SPATIAL PATTERNS OF SELECTED RETAIL ACTIVITIES

Abstract

Spatial Patterns of Selected Retail Activities:

Montreal 1950-1970

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In this thesis the point patterns formed by selected retail activities in Montreal were examined by use of a variety of quantitative techniques. The results of this analysis, with the help of existing theories of agglomeration and consumer behavior, yielded insights into the forces governing retail store location in cities. Moreover, this thesis suggested directions for further study of location and consumer behavior in urban space and for reformulation of location theory to deal with the complex urban environment.

Abstrait

Arrangements Spatiaux des Types Selectionnés du Commerce en Détail

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Dans cette thèse l'arrangement spatial des magasins de commerce en détail a été examiné pour des types de magasins selectionnés et par une variété de méthodes quantitatives pour l'analyse des arrangements de points. A travers les résultats de cette analyse, et avec l'aide des théories existantes de l'agglomeration et du comportement des consommateurs, on a pu mieux apercevoir les forces qui gouvernent, dans le contexte urbain, le choix de situation de la part des magasins. De plus, cette thèse a suggéré plusieurs orientations possibles pour l'étude plus étendue de la situation des entreprises et du comportement des consommateurs dans l'espace urbaine. Elle a aussi souligné le besoin de reformuler la théorie de la situation pour l'adapter à la complexité du milieu urbain.

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INTRODUCTION

It is generally assumed in geography that the location of retail stores is governed by a set of locational laws which are conceptually simple even if their empirical manifestations are complex. Although it is quite likely that the basis of these laws will ultimately be found in the study of consumer behavior, this study has not advanced to the point where it can be successfully employed to predict or explain retail location in the complex urban environment. Nevertheless, considerable information about these locational laws can be extracted by study of the spatial patterns formed by retail stores. Such patterns can be interpreted in the light of the theory of agglomeration and of postulated relationships between retail stores and socio-economic determinants, as well as of what we know regarding consumer behavior. The result will hopefully be a clarification of how retail stores of various types locate, and why they locate as they do.

This thesis will examine the spatial patterns of selected retail store types over a large part of the greater Montreal area, at two points in time, 1950 and 1970. The convenience goods-shopping goods distinction (to be defined later) and hypothesized relationships between population, income, and total retail store distributions and the observed store pattern will be used to gain insight into the laws governing retail location.

Note: Diagrams and tables occur on pages 129-150 with the exception of small ones in chapters 5 and 6.

CHAPTER 1

REVIEW OF THE LITERATURE

In this section various bodies of literature relevant to this thesis will be examined in order to provide a theoretical and methodological background for the present study.

A large and diverse body of geographic theory and practice has bearing on questions of retail location and concentration. In the field of location theory and land economics, the literature ranges from abstract theoretical constructs of market areas and industrial distributions through general theoretical explanations of urban land use patterns to concrete locational recommendations for retailers. Another body of literature treats consumer behavior both inside and outside the traditional concepts of economic man and distance minimization, and with stochastic and behavioral elements incorporated to varying degrees. Still a third area of the literature covers several methods of point pattern analysis and ranges from elaborate mathematical derivations to extensive empirical applications. All of these various streams of thought must be merged to answer questions relating to the concentration of retail activities and to trends in this concentration over time.

I. Location Theory and Agglomeration

The processes of agglomeration have been studied largely with respect to industrial plants, and therefore the factors discovered in these studies can be applied only with extreme caution to problems of retail location. Not only do industrially-oriented studies emphasize some factors of little significance in retail concentration and leave out some that are of vital importance, but they also discuss the problem on a regional rather than a local level; that is, they unearth the factors that cause industry to concentrate in cities rather than disperse itself over the countryside, instead of those that cause industry (or retail trade) to concentrate within cities. Nevertheless, an overview of the major developments in industrial agglomeration theory may sharpen the perception of agglomeration factors at a more detailed level and point the way to the creation of analogous theory for retail location.

Weber (1929) developed an extensive theoretical answer to the question: why do industries move? He distinguished three basic locational forces: transport costs, labor costs, and agglomeration economies. Considering the first as fundamental, he developed a method of calculating whether other economies would induce an industry away from its point of least transport cost. This method consisted of mapping isodapanes, or lines of equal transport-cost outlay, and comparing the other locational advantages of a site with the disadvantage suffered by deviation from the point of least transport cost. Agglomeration economies were one of the possible inducements for an industry to move from this point, but Weber points out that since agglomeration economies arise by definition from a complex of activities and cannot be studied for an industry in isolation, these economies are very difficult to measure.[1] However, he delves quite deeply into questions of the location and size of the agglomeration unit, and the relation of these to the isodapane gradient for a particular industry. The implication is that the nature of an industry's dependence on transport costs influences its agglomeration behavior, a fact which will later be seen to be significant. Weber also notes the existence of deglomerative forces but does not acknowledge them as a separate entity, preferring to consider them counter-tendencies resulting from too much agglomeration.

Weber's theory is strong in the area with which it was designed to cope, though Isard (1956) has pointed out that the physical setting and the bargaining power of individual firms also exert strong influences on the size and place of agglomerations. It is doubtful, however, that it can be carried over to retail location without extensive modifications. Firstly, transport costs tend to influence location of wholesalers and warehouses and their distribution patterns rather than the location of individual retail outlets.[2] The disutility incurred

1. Weber (1929), <u>Theory of the Location of Industries</u>, p. 125.
2. There is an extensive body of literature on physical distribution problems, warehousing, etc., in the field of business management.

by a storekeeper in having goods shipped a considerable distance to his store is nothing compared to the disutility he will suffer if consumers incur excessive transport costs in reaching his store and are therefore reluctant to patronize him. In other words, it is the consumers' transport costs that count. Labor costs can also be seen to be subordinate to the cost of the effort expended by consumers. Economies of agglomeration work in a manner more similar to industrial ones, but are more comprehensive, including not only economies of operation (e.g. sharing of facilities and a common labor pool) but greater efficiencies in reaching consumers who come for comparison shopping or multi-purpose shopping trips. Finally, considerations of style, buying habits, and patronage preferences, which are not considered at all in Weber's theory, enter strongly into the retail trade picture.

Hoover (1948) also discusses agglomerative factors in industry, though he emphasizes internal rather than external economies of scale. However, his basic principles of multiples, massing of reserves, and bulk transactions could fit equally well into Isard's urbanization economies.

Unlike Weber, Hoover applies the principles of location to the distribution of land uses within the city, and to activities other than industry. He acknowledges that many urban land users are primarily interested, not in minimum transfer costs or cheap production, but in maximum accessibility to consumers, a point of great significance for retail location. Land users are thus caught between the "pull" of a highly accessible central location and the "push" of land scarcity. In this situation, the process of competitive bidding assures that each site is used by that activity which can pay the highest rent per unit area. Individual users make a trade-off between space and accessibility with the object of maximizing their net returns. The trade-off between agglomeration economies and access to a diffuse population is also important. From these trade-offs arise characteristic rent gradients for each activity, which are in effect graphs of geographic location versus the rent the activity would be willing to pay at that location.

Hoover makes the further important observation that land is not always put to the use that is economically best for it. Lack of knowledge, non-economic motives, maladjustment in the rent structure, and short-sighted economic planning on the part of individuals all work to produce an economically suboptimal land use pattern.

From this analysis Hoover arrives at a typical set of urban structural components and a typical disposition of industrial, residential, and commercial areas within the city. The main components of city structure are given as: activities requiring rail and water transport (mainly heavy industry); centripetal "downtown" activities, such as many retail stores; light industry, unspecialized commerce, and residence, which fill in the land left over from the first two; and convenience-goods establishments which, needing closeness to consumers, spot themselves around residential and small commercial areas, and in areas such as office districts which have a large daytime population. Commercial activities tend to form a main downtown shopping district, "ribbon" commercial developments along major streets, subordinate outlying clusters, and a "shotgun" scatter of neighborhood stores.[3] The existence of several different "levels" of center within a large city suggests that central place theory might be applicable, with modifications, to intra-urban location patterns. Carol (1960) studies Zurich, Switzerland, for evidence of such "levels" and does find an intra-urban functional hierarchy. However, the elements of this hierarchy largely correspond to formerly autonomous towns and villages that have been incorporated into Zurich and might not have appeared in an already fully urbanized area.

Hoover also makes a couple of important points specifically about retail trade. He points out that so-called "shopping goods" (goods for which consumers want to comparison shop) reverse the usual industrial tendency to avoid locations close to competing units, and stresses that while the various retail outlets in a cluster are in market competition, they all contribute to the

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3. Hoover (1948), The Location of Economic Activity, pp. 130-135.

variety of offerings that attracts customers to the cluster as a whole. However, "convenience goods", for which comparison shopping is unimportant and residential location of consumers is the primary consideration, repel each other in space.[4] He also notes that the rent gradients for many commercial activities are very steep due to dependence on easy access and exposure to shopping crowds; that is, many such activities can tolerate very little deviation from their optimal location.

To a certain extent, Isard (1956; 1969) follows in the footsteps of Weber and seems in agreement with Weber's analysis of location forces and agglomeration economies. He does recognize the limitations in the applicability of Weberian location theory to intra-city location, noting that even when an activity benefits from agglomeration economies, "... subject to certain restraints, presence of these activities within a Greater Metropolitan Region in any of many possible patterns of scatter and concentration may more often than not satisfy the spatial associational requirement."[5] He classifies agglomeration factors into large-scale economies (within a firm), localization economies (within an industry), and urbanization economies (covering all firms and industries). The last involve all the localization fac-

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4. For definitions of these terms see Hoover (1948), p. 60; also Holton, R. H. (1958), "The Distinction between Convenience Goods, Shopping Goods, and Specialty Goods," J. of Marketing, 23, pp. 53-56.
5. Isard (1969), General Theory, pp. 13-14.

tors of a skilled labor pool, auxiliary facilities, and large-lot buying, and in addition the convenience of urban services and something which Isard calls "... a finer articulation of economic activities."[6] Urbanization diseconomies include high wages and cost of living, production under conditions of diminishing returns, high rents, and transportation costs. One wonders about the last, since according to Weber an industry would not agglomerate at all if transport costs were forbiddingly high. Theoretically, says Isard, we could construct curves of net economies against city size for any urban activity, and "... each curve in the resulting set of net economy curves would rise to a maximum and then fall significantly as deglomerative forces, such as congestion and co-ordination problems, grow in relative importance."[7] Unfortunately, all these curves are interdependent, since urban economies and diseconomies are not additive but "... multiplicative in a complex fashion,"[8] so a single index of urbanization economies cannot be constructed; recall Weber's similar difficulties in trying to construct an index of agglomeration economies.

Isard's analysis is subject to the same weakness as Weber's and Hoover's when applied to intra-urban retail location patterns. Urbanization economies dictate whether or not an activity will gravitate to cities,

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6. Isard (1956), Location and Space-Economy, p. 182.
7. ibid., p. 186.
8. ibid., p. 188.

but not where within each city. In an industrial context, he brushes off land cost differentials as not very important to industry, but fortunately he goes on to discuss the influence of land costs on location of an enterprise within the city, apparently considering it worth discussing for the importance it does have. He states that the price that a potential user is willing to bid for urban land depends on effective distance from the center, accessibility to potential customers, the number and location of competitors, the intensity of their competition, and the proximity of complementary uses. This is a somewhat more detailed analysis than Hoover provides, and one of great usefulness in understanding retail location. "Effective distance from center" embodies both the orientation of retail trade towards the central city as the point of highest accessibility (though this may be changing due to the automobile, to inner-city traffic congestion, and to the great spatial extent of the modern city), and the possibility of dependence on non-linear distance measures. Accessibility to potential customers is, as previously pointed out, the key determinant of retail location. Competition in the area increases the attractiveness of a site for many retail activities up to a point, beyond which disutilities may set in due to the market's becoming overly fragmented. The proximity of complementary uses plays a key role in attracting different types of retail stores together to form shopping centers or "ribbon" developments. From these considerations Isard derives a typical rent function for a typical user, which descends in a series of scallops from a peak in the CBD. He goes on to admit the role of historical and institutional forces in governing the extent to which urbanization economies are available. Isard says that such forces cannot be handled by current analytic methods, but analytically there is no reason why they could not be incorporated in an empirical surface, unique to each city, which could then be added to the rent surface.

Isard seems to consider a Löschian market-area diagram, suitably modified to account for the reduction in size of market areas by concentrations of consumers, as a better description of the distribution of commercial and service activities than a Weberian isodapane map based on substitution analysis. It is questionable whether market area analysis is suitable in an urban context, where market areas overlap constantly and are spatially ill-defined. More likely a substitution analysis, with suitable redefinition of the factors that go into defining each user's ceiling rent at a particular point, would give more insight into the actual operation of competition for urban land. Such a redefinition would minimize the role of raw materials and maximize that of accessibility and a congenial set of nearby uses.

More recently, Alonso (1964) has discussed urban land use in terms of a substitution equation and indifference curves for each land consumer. The individual income is divided among land costs, commuting costs, and a "composite good" covering all other expenditures. From this equation a locus-of-opportunities surface may be drawn, and the individual's preferences mapped by indifference curves. This is one of the first connections drawn between individual preference functions and the urban land-use pattern. Location is determined by the point at which the locus-of-opportunities surface is tangent to the highest indifference curve. Alonso does discuss internal economies of scale as they affect location, but makes no mention of localization or urbanization economies. He also maintains a strictly optimizing concept of man, though he admits that while firms seek to maximize profit, individuals may seek to maximize "satisfaction." With these limitations, and with the obvious patterning of his substitution equation on the spending of individual incomes for a residential location, Alonso's theory cannot be applied to retail location without modification, though he claims it can accommodate firms as well as individuals.

In a more empirical vein, land economists such as Ratcliff (1949) and Dorau and Hinman (1928) have described the observed patterns of land use in cities in terms of analytical land-use theory. Their work merges with that of urban ecologists, both the constructors of city geometries, such as Burgess (1927), Hoyt (1933), and Harris and Ullman (1953), and the more general theorists such as Hawley (1950), Quinn (1950), and Alihan (1938).

The land use theorists, of whom Ratcliff is probably the most noteworthy, derive the regularities of urban land use from the fundamental urbanization forces of location theory. The observed land use pattern is the result of competitive bidding for each site by a number of uses, each of which could derive a certain utility from the site and is therefore willing and able to pay a certain rent for it. Competition brings about an equilibrium in which each site is occupied by the "highest and best" use for it, and rents throughout the system are maximized. Land economic theory provides a valuable bridge between the theory of urbanization economies and the observed land use pattern, but it cannot move beyond generalities and contains no means for verifying or testing its conclusions.

The constructors of city geometries try to put the regularity of city structure in terms of a simple geometry. Burgess postulates a set of concentric zones centered on the CBD, while Hoyt prefers a sectorial model. Harris and Ullman, writing in 1953, propose a multinuclear city structure which is less rigid geometrically and probably the most plausible of the three, especially since many cities have outgrown their dependence on one business center.

The human ecologists try to explain the observed pattern of urban land use in terms of man's adaptation to his environment, both physical and social. Drawing heavily on such biological concepts as symbiosis, commensalism, and succession, they abstract the basic features of man's environment that condition the distribution of various types of land use. They are doubtful of the usefulness of rigid geometric models (Quinn gives a lengthy critique of the concentric-zone hypothesis) but seem to consider them useful starting points for analysis. Their theories of concentration and retail location are conceptually sound but very general and difficult to test empirically (e.g. Quinn's contention that the most efficient location for a store is at the median of its customers).[9] In other words, they suffer from much the same limitations as the land economists.

II. Theories of Consumer Behavior

Another substantial group of studies has focused on the description and modelling of consumer behavior with the intention of explaining retail location. The early human ecologists were the first to discuss consumer behavior in an urban environment, but it remained for Reilly (1931) to formulate the first model of consumer interaction with retail centers. Reilly's Law of Retail Gravitation, analogous to the gravity law of physics, states that the attractiveness of two given

9. Quinn (1950), Human Ecology, pp. 86-87.

centers for a given consumer increases with size of the center and decreases with the square of the distance from center to consumer. By algebraic manipulation he also obtains a formula for the "breaking point", or point of consumer indifference between two centers.

Reilly obtained reasonably good empirical results with his law, but later researchers saw several theoretical flaws in it. It was observed that trade areas do not have fixed boundaries, especially within cities where they may bear little relationship to distance; Reilly's law was found to give poor results in industrial or commercial areas with small populations relative to their amount of non-residential activities; it was found necessary to vary the distance exponent to fit observed data, a procedure for which no theoretical justification could be found; and the Law of Retail Gravitation could not generate an explanation of <u>why</u> it fit observed data, especially in view of the multiplicity of variables involved and our imperfect knowledge of them. There seemed to be no theoretical reason why such a simple law should fit such complex phenomena.

Some researchers, notably Zipf (1949) and Huff (1963), have tried to render the gravity model more plausible by theoretical refinements. Such refinements were in themselves important contributions to the theory of retail trade areas, but they did little to bolster the gravity law. Others, such as Russell (1957) and Thompson

(1964), have used correlation-regression analysis to forecast retail sales volume, without much success.

On a different tack, theorists such as Christaller (1927; tr. 1966) and Lösch (1943; tr. 1957) were developing abstract systems of market areas based on the concept of economic man and on the hypothesis, widely argued since among central place theorists, that consumers always purchase a good at the nearest center offering it. Their models have been widely tested empirically, with conflicting results, but mostly in rural areas; see for example Berry and Garrison (1958); Berry, Barnum, and Tennant (1962); Brush (1953); Brush and Bracey (1955); and Rushton, Golledge, and Clark (1967). For studies within urban areas see Carol (1960) and Clark (1968). Recently Dacey (1968) has developed a probabilistic central place model.

More serious criticism of central place theory involves questioning of its underlying assumptions, especially the concept of economic man. There are doubts as to the logical consistency of his definition: whether all economic men can optimize simultaneously, whether short-run and long-run solutions are compatible. It is also likely that the real-world costs of search and relocation keep the actual spatial economy at a suboptimal level. There is also the question of what quantities man seeks to optimize, and whether he accepts a satisfactory rather than an optimal solution in many situations (Simon (1957)). Such questions lead directly to such recent formulations as Pred's "behavioral matrix" (1967 and 1969), Huff's (1960) graph of the interrelationships among variables influencing spatial perception, and Huff's (1963) probabilistic definition of market areas.

More recently it has been realized that retail location and consumer behavior are two halves of a whole and that one cannot be effectively studied without the other. As Rushton (1969) puts it:

> "... spatial behavior patterns have adjusted to the system of central places just as much as the distribution of places has adjusted to spatial behavior patterns. Therefore, to explain the one solely in terms of the other is to miss the fundamental interdependence of both."[10]

It has also become clear that rules of spatial behavior are different from, and logically antecedent to, patterns of spatial behavior. This has led to an entirely new research approach, pioneered by Rushton, in which paired-comparison choice data are operated upon to give a preference structure which can then be used to generate real-world patterns. Empirical results from this approach are very promising, but so far all such studies have been conducted on an extremely small scale and with a more or less artificial choice setup; many problems remain to be solved before it can be applied on a city-wide scale and

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10. Rushton (1969), "Analysis of Spatial Behavior by Revealed Space Preference," A.A.A.G., 59, p. 391.

in a situation with multiple and poorly-defined alternatives, as in this study. Such work is a good reminder, though, that retail store patterns are but one half of the total picture. Rushton also points out the circularity and ambiguity of explaining consumer behavior in terms of the patterns it generates, noting in particular that a given location pattern could be generated by more than one preference structure.[11] In the context of this study, therefore, one must keep in mind that one is studying retail location patterns, not patterns of consumer behavior, and while one can make observations about consistency one cannot venture to prove any theories in the latter area.

Nevertheless, authors such as Curry (1960), Garner (1966), and Nystuen (1967) have found examination of observable consumer behavior in urban environments to yield valuable understanding of retail structure, especially at smaller scale levels. From such examination they have developed concepts which are of great value in explaining urban retail location. Examples are Nystuen's concepts of functional association and linkages and Curry's concepts of nodality, the shopping list, and periodicity of demand. Such authors have also approached methodological problems such as the definition of retail clusters and the formulation of measures of activity

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11. ibid., p. 392.

interdependence, with a fair degree of success.

In a more directly empirical vein, writers such as Applebaum (1968) and Nelson (1958) have examined store location decisions in the light of theories of consumer behavior and their effect on retail location, often with the practical intent of helping stores to locate more effectively. Their work does not add much to geographic theory but provides valuable illustrations and substantiations for it.

III. Point-Pattern Analysis

Studies of geographic pattern can make good use of point-pattern methods developed elsewhere, notably in botany and ecology. One of the most widely used is nearest neighbor analysis, pioneered by Clark and Evans (1954). These two researchers, building on previous work in measuring departures from randomness in a population, derive an expected nearest neighbor distance $\bar{r}_E$ for a random population following the Poisson distribution and set up a ratio R = (actual nearest neighbor distance) / (expected nearest neighbor distance) = $\bar{r}_A / \bar{r}_E$. It was found that $R < 1$ indicates a clustered, $R = 1$ a random, and $R > 1$ a regular (uniform) distribution, and that the maximum value of R, for a hexagonal lattice, is 2.1491. The chi-square test can be used on the frequency distribution of nearest neighbor distances as an additional check, and the significance of differences in R among populations can be tested by Student's t or by an

F test. Thompson (1956) extended the method to n nearest neighbors and elaborated further on the use of the chi-square test. Dacey (1958a; 1958b; 1960a; 1962; 1963) has developed a sector method of n-th nearest neighbor analysis and has done much to establish the mathematical underpinnings of both nearest neighbor and quadrat analysis. Recently he has worked with probabilistic formulations and with the analysis of class data (county seat and non-county seat towns).

Nearest neighbor analysis has not been much used in geography. King (1961) has applied it to the distribution of towns in various states of the United States, and Getis (1964) over time to the distribution of grocery stores in Lansing, Michigan. Dacey (1960b) has used it to counter a subjective analysis of the pattern of Mississippi River towns by Burghardt (1959). The scarcity of its use may partly reflect lack of contact with the botanical literature on the part of geographers, but it is also symptomatic of certain real difficulties with the method. Perhaps the most serious is the dependency of $\bar{r}_E$ on point density, which makes the definition of the study area a matter of crucial importance without providing any objective criteria for this definition. The aspatial character of the R index poses problems of interpretation when considerable areas like an entire city are being studied. Furthermore, in many cases the random distribution is not the proper one for comparison because points do not in fact occur on every subarea with equal probability, as is assumed in the Poisson distribution. Retail stores are restricted by zoning to certain areas of the city and their probability of occurrence is strongly influenced by existing traffic patterns. Nearest neighbor analysis can also fail to pick up the true spatial characteristics of certain distributions, for example one consisting of pairs of points.

Quadrat analysis is another technique borrowed from botanists and plant geographers, who have used this method extensively. Greig-Smith (1957) gives an excellent overview of the theoretical background and early empirical work in both quadrat and nearest neighbor analysis. Recent discussions of the method and its applicability to geography can be found in Artle (1965), Harvey (1966), McConnell (1966), Rogers (1969), and Rogers and Martin (1969). Basically, the method consists of dividing the study area into quadrats of equal size, counting the points in each, and forming a frequency distribution. The results can then be used in three ways. A simple variance/mean ratio, analogous to Clark and Evans's R statistic, can be taken. One of a number of probability distributions, such as the Poisson, Neyman Type A, or negative binomial, may be fitted to the data, and the fit evaluated by a chi-square test. After fitting a distribution, one may draw inferences by analogy to the geographical processes generating the distribution. This procedure is theoretically risky in view of the fact that a given distribution may be generated by more than one process. Distribution fitting is illustrated by the work of Harvey (1966) and Rogers (1969).

Quadrat analysis preserves more of the spatial variability of the point data than does nearest neighbor analysis, but nevertheless it has its shortcomings. The frequency distribution says nothing about the spatial distribution of heavily or lightly populated quadrats, so that a distribution concentrated in one corner of a study area could conceivably test as random. As well as depending on the size of the study area, results are heavily dependent on quadrat size, and while Greig-Smith (1957) gives some guidelines here, there is as yet no objective criterion for determining the optimum quadrat size. Moreover, it cannot describe geographic process as well as geographic pattern without help from outside theory, a failing shared by nearest neighbor analysis.

