.790	3	001
36	.315	.374	3.787	3	100
37	.334	.387	3.787	2	100
38	.345	.395	4.313	1	001
39	.238	.329	3.849	2	001
40	.201	.309	3.851	3	000

Appendix 5.3.1 Site Attributes, 1980, Continued

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
41	.192	.305	4.055	2	010
42	.209	.309	4.020	1	001
43	.213	.311	4.020	1	100
44	.221	.318	4.020	2	001
45	.227	.318	4.020	1	001
46	.237	.326	4.056	2	001
47	.231	.320	2.954	1	001
48	.233	.321	2.954	1	010
49	.168	.295	3.906	4	001
50	.113	.272	4.040	2	010
51	.107	.270	3.587	2	001
52	.098	.265	3.587	1	100
53	.088	.262	3.587	1	001
54	.103	.267	4.018	1	010
55	.121	.275	4.244	4	001
56	.155	.289	4.018	2	001
57	.162	.289	4.018	1	001
58	.169	.292	4.055	1	001
59	.077	.258	4.111	3	100
60	.074	.254	4.254	2	010
61	.055	.249	3.949	2	001
62	.025	.244	4.273	2	100
63	.038	.247	4.273	3	001
64	.045	.250	3.993	2	001
65	.050	.250	3.993	1	001
66	.065	.256	4.137	2	010
67	.141	.275	4.359	3	100
68	.106	.263	4.266	3	010
69	.158	.286	3.529	1	001
70	.153	.281	4.128	1	001
71	.158	.285	4.128	1	001
72	.126	.274	4.094	3	100
73	.062	.241	4.313	3	100
74	.071	.234	4.338	2	010
75	.055	.233	4.006	1	001
76	.048	.235	4.006	3	001
77	.023	.239	4.279	2	001
78	.144	.252	4.341	4	100
79	.134	.242	4.449	4	100
80	.169	.283	4.432	1	010

Appendix 5.3.1 Site Attributes, 1980, Continued

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
81	.116	.255	4.242	1	010
82	.095	.253	4.217	1	010
83	.177	.280	4.383	2	001
84	.193	.288	4.140	2	001
85	.210	.293	4.186	3	001
86	.203	.284	3.193	2	001
87	.187	.274	3.193	2	001
88	.170	.270	4.266	3	010
89	.161	.271	4.016	2	001
90	.169	.275	4.016	3	000
91	.176	.283	4.016	2	001
92	.182	.286	4.383	1	001
93	.253	.273	4.055	2	001
94	.231	.263	4.055	2	010
95	.219	.259	4.055	2	010
96	.207	.255	4.055	2	001
97	.197	.252	4.055	2	001
98	.188	.249	4.179	2	010
99	.190	.252	3.574	1	010
100	.191	.254	3.574	1	001
101	.206	.266	3.574	3	010
102	.214	.273	3.941	2	000
103	.232	.277	3.696	2	001
104	.250	.280	.000	2	001
105	.232	.272	.000	2	001
106	.242	.282	3.696	1	001
107	.260	.291	3.696	2	001
108	.276	.298	3.738	1	001
109	.311	.316	4.082	4	000
110	.375	.314	4.267	2	100
111	.313	.307	4.055	2	001
112	.299	.298	4.055	2	001
113	.287	.288	4.055	1	010
114	.280	.284	4.074	1	001
115	.244	.307	4.196	2	001
116	.252	.307	4.151	1	001
117	.268	.317	4.151	2	100
118	.197	.332	4.151	2	001
119	.309	.339	4.151	2	001
120	.319	.343	4.151	1	001

Appendix 5.3.1 Site Attributes, 1980, Continued

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
121	.350	.366	4.338	2	010
122	.354	.366	3.881	2	001
123	.331	.346	1.000	2	001
124	.313	.331	1.000	1	001
125	.321	.337	1.000	1	001
126	.344	.352	3.881	1	001
127	.339	.346	3.881	1	001
128	.322	.332	3.696	1	001
129	.310	.325	3.696	1	001
130	.294	.321	3.696	3	001
131	.245	.291	3.696	1	001
132	.258	.304	1.000	1	001
133	.235	.290	3.696	2	001
134	.214	.280	3.815	2	001
135	.219	.285	3.193	2	001
136	.224	.290	3.193	2	001
137	.230	.296	3.193	2	001
138	.299	.293	4.324	3	100
139	.310	.301	4.055	2	001
140	.319	.309	4.174	2	010
141	.325	.330	3.354	2	001
142	.331	.338	3.354	2	001
143	.335	.345	3.354	2	001
144	.349	.360	3.441	1	001
145	.307	.331	3.000	1	001
146	.310	.323	2.699	1	001
147	.309	.320	2.699	1	001
148	.320	.322	3.989	1	001
149	.313	.317	3.989	1	001
150	.306	.312	3.989	1	001
151	.300	.307	3.989	1	001
152	.112	.235	4.352	3	100
153	.139	.239	4.103	2	001
154	.151	.241	4.103	2	100
155	.163	.242	4.103	2	010
156	.175	.244	4.103	2	001
157	.182	.245	4.055	2	010
158	.189	.247	4.055	2	010
159	.201	.249	4.055	2	001
160	.222	.253	4.055	3	100