A direct approach to the question of the extent to which spatial contiguity influences an areal distribution is the contiguity index developed by Geary (1954):

$$c = \frac{(n - 1) \sum'_{t \neq t'} (z_t - z_{t'})^2}{2\, K_1 \sum_t (z_t - \overline{z})^2}$$

where n is the number of subareas,
z_t is the measure of the phenomenon on the t-th subarea,
k_t is the number of subareas contiguous to the t-th subarea,

$$K_1 = \sum k_t,$$
$\sum$ = sum over all subareas,
$\sum'$ = sum over contiguous subareas.

Unlike the other methods discussed above, this method provides a direct measure of contiguity effect, as well as taking into account the number of connections among subareas. Geary intended his index to be used in conjunction with regression analysis to determine when sufficient variables had been included in the regression equation, but there is no reason why it cannot be used by itself as a measure. Geary establishes by empirical test that the sampling distribution of c is normal for $n \geqslant 30$ and therefore the standard deviation can be used for tests of significance. Although this index was developed in 1954, it has been very little used in geography, though it appears to be superior to nearest neighbor and variance/mean indices in that it directly measures contiguity effects. It is, however, best used in conjunction with a map in order to interpret the results geographically. It also has the great advantage of not being crucially dependent on the size of the study area.

It must be noted that all existing point pattern analyses measure patterns composed of points and distances in Euclidean space, whereas a considerable body of geographical literature asserts that human activities actually take place in non-Euclidean spaces which have been stretched, shrunk, and warped by modes and systems of mobility, perceptual structures, and personal interaction patterns. Getis (1963) explores the possibilities of using a map transformation in the study of grocery store location patterns, and Tobler (1961) approaches the question of map transformations in geography in a more general vein. The question of non-Euclidean distance measures will reappear in the interpretation of some of the more surprising results of the point-pattern analysis.

Recently various other methods of describing spatial pattern have been evolved, but for reasons of time and space they are not developed in this study. Angel's dendrite method (1969) consists of connecting each point to its nearest neighbor, then each resulting cluster to its nearest cluster, and so forth. A "pattern profile" can be formed by graphing lengths of links in increasing order; the envelope of this graph characterizes the clustering properties of the point pattern. A contour map can be constructed by drawing lines around clusters with a maximum link length of 10%, 20%, etc., of the longest link length. This method has the advantage of picking out linear clusters, which none of the other methods do very well, and of providing with the percentage contour map a semi-objective criterion of the extent of a cluster, but it has the disadvantage of not providing a composite index, so that comparison between patterns is dependent on visual comparison of their pattern profiles. Again, it has the merit of not depending on the size of the study area.

Arie Shachar, in a 1966 study of Tel Aviv, developed several "geo-statistical measures", including an index of concentration based on mean and standard distance and the Lorenz curve. Most of his measures are extremely spatial in the sense that they make little or no sense without a map; they would be of no use in comparing cities, but of considerable value in summarizing changes in the same city through time. Most of his measures in effect collapse a distribution to a point and therefore have limited descriptive value. Their greatest utility might be as a planning tool.

Bell (1970) uses discriminant analysis to measure the effectiveness of several hypothesized causative variables in separating successful from unsuccessful grocery stores in Cedar Rapids, Iowa. Many of his variables did not test out as significant, but his idea of analyzing store distribution together with some of its postulated determinants is promising and will be implemented in a somewhat different way in this thesis.

Given the various strengths and weaknesses of the various methods of point pattern analysis, it seems wise to do as Getis did in his paper and analyze one's data by more than one method, with each shedding its own particular light on the overall character of the distribution. In this study the author proposes to use three methods: nearest neighbor analysis with ten nearest neighbors, quadrat analysis (calculation of the variance/mean ratio and distribution fitting), and the Geary contiguity index. Hopefully this analysis will make it possible to piece together a composite picture of the location patterns of the types of retail stores under consideration.

In the following section, hypotheses based on the above theoretical material will be stated as a prelude to their testing by empirical study.

CHAPTER 2

HYPOTHESES AND THEIR EXPLANATION

This chapter will structure a series of suggested relationships between the spatial patterns of store types and such factors as characteristics of the store type and population, income, and overall retail store distributions. These relationships will be stated briefly and then discussed in further detail.

Although the number of hypotheses is large for a work of this nature, the possibility of combining hypotheses was rejected in the interests of clarity.

The following hypotheses will be examined in this thesis:

1. The locational patterns of convenience and shopping goods outlets are markedly different in urban space, with shopping goods exhibiting intense clustering and convenience goods being much less clustered.

2. Within the shopping-goods category, the tendency towards clustering decreases as the good offered becomes more expensive.

3. The number of each store type is increasing over time in the total study area, but remaining constant through time in the central city.

4. The degree of spatial concentration is decreasing over time for all store types over the total study area, but remaining constant through time in the central city.

5. Positive spatial correlations exist between

distributions of all retail store types and population and income distributions.

6. Spatial correlations with population are stronger for convenience than for shopping goods; spatial correlations with income are stronger for shopping than for convenience goods; and both sets of correlations are decreasing through time.

7. Shopping goods stores show high positive spatial correlations with the distribution of retail stores as a whole, and these correlations are increasing over time; whereas convenience goods stores are relatively independent of this distribution and their correlations with it are remaining stable through time.

A word should be said about the theoretical underpinnings of these hypotheses with regard to previously mentioned theories of agglomeration and consumer behavior. Hypothesis 1 is an expression of the opinion that the value consumers place on their transportation costs relative to other considerations differs according to the convenience goods-shopping goods dichotomy. For convenience goods, minimizing of transportation costs is the prime consideration, for purchases are frequent and the good offered is cheap and standard. Therefore, proximity to the residences of consumers is the overriding locational factor for convenience goods stores, and even if they were to derive some benefit from spatial clustering, they would not be locationally free to take advantage of it. Therefore, their spatial pattern should not exhibit pronounced clustering. Shopping-goods retailers, on the other hand, cluster together to realize large agglomeration economies from consumer propensities for comparison shopping and from the large volume of pedestrian traffic that the clustering of many shopping opportunities in a small area brings. The consumer's desire for comparison shopping without lengthy journeys between stores overcomes some of his reluctance to lengthen his initial journey from home. Thus shopping goods stores can locate at some distance from the consumer's residence without losing his patronage and are therefore free to take advantage of agglomeration economies, as convenience goods retailers are not.

Hypothesis 2 is based on the assumption that consumers are willing to incur higher search costs for a more expensive item. This seems reasonable since the consumer can incur large travel costs, even to the point of making special single-purpose trips, without "cancelling out" the value of the item sought, and since even a slight percentage saving obtained by further search may be enough to amortize additional search costs because of the high value of the item involved. The agglomerative forces of consumer accessibility and opportunity for comparison shopping remain quite strong even for high-value goods, and it is well known that retailers of high-value, low-bulk goods, such as jewelry and antiques, exhibit extreme clustering (Artle (1965)). However, retailers of expensive goods which are also bulky are prevented by their space requirements from taking advantage of areas of high consumer accessibility and consequent high rent. Thus they are forced onto the fringes of retail clusters or into isolated locations (though sometimes clusters of such stores will form, such as "automobile rows"), and can be expected to show less clustering than either less expensive goods or expensive but non-bulky goods.

Hypothesis 3 is based on the assumption that as the population of the study area grows, more stores will be required to service it. However, because modern urban growth is characterized by a lateral outward expansion of population rather than by a denser concentration of population in central areas, it is expected that most of this increase in numbers will consist of additional stores in outlying areas. Even though the population of some central areas may increase over time, the low purchasing power of this segment of the population makes it unlikely that new stores will locate in these central areas. Therefore, the number of stores in central areas is expected to remain more or less constant over time.

Hypothesis 4 is based on the observed decentralization of cities over the past twenty years, largely because of the widespread use of the automobile. In addition to spreading out population, the automobile has flattened consumers' transport-cost gradients, increasing the area within which it is economically feasible for them to shop and buy. This in turn decreases the relative attractiveness of the central city for shopping, although the central city is still the place with the greatest number and variety of offerings. Inner-city traffic congestion and parking problems and the emergence of large suburban shopping centers further decrease the pull of the CBD. Therefore it is expected that the overall retail pattern will show decreasing concentration over time. It must be noted, however, that an observed "deconcentration" can arise in two ways: by out-migration of existing stores, without much change in the number of stores; or by addition of outlying stores to a largely unchanged inner core. The preceding paragraph suggests that the latter situation prevails, and that while indices for the total study area will suggest deconcentration over time, those for the inner city will reveal a more or less stable degree of concentration. There may be some out-migration of CBD stores to outlying shopping centers, but this appears unlikely given the persistent attractiveness of the CBD as a shopping area; CBD stores, it seems, are more likely to add suburban branches than to close and move their downtown establishment. As for stores in poorer inner-city areas, they generally do not have the means to migrate anywhere else or to pay the rents in more attractive locations and so remain where they are.

Hypothesis 5 is based on the assumptions that population and income are both surrogates for purchasing power, which is the major support of retail trade, and that the majority of purchasing trips will be made with some sort of distance minimization consideration in mind. It is recognized, however, that these correlations will be somewhat weakened by the existence of purchasing journeys over longer distances, such as those from suburban areas to the CBD.

Hypothesis 6 expresses the idea that the close ties between convenience-goods outlets and residential population (explained in the discussion of Hypothesis 1) produce high correlations between these two factors, whereas the correlations between shopping goods outlets and residential population should be lower because, as explained above, these stores are not as closely bound spatially to population. As for the second part of the hypothesis, low-income areas are expected to have little purchasing power left over from the provision of necessities to support shopping goods stores other than those selling the cheapest merchandise, so shopping goods establishments will tend to cluster in areas where disposable income is higher. It is not expected, though, that the positive correlation between shopping goods stores and income will be extraordinarily high, for due to zoning restrictions stores serving high-income consumers are often located, not in immediate proximity to the consumers' residences, but in retail areas attractive to mobile high-income populations. The increasing mobility of the consumer due to the automobile (mentioned in the discussion of Hypothesis 4) is considered responsible for the decrease in these correlations over time.

Hypothesis 7 arises from the fact that shopping goods stores reap economies of agglomeration both internal to and external to their store type. In other words, the large numbers of consumers attracted by the shopping opportunities in a conglomeration of stores of various types constitute an advantage to every store in that conglomeration, as the accessibility to consumers of every store is increased. It is to be expected, then, that the distribution of each individual retail store type in the shopping goods category would correlate highly with the distribution of all retail stores. The increasing numbers of planned shopping centers and the confinement of the increasing numbers of stores by zoning restrictions suggest that this correlation should increase through time. Convenience-goods stores, on the other hand, are presumed to gain little by spatial association with other retail stores. Therefore, it is expected that correlations between convenience-goods store types and retail stores as a whole should be low, and since there is no apparent theoretical reason for this situation to change through time, the correlations should be stable.

The following chapter will discuss the data and the analytical procedures to be used in testing the above hypotheses.

CHAPTER 3

DATA SOURCES AND ANALYTICAL PROCEDURES

In this chapter, the sources of data used in the present study will be identified and the methods used in the analysis of this data will be explained.

With the hypotheses that were formulated in Chapter 2 in mind, four types of stores were chosen for analysis: grocery stores, representing convenience outlets; and shoe stores, furniture stores, and new automobile dealers, representing shopping-goods outlets in a hierarchy of increasing expensiveness. Grocery stores belonging to the three large chains in Montreal (Steinberg's, Dominion, and A & P) were excluded from the analysis because their stores are designed primarily for the use of consumers travelling by car and making their purchases less frequently and in larger lots than the customers of small grocery stores. Used furniture and automobile dealers were excluded because their locational patterns would likely be different from those of dealers in new merchandise, since they cater to a different market. Patterns of these four types of stores were analyzed for 1950 and 1970, for the City of Montreal and certain enclosed or nearby municipalities (see Figure A1).

The addresses of stores in the above categories were obtained from Yellow Pages directories for 1950 and 1970. These addresses were then plotted on a Montreal street map of scale 1500 feet to the inch, with the help of a street address directory. Each point was then given X-Y coordinates by superposing a transparent grid over the map, and the coordinates were punched up on computer cards for use with the point pattern analysis programs.

A number of minor inaccuracies probably occurred in the plotting procedure. Locations derived from the street address directory could be precise only within about half a block. While the coordinate grid used was very fine (1/20 of an inch), crowding of points in some areas and minor errors in the alignment of the grid were other possible sources of inaccuracy. Possible distortion of the Montreal street map in the process of its reproduction could also introduce slight errors. Since what is being studied is the overall pattern of points rather than the locations of individual stores, it is expected that these errors will not significantly alter the results.

Three types of analysis were performed on the point patterns. First, a nearest neighbor analysis was carried out to ten orders of nearest neighbor. Then a quadrat analysis was conducted for three different quadrat sizes (3000', 1500', and 750' on a side - see Figure A2), and thirdly the results of one of the quadrat analyses were input to the calculation of the Geary contiguity index. The results of these analyses will be discussed shortly.

Because of the considerable amount of computer time required for execution of the nearest neighbor program, some experimentation was done with the possibility of using point samples to calculate the nearest neighbor statistics for the larger data sets. To establish the variability of R with different sizes of sample, the nearest neighbor analysis was run with varying sizes of sample from one of the smaller data sets (furniture stores, 1950). It was found that samples quite consistently overestimated R, and that while there was a levelling-off trend at about a 35 per cent sample, the amount or percentage of overestimation at that point was quite unpredictable. The results of this experiment are shown graphically in Figure A3. The use of samples for estimating R was therefore rejected, except for the grocery stores for which costs of computing population values were prohibitive.

In the course of the quadrat analysis, it was also realized that some of the observed concentration might be due to the fact that the large extent of the original study area included many incompletely urbanized areas. In other words, some concentration that was simply due to urbanization might be appearing in the mean/variance ratios along with concentration due to agglomeration within the city. To test this suspicion, the quadrat analysis was performed on two smaller subareas within the city, for the three sizes of quadrat. Although the urbanization concentration was effectively extracted by this method, the basic trends observed for the larger area remained basically unchanged.

It was realized after some study of the data and of the research problem that the random distribution was in fact a poor standard of comparison for retail store distributions. Urban zoning and the pattern of transportation lines assure that every point in the city does not have an equal probability of receiving a retail store, and thus one of the fundamental presuppositions of the Poisson distribution is violated. The question then arises as to what standard of comparison should be used. This thesis offers two answers: a comparison of quadrat values for retail stores and for certain postulated locational determinants, namely population, income, and retail stores as a group; and comparison of the retail store quadrat values with theoretical probability distributions which can shed some light on possible generating processes for the observed retail store pattern.

The first approach, comparison of the point-pattern indices and quadrat distributions with indices and distributions of some hypothesized determining variables, was made more difficult by the fact that appropriate data were available only by census tracts and had to be converted to quadrat data by areal interpolation for comparison purposes. The interpolation formula used was:

$$Q(i) = \sum_{j=1}^{k(i)} P(i,j)/W(i,j) \times V(m)$$

where Q(i) is the value for the i-th quadrat,

k(i) is the number of census tracts wholly or partly within the i-th quadrat,

P(i,j) is the area of the part of the j-th census tract within the i-th quadrat,

W(i,j) is the overall area of the j-th census tract,

V is the census tract value,

m is the official number of the census tract, input as a subscript.

The data used were as follows: population by census tract, 1951 and 1966; retail stores per census tract, 1951 and 1966; average wage and salary income per family, 1951 and 1961. It was unfortunate that 1971 census data were not available at the time of this writing; the above are the closest available data in time to the 1950 and 1970 dates of the point-pattern analysis. The time gaps between the census data and 1970 perhaps seem less serious when one realizes that retail location patterns may take several years to adjust to population and income changes.

The interpolated values of the census variables were then standardized, as were the quadrat values for the point store-location data, and matrices of the differences between the two standard values for each quadrat were produced. These matrices were used in the manner of residual maps to identify areas of over- and under-concentration of a given store type relative to a postulated determining factor. Thus, if S_i is the standardized value of a store type for the i-th quadrat, and C_i is the standardized value of an interpolated census variable for the i-th quadrat, then the difference

$$D_i = S_i - C_i$$

will be positive if there is an "excess" of stores relative to the factor, and negative if there is a "deficiency." Such an analysis implies, of course, that the optimal value, the "equilibrium position", is a zero value, an assumption which will be seen to be questionable on a number of grounds. Nevertheless, study of the difference matrices unearthed a number of significant trends and relationships, and gave the total project a spatial dimension which the statistical indices, distribution fitting, and correlation analysis all lacked.

An experimental mapping of the information from the standardized data matrices was carried out on those derived from the store location data. This served to illustrate one possibility for use of the standardized data and difference matrices. It also made clear the linear trends in many of the store location patterns, which derive from the pattern of transportation arteries, and which are not picked up by any of the statistical indices used, with the possible exception of the Geary contiguity index. A simple correlation coefficient was also calculated between each set of store data and each set of census data, for both points in time.

The second approach, the fitting of theoretical distributions, can provide not only a mathematical description of the retail store pattern but a clue to the sort of process that could have generated the pattern (Harvey, 1966). It is to be remembered, of course, that definitive inferences from pattern to process are unreliable, as more than one process can generate the same pattern. Four distributions were fitted to the data: Poisson, binomial, negative binomial, and Neyman Type A. From the results of previous researchers such as Rogers (1969) and Harvey (1966), it was expected that the negative binomial distribution would give the best fit to the retail store patterns. Since this was in fact true, and since none of the other distributions gave significant fits, only the results for the negative binomial were tabulated.

It would have been desirable to fit some compound distributions to the data, especially the Poisson negative binomial, since it appeared reasonable that the existing point patterns were in fact the result of the simultaneous action of Poisson and negative binomial processes, and since Rogers (1969) obtained exceptionally good fits to his data with this distribution. However, an existing computer program written to fit this distribution did not give good results, and in the absence of mathematical information sufficient to improve the estimators used, this part of the project was abandoned. Upon further reflection, it seemed theoretically plausible that the Poisson and negative binomial processes were not operating on the same points at the same time, but that the earlier location decisions were made according to a Poisson process and that then later entrepreneurs located around the first ones according to a negative binomial process. If this were true, then without detailed knowledge of the time-sequence of the establishment of individual stores, fitting of such a compound distribution would be an exercise of dubious value. At any rate, it proved difficult to clarify whether the existing formula for the Poisson negative binomial distribution represented the operation of concurrent processes or of a sequence of processes through time.

It also proved impossible, within the existing limits of time and money, to fit the four distributions for the two smaller sizes of quadrat or for the two smaller study areas which were eventually examined. It is suspected that for the smaller quadrat sizes the number of zero quadrats would be so large and the number of quadrats with more than one or two points so small that no degrees of freedom would be available for a chi-square test of the goodness of fit of the distribution. This problem was already apparent at the large quadrat scale when the number of points was relatively small (mainly in the automobile-dealer distributions). For the smaller inner-city study areas, the number of zero quadrats would be relatively small, so a binomial distribution might well give a satisfactory fit to some or all of the store patterns.

The following chapter presents and interprets the specific numerical results obtained from the analyses described above.

CHAPTER 4

NUMERICAL RESULTS AND SPECIFIC INTERPRETATION

Let us now turn to the specific results of the analyses outlined in the last chapter. The results will be considered under the following headings:

I. Store Counts
II. Nearest Neighbor Analysis
III. Quadrat Analysis: Mean/Variance Ratios
IV. Geary Contiguity Index
V. Distribution Fitting
VI. Comparison of Store Patterns with Postulated Locational Factors
VII. Correlation Analysis

The standardized difference matrices will be discussed in a separate chapter.

I. Store Counts

From 1950 to 1970 the expected increase in store numbers took place in the furniture and shoe store categories (see Table 8a). The number of automobile dealers remained approximately constant; this can be explained by the large amount of capital required to start an automobile dealership, which prevents many entrepreneurs from entering this field, and also by the fact that increased demand can be serviced by factory orders from existing dealers, without an increase in the number of dealers. The number of small grocery stores actually decreased slightly, reflecting most probably the invasion of the grocery retailing field by the supermarket chains.

In the central city, similar numerical trends appear, but the increases in shoe and furniture store numbers are much less marked and both automobile dealers and small grocery stores show substantial decreases (see Table 8b). It is noteworthy that in all cases the percentage of total stores located in the small central-city subarea declined from 1950 to 1970. This fact supports the contention that the observed deconcentration of retail stores has as its primary component the addition of new stores outside the city center, although since the small subarea did not include all of downtown these results cannot be taken as conclusive.

II. Nearest Neighbor Analysis

The results of the nearest neighbor analysis are given in Table 1. Contrary to expectations, clustering was observed for all types of stores at all ten orders of nearest neighbor. The R index increases with the order of nearest neighbor, but nowhere is it even close to 1.

In 1950, shoe stores were the most concentrated, followed by automobile dealers, furniture dealers, and grocery stores, in that order. In 1970, shoe stores remain the most concentrated, but grocery stores have moved up to second place, and furniture and automobile dealers follow with almost equal indices. All R values increase from 1950 to 1970, suggesting that urban deconcentration is indeed bringing about a deconcentration of the overall retail store pattern. The shift in ranking of the grocery stores may point to some influence, most likely socio-economic and related to new patterns of grocery merchandising, that is inhibiting the spread of small grocery stores into newly built-up areas. Since the R statistic is not on a ratio scale, percentage-change figures or similar statistical measures of change become meaningless, and comparison must be limited to inspection of the 1950 and 1970 R values.

It must be pointed out again that the grocery store R values are derived from a 37% sample, and that, as mentioned earlier, the relationship between sample and population R values could not be clearly established except for the fact that sample values are consistently and markedly too large. Therefore, any inferences about grocery store concentrations made on the basis of this nearest neighbor analysis must be considered questionable and in need of substantiation by other methods. One must also note that the formulae used to establish the expected nearest neighbor distances (Table 1a) involve the density of points per unit area, and since in retrospect the study area was thought to be probably too large, the densities obtained may be inordinately small, the expected distances may thus be inflated, and the ratio $\bar{r}_A$ / $\bar{r}_E$ may be smaller than is justified by reality. Unfortunately time did not permit repetition of this analysis at a smaller scale.

III. Quadrat Analysis: Mean/Variance Ratios

The quadrat analysis of the retail store distributions may be considered as a three-phase procedure, consisting of: calculation of mean/variance ratios; calculation of the Geary contiguity index; and fitting of theoretical distributions to the observed quadrat data.

In the first phase, the mean/variance ratio was used instead of the usual variance/mean ratio because the latter indicates clustering by a value greater than 1. This would have led to confusion with the nearest neighbor results. In addition, comparison of the degree of concentration suggested by the two indices would have been very difficult, as the variance/mean ratio can vary from 1 to infinity for a clustered pattern, but for the same pattern the nearest-neighbor R statistic could vary only between 0 and 1. In view of suspicions that the original study area was too large, two subareas (see Figure A1) were also analyzed. Three sizes of quadrat (3000', 1500', and 750' on a side) were used, both to see whether different patterns appeared at different quadrat scales and to look for a quadrat size that would give results comparable to nearest neighbor analysis. This last experiment was considered important because the nearest-neighbor program proved expensive and time-consuming to run and produced only an aspatial index, whereas the quadrat analysis program worked much more cheaply and expeditiously and produced frequency counts and output matrices of quadrat values as well as a statistical index of concentration.

The first run-through of this analysis showed clustering so extreme as to generate suspicions about the accuracy of the method. Upon further thought, it was realized that the large number of zero quadrats in the large study area was deflating the mean $\sum x/n$ (by adding to the number of quadrats, n, while adding nothing to the sum of terms in the numerator) and distorting the variance $\sum(x - \bar{x})^2/n$ in an unpredictable way, though it was thought likely that the variance was being inflated. (In effect, each zero term was increasing n by 1 but adding a relatively large "artificial" $(0 - \bar{x})^2$ term to the numerator). Consideration had to be given, however, to the fact that there were two types of zero quadrat: one that was zero because it was outside the study area but still within the quadrat grid (and which might actually contain stores of the type under consideration); and one that was zero because it actually did not contain any stores of the given type. The latter type of zero quadrat is, of course, significant and should not be ignored. Therefore, zero quadrats of the first type were counted on a work map and eliminated from the analysis, while zero quadrats of the second type were retained.