Appendix 5.3.1 Site Attributes, 1980, Continued

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
161	.236	.258	4.055	1	010
162	.243	.261	4.055	2	000
163	.257	.267	4.074	2	100
164	.190	.251	3.989	4	000
165	.126	.246	4.239	2	001
166	.172	.255	3.989	1	001
167	.201	.263	3.989	2	001
168	.210	.265	3.989	1	001
169	.216	.267	3.989	1	001
170	.225	.270	3.989	1	001
171	.253	.281	3.989	2	001
172	.266	.290	2.699	2	001
173	.255	.219	2.699	3	001
174	.271	.301	2.699	1	010
175	.272	.306	2.699	2	001
176	.260	.300	2.699	1	001
177	.254	.297	2.699	1	001
178	.240	.287	2.699	2	001
179	.228	.281	2.699	2	001
180	.218	.281	2.699	1	001
181	.177	.265	2.699	3	001
182	.212	.279	2.699	1	010
183	.159	.263	3.908	3	001
184	.030	.234	4.006	1	001
185	.020	.237	4.287	1	001
186	.043	.233	4.006	2	010
187	.057	.231	4.006	2	010
188	.071	.229	4.006	2	100
189	.082	.236	4.061	2	000
190	.071	.236	4.061	2	000
191	.061	.237	4.061	2	000
192	.041	.238	3.966	1	001
193	.089	.246	4.061	3	000
194	.095	.250	4.030	2	100
195	.104	.257	3.908	1	001
196	.109	.255	2.699	1	001
197	.063	.255	4.140	2	001
198	.052	.250	3.993	1	010
199	.048	.249	3.993	1	001
200	.043	.248	3.993	1	001

Appendix 5.3.1 Site Attributes, 1980, Continued

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
201	.038	.247	3.993	2	001
202	.024	.242	4.281	2	001
203	.057	.248	3.966	2	001
204	.068	.249	4.298	2	001
205	.079	.258	4.164	2	000
206	.059	.251	4.122	2	001
207	.109	.269	3.525	2	001
208	.152	.291	3.983	1	001
209	.096	.260	4.329	2	001
210	.113	.268	4.030	1	001
211	.130	.277	4.198	3	001
212	.139	.281	4.030	1	001
213	.148	.286	4.230	1	001
214	.146	.285	3.797	2	001
215	.187	.301	4.088	1	010
216	.178	.299	4.018	2	001
217	.168	.295	4.018	2	001
218	.159	.291	4.018	2	100
219	.146	.284	4.018	1	001
220	.137	.282	4.018	2	001
221	.123	.277	4.018	2	001
222	.114	.273	4,018	2	001
223	.085	.263	4.395	2	000
224	.108	.269	3.600	2	000
225	.109	.271	3.600	1	001
226	.111	.272	4.134	2	010
227	.134	.281	3.984	2	001
228	.162	.293	4.059	3	001
229	.171	.297	3.262	2	001
230	.157	.293	4.353	4	001
231	.159	.295	3.983	3	010
232	.154	.292	3.525	2	001
233	.196	.314	3.981	2	010
234	.289	.356	4.209	2	010
235	.270	.344	4.020	2	010
236	.251	.333	4.020	3	100
237	.230	.322	4.020	2	001
238	.202	.309	4.090	2	010
239	.213	.315	4.006	3	010
240	.264	.340	4.147	4	100

Appendix 5.3.1 Site Attributes, 1980, Continued

Site ID No.	DCC	ARD	log TV	SS cat.	BA 123
241	.286	.363	4.273	4	100
242	.382	.423	4.195	3	010
243	.356	.403	3.956	2	000
244	.341	.392	3.956	2	001
245	.320	.377	4.169	3	010
246	.318	.378	3.757	2	100
247	.354	.405	4.091	3	000
248	.356	.413	4.102	4	000
249	.348	.411	3.980	3	001
250	.370	.428	3.703	2	001
251	.383	.438	3.703	2	001
252	.388	.450	2.301	2	001
253	.477	.510	4.473	3	010
254	.453	.487	4.172	2	000
255	.435	.470	4.172	2	010
256	.420	.457	4.332	2	000
257	.428	.467	3.960	3	001
258	.473	.508	4.2390	3	010
259	.470	.511	4.354	4	001