These problems in their turn raise the question of the size and orientation of the grid in quadrat analysis. In this case, these characteristics were arbitrarily determined by the size and orientation of the Montreal street map used, but in retrospect it appears that some preliminary study of the size and shape of the urbanized area, by means of census or Montreal Planning Department data, would have brought about a more satisfactory decision. The author proposes that an ideal quadrat grid should fit the study area as closely as possible (i.e. with the smallest possible number of "artificial" zero quadrats). The orientation of the grid will obviously influence the results, but it is difficult to determine an optimum orientation. A good but time-consuming method would be to drop several quadrat grids at random over the map, doing the quadrat analysis for each one, and taking the mean and variance of the resulting set of indices. Such an experiment might suggest criteria for optimal grid orientation. The excessive bisection of important clusters by quadrat boundaries may also affect the results, but this is not certain.

The results obtained from the mean/variance ratios (Table 2) were more consistent over time than those from nearest neighbor analysis. At both points in time grocery stores are the most clustered, followed by shoe, furniture, and automobile stores, in that order. This and the results of the Geary contiguity analysis (to be discussed later) lend added weight to the conclusion that the grocery-store results from the nearest neighbor analysis were aberrations based on the sample behavior of the R statistic. This hierarchy is maintained over all three quadrat sizes and all three study areas with only minor variations. The 3000' quadrats produce smaller values than the nearest neighbor statistics for the large study area, but as quadrat size decreases, the values for the mean/variance ratio seem to approach those for the comparable nearest neighbor statistics. For the small (750') quadrats, grocery stores and shoe stores have mean/variance ratios approximately equal to the corresponding first nearest neighbor R statistics, while the ratios for furniture and automobile dealers are now larger than their nearest-neighbor counterparts. Since the expected nearest neighbor distances for grocery stores and shoe stores fall approximately in the 600-1000' range, these results suggest that quadrats with a side approximately equal to the expected first nearest neighbor distance produce results more or less equal to those for nearest neighbor analysis. It remains, however, to verify this relationship mathematically, a task which lies beyond the scope of this paper, and to identify the influence of quadrat grid orientation on the results of the analysis.

The mean/variance ratio indicates that the smaller the quadrat size, the less clustering there is. This is plausible because on a fine quadrat grid, many agglomerations that would fall within one or two large quadrats and give the statistical impression of clustering are instead broken up by interspersed zero quadrats. In a sense, the large quadrats measure larger-scale clustering over the entire urban area, while the small quadrats measure the extent of local clustering over the same urban area.

On the other hand, the medium and small subareas are meant to remove from the mean/variance ratios the effect of the drastic decrease in the density of urban phenomena, including retail stores, on the city fringes. The medium subarea covers a heterogeneous but clearly urbanized section of Montreal north and northeast of the city center; the small subarea is a much more homogeneous, very densely urbanized section to the northeast of the CBD. There is not much change in the mean/variance ratios in moving from the large to the medium study area, suggesting that the elimination of "artificial" zero quadrats had much the same effect as reducing the size of the study area. For the small subarea, however, there is a marked decrease in clustering tendencies, except for shoe stores, which reflects the greater homogeneity of the area. The falling-off of grocery store clustering is especially noticeable; one concludes that a great deal of the clustering apparent in the larger-area ratios in fact represents a concentration of grocery stores in this section of the city (due to socio-economic factors, it is suspected) and not concentration in the sense of local agglomeration. Note, however, that the pattern is still far from being random or regular. Only automobile dealers in 1970 could be said to form a random pattern in the small subarea.

nature and should ideally take the form of a proof that for a point pattern without specified anomalies, the three measures give equivalent results within a certain region of stochastic variability. If this could be done, then research could proceed without the piling up of analytical procedures that was felt to be necessary in this thesis.

V. Distribution Fitting

The Poisson, binomial, and Neyman Type A distributions gave very poor fits to the observed data; in every case there was a probability less than .001 that a chi-square value exceeding that calculated would arise by chance. By contrast, the negative binomial gave reasonably good fits, except for the grocery store distributions. Both moment and maximum likelihood estimators for the negative binomial distribution were used, and chi-square tests were performed for minimum class expectations of 5 and 1. The use of the two class expectations, in spite of the fact that standard statistical theory insists that the chi-square test is not valid for a class expectation of less than 5, is justified by Cochran:

> "Since the discrepancy between an observed and a postulated distribution is often most apparent at the tails, the sensitivity of the chi-square test is likely to be decreased by an overdose of pooling at the tails. Thus considerations of the power of the test urge us to use cells with as small expectations as we dare from distributional considerations."[1]

1. Cochran, W. D. (1952), "The chi-square test of goodness of fit," Ann.Math.Statist., 23, p. 329.

This phase of the analysis was carried out for all three quadrat sizes, but for only the large study area. Restrictions of time and computer funds prohibited the extension of the analysis to the medium and small subareas. The author suspects that the binomial distribution might conceivably give good fits for the subareas because of the small number of zero quadrats in the central city.

The results of the analysis were somewhat erratic (Tables 6 and 7). Chi-square tests for a minimum class expectation of 5 almost invariably produced better results than those with a minimum class expectation of 1. One reason for this may be that the random element in store location may produce inflections in the tail of the curve that are difficult to account for mathematically. The presence of fractional values in the theoretical distribution that cannot occur in the discrete observed distribution, which is composed exclusively of integers, may also accentuate this effect, especially in the tail of the distribution. There seemed to be no pattern in the types of stores whose distribution was best explained by a given type of estimator or a given quadrat size. It does appear, though, that better fits were obtained for 1950 than for 1970 data. Moreover, none of the distributions gave a good fit to the grocery stores. This suggests that the complexity of the retailing system may be increasing to a point where the use of compound or generalized distributions will be necessary to describe the existing patterns adequately, and indeed that the pattern of grocery stores already required a more complex description in 1950. Distributions which could conceivably give good fits to complex store patterns include the Poisson binomial, the Poisson negative binomial (Rogers, 1969), and the binomial-negative binomial (Khatri and Patel, 1961). However, it is not conceptually clear exactly what the mathematical compounding or generalizing processes represent in geographical terms: the simultaneous operation of two processes on a point set, the operation of two processes simultaneously but on different levels of aggregation, or a sequence of processes operating on a point set at different times.

It is tempting to follow the suggestion of Harvey (1966) and make inferences from the fitting of the negative binomial distribution to the processes generating the store patterns. Unfortunately it is not logical to do this, as there are several processes that can give rise to a negative binomial distribution. Rogers (1969) names two: a random distribution of clusters, with the number of establishments in each cluster following a logarithmic distribution; and a random allotment of number of stores per cell (i.e. according to a Poisson distribution), with the mean varying according to a gamma probability distribution. Harvey (1969) points out that evidence from other sources can be of some help in choosing among hypothesized generating processes, but in the case of the negative binomial distribution this is not likely to be of much help, for Dacey (1967) has found that this distribution can be generated by at least six processes. Rogers argues that the non-random element in these processes represents the distribution of purchasing power over the urban landscape and that if this distribution could be described mathematically, a choice between these processes could be made. The difficulties one encounters here are the determination of an adequate surrogate for purchasing power and the choice of the appropriate distribution to consider, i.e. daytime (working), residential, or some combination of the two. The first process might be better tested by defining clusters by some sort of grouping algorithm, establishing a center of gravity for each cluster (spatially or otherwise), and then directly testing the two parts of the process. At this stage of research it seems impossible to make any inferences regarding process from the negative binomial distribution.

VI. Comparison of Store Patterns with Postulated Locational Factors

In his 1969 study, Rogers explained the observed concentration of grocery stores in Ljubljana, Yugoslavia, with reference to an equivalent concentration of population. His success in doing this encouraged a further investigation in this thesis of the relationship between store patterns and theoretically identified locational determinants. The methods used in effecting this comparison have been described earlier.

When mean/variance ratios were calculated for the transformed census data (Table 4), retail stores as a group were found to be the most concentrated, followed fairly closely by population. Retail concentration is easily explained by the existence of agglomeration economies and by zoning restrictions. The population concentration is probably caused by a more complex mix of factors: the necessary inclusion of extremely high-density areas with areas of low population density, such as Mount Royal Park or industrial areas in St. Laurent and the East End; the low population figures of quadrats only partially within the study area; the large percentage of apartment and flat dwellers in Montreal, which tends to produce large population densities; and the sheer size of the study area, though concentration was evident even in the urbanized subareas.

Income, on the other hand, turned out to have a regular distribution. This is most likely a statistical aberration. The census income figures were "per family" and it was necessary to adjust them for size of family to obtain meaningful figures, thus introducing one "evening-out" influence; moreover, per capita income figures are not necessarily low in low-population and partially included quadrats, as are the population figures. With the elimination of most zero quadrats from the analysis (as in the preceding mean/variance analysis of store distributions), the variance becomes very small relative to the mean and causes high mean/variance ratios to occur. It must also be noted that the social significance of income variations is much greater than numerical or percentage differences would suggest. Because of the above results, it will be necessary to treat with some caution all comparisons involving income data.

All the mean/variance ratios for locational factors show less pronounced clustering in the smaller subareas, for reasons previously explained with regard to the store analysis. Population and retail stores become less clustered between 1950 and 1970, while income moves in the other direction, becoming less regular.

As for the relationships between the mean/variance ratios for the stores and the census data, the relationships of the store ratios to population and income are clearly defined and stable over the 1950-1970 period. Shoe and grocery stores are consistently more concentrated than population; furniture and automobile dealers are consistently less concentrated (except for furniture stores in the small subarea); and all stores are more concentrated than income. The situation with retail stores as a whole is more complex, to a point where similar generalizations are not possible. However, the concentration of shoe and grocery stores does tend to equal if not surpass that of retail stores as a whole, while the concentration of furniture and automobile dealers is consistently less.

VII. Correlation Analysis

When two spatially distributed phenomena have similar mean/variance ratios, this fact cannot be taken as proof that the two distributions coincide or are even similar. A given mean/variance ratio is produced by a certain amount of concentration in the spatial pattern of the phenomenon under study, but it says nothing about the number or spatial arrangement of the foci of concentration. In order to confront this problem, a pairwise correlation analysis was run on the store and census quadrat data, to give some idea of the actual degree of spatial association between each pair of quadrat data matrices.

The results of the correlation analysis were fairly straightforward (Table 5). High correlations emerged between individual store types and population and between individual store types and retail stores as a whole (except for automobiles in 1950). Correlations with income were noticeably lower but still highly significant. All correlation coefficients were significant at the one per cent level.

Some interesting changes occurred in the correlation coefficients between 1950 and 1970. Correlations with population decreased, probably reflecting a greater mobility, due to widespread automobile ownership, that has increased the size and blurred the definition of stores' tributary areas. However, correlations with income increased. It is unlikely (as will be seen later from the standardized difference matrices) that this reflects a surplus of retail services in high-income areas and a deficit in low-income areas. Rather, it is proposed that the improved correlation is a function of the time lag between the 1961 income figures and the 1970 store data. The 1970 store distributions had time to adjust to the 1961 income distribution, whereas the 1950 store data were correlated with more or less contemporaneous income figures and could not have adjusted fully to that income pattern. This subject of time lag will be discussed later in more detail. Correlations of individual store types with retail stores as a whole decreased, with the exception of furniture stores. This exception may well be due to a developing tendency for furniture dealers to locate a small- to medium-sized showroom in a shopping center and to supply it from a larger warehouse on an order basis. The general decrease in these correlation coefficients is supposed to reflect the increasing complexity of the retailing situation, which will be discussed more fully later.

Grocery stores invariably had the highest correlations with location factors. Otherwise, the hierarchy of correlations is unclear. There are evident tendencies, however, for greater expensiveness of goods to be associated with a higher correlation with income (but we should note that the income correlations, though highly significant, are not very large), and for automobile dealers to be relatively loosely associated with population and income.

It must be remembered that, due to the large quadrat size (3000' on an edge) and the large study area, the more local forms of agglomeration are not being dealt with. It would have been difficult to carry out a similar analysis for a smaller quadrat size since data for population, income, and retail stores as a whole were available only by census tracts. A smaller quadrat would be so much smaller than many of the census tracts that large blocks of artificially identical values would appear and much of the detail would be lost from the analysis.

On a theoretical subject, it must also be recalled that correlation does not necessarily indicate causation, but can arise through the relationship of each of two variables, A and B, to a third variable, C. More will be said on this point later in the thesis in a discussion of the role of shopping centers in the retail pattern.

The high correlation of grocery stores to population ($r \approx .85$) was expected from geographic theory and accords well with experiential knowledge of the city. On the other hand, even a fair correlation of grocery stores with income ($r \approx .4$) was highly unexpected, since by simple observation small grocery stores seem to be typical of low-income rather than high-income areas of the city. The use of standardized difference matrices may help to pinpoint the sources of this correlation. The fair-to-good correlations of individual store types with retail stores in general (r ranging from 0.4036 to 0.8399) were to be expected because of the prevalence of multi-purpose shopping trips. Note that with increasing expensiveness of the good offered, the association with retail stores in general weakens, indicating that multi-purpose trips for expensive goods are less frequent than for cheaper goods.

As for shopping-goods stores, positive correlations with income and with retail stores as a whole were as expected ($r \approx .3$ for income; $r \approx .6$ for retail stores). The weak correlations with income are probably affected by the exclusion of retail stores by zoning restrictions from many high-income residential areas. However, the fair correlation of shopping-goods stores with population ($r \approx .6$) was unexpected; it was hypothesized earlier that shopping goods should be largely independent of residential population distribution. These results are possibly related to quadrat size; it is also conceivable that high population density tends to shrink tributary areas of stores and bring about a closer association of stores with population. This line of reasoning must take into account, however, the observation that the boundaries of urban market areas may be probabilistically determined (Huff, 1963), the extensive overlapping of urban market areas, and the influence on patronage probabilities of activity foci other than residence, most notably place of work.

It seems evident that correlation analysis is not sufficient to give a truly spatial dimension to the comparison of store and location factor distributions. To do this, and to pin down the areas of agreement and discrepancy with theory and empirical expectation, one must turn to the standardized difference matrices, to which attention is directed in a separate chapter.

CHAPTER 5

STANDARDIZED DIFFERENCE MATRICES

I. Introductory Remarks

Due to the strong subjective element in the interpretation of the standardized difference matrices, these matrices will here be discussed in a chapter separate from the previous one, which dealt with more objective indices.

The standardized difference matrices, obtained by a method described previously, can be used much like a map of residuals from a trend surface to locate areas where the number of a given type of store departs markedly from expectations based on location factors. For reasons of space, only one of the output matrices was included in this thesis as an example (Table 9), with the eight quadrat maps prepared from the standardized store data matrices (Figures A4 through A11).

Certain mathematical attributes of the method reduce its informational value in particular situations. The assumption that a standardized difference value of zero indicates an equilibrium retailing situation, with the population being optimally served, is not necessarily tenable due to variations in store size and offerings and consumer movement across quadrat boundaries. Therefore, it was never possible to state with certainty that a large deviation was evidence of disequilibrium. It was also assumed that the process of standardizing the data would produce a more or less continuous distribution of values about a mean, but in some cases it did not. If the mean and variance of the original distribution were small, the standardized data did not form a continuum but took on certain discrete values corresponding to the integer steps of the original distribution. This obviously gave a certain degree of arbitrariness to the standardized difference matrix. It was also noted that on the periphery of the study area, positive or slightly negative values tended to appear in unpredictable patterns. Theoretically one would expect strong negative values because of "underservicing" due to the lack of threshold populations for store entry. It was suggested that in these areas both stores and locational factors would have strongly negative standardized values, and depending on the idiosyncracies of the two distributions, one or the other would have a larger absolute value and the resulting difference would be positive or negative. It proved impossible, therefore, to draw conclusions from the peripheral areas.

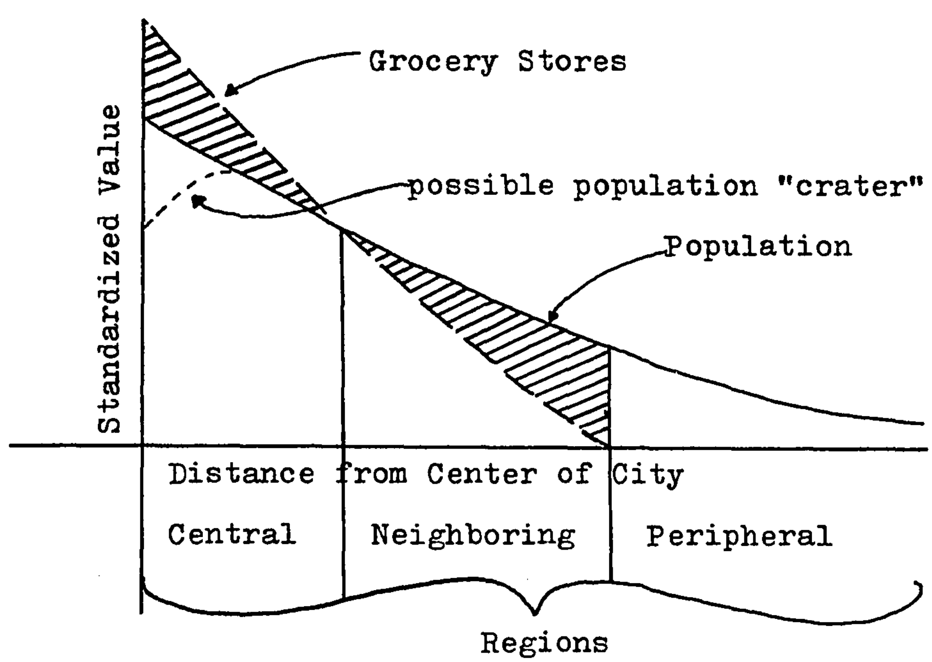
The relationships between store location patterns and population and income distributions were clear at the large-scale level of analysis, so that hypothetical west-to-east cross-sections of store and factor surfaces could be constructed. These will be drawn at the appropriate points in the text. The relationships between the location patterns of individual stores and the overall retail store pattern were so complicated that no such profile could be drawn. The author suspects that these relationships are effective at such a small scale that the 3000' quadrat grid failed to pick them up.

The discussion will now proceed to an explanatory summarization of the standardized difference matrices. This summarization will of necessity be subjective, especially since for lack of space all of the standardized difference matrices could not be included in this thesis. However, the summary has a firm grounding in objective results, and some of the more outstanding or representative values will be included as illustrations.

II. Store Types and Population

The matrices relating grocery stores to population can be summarized by the curve in Figure 5.1.

Figure 5.1
Typical Curve of Relationships among Stores, Population, and Distance from City Center



It is evident that the curve divides itself into three regions. In the central city, there are high population values but still a slight excess of grocery stores relative to population (e.g. standard values of 1.88, 1.22 in 1970); these areas are theoretically "overserviced." In "neighboring" areas a little farther out, especially to the west, there appears to be a deficiency of grocery stores (e.g. -1.81, -1.59 in 1970); these areas are theoretically "underserviced." In fact, the "neighboring" area is in most cases well defined only to the west and northwest of the city center. Finally, there is the peripheral area, about which little can be said for reasons given above.

The author's experiential knowledge of the city indicates that people do not travel from the "underserviced" west-neighboring areas,(e.g. Notre-Dame-de-Grâce, Côte des Neiges, Westmount) to the "overserviced" central areas north and east of downtown to do their grocery shopping. This suggests that the cross-hatched areas of the diagram represent only apparent discrepancies, i.e. that the needs of these consumers are actually being satisfied within their respective areas (or by travel to yet other areas). A crucial variable which has been totally neglected is the size of the grocery stores. A single large store may serve a fair-sized area adequately and yet on the basis of a simple count of grocery stores show up as a below-average quadrat value. In the western section of the city, the population is more affluent and therefore car ownership and high mobility are prevalent; grocery stores (and others) can grow in order to reap internal economies of scale and still keep a tributary population sufficient to support the expanded store. In the east central areas which have the most marked "excesses" of grocery stores, the stores are small and are prevented from growing by the low mobility of their tributary populations. A further important consideration is the omission of supermarket chains from the analysis; in 1950 their influence was probably not overpowering, but in 1970 they were undoubtably the dominant form of grocery retailing in middle- and upper-income areas. In the east-central area, it is suspected from the author's experiential observation of business failures, and from remarks in Simmons (1964) concerning low-income areas in cities, that the store pattern at any given point in time contains a fair number of non-viable units. A further point is that many small grocery stores in Quebec have beer licenses and in effect survive on their beer sales; this can lead to concentrations of grocery stores which could not be supported by grocery sales alone.

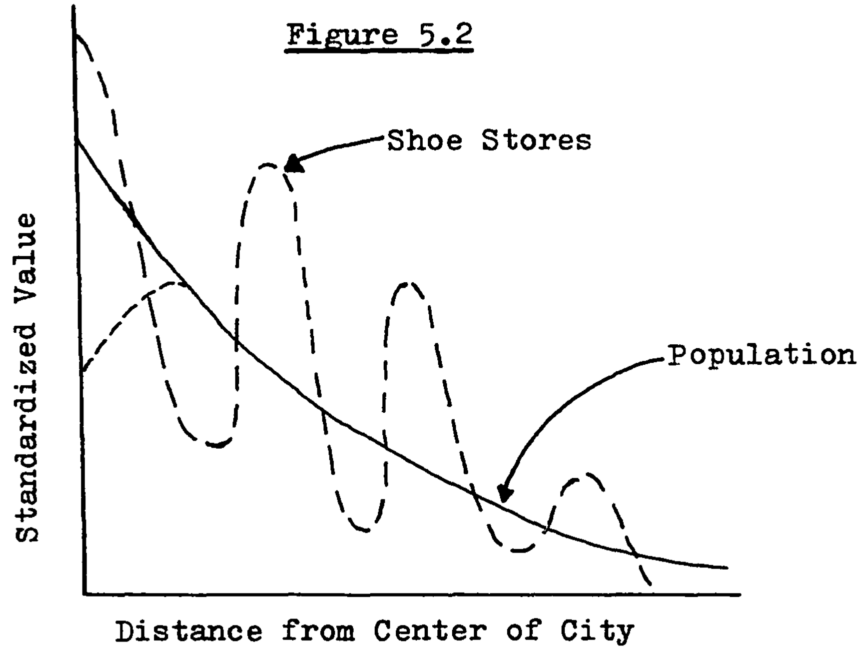
In summary, one may propose that the west-neighboring region is actually being adequately serviced (i.e. that the grocery store curve should move up to coincide with the population curve), while the central region is not as overserviced as it may seem but may still have an excess of stores due to poor entrepreneurship. One may also assert that service in the peripheral areas is adequate because their populations have high mobility and can move either inward to stores in the neighboring zone or outward to suburban shopping centers beyond the range of this study.

In addition to the above-mentioned areas, there are large sections of positive and negative values which show no apparent pattern. This phenomenon may be partly due to the effect of quadrat size and its relation to the transportation grid, but it also lends added weight to the results of the distribution fitting, which showed that the grocery store pattern was too complex to be fit by a simple probabilistic model.

There was little overall change in the pattern of standardized differences between 1950 and 1970, except that both the negative tendencies of the western neighboring area and the positive tendencies of the east-central area seem to be stronger in 1970. Actually, in 1950 the central area of overservicing was not very clearly defined.

The shoe stores show quite a different pattern from the grocery stores (Figure 5.2). Spotted around the difference matrix there appear isolated quadrat "peaks" composed of, say, one to five quadrats, quite strongly defined in terms of standard values (e.g. 4.87, 2.94,

Figure 5.2



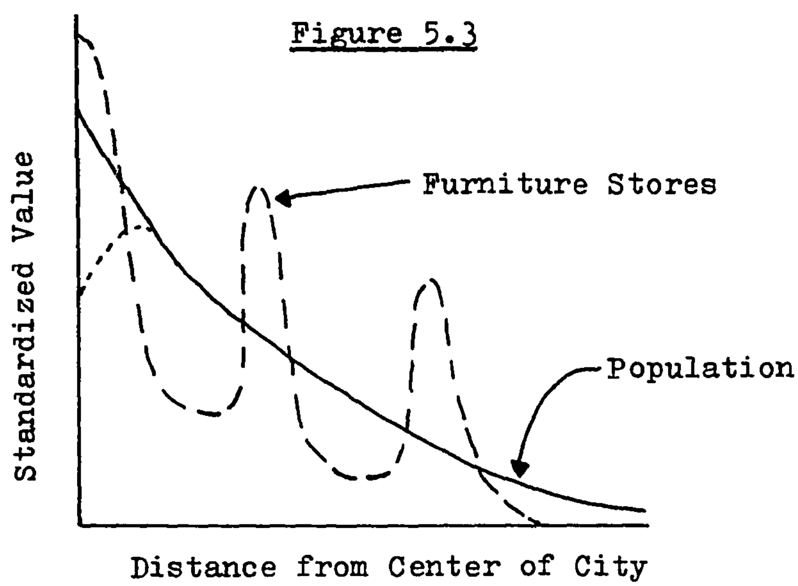
For title see Figure 5.1.

3.75 in 1950; 7.88, 8.63, 3.63 in 1970), and surrounded by sizeable areas of strongly negative values (often two or three standard deviations below the mean). This is evidence of a considerable degree of small-scale clustering relative to population, in contrast to the large-area clustering shown by the grocery stores. The overall pattern does not vary among the central, neighboring, and peripheral areas, except that the peak values tend to decrease with increasing distance from the city center. An exception to this trend is the very pronounced St. Hubert Street cluster, well to the northeast of the CBD. The slight positive values in the peripheral areas are probably spurious, for reasons given earlier. The pattern does not change much from 1950 to 1970 except that the standardized values of the peaks increase.

This suggests that of the considerably greater number of shoe stores existing in 1970 (493 as opposed to 285) most have intensified the concentration of stores in nucleations that existed already in 1950, rather than forming new nucleations. Outlying shopping centers such as Les Galeries d'Anjou in the east end are exceptions to this tendency.

Furniture stores form a pattern similar to that of shoe stores (Figure 5.3) but with somewhat fewer peaks, perhaps of slightly lesser intensity (e.g. 3.66, 4.23 in 1950; 5.81, 4.12, 2.11 in 1970). There also seem to be fewer peaks more than one quadrat in extent, suggesting that furniture "districts" may be more sharply localized than shoe stores, which may tend to spread over larger and more generalized shopping districts. This absence

Figure 5.3

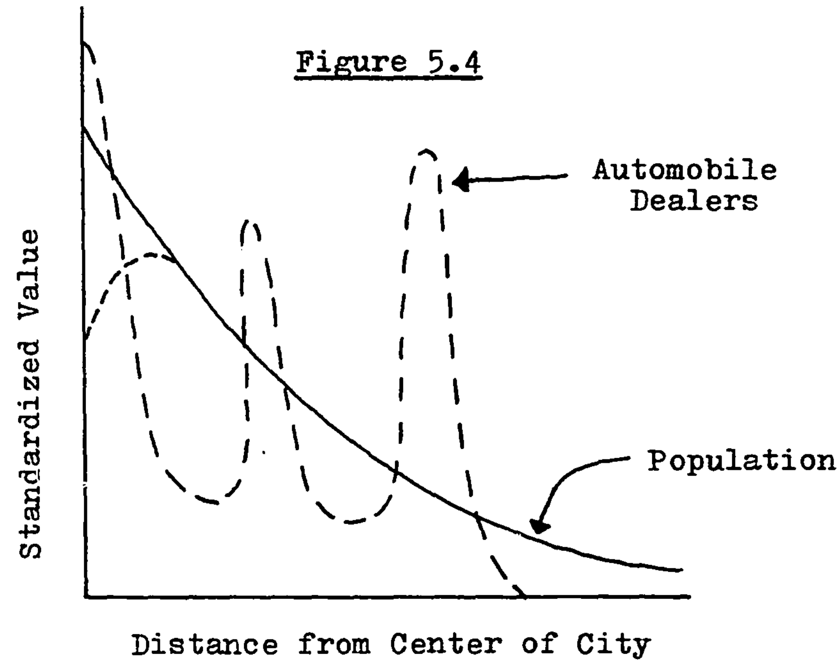


For title see Figure 5.1.

of a strongly defined downtown peak is noteworthy; there is no noticeable downtown concentration in 1950 and only a small and ill-defined one in 1970, probably composed largely of small "prestige" shops such as Scandinavian-furniture dealers. This lack of strong downtown concentration almost certainly reflects the space-consuming nature of furniture stores, which renders them unable to pay the high rents at the center of the CBD. It was also noted that, in contrast to the shoe stores, the size and location of furniture-store concentrations changed considerably between 1950 and 1970. For example, a peak on Ste. Catherine East was quite prominent in 1950 but hardly noticeable in 1970. However, examination of the original telephone-company data indicates that this "shifting" does not indicate a high degree of instability among furniture stores.

It was hard to interpret the pattern of automobile dealers or to gauge the number and intensity of concentrations because of the small mean and standard deviation of the original data. (To illustrate, the presence of only two automobile dealers in a quadrat would give that quadrat a standard value of 1.51 in the standardized automobile matrix. This problem also appeared to a lesser extent with the furniture stores. Linear trends appear stronger than for other types of stores, suggesting a closer association with main traffic arteries.

Figure 5.4



For title see Figure 5.1.

There appears to be a wider dispersion of peaks than for other stores and an absence of the tendency for peaks to decrease in intensity with increasing distance from downtown, but it is hard to be certain even of these tendencies (Figure 5.4). There is a considerable concentration of automobile dealers in the west end of downtown which persists from 1950 to 1970, in spite of the large space requirements of automobile showrooms. This persistence can be explained partly by the fact that this concentration is actually on the western edge of the CBD and in an area which high-density CBD development has not shown a tendency to invade until very recently (specifically, until the Atwater Metro terminus brought about the Westmount Square and Alexis Nihon Plaza developments).

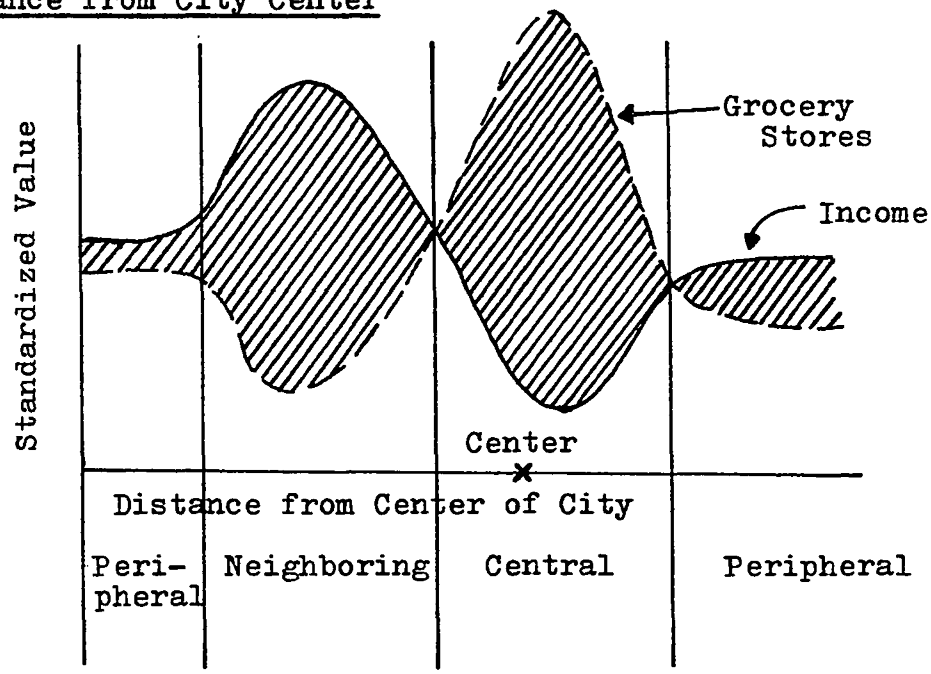
One may also refer to the observation, made from the telephone-company data, that stability of firms seems to increase with the expensiveness of the good offered, probably because an incompetent entrepreneur who would be likely to fail in business could never amass the capital to start a store selling expensive goods. Therefore, a pattern of automobile dealers which responded to population needs in 1950 would be more likely to persist in 1970 (with changing needs reflected by additions to the pattern) than, say, an analogous pattern of grocery or shoe stores. In fact, the changes in the pattern from 1950 to 1970 do consist primarily of the addition of peaks on the outer fringes of the urbanized area. One must note, however, that several automobile dealers have gone out of business in or moved away from the western edge of the CBD in the last few years, which suggests a forthcoming change in the locational pattern.

III. Store Types and Income

The delimitation of areas of excess and deficiency of grocery stores relative to income was much clearer than that relative to population, though it followed much the same pattern (Figure 5.5). The strongly positive east-central area and the strongly negative west-neighboring area are much more clearly defined than for grocery stores and population. In addition, there is a clearly defined region of positive values (excess of grocery stores) southwest of the city center, in the low-

Figure 5.5

Typical Curve of Relationships among Stores, Income, and Distance from City Center



income Pointe St. Charles and Little Burgundy areas, which did not show up with regard to population. This discovery suggests strongly that high grocery store concentration should be correlated with low income, whereas the correlation analysis found the reverse to be true. These findings also conflict with trends observable from the maps of store locations and the quadrat value matrices, with theoretical expectations about purchasing power and consumer mobility, and with the author's empirical observations. The suggestion that high-income areas might be areas of large aggregate purchasing power and therefore attract large numbers of grocery stores was rejected on the grounds that low population density in such areas more than compensates for the higher level of per-family income. It would be interesting to calculate the aggregate purchasing power, defined as (income per family) x (number of families) for each quadrat and to perform correlation and difference matrix analyses using these values. In the present case, the only plausible explanation for the positive correlation of grocery stores with income is chance variation. Although the correlation coefficients were significant at the one per cent level, the coefficient of determination (R^2) of these values is nowhere higher than 0.2, so in fact income explains very little of the spatial distribution of grocery stores. Quadrat boundaries may also have had some effect.

In the peripheral areas there is a marked tendency towards negative values, whereas the values in comparison to population tended to be positive in this area. Recalling earlier cautions about the unreliability of fringe values, one may still suggest tentatively that these peripheral areas are overserviced with regard to population but underserviced with regard to income. Further study of this question would involve detailed study of the tributary areas of peripheral urban stores and of the movement patterns of people in peripheral urban areas.

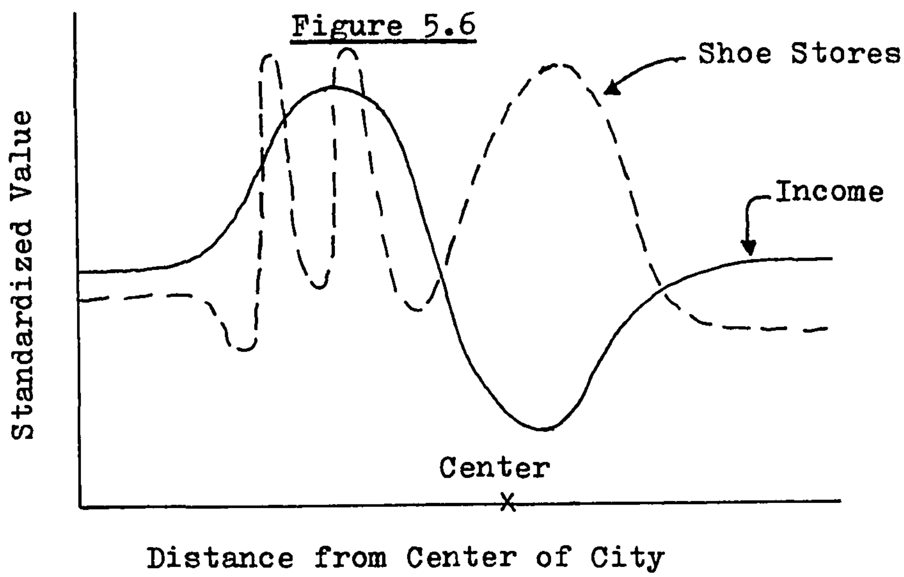
Representative standard values from the outstanding regions of excess and deficiency are: 5.26, 5.35, 6.74 for the east-central area; -4.05, -4.62, -4.41 for the west-neighboring area; 2.87, 2.84, 2.09 for the Pointe St. Charles area.

It is worth noting that, as with store-population differences, there is no strongly negative eastern region corresponding to the west-neighboring area. This lack is much more pronounced in relation to income than in relation to population. It is probably due to the presence in this eastern-neighboring area of an equally sparse scattering of stores as in its western counterpart, but the absence of the high income levels that would produce strongly negative difference values.

The discrepancies between the grocery store and income distributions are mostly accounted for by the same factors that explain discrepancies between grocery stores and population. The overall pattern remained remarkably stable from 1950 to 1970, not because of stability of individual grocery stores (this is contradicted by inspection of the original data) but because supermarket chains have taken up much of the slack caused by any changes in income distribution, because income patterns themselves have been remarkably stable, and probably because of a certain inertia in the locational preference structures of small grocers.

Shoe stores exhibit much the same relationships to income as do grocery stores (Figure 5.6), except that the neighboring and even the peripheral areas are spotted with strong positive values which reflect concentrations of these stores in shopping centers, both planned and unplanned (e.g. 6.01, 4.62 for the St. Hubert Street center in 1950; 1.35 for Les Galeries d'Anjou in 1970). A clear dependence on pedestrian traffic is reflected in the downtown and St. Hubert Street concentrations and in the east central area, where automobiles are few and population dense and the consequent large volume of foot traffic seems to attract shoe retailers in spite of the low incomes prevalent in the area. It is always possible, however, that since a shoe store is not too expensive to set up, there are at any given moment a number of non-viable stores in existence, as with grocery stores. In interpreting the shoe store pattern, one must remember that many distinctions have been obscured in the analysis: size of store; men's, women's, and children's shoe stores, which involve different consumer habits and preferences and therefore have different locational tendencies; and

Figure 5.6



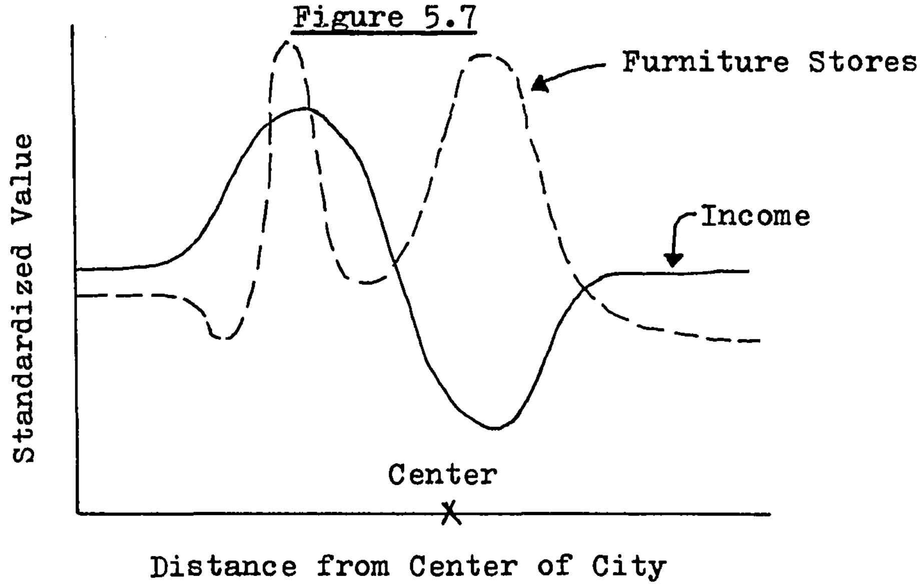
For title see Figure 5.5.

quality of shoes offered (stores range from discount and cancellation outlets to boutiques selling high-quality and even hand-crafted or custom-made shoes). There is perhaps a greater variety of locational preferences within a broad category of clothing store than within any other store category. Peripheral areas tend to be negative relative to income, as do grocery stores.

In 1950, the absence of many positive peaks in the neighboring and peripheral areas is evidence that shopping centers, especially planned ones, were not well-developed outside the downtown area, and that the CBD was still clearly the focus of shoe shopping. It is interesting to note in this connection that the newer planned shopping centers are much more likely to include shoe stores than small groceries, except for specialty food stores such as delicatessens. Therefore, a wider divergence between shoe store and grocery store location patterns appears likely in the near future. In 1970, there were many more outlying peaks and some of the inner-city concentrations, such as that on Ste. Catherine East, had actually shrunk slightly.

Except for the absence of a strong downtown peak, the standardized difference matrices between furniture stores and income exhibit generally the same pattern as those for shoe stores and income (Figure 5.7). Surprisingly enough, high positive values persist in the east-central and Pointe St. Charles areas (e.g. 5.22, 4.50 in 1950; 2.41, 6.91 in 1970), indicating that there is a surplus of stores relative to the low incomes in this area. Some of this concentration may be explained by the presence of firms such as office furniture stores which do not sell to residential consumers, and by size and price differences among stores. However, it still seems necessary to postulate some breaking down of the socio-economic barriers (to be discussed later) which prevent "outsiders" from coming into the poorer areas of the city to shop. Firms are probably taking advantage of economies in the form of older buildings and land which is cheaper than that in the CBD (though still expensive relative to suburban land) and counting on the high utility offered by their merchandise to induce consumers to travel a considerable distance (incur travel disutility)

Figure 5.7



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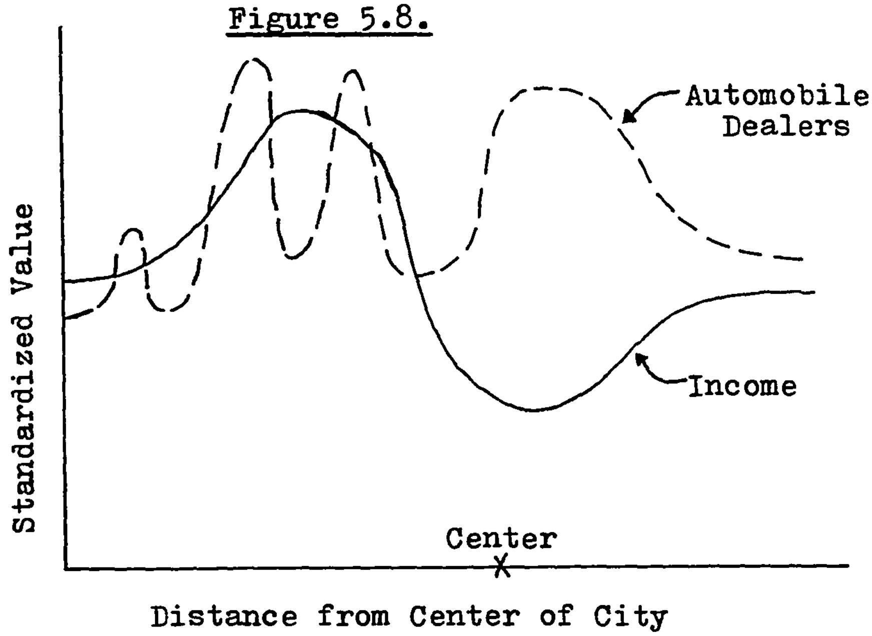
to reach their store. These inner-city concentrations probably also reflect the observed stability of retailers of more expensive goods. In spite of the space-consuming nature of the business, there is a certain concentration of furniture stores in the general downtown area; it is hard to tell at the 3000-foot quadrat scale whether this slight concentration is actually a little "off-center", but at any rate it gives evidence that the CBD has a considerable "pull" even for space-consuming activities. The western neighboring area shows some positive peaks, but they are less pronounced than those for shoe stores; this suggests that a cluster of furniture stores contains fewer (though perhaps larger) units than a cluster of shoe stores.

The main difference between the 1950 and 1970 patterns is that the concentrations in the western neighboring areas were not apparent in 1950. It is proposed that at that date most of the purchasing power in this area was still oriented towards downtown, whereas in 1970 more western consumers satisfied their furniture needs without going downtown. This would of course have to be confirmed by study of consumer travel patterns.

Automobile dealers exhibit much the same relationships to income as do shoe and furniture stores (Figure 5.8). Concentrations are relatively pronounced and persist in the poorer areas east and southeast of the city center (e.g. 1.98, 5.26 in 1950; 2.75, 3.24 in 1970). In this case, it is clear that many buyers must come from other sections of the city

Figure 5.8.



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and even from outside Montreal. The only important change from 1950 to 1970 is the addition of peaks at the outer edges of the city.

IV. Store Types and Retail Stores as a Group

The relationships between individual store types and retail stores as a group are much more complex than those involving population and income, to the point where no hypothetical profiles could be drawn of them. Though correlation coefficients between quadrat values of individual store types and retail stores as a whole were quite large and highly significant, the standardized difference matrices do not show such a consistency of association, and therefore the areal generalizations used in the preceding sections could not be made.

Grocery stores exhibit a marked deficit in the downtown area, which is clear even in 1950 (e.g. -0.92, -1.34) and much more extensive and pronounced in 1970 (-4.60, -6.14), and which is possibly caused by the crowding out of grocery stores from the CBD retail mix due to land-use competition. The area northeast of the city center, where the relationships between stores and population and between stores and income were quite clear, is characterized by a mixture of positive and negative values that defies generalized description. Examination of the standardized data matrices for grocery stores and for retail stores in general reveals that both are highly concentrated in this general area, but that they do not covary from quadrat to quadrat. It is suspected from this and the results of the distribution fitting that the association between grocery stores and retail stores in general (which gives rise to the high correlation) is operative at a small enough scale so that it is not reflected in this analysis. Some statistical attributes of the analytical method which may be affecting the retail store results will be discussed at the end of this section.

Outside the central city, peaks are found which generally indicate an excess of grocery stores in an existing retail agglomeration. It is worth pointing out, however, that in many cases the retail agglomerations themselves are small, so that two or three grocery stores look like a heavy concentration, and also that most of the peaks are not outstandingly large. It is clear that these peaks represent centers where land-use competition has not yet reached such an intensity as to crowd out the grocery stores. A general deficit in the western sections of the city suggests that the supermarket has taken over the majority of grocery retailing functions in that area.

The areas of concentration changed little between 1950 and 1970, supporting the observation of "inertia" in grocery store locational preferences in spite of high turnover of individual stores. The only noticeable changes were the expansion of the downtown area of negative values and the appearance of a few more small peaks in the western areas of the city.

Shoe stores exhibit a strong downtown concentration (e.g. 3.03 in 1950; 2.57, 6.83 in 1970) relative to retail stores in general, surrounded, except to the west, by regions of strong negative values (e.g. -3.16 in 1950; -3.51 in 1970). This suggests that shoe stores locating downtown show a strong preference for the CBD over peripheral downtown areas and that they have the rent-paying ability to locate there. The east-central area is a region of negative values (e.g. -2.75, -3.81, -2.20) due to the fact that though there is a concentration of shoe stores there, the area contains an even more pronounced concentration of retail stores in general. It appears likely that the economic limitations of the area, together with the inability of the utility offered by shoes to attract customers from other areas of the city, place a rather low ceiling on the number of shoe stores that can survive there and keep their numbers at a lower level than would be expected from the number of retail stores. It is also quite possible that many residents of the east-central area do their shoe shopping in the CBD to take advantage of the lower prices, wider selection, and better entrepreneurship offered by large downtown firms.

To the west, north, and east of the central city, one finds small, irregularly located concentrations surrounded by deficits or low positive values. The standard values of the peaks tend to decrease as one moves outward from the city center.

The most remarkable change between 1950 and 1970 was a marked increase in the concentration of shoe stores downtown and in the St. Hubert district. It seems contradictory that while all the statistical indices obtained earlier pointed towards a decentralization over time, the clustering tendencies of certain stores should appear to be increasing according to the standardized difference matrices. This phenomenon would be explained if the real tendency were one towards "dispersed concentrations" in the CBD and in outlying shopping centers. Depending on the scale of analysis, this process might well test out as a decentralizing one. One should also note that outlying peaks were much less numerous and less pronounced in 1950 than in 1970; this reinforces the impression that in 1950 consumers from all over Montreal still did quite a bit of their shopping in the CBD, and also indicates that population in the outlying areas was not sufficient to generate sufficient pedestrian traffic in outlying shopping centers to support many shoe stores.