Appendix 5.3.2 Non-Redeveloped Sites: Location and Age Data

Site ID No.	Location Coordinates X	Y	Bldg. Age (Yrs)	Site ID No.	Location Coordinates X	Y	Bldg. Age (Yrs)
1	-183.	28.	65.	5	-143.	61.	65.
2	-190.	7.	65.	6	-145.	55.	65.
3	-153.	69.	65.	7	-149.	53.	65.
4	-141.	67.	65.	8	-151.	50.	65.
9	-158.	40.	65.	13	-171.	39.	65.
10	-159.	35.	65.	14	-175.	42.	65.
11	-163.	30.	65.	15	-168.	50.	65.
12	-164.	39.	65.	16	-164.	55.	65.
17	-161.	62.	53.	21	-140.	-1.	31.
18	-151.	10.	43.	22	-145.	-2.	65.
19	-136.	3.	51.	23	-157.	-3.	34.
20	-135.	-3.	29.	24	-141.	28.	16.
25	-140.	33.	65.	29	-114.	67.	65.
26	-110.	16.	65.	30	-114.	60.	65.
27	-111.	3.	32.	31	-114.	55.	65.
28	-122.	2.	33.	32	-111.	47.	65.
33	-110.	40.	65.	37	-126.	63.	4.
34	-110.	31.	20.	38	-128.	70.	65.
35	-120.	33.	65.	39	-97.	25.	65.
36	-123.	50.	10.	40	-83.	17.	999.
41	-81.	4.	23.	45	-96.	4.	65.
42	-88.	5.	59.	46	-100.	4.	65.
43	-90.	5.	11.	47	-96.	18.	65.
44	-93.	4.	65.	48	-96.	21.	29.
49	-66.	26.	65.	53	-36.	10.	65.
50	-37.	30.	20.	54	-43.	7.	20.
51	-38.	24.	65.	55	-48.	17.	65.
52	-37.	19.	12.	56	-65.	6.	65.
57	-68.	6.	65.	61	-7.	22.	65.
58	-71.	6.	65.	62	-5.	9.	5.
59	-22.	24.	13.	63	-11.	12.	65.
60	-9.	30.	52.	64	-17.	8.	65.
65	-20.	7.	65.	69	-27.	61.	65.
66	-26.	9.	18.	70	-18.	62.	65.
67	-8.	59.	3.	71	-22.	63.	65.
68	-8.	44.	31.	72	-23.	48.	11.
73	17.	20.	8.	77	5.	8.	65.
74	29.	8.	22.	78	54.	28.	7.
75	22.	8.	65.	79	55.	13.	8.
76	19.	8.	65.	80	27.	66.	49.

Appendix 5.3.2 Non-Redeveloped Sites: Location and Age Data, Continued

Site ID No.	Location Coordinates X	Location Coordinates y	Bldg. Age (Yrs)	Site ID No.	Location Coordinates X	Location Coordinates Y	Bldg. Age (Yrs)
81	27.	41.	45.	85	64.	61.	65.
82	9.	39.	49.	86	68.	52.	65.
83	48.	57.	65.	87	65.	45.	65.
84	54.	61.	65.	88	53.	47.	16.
89	46.	50.	65.	93	106.	11.	65.
90	49.	52.	999.	94	97.	9.	53.
91	42.	61.	65.	95	92.	9.	26.
92	41.	65.	65.	96	87.	9.	65.
97	83.	7.	65.	101	83.	26.	30.
98	79.	6.	25.	102	84.	33.	999.
99	79.	13.	16.	103	93.	30.	65.
100	79.	16.	65.	104	103.	23.	65.
105	95.	23.	65.	109	129.	25.	999.
106	97.	32.	65.	110	137.	6.	2.
107	105.	32.	65.	111	132.	9.	65.
108	112.	32.	65.	112	126.	10.	65.
113	121.	7.	32.	117	95.	61.	11.
114	118.	7.	65.	118	110.	60.	65.
115	82.	62.	65.	119	116.	60.	65.
116	88.	60.	65.	120	121.	59.	65.
121	135.	60.	50.	125	127.	48.	65.
122	139.	55.	65.	126	138.	46.	65.
123	131.	49.	65.	127	137.	42.	65.
124	123.	48.	65.	128	130.	40.	65.
129	125.	40.	65.	133	89.	44.	65.
130	115.	47.	65.	134	80.	42.	65.
131	94.	43.	65.	135	80.	46.	65.
132	96.	52.	65.	136	80.	50.	65.
137	80.	55.	65.	141	130.	-44.	65.
138	125.	-16.	1.	142	130.	-51.	65.
139	130.	-13.	65.	143	130.	-56.	65.
140	134.	-12.	16.	144	133.	-64.	65.
145	114.	-62.	65.	149	127.	-37.	65.
146	121.	-50.	65.	150	124.	-37.	65.
147	122.	-46.	65.	151	121.	-37.	65.
148	130.	-37.	65.	152	46.	-10.	11.
153	58.	-9.	65.	157	76.	-10.	39.
154	63.	-10.	15.	158	79.	-10.	39.
155	68.	-10.	39.	159	84.	-11.	65.
156	73.	-10.	65.	160	93.	-11.	4.