There is no evidence of a marked excess or deficit of furniture stores relative to the overall downtown retail mix. Instead, one finds small, irregularly located concentrations in neighboring areas to the north, west, and east of the city center (e.g. 4.27, 3.23, 2.39). These results may seem surprising in view of the fact that CBD concentrations relative to population and income were observed. One must remember, however, that CBD quadrats have average or below-average values of population and income; relative to these low figures, there does appear to be a surplus of furniture stores. (Of course, these stores are drawing on much more purchasing power than that in their immediate vicinity). Relative to the large CBD agglomeration of retail stores, however, the "surplus" disappears. The neighboring furniture stores are probably those that cannot compete for CBD land due to their high space requirements and yet want some measure of the consumer accessibility that downtown offers.

The absence of concentrations at the edges of the map is also noteworthy. This phenomenon is not unique to furniture stores and raises anew the question of study area size. Was the original study area too large, including people who travel considerable distances to satisfy their shopping needs and whose travel patterns are therefore not strictly urban? Or was it in fact too small to include shopping centers such as those in the West Island, to which people on the edges of the study area may travel outwards? Where, in fact, is the "watershed" between the CBD and peripheral centers? Studies of consumer travel behavior are needed to answer such questions.

The patterns in 1950 and 1970 are similar except that there are fewer peaks in 1950 and a great deal of "shifting around" of furniture store concentrations relative to the overall retail pattern occurs between 1950 and 1970. This last result is unexpected both in view of the observed stability of the furniture-store distribution with respect to population and the generally greater permanence of stores offering higher-priced goods. Perhaps the change in fact took place in the retail store patterns, "around" the furniture stores, so to speak.

The pattern of automobile dealers relative to retail stores as a whole is characterized by strongly positive peaks (e.g. 5.58, 6.01) and strongly negative valleys (e.g. -5.46, -2.89), with a relatively small proportion of quadrats where automobile dealers are "in balance" with the retail store mix. These results strongly suggest a variety in the retail store mix in different shopping centers and point to a need for further research in this direction. One must also note a tendency for automobile dealers to locate in conjunction with compatible establishments such as gas stations and repair garages and in the absence of retail stores of other types.

In 1950, the noteworthy concentrations were the western downtown area, the Decarie Circle area (northwest of the CBD), and a stretch along St. Lawrence Boulevard (northeast of the CBD). In 1970, the St. Lawrence Boulevard concentration had disappeared and a strong new one in St. Leonard, much farther to the northeast, had emerged. These all seem to be areas where major traffic flows not only within the city but from outside would converge, but there appears to be no reason other than chance why these areas of confluence were chosen above others. In the east-central area, one finds deficits or small positive values, except for the St. Lawrence concentration in 1950. The general deficiency of automobile dealers in relation to the total retail mix is attributable to the low purchasing power in the area and the socio-economic barriers between this part of the city and the wealthier western sections. Even in western areas, many moderately negative quadrats are found; most of these turn out to be small-to-moderate retail store concentrations with no automobile dealers. It is worth remembering in this context that automobile dealers tend to be large enterprises and the frequency of purchase of automobiles is low, so that a few dealers can adequately service a large population. This question of frequency of purchase is an important one and will be dealt with further later on.

V. Further Considerations

It is worth noting that the entire statistical process of standardization was carried out without taking into account one basic fact: the store and census data were both integer data, whereas their standardized equivalents theoretically formed a continuum. Where the mean and variance were both large, the discreteness of the original data could be assumed to have little effect. However, in those distributions where the mean and variance were both small (e.g. for the automobile dealers), a tendency was noted for the standardized values to vary in steps rather than over a smooth continuum. This fact introduces a certain element of unreliability and arbitrariness into the conclusions regarding automobile dealers and possibly furniture stores. The income distributions, which had a large mean but a comparatively small variance, may also have been affected, and the distributions of retail stores as a whole certainly were. One explanation of the confusing patterns shown by the standardized difference values relating to retail stores as a whole may lie in the fact that two store distributions, both with relatively small means and variances, were being compared, and such distributions, with their tendency to clump around certain values rather than form a continuum, may be less stable under the influence of random fluctuations in the observed data than the population and income distributions.

One must also note that there are considerable differences in the means and variances of the census data between 1950 and 1970. With this in mind, one must question whether comparison of the standardized data through time is justifiable. On a macro scale, it probably is, for there it is the relationship of a local retailing situation to the prevailing pattern over the whole city that is under study. On a micro scale (i.e. individual quadrats), it is very possible to misrepresent the situation, for a given quadrat could contain the same number of stores (indeed, the very same stores) in 1970 as in 1950 and yet show a substantial change in standardized value because of changes in the mean and variance for the whole study area. It seems that one must keep constantly in mind that the standardized difference matrices do not describe local retailing conditions absolutely and in isolation but only in relation to city-wide trends; they measure concentration of a particular store type not only relative to other conditions in a particular quadrat but relative to the overall distribution of that store type over the urban area.

One of the obvious large-scale patterns evident in many of the standardized difference matrices is a large area of store deficiency in the west-neighboring area and a relatively nearby area of store excess in the east-central area. While much of this tendency is probably accounted for by differences in store size, much of it is also probably compensated for by consumer mobility from one part of the city to another. For example, it is well known that consumers from the highly mobile population in the western part of the city still do much shopping in the CBD (among female consumers from this population, "going downtown shopping" is almost a ritual). In effect, mobility compensates for possible underservicing of some of the western residential areas.

It is noteworthy, however, that very little cross-movement seems to take place between the west-neighboring and east-central areas, the regions of most pronounced deficiency and excess, respectively. The most likely explanation for this is the existence of a socio-economic barrier which has been erected not only by differences in income, ethnic origin, etc., but more specifically by differences in shopping habits and preferences which arise therefrom. Experiential observation suggests that the population of the western sections of Montreal exhibits the following traits relevant to shopping behavior: a high valuation of bigness and efficiency, leading to a preference for large chain stores over small groceries; a conservatism as businessmen and investors, leading to a greater trust in large, well-established firms than in smaller, more unstable ones; a high cultural value placed on cleanliness and newness; a widely varied diet and a demand for consistently high-quality food, including expensive items such as out-of-season vegetables and prepackaged dinners. On the other hand, the population of the eastern inner-city area places more value on: the friendliness of a small store where often one knows the grocer personally; a high frequency of personal contact with employees and other shoppers; the possibility of obtaining a certain amount of credit on a friendly, informal basis; a sense of community and neighborhood; a trust in small enterprises which are "closer to home" and not under the control of outside, presumably hostile interests (cf. preference of "caisses populaires" to banks by people in poorer areas); established and somewhat limited food preferences; familiarity with small stores as opposed to large ones, often derived from a rural background. In fact, the people of this area often seem to patronize the small groceries in spite of the fact that the big chain stores, which benefit from economies of scale, can charge less. Direct study of these cultural variables and their influence on shopping mobility would be an interesting direction for further research. Another possibility would be incorporation of the concepts of diffusion research, with "barriers" conceived as inhibiting the flows of consumers, much in the manner of existing migration studies.

A further reason for the lack of consumer movement to the east-central area from other parts of the city is that this part of town is not designed to handle the automobile. Narrow streets, lack of parking facilities, heavy traffic including many commercial and industrial vehicles, a complex traffic pattern, the obstacles caused by parked and stopped vehicles, all discourage the car-borne consumer from shopping here. In effect, a whole area of the city has become functionally obsolete in a retailing sense, and its retail clientele is stringently limited to pedestrians and users of public transportation.

In moving from the edges to the center of the standardized difference matrices, one notes a progression from indeterminate values at the city fringes to strongly apparent concentrations and deficits near the city center. It is tempting to postulate a sort of evolution in the pattern of retail servicing as urbanization increases. Perhaps a Poisson pattern of store location in a peripheral area becomes a more or less "balanced" servicing pattern (with maybe a slight deficit due to CBD shopping) as the area becomes more developed. As urbanization continues, imbalances develop, either functional ones well-supported by outside consumers (the CBD) or dysfunctional ones with an excess of stores relative to purchasing power, a high rate of business failures,[1] and characteristics which make it difficult for the area to attract consumers (the east-central area). To verify this postulated development, a study over a long period of time, carefully related to the degree of urbanization at each point in time, would be needed. A precise definition of "urbanization", including components of

1. Simmons (1964), p. 72.

areal growth, population density, and extension of urban transportation and service centers, would have to be formulated if such an evolutionary theory were to have any meaning. It is also evident that detailed study of consumer travel patterns and the various sets of consumer needs is necessary to judge whether the retail pattern in a given area is serving the population in a satisfactory way, and in fact to determine what population is being served from a given set of retail stores.

CHAPTER 6

GENERAL DISCUSSION

The preceding chapter contained detailed interpretation of the results of the various types of analysis as each was considered in its turn. The remarks which follow are meant to apply either to the whole spectrum of results or to a considerable segment of them. Characteristics of and changes in the urban environment which presumably affected the entire analysis will also be examined. Some of the points raised here will hopefully provide a clearer perspective on the interaction between consumers and retail stores in urban space. Finally, an attempt will be made to relate the results to existing theories of consumer behavior and of agglomeration.

I. Meaning and Validity of the Statistical Measures

Several of the analytical methods used, namely nearest neighbor analysis, quadrat analysis, and Geary contiguity analysis, provide a statistical index of something vaguely termed "clustering" or "concentration". As long as one looks at one data set, or at the same data set at different points in time, the results can be interpreted in a straightforward manner. However, if there is any variation in the composition of the data sets under comparison, problems arise. This applies particularly to the case where the two data sets contain different numbers of points, and to the case where specific points appear or disappear in the course of a time period. Both of these conditions are obviously present in a comparison of retail store distributions across time. Now an index suggesting deconcentration can arise (as previously remarked in the section on hypotheses) in two ways: by the dispersal of a given number of points over a wider area, or by the addition of points at the vacant outer fringes of the study area. When the number of points involved is not constant, it is impossible to tell from the index alone whether the first, the second, or both processes are operative. In other words, the index describes only the way the pattern _is_ at a given point in time, without any indication as to how it came about. As with distribution fitting, process cannot be inferred from pattern. Some insight into this confusion may be gained in the present case by use of the mean/variance ratios from the medium and small subareas, which presumably exclude the fringe areas where addition of points would take place. However, the "presumably" is an important qualification; granted that a central-city area may exist where the degree of concentration of a particular store type is more or less constant over time, no criteria exist for outlining this area in advance and therefore there is no guarantee that the medium and small subareas used in this study coincide with such areas of stability. Some additional insight into the manner in which deconcentration tendencies are operating over space can be gained from the standardized difference matrices, but the difficulties involved in comparing these over time have already been noted. Another approach to the problem is to "tag" points as appearing, disappearing, or persisting over a given time period, as Bell (1970) did in his discriminant analysis. It is not clear, however, how such a system could be incorporated into point pattern analysis.

It has been previously noted that the above statistical indices are all aspatial, and that only with the correlation analysis and the standardized difference matrices was it possible to give the problem some spatial dimension. However, in the latter analyses there were many anomalies and difficulties of interpretation, and the results were so closely tied to the geography of Montreal that they would have no meaning in any other circumstances, whereas the statistical indices can be compared for different cities as well as different activities and different points in time (as in Rogers (1969)). Clearly there exists a trade-off between spatial definition on the one hand and conciseness and comparability on the other, which any research in point pattern analysis has to take into account.

Previous discussion has also touched on the question of the importance of the pattern of clusters as well as the pattern of individual stores. Further speculation on this problem immediately runs into the difficulties of defining clusters (Garner, 1966) and of assigning them point locations for analytical purposes. The possibilities of better distribution fits when cluster patterns are taken into account, and of theoretical connections with central place theory, seem to justify further efforts in this direction, in spite of the operational problems involved.

Point pattern analysis must also confront at some time the problem of causality. In one form, this is the problem of identifying the process that generated a given pattern. In this study, only the distribution-fitting exercise directly approached the question of process, with little success. Due to the fact that inferring process from pattern is logically inadmissable anyway, one may well conclude that studying process directly or developing theoretical justifications for the existence of processes may be more fruitful approaches. Harvey (1966, 1969) does suggest that distribution fitting can at least give clues about generative processes, but this seems feasible only in the case of an exceptionally good fit using a distribution of unequivocal origins, a situation which did not obtain in the present study.

In another form, the problem of causality is that of interpreting correlations, a question which has already been touched upon. It will be seen that in some cases the causal links between two highly correlated phenomena are most likely not direct and probably consist precisely of the factors of functional association, agglomeration economies, and consumer accessibility which are considered elsewhere in this thesis.

II. Lag Effects

In the present analysis, the 1950 store data were compared with 1951 census data, and the 1970 store data with

1966 and 1961 census data. As noted in the earlier section on the correlation analysis, the correlations between store types and population and between store types and retail stores as a whole (both involving 1966 census data) decreased from 1950 to 1970, but those between store types and income (involving 1961 census data) increased. This result is surprising in view of the extreme stability of the income distribution over the period 1950-1970; there seemed to be no major shifts requiring readjustments that might raise the correlation. One tentative suggestion is that the greater prevalence of CBD shopping in 1950 diminished the need for store concentrations in higher-income areas, but another interesting possibility is that the increased correlation is accounted for by the time lag between the 1961 income data and the 1970 store data. In retrospect, it seems logical that the distributions of various store types would take a certain amount of time to adjust to a given population, income, or retailing pattern, or to changes therein. The capital investment required to establish a store has a certain fixity, since it is largely tied up in buildings, equipment, and stock; selling out and moving is onerous and expensive, so most stores will be locationally conservative in the face of short-term change. Furthermore, breaking with an established clientele and with existing external economies of scale entails a risk which many businessmen are reluctant to take. Over the longer term, however, a change in population, income, or retailing patterns might deprive some stores of some of the purchasing power or consumer accessibility on which they formerly drew, resulting in decreasing revenues and increasing pressures to move or go out of business. Thus the store pattern would adjust, with a lag of several years, to a more recent pattern. The lagging of variables is a technique in wide use in economic analysis and would possibly have yielded interesting results in this case.

III. Non-Linear Distance Measures

As has been pointed out previously, many of the indifferent results obtained from point pattern analysis are probably attributable to the fact that the analyses are performed in Euclidean space, or, more specifically, using linear distance measures, whereas man's activities in fact happen in a space where distance is not linear (Watson (1955); Olsson (1965); Bunge (1966)). In other areas of geographical research such as journey-to-work and consumer behavior studies, many attempts have been made to replace straight-line distance by a measure which would more closely approximate the way man views distance. Other objectively measurable quantities such as time-distance have been tried, on the theory that man is more personally involved with his own time than with abstract space and budgets more in terms of it, but the results obtained have not been appreciably different from those using linear distance. In the same vein, it would be interesting in an urban environment to take one's measurements along existing streets, instead of "as the crow flies", perhaps throwing in a delay factor for traffic, to allow for the strong influence of the street grid on urban travel patterns. However, a more direct approach is to try to define "perceptual distance", i.e. to construct an urban space in which distances are as a given person at a given point with a given set of attitudes perceives them. Such a space would probably be extremely "warped" compared to that of an objective map, with short distances indicating a strong orientation towards or preference for a journey along that line and long distances indicating a dislike for travel in that direction. Of course such a map would be different for every person and every location, but undoubtably there would be broad social and locational similarities. One must also point out that distance perception varies enormously with mode of transport, and that there are most likely maximum distances consumers are willing to travel for various goods, beyond which perceived distance in effect goes rapidly to infinity. Further pursuit of this topic leads to discussion of mobility patterns, which will be dealt with later in this paper.

IV. Changes in Retailing, 1950-1970

In interpreting the results of the foregoing analysis, one must bear in mind that several significant changes in retailing occurred between 1950 and 1970. A retail store type is in fact a particular kind of vehicle for moving goods from wholesalers to consumers; if the definition, design, or character of this vehicle changes, clearly pattern analysis based on the old definitions loses much of its value.

The most conspicuous change in retailing between 1950 and 1970 was probably the dramatic increase in scale made possible by the increase in consumer mobility brought about by the automobile, which enabled stores to reap economies of scale due to wider market areas that previously had not been accessible to them. Other results of the advent of the automobile have been the obsolescence of older shopping areas where parking facilities are inadequate and the abandonment of the lowest orders of shopping centers as consumers could reach centers offering a much wider selection of goods with minimal added travel disutility. This last trend has been reinforced by increased consumption of higher-order relative to lower-order goods by an increasingly prosperous consuming population.

An equally important development has been the rise of the planned shopping center, which "... is isolated from arterial uses, specialized areas, and office development, becoming specifically a retailing location."[1] The large parking space needs of these centers and their flexibility of location due to the automobile in effect place them outside the traditional central place hierarchy, with its close dependencies between town population and level of retail services provided. (Note, however, that the total

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1. Simmons (1964); reprinted in Berry and Horton (1970), p. 474.

population that can be served from a given location is still a crucial factor, as witness several of the specific location studies in Applebaum (1968)). The growing preponderance of such centers has vast implications for urban consumer behavior, as will be explained later. Suffice it to point out now that, "... in effect, all older retail concepts-specialization, competition, trade area, and so forth - are being applied to a different level, the center, rather than the establishment."[2]

The classification of stores is also becoming more and more difficult. On the one hand, a variety of types of merchandise is often being sold by the same store. Affiliations between several stores selling the same or different types of merchandise (i.e. the "chain store") have become common. In addition, stratification by price and quality is taking place within store types, producing gradations from the discount or warehouse store to the "boutique" offering high-priced, prestigious merchandise. The provision of services and other non-price inducements is also becoming increasingly important in the retail picture.

One final point to be made here is that the location of retail establishments and the merchandising of goods within these establishments has developed into a science practised by analysts employed by large store chains or by

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2. Simmons (1964); reprinted in Berry and Horton (1970), p. 474.

economic consultants. The author suspects that store location without some sort of scientific advice probably occurs now only on the lower socio-economic levels, where entrepreneurs cannot afford, may not even know about, and probably distrust the advice of "experts." Whether scientific store location will lead to fewer sub-optimal locations and fewer business failures, however, remains to be seen.

V. Significant Characteristics of Urban Space

One fact worth noting about research into consumer behavior is that much of it has been conducted in rural areas (Golledge, Rushton, and Clark (1966); Berry (1967); Berry and Garrison (1958), et al.). As this research continues, studies are also being undertaken in urban environments (Garner (1966); Curry (1960, 1967); Nystuen (1967)). Often, however, these latter studies do not fully take into account the many ways in which urban space differs from rural space, and the effect these differences are likely to have on consumer behavior.

The city contains a high density not only of population and of purchasing power, but of retail stores of all types, and this density, together with the concentration of advertising and mass media in urban areas, entails a high frequency of contact with opportunities for retail purchase by the urban population. The consumer has to choose not only among a large number of stores but among a wider variety of offerings (of total goods and within categories of goods) than is present in the rural environment. The implications of this plethora of choices for his patterns of behavior are interesting and largely unexplored.

Another important characteristic of the urban environment is that distances within it are small, especially in relation to the mobility afforded by the automobile. This suggests that in many cases the friction of distance could be almost neglected as a factor in urban consumer behavior, at least for the car-borne consumer; this point will be discussed later at more length. Of course one must note that the city contains perceptual barriers set up by socio-economic differences, variations in the transportation network, and retailing preference structures, so that, in terms of perceptual distance, the "friction of distance" may in fact be operative.

A third characteristic of the city is the separation between work and residence, which in effect gives many consumers two foci from which their retail interactions emanate. Additional foci may be provided by previously existing social connections or by spare-time activities. The effect of this separation in determining the location and composition of retail centers is considered to be quite important.

In short, the urban environment is a very different "space" from that in which much existing consumer behavior theory has been formulated, and one must be very careful in applying this theory to an environment different from that in which it was developed.

VI. Retail Clustering Tendencies and Consumer Behavior

In this section it will be shown that, given the characteristics of consumer behavior in an urban environment, most retail firms will seek locations within business clusters and show a strong affinity for complementary establishment types, including others of the same type. This discovery not only explains the concentrations observed in this study but points the way to a reformulation of consumer behavior theory in an urban context.

Many researchers, among them Garrison et al. (1959), Curry (1960), Garner (1966), and Nystuen (1967), have shown that multiple-purpose shopping trips are the rule rather than the exception, especially in urban areas. The preference for multiple-purpose trips is explained by the concept that consumers seek to maximize their net expected utility over all purchases. Maximum net utility is determined by deducting disutilities due to travel, absence from home, and time expenditure from the expected value of the goods and services sought. Multiple-purpose trips are conducive to attaining maximum net utility because they permit acquisition of additional goods and services with a minimum of additional travel. The more clustered the store pattern, the greater the saving in travel costs on the part of the consumer.

According to Nystuen (1967), the elements of multiple-purpose trips do not combine randomly but rather according to "functional associations" or "linkages" under the influence of periodicity of demand (Curry (1960)) and compatibility of purchase characteristics (e.g. size, bulk, cost, fragility). Stores offering goods and services frequently purchased on the same trip will tend to cluster together in order to attract the consumer by offering a great reduction in his travel disutility in addition to the positive value of their goods and services. Since convenience goods, with their low cost and frequent demand, are prime candidates for inclusion in multiple-purpose trips, they may well expect to draw more customers in a cluster location than in an isolated location where they could attract only customers on single-purpose trips. This constitutes an explanation of the observed clustering of convenience-goods stores.

The question must be raised, however, whether convenience-goods stores, which generally sell low-value goods, can pay the high rent that a prime site in a business cluster demands, regardless of their desire to occupy it. After all, land-economic theory suggests that all stores covet the most highly accessible locations, but rent-paying ability determines who shall obtain those locations. The obvious explanation is that the economic benefits that convenience-goods stores reap from cluster locations more than offset the high rents they must pay for such locations.

The above discussion suggests that consumers orient their behavior primarily to the shopping center and only secondarily to individual stores. In other words, consumers have perceptual and behavioral orientations relating to shopping centers, and as needs arise they are fitted into this pattern. In turn, each shopping trip serves to reinforce or change the existing orientations, and thus arises a circular causal process between need satisfaction and choice of purchase place, operating strongly in favor of center orientation. The consumer's goal on any one journey will be to find a center which will satisfy all or most of his current set of needs, thus minimizing travel disutility and increasing the utility obtainable from the journey.

This conclusion is supported both by the empirical results obtained in this thesis and by theoretical arguments. As noted above, the theory that consumers seek to maximize the net utility of shopping trips supports center orientation on the part of consumers. The fact that the consumer generally operates under conditions of risk and uncertainty (Marble (1967)) also predisposes him to think in terms of centers and their inventory of stores rather than in terms of individual stores, for thus he maximizes the probability of satisfying all his needs without unexpectedly incurring large amounts of travel disutility. The theory of human decision-making (Shepard (1964)) suggests that the urban environment is too large and complex for man's decision-making capacities to handle, and that for practical purposes he must simplify his perception of it. It is proposed that man as consumer achieves this simplification partly by orienting himself to centers rather than individual stores and partly by limiting the set of stores he will consider. The existence of consumer mobility patterns, which are aggregate expressions of many trips, together with the above-mentioned circular causation which makes repeated trips to the same center highly probable, further reinforces the proposition that the consumer's primary orientation is to the shopping center. Finally, the advent of the automobile has reduced the friction of distance to insignificance for many urban consumers, thus allowing them to take advantage of the opportunities of large shopping centers with minimal added travel disutility, and increasing the attractiveness of centers at the expense of individual stores.

Within the shopping center, where the consumer is on foot, the friction of distance still has considerable importance and may be used to explain the variation in intensity of clustering observed among store types. The hierarchy of concentration observed in this thesis suggests that stores offering the least expensive goods are the most tightly clustered, while stores offering the most expensive goods locate more independently. In other words, mean distance from the nuclei of retail clusters varies directly with the expensiveness of the good offered. It is doubtful, however, that expensiveness is the real causative variable, as it is only one element in the consumer's calculation of anticipated net utility. More likely it is a surrogate for some unidentified variable in the consumer's utility trade-off or behavior patterns.

It is further proposed that the friction of distance from place of residence to the shopping center or store has become negligible in comparison with the friction of distance from the nuclei of shopping centers. This proposition accords well with the empirical findings of this thesis and the concept of utility trade-off. If distance from residence were the main component of the consumer's travel-disutility calculations, as in traditional location theory, the concept of utility trade-off would imply the reverse of the existing situation. Low-utility (convenience) goods would be able to motivate only short trips from home and would be the least free to agglomerate; in fact, these goods show the greatest degree of clustering. One is forced, therefore, either to abandon the eminently reasonable concept of utility trade-off or to accept the conclusion that distance from center nuclei is more important to the consumer than distance from residence. The choice of center, being less constrained by distance than the choice of store within a center, becomes the primary focus of consumer decision, and thus the findings of this thesis support the conclusion that consumers orient themselves primarily in terms of shopping centers.

Since the unit of the urban retail structure has to a great extent become the retail cluster rather than the individual store, it is logical to recommend that future analyses of urban retail patterns should be performed on clusters rather than on individual stores. Such analyses should be accompanied by a fundamental rethinking of the theories of retail location and consumer behavior in the urban framework.

VII. Retail Location and the Theory of Consumer Behavior

In this section, the findings and suggestions of this thesis will be related to existing theories of consumer behavior. Before proceeding with the body of the discussion, the author would like to clarify what can and cannot be proven about consumer behavior from pattern analysis, and what justification exists for assertions about consumer behavior in such a context.

Given a description of retail location patterns, one can theoretically acknowledge the dependence of retail store locations on the behavior patterns of their customers. One can generate and prove theories as to how consumer behavior influences location patterns, starting from a priori assumptions about consumer behavior (see Alonso (1964)). Finally, one can postulate new theories of consumer behavior that are suggested by and consistent with existing retail location patterns and recommend them for proof by other means.

However, there is much that one cannot say about consumer behavior from examination of an existing location pattern. Above all, one cannot prove a theory of consumer behavior from an observed location pattern, since a given pattern can be generated by more than one process, and observed locations reveal nothing about the choice sets or preference structures of the consumer. Moreover, one must remember that any assumptions made about consumer behavior in laying the foundations of the analysis may affect the validity or the applicability of the results.

Furthermore, one must remember that any empirical test of a relationship between consumer behavior and observed location patterns can return only a verdict of consistency or inconsistency; it cannot constitute a proof of a theory in either domain. Since the basic locational factors for retail stores are in fact characteristics of consumer behavior, and since these characteristics set rather narrow constraints around retail location, study of store location patterns without consideration of theories of consumer behavior would likely prove fruitless. To be strictly logical, geographers would have to confine themselves to studies of consumer behavior without any reference to existing store locations, as suggested by Rushton (1969). However, though consumer behavior and retail location interact, consumer behavior is the more fundamental of the two, for a retail firm in its locational decision cannot step outside the bounds that existing consumer preference functions set around it, under pain of bankruptcy; whereas consumer demand, which is often linked to urgent human needs and desires, will likely satisfy itself in some way within any configuration of retail stores. In other words, consumers are more adaptable than stores, and thus the abovementioned interaction is much stronger in one direction (consumers influencing stores) than in the other (stores influencing consumers). Because of this flexibility on the part of consumers, which makes the constraint of retail stores upon their behavior much less tight than the reverse constraint of their behavior on retail stores, studies of consumer behavior relative to existing retail stores and shopping centers can yield much valuable information. In particular, researchers should eventually be able to reject (at least in an urban context) models of retail location based upon assumptions that turn out to conflict with their findings. Studies such as the present one can help in this elimination process and also point out areas of research where analyses of consumer preference structures and journeys-to-consume may be profitably made.

On the basis of the present study, it appears that clustering within types of retail stores makes a hexagonal market area within the city[3] all but impossible. In any case, the hexagonal framework has probably been rendered obsolete in the urban context by the automobile mobility of consumers, the smallness of urban distances relative to rural ones, and deviations caused by such factors as store size, merchandise quality, and patronage preferences. A more tenable approach to the problem of market area definition and central place location in cities can be found in the stochastically oriented studies of Huff (1963) on urban market areas and of Dacey (1966a; 1966b; 1969b) on

3. Isard (1956), pp. 271-273.

central place location.

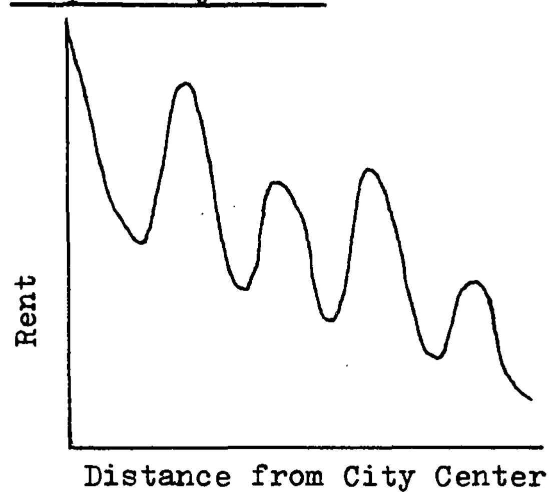
The relationships between preference functions and retail store locations form a topic which deserves much more attention than it has received. Consumer preference functions determine the range of viable store sizes and offerings, the retail mix within centers (by defining functional associations), the rent gradients of store types within centers, the location and spacing of centers, and many other fundamental elements of retail location. In effect, they are the generators of consumer behavior patterns, which are the crucial determinants of retail patterns. It is important to differentiate between individual and collective preference functions, for it is the latter, a sort of "mean" preference function, that affects retail location. However, retail entrepreneurs must also concern themselves with the pattern of individual variations around the "mean" collective preference structures, and with the different "means" of different socio-economic groups.

The results of this thesis contradict the findings of several other researchers (e.g. Rushton, Golledge, and Clark (1967), Rogers (1969)), who have found regular distributions of grocery stores both in rural and in urban contexts. The results of rural studies may here be ignored because of the different geographic scale at which consumer relationships operate in an urban context, which makes distance-minimization assumptions derived from rural research inappropriate. The occasional piece of evidence for regular patterns of convenience-goods stores in an urban setting may, the author thinks, be explained on the basis of interurban and intercultural variation and on differences of scale among the studies.

VIII. Retail Location and the Theory of Agglomeration

It is clear from the present study that, due to consumer propensities for comparison shopping and multiple-purpose trips, agglomeration economies are realized for retail stores to the point where many types of retail activities cannot survive except in an extremely clustered pattern. The following paragraphs will examine some of the relationships between specific elements of agglomeration theory and the results of this study.

Figure 6.1
Cross-Sectional Rent Function Proposed by Isard



The typical cross-sectional rent function (Figure 6.1) proposed by Isard, which plots rent against distance from the city center, appeared to be validated by the standardized difference matrices, though the pattern of subordinate peaks seemed to vary with directional orientation; that is, one cross-sectional curve may well not represent adequately the rent tendencies in an entire city, useful though it may be as an abstract summary.

The contention that shopping-goods retailers benefit from agglomeration economies whereas convenience-goods retailers do not was almost entirely unsupported by the evidence of this thesis. The observed concentration patterns can be better explained by theories such as that of consumer utility substitution, which take no account of the distinction between convenience and shopping goods. However, it remains possible that the causal mechanisms that induce clustering are different for the two types of goods. It is suspected that shopping goods cluster because of a direct attraction of two or more stores of type A for each other, due to the consumer's desire for comparison shopping. On the other hand, two or more convenience-goods stores of type A' are presumed not to have any particular attraction for each other, since comparison shopping is of minimal importance to them. They are, however, involved in functional associations with stores of types B, C, D, etc., and therefore they exhibit clustering. The economies reaped may be compared to Hoover's (1948) localization and urbanization economies for shopping and convenience goods respectively. In other words, in the case of shopping goods stores, the presence of store S_1 directly causes an increase in the probability that stores S_2, S_3, ..., will locate nearby. In the case of convenience goods, the presence of a complex of stores which have functional associations with store type C causes location of stores C_1, C_2, ..., in the cluster; if the presence of C_1 causes any increase in the probability of C_2's locating nearby, it is indirect causation through the medium of functional association. Of course, it is equally possible that functional association is the primary direct causative factor for clustering of both types of stores, in which case the convenience-shopping goods distinction would become meaningless for urban location theory.

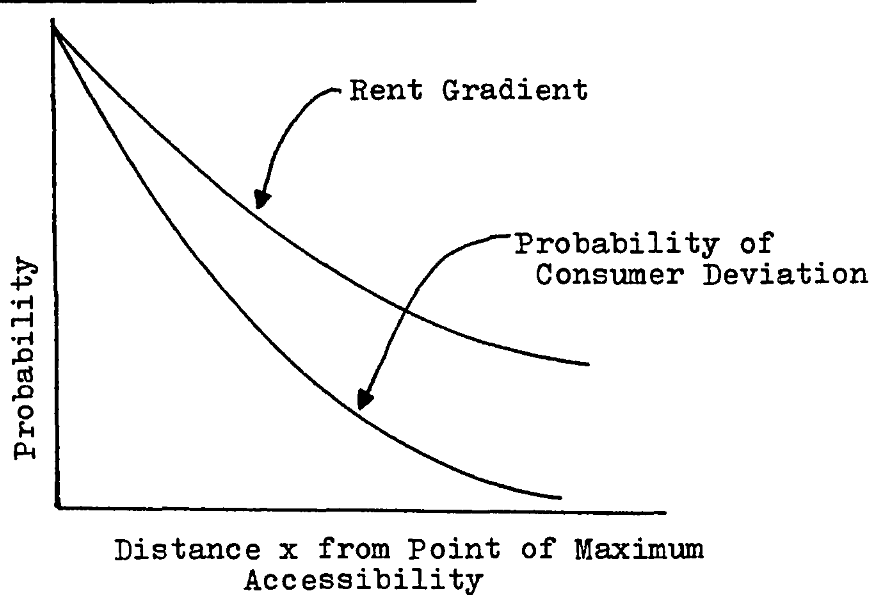
It is important to emphasize at this point the role of time in the development of agglomerations. On the one hand, the character of a retail cluster changes as each new store is added. More precisely, the agglomeration economies that are available for each store type, and the probability that a store of each type will enter the cluster, change. Thus the direction of development of a retail cluster and the spatial patterns that result are heavily dependent on a temporal sequence of events. On the other hand, changes which occur in the larger urban environment affect agglomeration economies and locational probabilities in given retail clusters. Population and income shifts and technological and cultural evolution are examples of such change. The role of time in retail location, especially at the small scale of the individual cluster, has received only superficial attention in this thesis and has seldom been dealt with in the existing literature.

Hoover's (1948) discussion of rent gradients and their relationship to the agglomeration tendencies of the firm provides material particularly relevant to questions of retail location within clusters. His theory is that firms whose rent-paying ability falls off most sharply with distance from the point of maximum accessibility to consumers within a cluster of stores will show the strongest tendencies to agglomerate. However, the causal connection between distance and rent-paying ability seems to require an intermediate causal agent related to consumer behavior patterns. The introduction of the concept of net utility maximization, a probabilistic model of consumer behavior, and a probabilistic view of the rent-paying ability of the firm (stating that for firms which reap agglomeration economies, the probability of being able to pay the rent for a site decreases in all directions from the point of maximum accessibility within a cluster) make it possible to identify this intermediate factor. It becomes apparent that the probability of consumer deviation from the point of maximum accessibility (or, in other words, the probability of patronage) varies inversely with a firm's distance from that point and thus decreases the rent-paying ability of the retail firm at greater distances. This probability of consumer deviation represents the mechanism by which increase in distance from the point of maximum accessibility causes a decrease in rent-paying ability.

As a store selling low-value goods deviates farther and farther from a central location, the probability of a consumer's patronizing the store drops off sharply, because the utility of the good can no longer compensate for the travel disutility he must incur. Thus it becomes less probable that the entrepreneur can pay the rent at the more distant location, even though it is lower than the rent at the central location. On the other hand, a store selling high-value goods can move a considerable distance away from the optimal location and still attract customers by virtue of the large utility its good can offer. Therefore a theoretical curve of probability of consumer deviation against distance can be drawn, similar to the curve of rent against distance, and by the above arguments the former curve should fall off faster than the latter. These relationships are illustrated in the following diagram.

Figure 6.2.

Relationships among Rent, Distance from Cluster Center, and Probability of Consumer Deviation



"Probability" = with reference to the consumer, the probability that he is willing to deviate a distance x from the point of maximum accessibility within a cluster.
With reference to the firm, the probability that the firm in question can pay the rent at distance x.

With all this emphasis on the strength of agglomeration economies for retail stores, one must still ask whether deglomerative forces have begun to operate in certain over-congested areas of the city. Montreal does not seem, to the author, to have felt the effects of deglomerative forces on its CBD to any great extent, but in the area northeast of the CBD, some types of stores registered substantial decreases in numbers during the period 1950-1970, indicating that the area has reached a sort of saturation for certain stores and that deglomerative forces are at work. It should be further noted that "deglomeration" in a declining business area may in part take the form of a reduction of the profit margin of existing firms and thus be invisible on a map.

Several instructive comparisons between Weber's industrial location theory and the factors governing retail location are possible. Whereas Weber uses three factors (transport costs, labor costs, and agglomeration economies) to explain industrial location, retail location requires only two: accessibility and site rent. Retail location theory is, however, complicated by the fact that one must look at retail location simultaneously from two points of view: that of the firm, in which case accessibility and site rent are the important factors; and that of the consumer, in which case some form of utility substitution analysis is recommended. In industrial location theory, the firm's transport costs on raw materials and finished product are the crucial variable; in retail location, the firm's transport costs are less significant, while the consumer's travel costs are an important element of his utility trade-off, which is in turn a crucial determinant of retail location. Finally, non-economic inducements to deviate from the theoretically optimal location must be included in retail location theory, since consumer behavior, with its many non-economic and non-optimizing elements, forms a crucial part of this theory.

CHAPTER 7

CONCLUSION

In this chapter, the validity of the hypotheses which were formulated in Chapter 2 will be briefly discussed. Conclusions and suggestions for future research will also be included.

I. Relation of Results to Hypotheses

Clearly Hypothesis 1 does not stand in the form in which it was stated. Not only shopping-goods stores but all stores exhibit marked clustering in the urban environment. The theoretical explanations that were found for this observation bore no relationship to the traditional convenience-shopping goods distinction, and therefore one may conclude that this distinction is irrelevant to the determination of urban retail location patterns, whatever other theoretical value it may have.

Hypothesis 2 was upheld by the research results, and can even be extended to all stores rather than just shopping goods outlets. It was further noted that "expensiveness" appeared to be a surrogate for some utility-related variable which could be of great significance in the geography of retail location.

The first part of Hypothesis 3 was only partially substantiated. The numbers of furniture dealers and shoe shops increased markedly from 1950 to 1970, but those of automobile dealers and small grocery stores remained more or less constant, for reasons explained earlier. The second part of the hypothesis, that the number of stores would remain more or less constant in the central city, did not stand; noteworthy changes, both increases and decreases, were observed for all store types studied. However, this may in part be due to the arbitrary nature of the central subarea used in this analysis.

The first part of Hypothesis 4 was upheld by the study results; an overall deconcentration over time was shown by all the statistical indices. However, the second part of the hypothesis, that stability would be observed in the central city, proved not to be true in general. Both increasing and decreasing concentration tendencies were observed, in addition to some cases of stability. Again, the arbitrariness of the central study area may have influenced the results.

Hypothesis 5 and the first part of Hypothesis 6 stand without qualification. However, correlations of convenience goods stores with income proved to be higher than those of shopping goods stores with income, which constitutes a reversal of the second part of Hypothesis 6. The third part of Hypothesis 6, that both sets of correlations are decreasing through time, was considered to stand, since the increase in the income correlations was believed due to methodological factors.

Hypothesis 7 stands only in part, and not in the spirit in which it was intended. Not only shopping goods stores but also convenience goods stores showed high correlations with retail stores as a whole (in fact, the grocery store correlations were the highest of all), and, with the exception of furniture stores, the correlations of individual store types with retail stores as a whole decreased over the period 1950-1970. This last fact is perhaps evidence of the development of a certain degree of specialization among retail centers, along the lines suggested by functional associations, during this time period. If this were true, an individual store type would have a reasonable probability of association with any retail center in 1950, but in 1970 the set of retail centers with which this store type would associate with more than a negligible probability would consist only of those centers with the proper functional mix. Further empirical research would be needed to determine whether such a specialization of centers had in fact taken place.

II. Concluding Remarks

The results of this research have tended to strengthen the hope expressed at the beginning of this thesis, that a conceptually simple lawful explanation of retail store location exists and is attainable. Such an explanation could not be achieved in this study because the research did not include the detailed study of consumer behavior patterns without which observed store patterns are only the spatial evidence of unknown processes, nor did it study the observable structure of retail clusters. It became clear, however, that the concept of utility could well afford a solid foundation on which to construct such an explanation in future.

The point pattern analysis undertaken in this thesis was extremely comprehensive, and one might well assume that any information that could possibly be extracted by these methods emerged in the present study. However, due to time limitations, many extensions of the analysis were left undone, for example, the extension of the Geary contiguity analysis to smaller quadrat sizes and smaller study areas. However, one point became very clear in the course of interpreting the results: point pattern analysis is in most cases a sterile exercise without the help of existing theory on probable generating processes and direct empirical study of the factors that produce the pattern. By itself, point pattern analysis yields a minuscule amount of information compared to the amount of effort that generally must be put into it, especially for a large number of points. It is useful, however, in sorting out theories in terms of their consistency with observed results, in quantifying, ranking, and classifying a set of observed patterns, and in describing the spatial expression of observed processes.

The influence of the urban setting of the study proved to be of the highest importance. The urban environment has its own particular characteristics, such as: high population density; short and generally non-linear distance relationships; complex interaction patterns; a high degree of social, economic, and cultural diversity; and multiple foci of interaction, among many others. These characteristics must be taken into account in any empirical study and any elaboration of theory in an urban context.

III. Suggestions for Further Research

The results of this thesis suggest many directions for future research. In the area of point pattern analysis, one of the most urgent needs is for a mathematical justification of the equivalence or non-equivalence of the various methods for the sorts of point pattern most frequently encountered. Without this, any researcher is forced to use more than one method on the same data to avoid being deceived by the shortcomings of any one method, and the magnitude of the resulting research effort may prevent him from exploring any of his methods fully enough to realize their potential. Even a method for testing a point pattern beforehand for the existence of certain definite abnormal situations which would distort a given method of analysis would be helpful. Some method of weighting the points, and of incorporating the weighting into the pattern index, would also be highly desirable.

In a more empirical vein, the identification and pattern analysis of retail clusters would seem to be a logical development from the arguments of the present thesis. Such a project would involve many methodological problems, such as the definition of a cluster, the determination of the limits of a cluster, and the location of some sort of "center of gravity" for the cluster so that point pattern analysis could be applied. It might even be desirable to devise methods of pattern analysis that permitted the elements of the pattern to be areal figures instead of points.

In the very specific context of the subject matter of this research, there seems to be a need for a comparative study of the locational patterns of supermarkets and of small grocery stores, and for some determination of the extent to which their functions and their tributary populations overlap. Further study of the effect of socio-economic variation on retail store patterns is also indicated.

A large-scale study such as this one necessarily loses much detailed information and must be complemented by small-scale research. Detailed studies of the spatial and functional structure of retail nucleations, and on the structure, composition, and periodicity of the journey to consume, are needed in much greater number, variety, and depth.

The possibility of gaining information about process via a more enlightened application of distribution fitting, especially of compound distributions, must not be ignored, though information about process can logically be inferred only if the generating process for the distribution is unique or if there are clear theoretical reasons for a choice among more than one generating process (Harvey (1969)).

Finally, non-linear distance measures have many promising applications in the urban field. Hopefully means will be found to construct or approximate the perceptual space in which urban consumer behavior actually takes place. The author thinks that only in this way will we be able to test conclusively in urban space many of the classic geographic theories about distance. Unfortunately, such research is in an early and tentative stage, as, in fact, is much of urban retail geography.

APPENDIX: TABLES AND SUPPLEMENTARY FIGURES

Key for Figures A4-All

0 stores
1 store
2 stores
3 stores
4-5 stores
6-9 stores
10-24 stores
25+ stores

TABLE 1

Nearest Neighbor Statistics by Year and Store Type, for Ten Orders of Nearest Neighbor

	Order of Nearest Neighbor									
	1	2	3	4	5	6	7	8	9	10
Automobiles 1950	.3335	.3794	.3900	.4183	.4195	.4286	.4505	.4583	.4644	.4955
Furniture 1950	.3594	.3744	.3851	.3980	.3997	.4077	.4126	.4152	.4288	.4401
Shoes 1950	.2987	.3198	.3247	.3421	.3362	.3719	.3684	.3691	.3665	.3811
Groceries 1950*	.4170	.4193	.4648	.4901	.4773	.4941	.4975	.4982	.5118	.5140
Automobiles 1970	.5071	.6450	.6683	.6541	.6525	.6880	.6867	.7308	.7367	.7454
Furniture 1970	.5067	.5494	.5982	.6084	.6255	.6264	.6310	.6284	.6334	.6422
Shoes 1970	.3158	.3696	.3920	.4201	.4357	.4706	.5070	.5152	.5304	.5393
Groceries 1970*	.5005	.5489	.5496	.5501	.5462	.5659	.5753	.5845	.5899	.5966

* Values from 37% sample.

Table 1a

Formulae for Expected Nearest Neighbor Distances, Orders 1-10

Order of Nearest Neighbor	Formula
1	$\bar{r}_{E(1)} = 0.5000 / \sqrt{D}$
2	$\bar{r}_{E(2)} = 0.7500 / \sqrt{D}$
3	$\bar{r}_{E(3)} = 0.9375 / \sqrt{D}$
4	$\bar{r}_{E(4)} = 1.0937 / \sqrt{D}$
5	$\bar{r}_{E(5)} = \bar{r}_{E(1)} \times 2.5267$
6	$\bar{r}_{E(6)} = \bar{r}_{E(1)} \times 2.7672$
7	$\bar{r}_{E(7)} = \bar{r}_{E(1)} \times 2.9900$
8	$\bar{r}_{E(8)} = \bar{r}_{E(1)} \times 3.1956$
9	$\bar{r}_{E(9)} = \bar{r}_{E(1)} \times 3.3900$
10	$\bar{r}_{E(10)} = \bar{r}_{E(1)} \times 3.5731$

where D is the density of points per unit area.

Thompson (1956) gives a general formula for calculating expected distance values for the fifth and higher orders of nearest neighbor.

Table 2

Mean/Variance Ratios

Quadrat Size	Large Area 3000'	Large Area 1500'	Large Area 750'	Medium Area 3000'	Medium Area 1500'	Medium Area 750'	Small Area 3000'	Small Area 1500'	Small Area 750'
Automobiles 1950	.2875	.4169	.6117	.2884	.4096	.5983	.3977	.5500	.7224
Furniture 1950	.2196	.3773	.5302	.2392	.4246	.5430	.2960	.4718	.5487
Shoes 1950	.1170	.1804	.3171	.1227	.1818	.3145	.1278	.1580	.2669
Groceries 1950	.0401	.1103	.2928	.0757	.1227	.3119	.2038	.1652	.3818
Automobiles 1970	.5068	.6523	.7501	.5014	.6073	.6914	.8382	1.0603	.9800
Furniture 1970	.2866	.4428	.6420	.2710	.4335	.6182	.3201	.4477	.5795
Shoes 1970	.0933	.1370	.2215	.0960	.1218	.1958	.0931	.1061	.1544
Groceries 1970	.0775	.1884	.4474	.0929	.2040	.4676	.2488	.2809	.5769

Table 3

Geary Contiguity Index Values, for Large Study Area and 3000' x 3000' Quadrats

Automobiles 1950	0.6501
Furniture 1950	0.5475
Shoes 1950	0.5571
Groceries 1950	0.2391
Automobiles 1970	0.7334
Furniture 1970	0.5858
Shoes 1970	0.5911
Groceries 1970	0.2657

Table 4

Mean/Variance Ratios for Interpolated Quadrat Census Data: 3000' x 3000' Quadrats

	Large Study Area	Medium Study Area	Small Study Area
Population 1951	0.1336	0.1829	0.3547
Income 1951	5.5286	2.2789	75.0857
Retail Stores 1951	0.0624	0.0724	0.1266
Population 1966	0.1772	0.2109	0.6276
Income 1961	1.6428	1.0679	24.0000
Retail Stores 1966	0.0931	0.1032	0.2057

Table 5

Correlation Coefficients between Store and Census Data

	Population 1951	Income 1951	Retail Stores 1951
Automobiles 1950	0.5257	0.2766	0.5387
Furniture 1950	0.6752	0.2790	0.6843
Shoes 1950	0.6624	0.2589	0.7204
Groceries 1950	0.8653	0.3498	0.8399
	Population 1966	Income 1961	Retail Stores 1966
Automobiles 1970	0.4105	0.3743	0.4036
Furniture 1970	0.6706	0.3418	0.7323
Shoes 1970	0.5687	0.2945	0.5817
Groceries 1970	0.8326	0.4309	0.7875

All correlation coefficients were found to be significant at the one per cent level.