Appendix 5.3.2 Non-Redeveloped Sites: Location and Age Data, Continued

Site ID No.	Location Coordinates X	Y	Bldg. Age (Yrs)	Site ID No.	Location Coordinates X	Y	Bldg. Age (Yrs)
161	99.	-12.	45.	165	41.	-34.	65.
162	102.	-12.	999.	166	63.	-36.	65.
163	108.	-10.	3.	167	77.	-36.	65.
164	77.	-22.	999.	168	81.	-36.	65.
169	84.	-36.	65.	173	97.	-47.	65.
170	88.	-36.	65.	174	103.	-50.	49.
171	100.	-37.	65.	175	100.	-56.	65.
172	105.	-40.	65.	176	95.	-55.	65.
177	92.	-55.	65.	181	58.	-47.	65.
178	88.	-50.	65.	182	73.	-52.	32.
179	83.	-49.	65.	183	46.	-49.	65.
180	76.	-52.	65.	184	9.	-9.	65.
185	3.	-8.	65.	189	26.	-23.	999.
186	15.	-10.	19.	190	20.	-22.	999.
187	22.	-10.	50.	191	13.	-22.	999.
188	28.	-10.	5.	192	4.	-17.	65.
193	11.	-36.	999.	197	-25.	-9.	65.
194	3.	-40.	4.	198	-20.	-9.	49.
195	0.	-44.	65.	199	-18.	-9.	65.
196	7.	-45.	65.	200	-16.	-9.	65.
201	-13.	-9.	65.	205	-22.	-25.	999.
202	-6.	-8.	65.	206	-16.	-19.	65.
203	-10.	-22.	65.	207	-26.	-38.	65.
204	-9.	-27.	65.	208	-28.	-58.	65.
209	-14.	-38.	65.	213	-14.	-61.	65.
210	-16.	-45.	65.	214	-21.	-58.	65.
211	-22.	-50.	65.	215	-78.	-12.	19.
212	-14.	-57.	65.	216	-74.	-12.	65.
217	-70.	-12.	65.	221	-51.	-10.	65.
218	-66.	-11.	15.	222	-47.	-10.	65.
219	-61.	-8.	65.	223	-35.	-8.	999.
220	-57.	-10.	65.	224	-39.	-20.	999.
225	-40.	-23.	65.	229	-69.	-21.	65.
226	-39.	-26.	65.	230	-53.	-40.	65.
227	-52.	-22.	65.	231	-48.	-47.	51.
228	-63.	-26.	65.	232	-40.	-51.	65.
233	-66.	-50.	31.	237	-96.	-14.	65.
234	-121.	-16.	21.	238	-84.	-14.	48.
235	-113.	-16.	20.	239	-86.	-26.	50.
236	-105.	-15.	1.	240	-108.	-28.	1.

Appendix 5.3.2 Non-Redeveloped Sites: Location and Age Data, Continued

Site ID No.	Location Coordinates X	Location Coordinates Y	Bldg. Age (Yrs)	Site ID No.	Location Coordinates X	Location Coordinates Y	Bldg. Age (Yrs)
241	-109.	-52.	1.	245	-134.	-17.	17.
242	-160.	-20.	28.	246	-131.	-29.	9.
243	-149.	-19.	999.	247	-146.	-32.	999.
244	-143.	-18.	65.	248	-142.	-50.	999.
249	-132.	-64.	65.	253	-200.	-24.	52.
250	-142.	-65.	65.	254	-190.	-23.	999.
251	-148.	-65.	65.	255	-182.	-23.	31.
252	-157.	-61.	65.	256	-176.	-23.	999.
257	-177.	-36.	65.	259	-188.	-63.	65.
258	-196.	-38.	33.				

Appendix 5.3.3

Location Coordinates and Year, Redeveloped Sites since 1976

Year	Location Coordinates X	Y
1976	-165	-5
1976	93	-11
1976	-126	63
1976	3	-40
1977	-8	59
1977	108	-8
1978	-107	-31
1978	137	6
1979	125	-13
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

Appendix 5.3.4

Redevelopment Level Forecast: Annual Number of Redeveloped Sites and 5 Year Cumulative Totals

Time Per.	Year	No. of Sites (/yr.)	No. of Sites in Previous 5 Yrs.
1	1980	4	10
2	1981	2	13
3	1982	0	11
4	1983	1	9
5	1984	4	8
6	1985	2	11
7	1986	0	9
8	1987	1	7
9	1988	4	8
10	1989	2	11

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