Table 6

Fitting of a Negative Binomial Distribution - Moment Estimators

	3000' Quadrats			1500' Quadrats			750' Quadrats		
	Chi Square	df	Prob.of* Chi-Sq. Obs.	Chi Square	df	Prob.of* Chi-Sq. Obs.	Chi Square	df	Prob.of* Chi-Sq. Obs.
Automobiles 1950									
Min.Exp.=5	5.447	2	.10-.05	0.818	1	.50-.30	0.619	1	.90-.80
Min.Exp.=1	17.741	5	.01-.001	7.581	4	.20-.10	8.834	2	.02-.01
Automobiles 1970									
Min.Exp.=5	x	x	x	-	0	-	-	0	-
Min.Exp.=1	x	x	x	18.883	2	< .001	21.044	1	<.001
Furniture 1950									
Min.Exp.=5	5.344	4	.30-.20	1.012	2	.70-.50	2.999	1	.10-.05
Min.Exp.=1	21.295	8	.01-.001	11.726	5	.05-.02	17.572	3	<.001
Furniture 1970									
Min.Exp.=5	0.941	4	.95-.90	2.923	2	.30-.20	1.843	1	.20-.10
Min.Exp.=1	19.595	8	.02-.01	12.361	5	.05-.02	14.115	2	< .001
Shoes 1950									
Min.Exp.=5	4.150	5	.70-.50	2.397	4	.70-.50	5.102	3	.20-.10
Min.Exp.=1	36.100	12	<.001	31.146	10	< .001	15.055	6	.02-.01
Shoes 1970									
Min.Exp.=5	7.330	7	.50-.30	23.647	7	.01-.001	29.723	6	< .001
Min.Exp.=1	42.034	16	<.001	54.816	14	< .001	43.460	10	< .001
Groceries 1950									
Min.Exp.=5	53.945	14	<.001	52.491	13	< .001	63.392	8	<.001
Min.Exp.=1	155.927	24	<.001	96.148	23	< .001	63.434	12	<.001
Groceries 1970									
Min.Exp.=5	35.651	15	.01-.001	40.991	11	<.001	45.142	5	<.001
Min.Exp.=1	117.911	25	<.001	53.783	17	<.001	46.263	8	<.001

* i.e. the probability that differences between observed and expected values greater than those given would arise by chance.

x - Variance smaller than mean - negative binomial distribution could not be fitted.

Table 7

Fitting of a Negative Binomial Distribution - Maximum Likelihood Estimators

	3000' Quadrats			1500' Quadrats			750' Quadrats		
	Chi Square	df	Prob.of* Chi-Sq. Obs.	Chi Square	df	Prob.of* Chi-Sq. Obs.	Chi Square	df	Prob.of* Chi-Sq. Obs.
Automobiles 1950									
Min.Exp.=5	4.098	2	.20-.10	1.181	1	.30-.20	0.501	1	.90-.80
Min.Exp.=1	17.546	6	.01-.001	7.810	4	.10-.05	8.571	2	.02-.01
Automobiles 1970									
Min.Exp.=5	x	x	x	7.353	1	.01-.001	-	0	-
Min.Exp.=1	x	x	x	21.401	2	< .001	21.581	1	< .001
Furniture 1950									
Min.Exp.=5	4.384	3	.30-.20	1.213	2	.70-.50	4.758	2	.10-.05
Min.Exp.=1	21.251	9	.02-.01	11.436	5	.05-.02	17.487	3	< .001
Furniture 1970									
Min.Exp.=5	6.831	4	.20-.10	10.485	3	.02-.01	4.467	1	.05-.02
Min.Exp.=1	27.737	9	.01-.001	15.890	5	.01-.001	8.589	3	.05-.02
Shoes 1950									
Min.Exp.=5	0.806	4	.50-.30	2.625	4	.70-.50	4.701	3	.50-.30
Min.Exp.=1	34.469	13	.01-.001	30.963	10	< .001	14.776	6	.05-.02
Shoes 1970									
Min.Exp.=5	9.355	7	.30-.20	7.809	6	.30-.20	4.830	4	.50-.30
Min.Exp.=1	43.578	16	< .001	45.688	12	< .001	25.420	8	.01-.001
Groceries 1950									
Min.Exp.=5	12.191	11	.50-.30	35.927	15	.01-.001	41.430	9	< .001
Min.Exp.=1	124.680	24	< .001	59.482	25	< .001	42.233	14	< .001
Groceries 1970									
Min.Exp.=5	39.467	14	< .001	47.425	13	< .001	60.918	7	< .001
Min.Exp.=1	107.396	25	< .001	48.915	22	< .001	60.918	10	< .001

* i.e. the probability that differences between observed and expected values greater than those given would arise by chance.

x Variance smaller than mean - negative binomial distribution could not be fitted.

Table 8a

Store Numbers - Total Area

	1950	1970	% change 1950-1970
Automobiles	114	115	+0.86
Furniture	189	252	+33.33
Shoes	285	493	+72.98
Groceries	1763	1698	-3.68

Table 8b

Store Numbers - Central City Subarea

	1950		1970		
	Number of stores	% of total stores	Number of stores	% of total stores	% increase in central city, 1950-1970
Automobiles	36	31.6	29	25.4	-19.4
Furniture	104	55.0	122	48.4	+17.3
Shoes	176	61.8	235	47.6	+33.5
Groceries	992	56.2	736	47.6	-25.8

Table 9

Standardized Difference Matrix, Grocery Stores 1950 and Population 1951

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	0.53	0.57	0.66	0.62	0.0	0.0	0.0	0.0
0.0	0.72	0.72	0.72	0.0	0.0	0.72	0.41	0.40	0.48	0.40	0.0	0.0	0.0
0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.36	0.39	0.34	0.34	0.41	-0.25	-0.23
0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.31	0.38	0.58	0.52	0.40	-0.21	0.19
0.0	0.0	0.0	0.72	0.72	0.70	0.50	0.24	0.13	0.70	0.55	-0.35	0.63	0.69
0.0	0.0	0.0	0.72	0.72	0.68	0.23	0.16	0.16	0.70	0.64	0.30	-1.35	0.48
0.0	0.0	0.0	0.72	0.72	0.65	0.56	0.37	-0.03	0.39	0.02	-0.92	-1.26	-0.61
0.0	0.0	0.0	0.72	0.71	0.72	0.68	0.69	0.51	-0.23	0.38	-0.78	-0.73	-0.21
0.0	0.0	0.72	0.71	0.70	0.68	0.57	0.14	-0.36	-0.67	-0.63	-1.25	-0.77	-0.36
0.0	0.0	0.68	0.65	0.70	0.70	0.45	-0.99	-0.89	-0.48	-0.25	-0.85	-1.55	0.76
0.0	0.0	0.57	0.35	-0.36	-0.32	-0.12	-0.96	-1.27	-0.28	0.01	0.34	-2.06	0.56
0.33	0.70	0.56	-0.07	-0.66	-0.42	-0.92	-1.92	-0.40	0.10	0.18	0.27	0.47	0.12
0.59	0.61	0.65	0.33	0.37	0.30	-0.03	-1.01	-0.63	-0.74	0.01	0.54	-0.74	0.47
0.60	0.55	0.70	0.70	0.70	0.66	0.12	0.13	-0.42	-0.27	-0.44	-0.45	-0.33	-0.32
0.63	0.48	0.65	0.70	0.59	0.46	-0.01	-0.54	-0.14	-0.74	0.24	-0.06	-0.25	0.51
0.0	0.28	0.52	0.59	0.58	0.12	-0.57	-0.62	-1.30	-0.69	-0.26	0.03	0.29	0.64
0.0	0.57	0.53	0.53	0.36	-0.57	-2.12	-3.22	0.78	0.49	0.53	0.68	0.0	0.0

All cells with both store and population values=0 were zeroed. Table cont. next page.

Table 9 (matrix continued from right-hand side of previous page)

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	0.32	0.37	0.63	0.69	0.0	0.0	0.0	0.0	0.0
0.52	0.28	0.18	0.44	0.67	0.23	0.59	0.69	0.0	0.0	0.0	0.0	0.0
0.30	0.29	-0.08	0.59	0.59	0.59	0.59	0.0	0.0	0.0	0.0	0.0	0.0
0.36	0.00	0.35	0.57	0.70	0.72	0.67	0.71	0.72	0.72	0.72	0.0	0.0
0.50	0.50	0.32	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.0	0.0
0.27	0.50	0.50	0.67	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.0	0.0
-0.05	-0.34	0.50	0.64	0.72	0.72	0.72	0.69	0.71	0.71	0.71	0.0	0.0
1.18	0.23	0.54	0.12	0.24	0.23	0.64	0.65	0.71	0.57	0.32	0.0	0.0
0.35	-0.58	0.42	0.15	0.33	0.40	0.57	0.59	0.28	0.38	0.25	0.33	0.0
-0.99	0.07	-1.31	0.29	0.51	0.36	0.30	0.57	-0.23	0.34	0.54	0.38	-0.19
1.75	1.59	0.18	-0.19	0.85	0.14	0.53	0.16	0.12	-0.38	0.23	0.0	0.0
0.47	0.12	0.89	-0.95	1.97	1.91	0.23	0.18	-0.04	0.39	0.0	0.0	0.0
2.03	1.71	0.77	-0.90	-0.63	-0.85	0.70	0.0	0.0	0.0	0.0	0.0	0.0
-0.71	-1.35	0.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.68	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

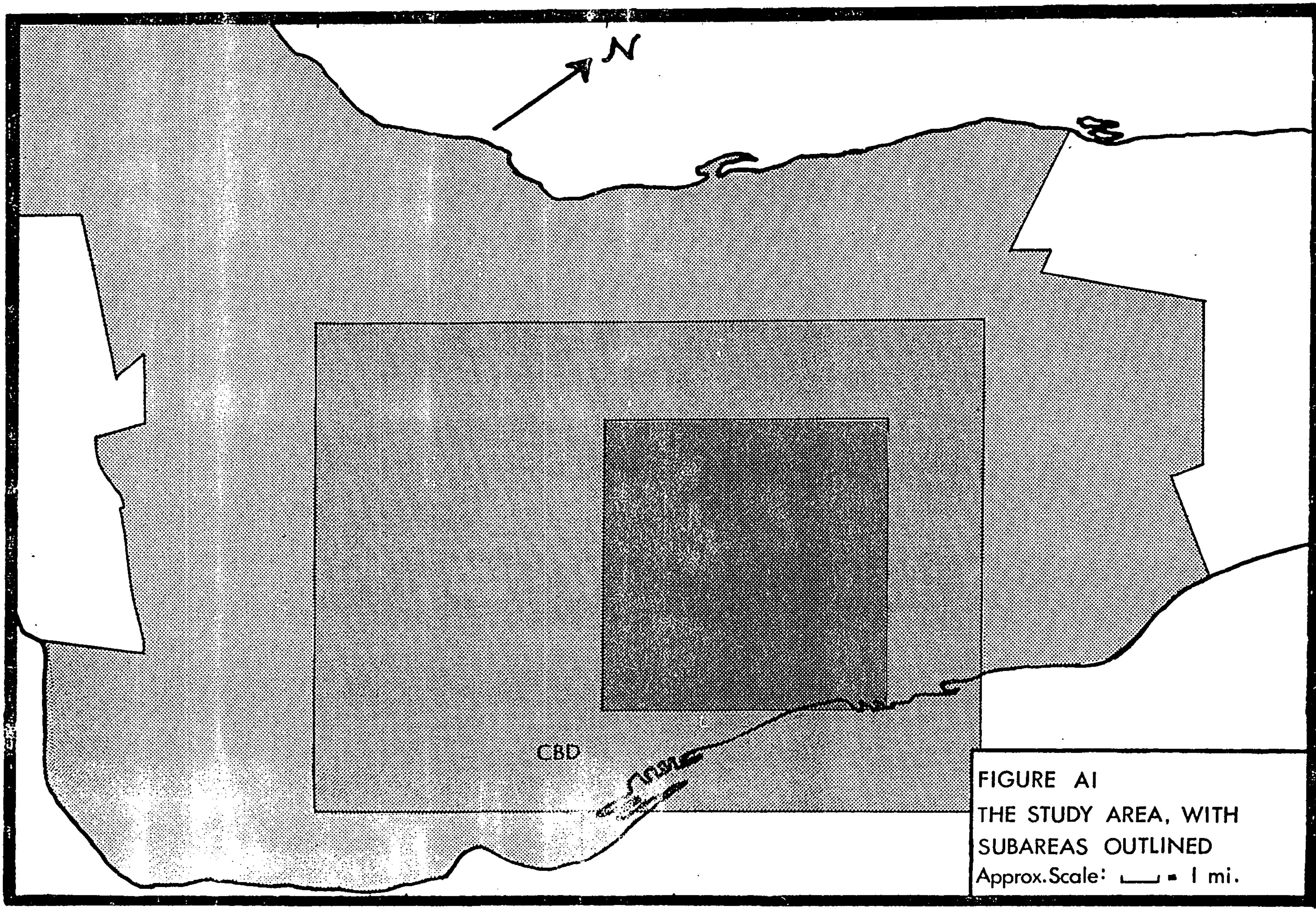


FIGURE A1
THE STUDY AREA, WITH SUBAREAS OUTLINED
Approx. Scale: ⌴ = 1 mi.

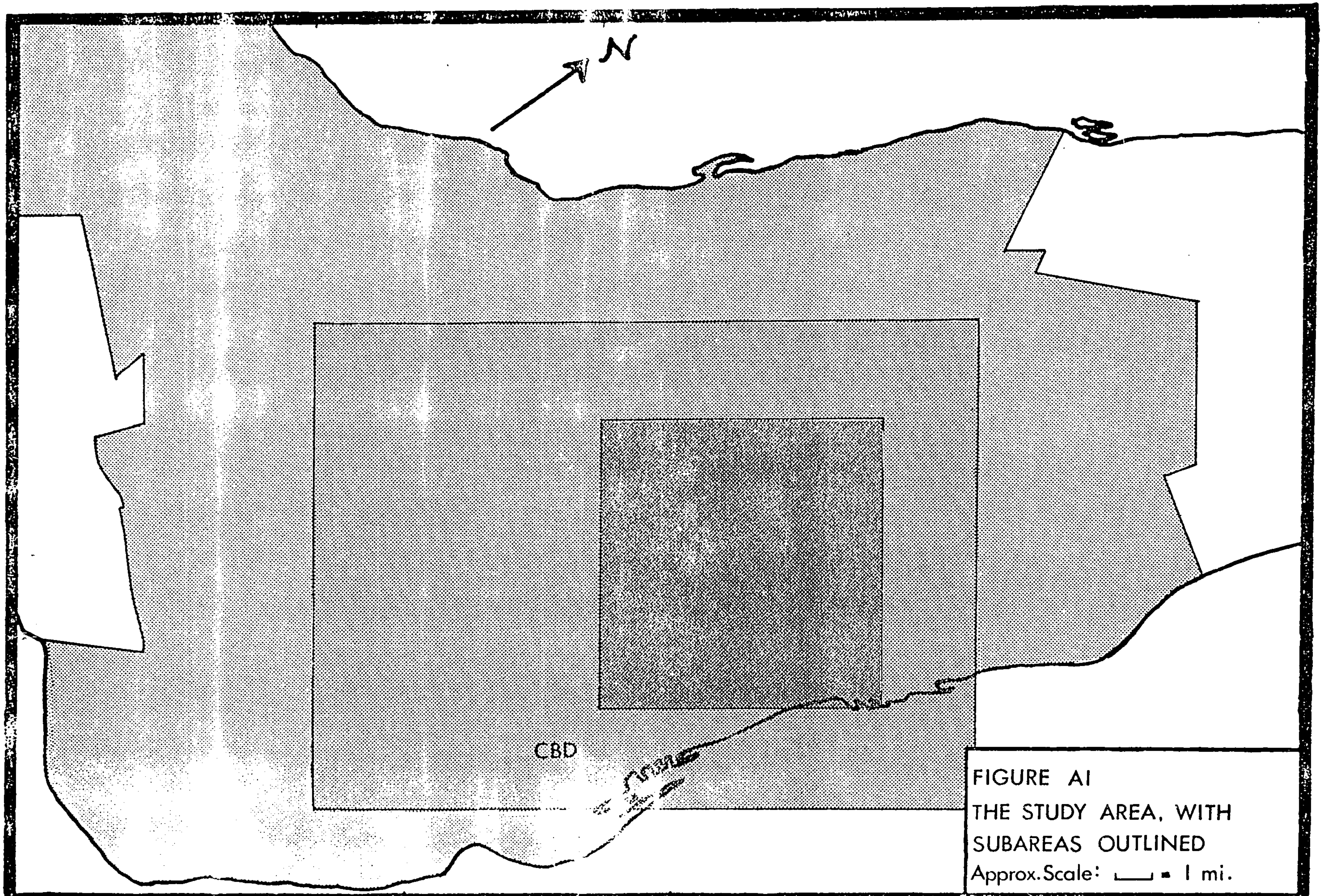


FIGURE A1
THE STUDY AREA, WITH SUBAREAS OUTLINED
Approx. Scale: ⎵ = 1 mi.

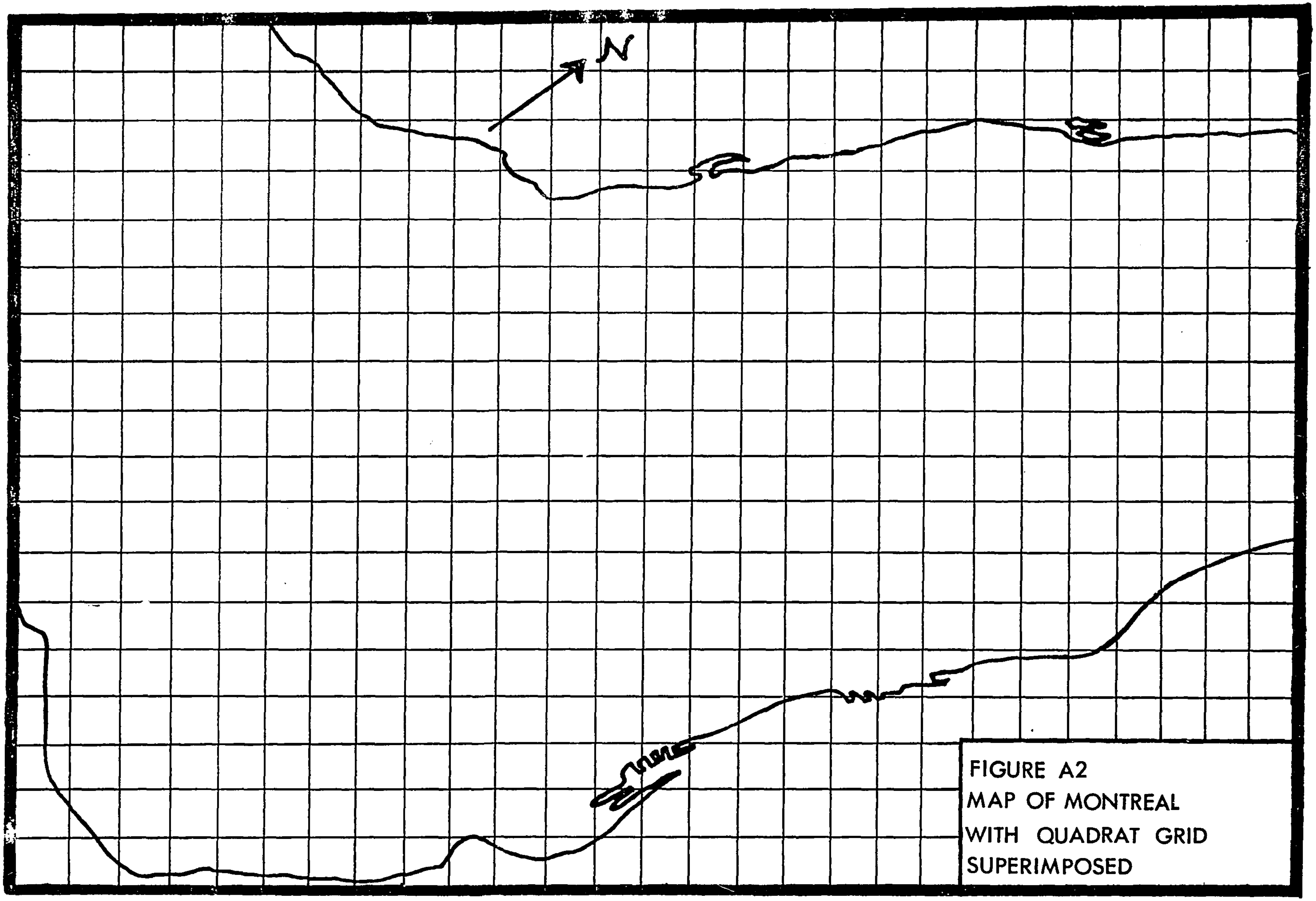
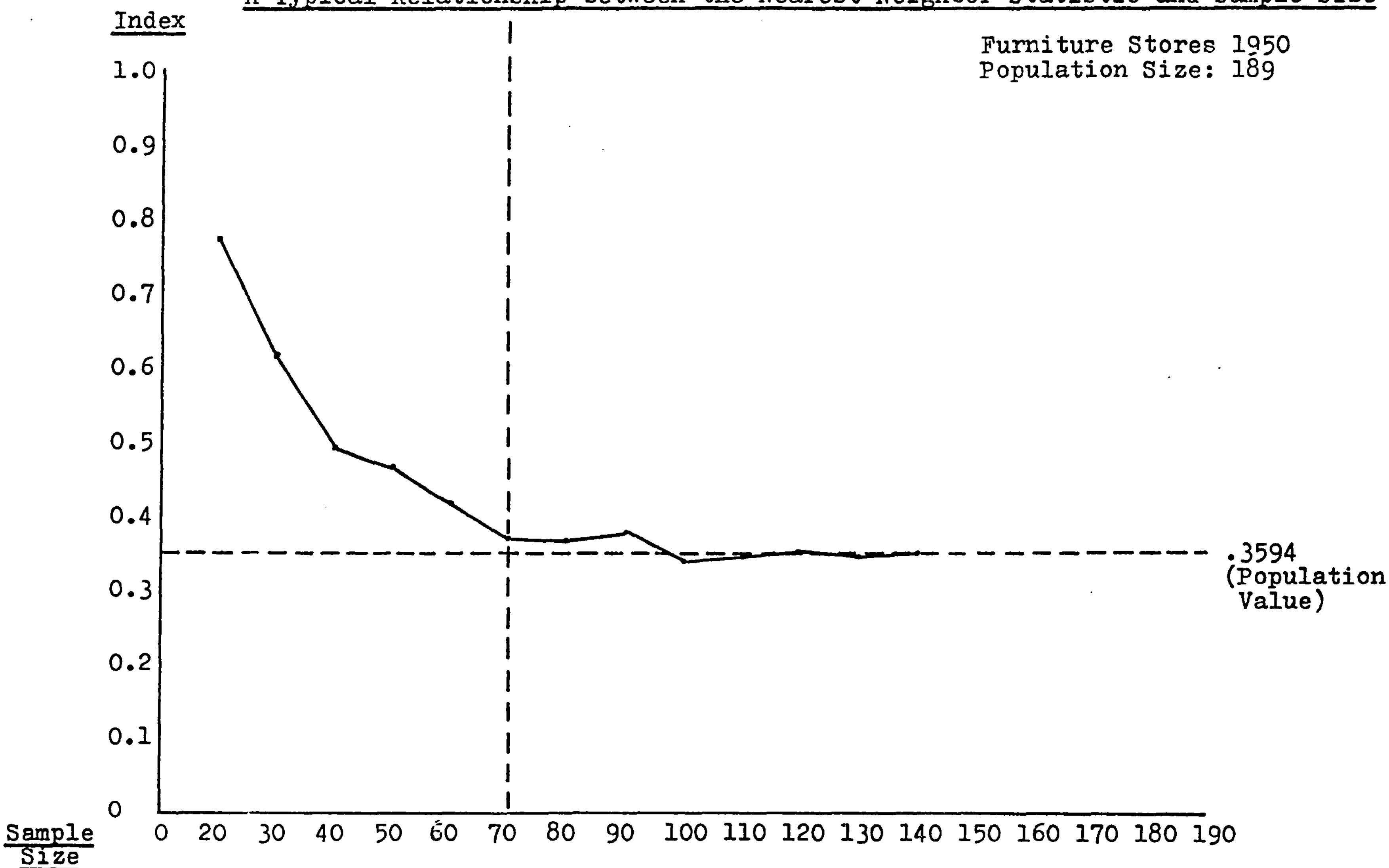


FIGURE A2
MAP OF MONTREAL
WITH QUADRAT GRID
SUPERIMPOSED

Figure A3

A Typical Relationship between the Nearest Neighbor Statistic and Sample Size



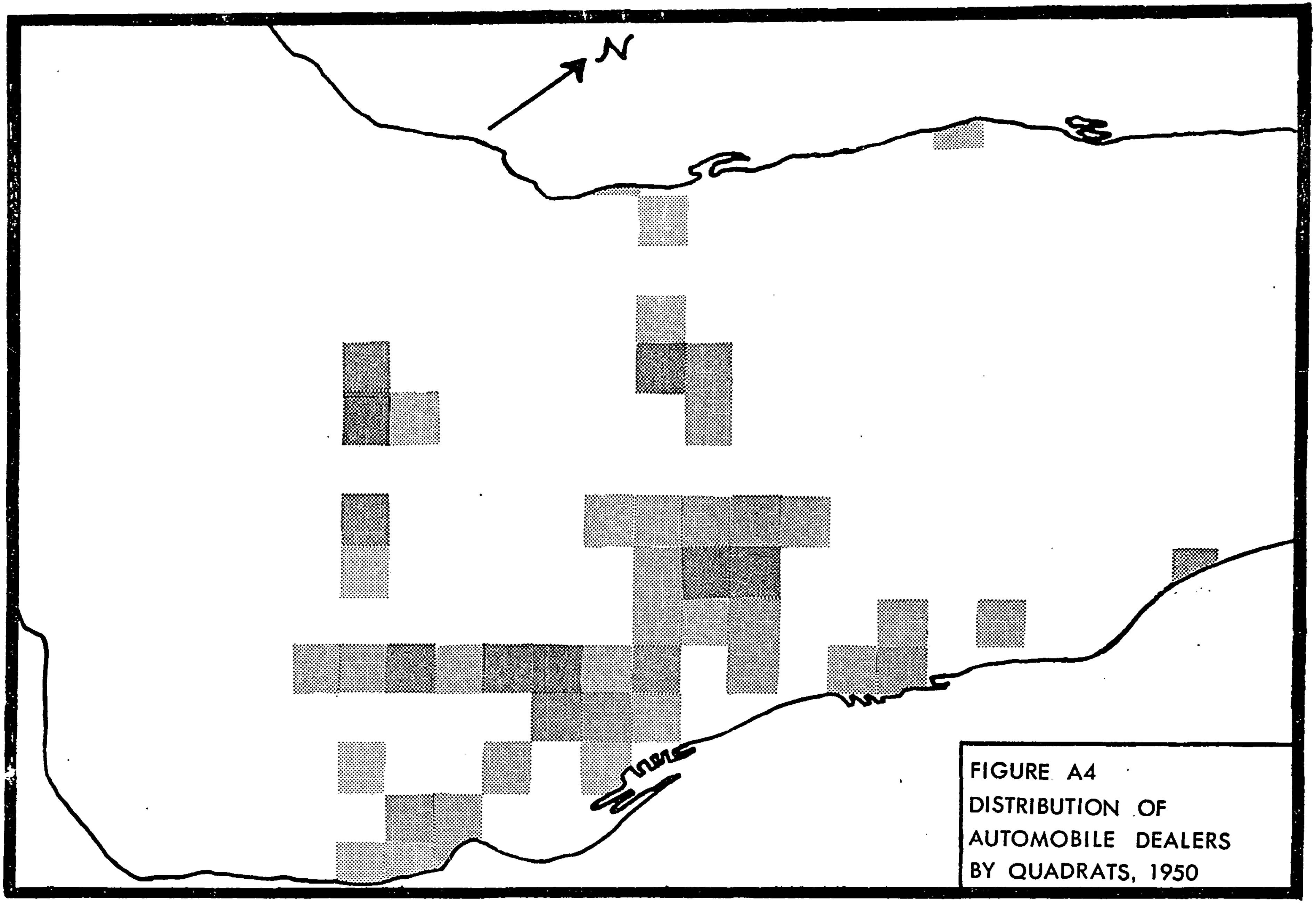


FIGURE A4
DISTRIBUTION OF
AUTOMOBILE DEALERS
BY QUADRATS, 1950

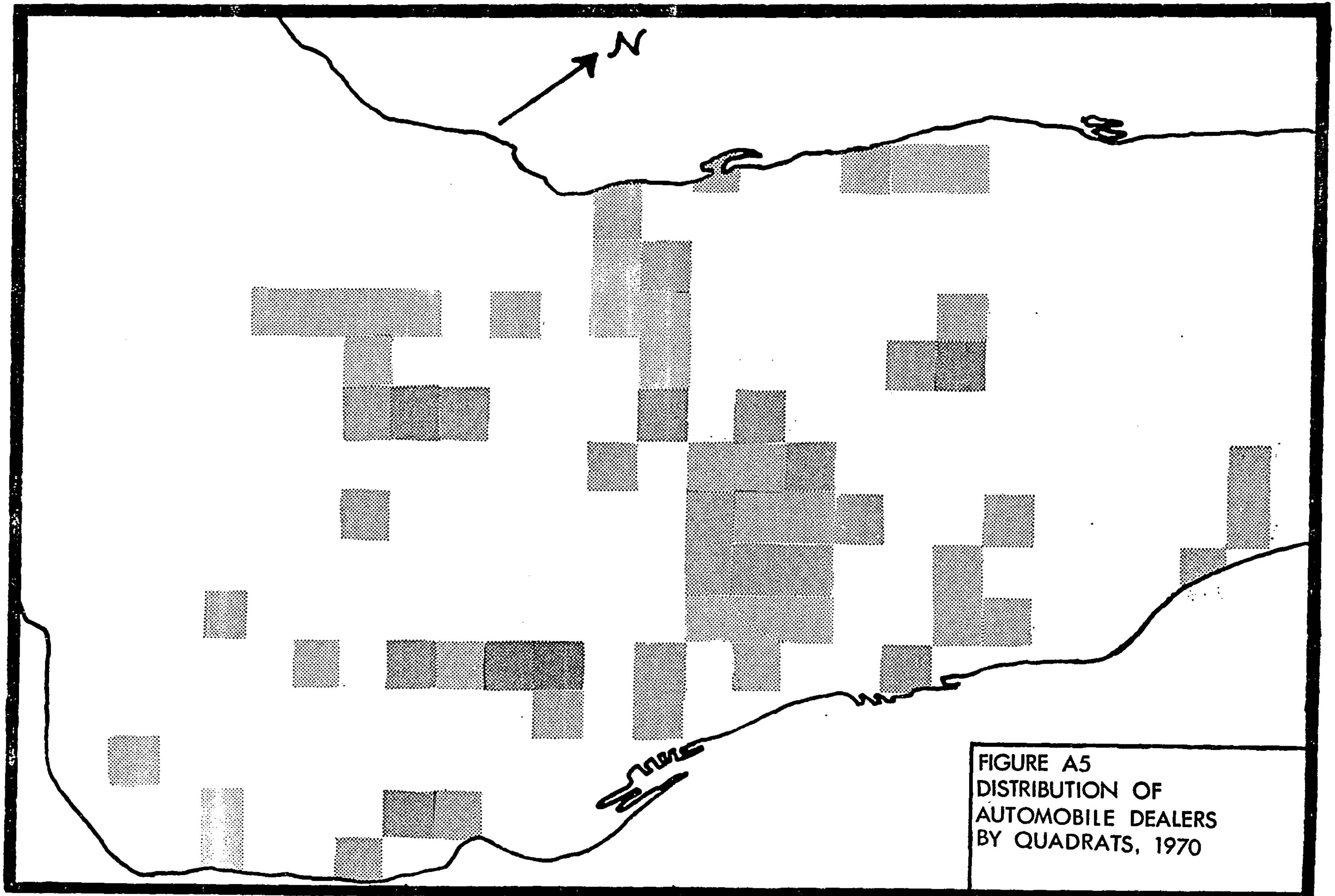


FIGURE A5
DISTRIBUTION OF
AUTOMOBILE DEALERS
BY QUADRATS, 1970

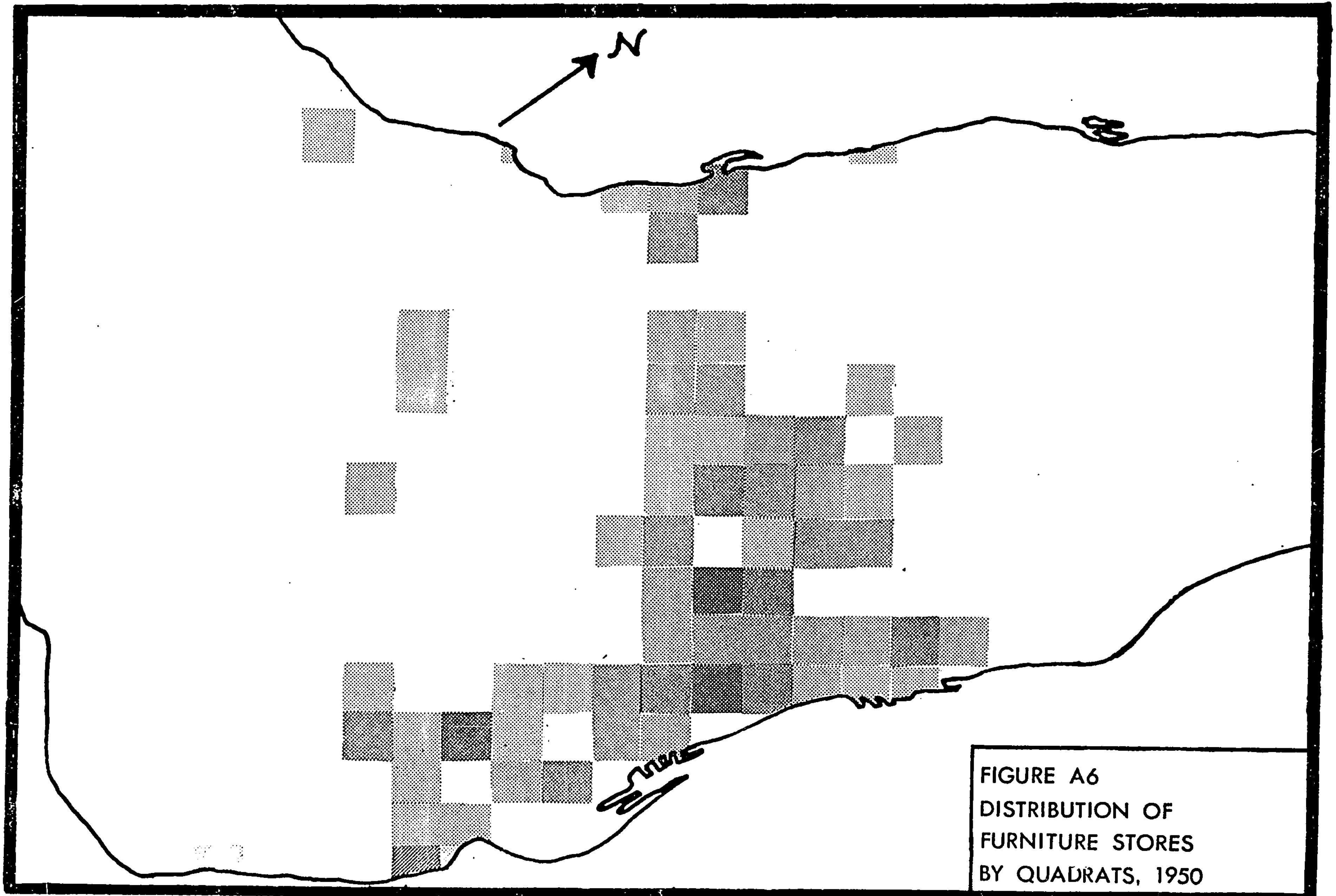


FIGURE A6
DISTRIBUTION OF
FURNITURE STORES
BY QUADRATS, 1950

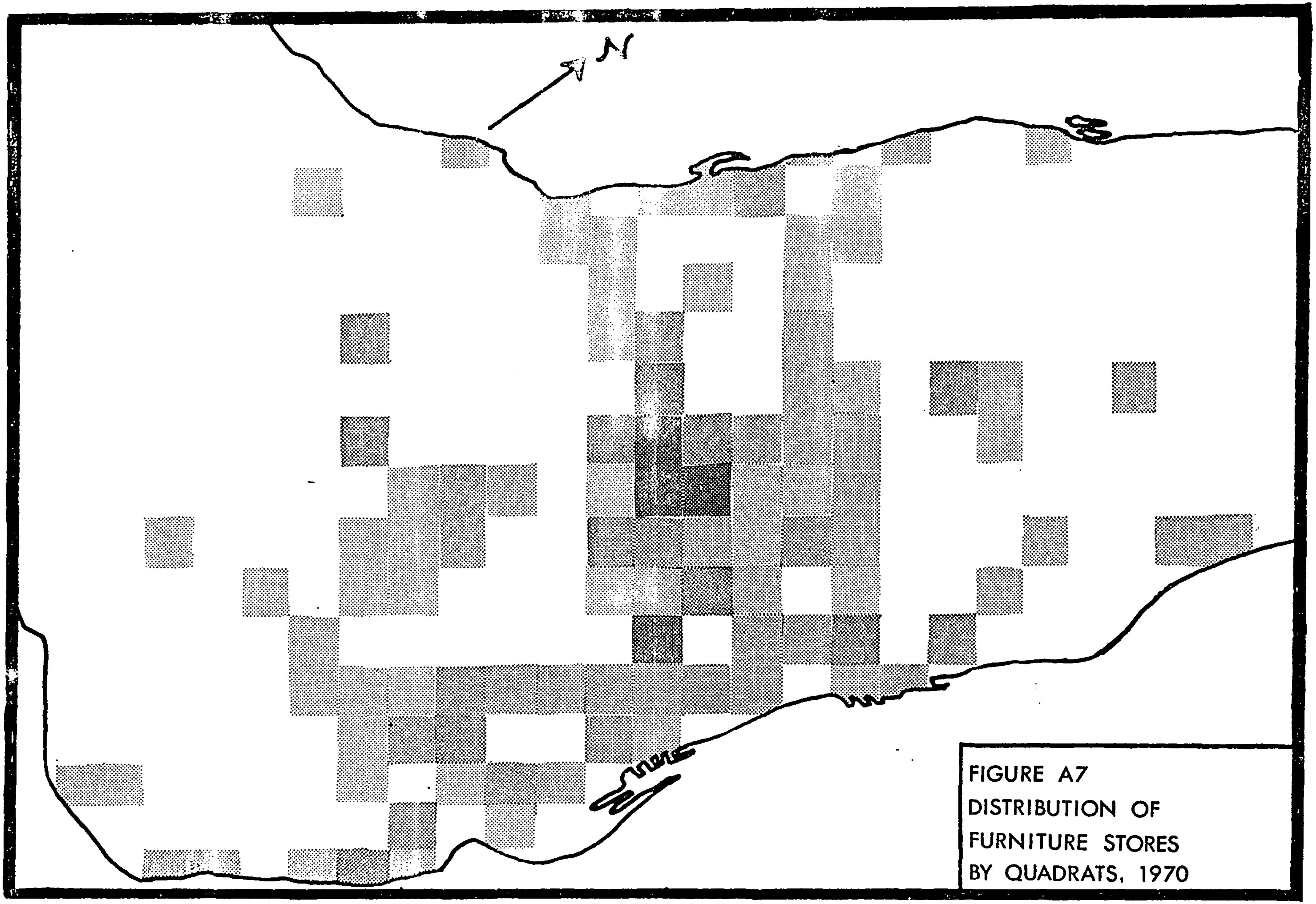


FIGURE A7
DISTRIBUTION OF
FURNITURE STORES
BY QUADRATS, 1970

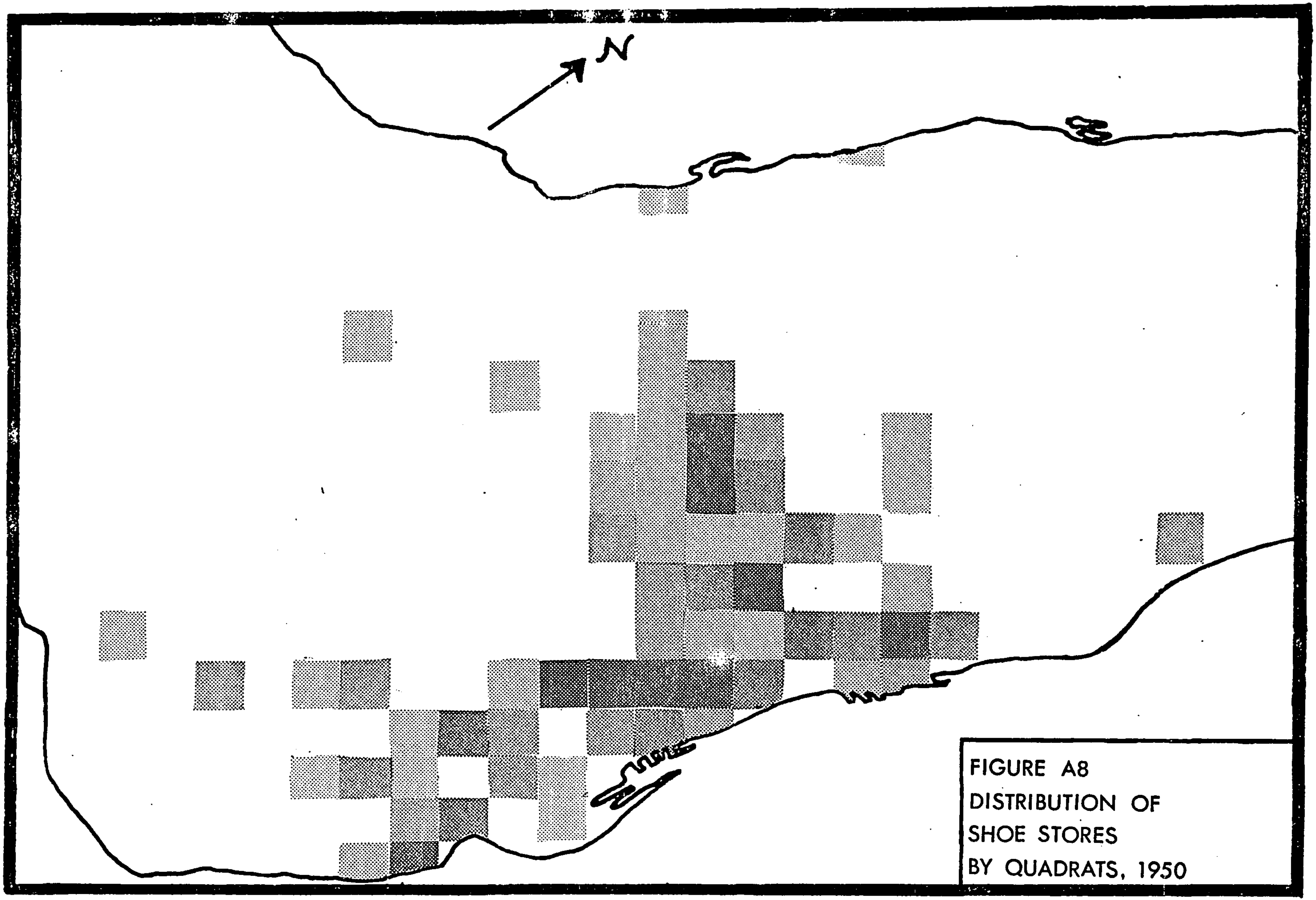


FIGURE A8
DISTRIBUTION OF
SHOE STORES
BY QUADRATS, 1950

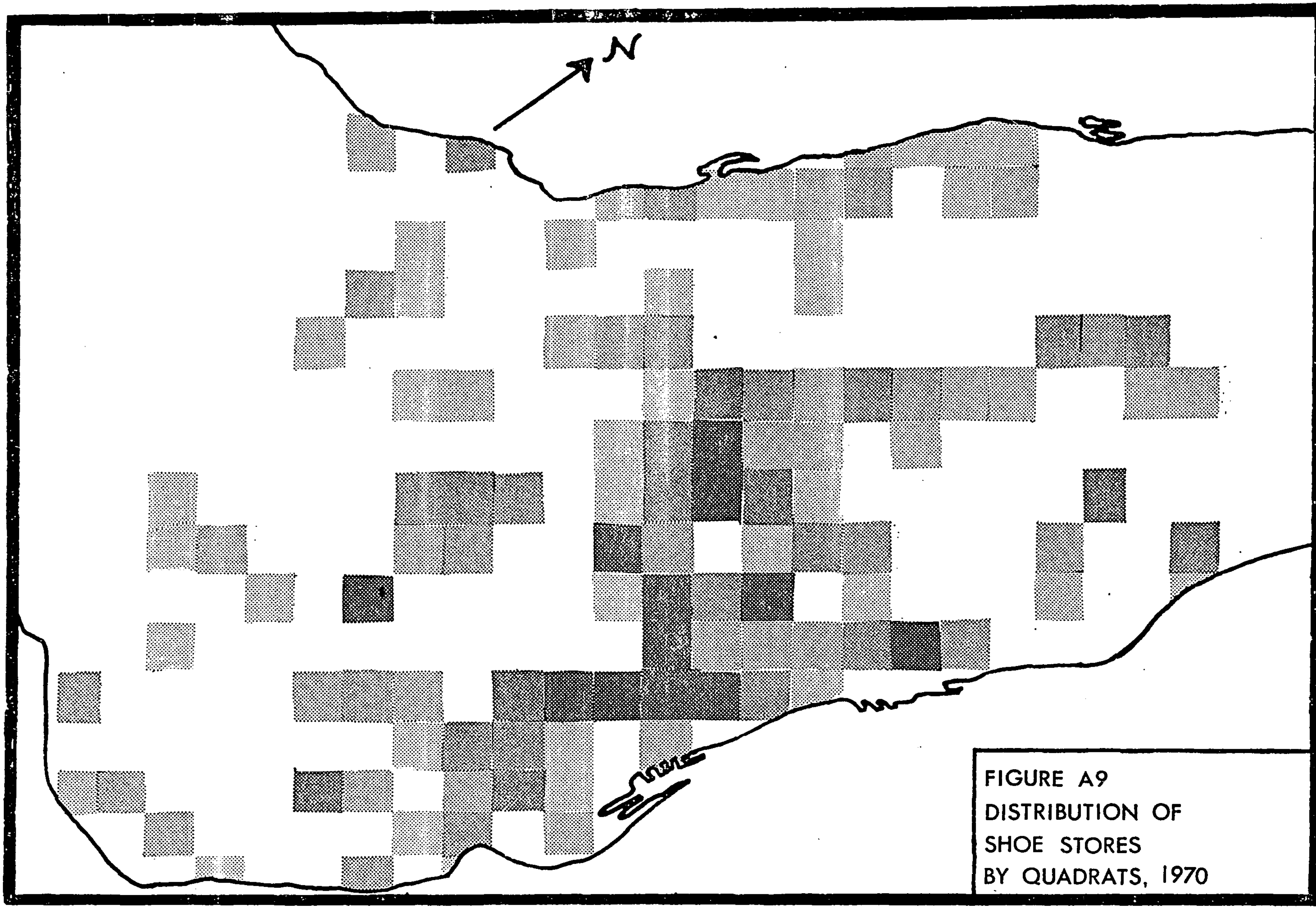


FIGURE A9
DISTRIBUTION OF
SHOE STORES
BY QUADRATS, 1970

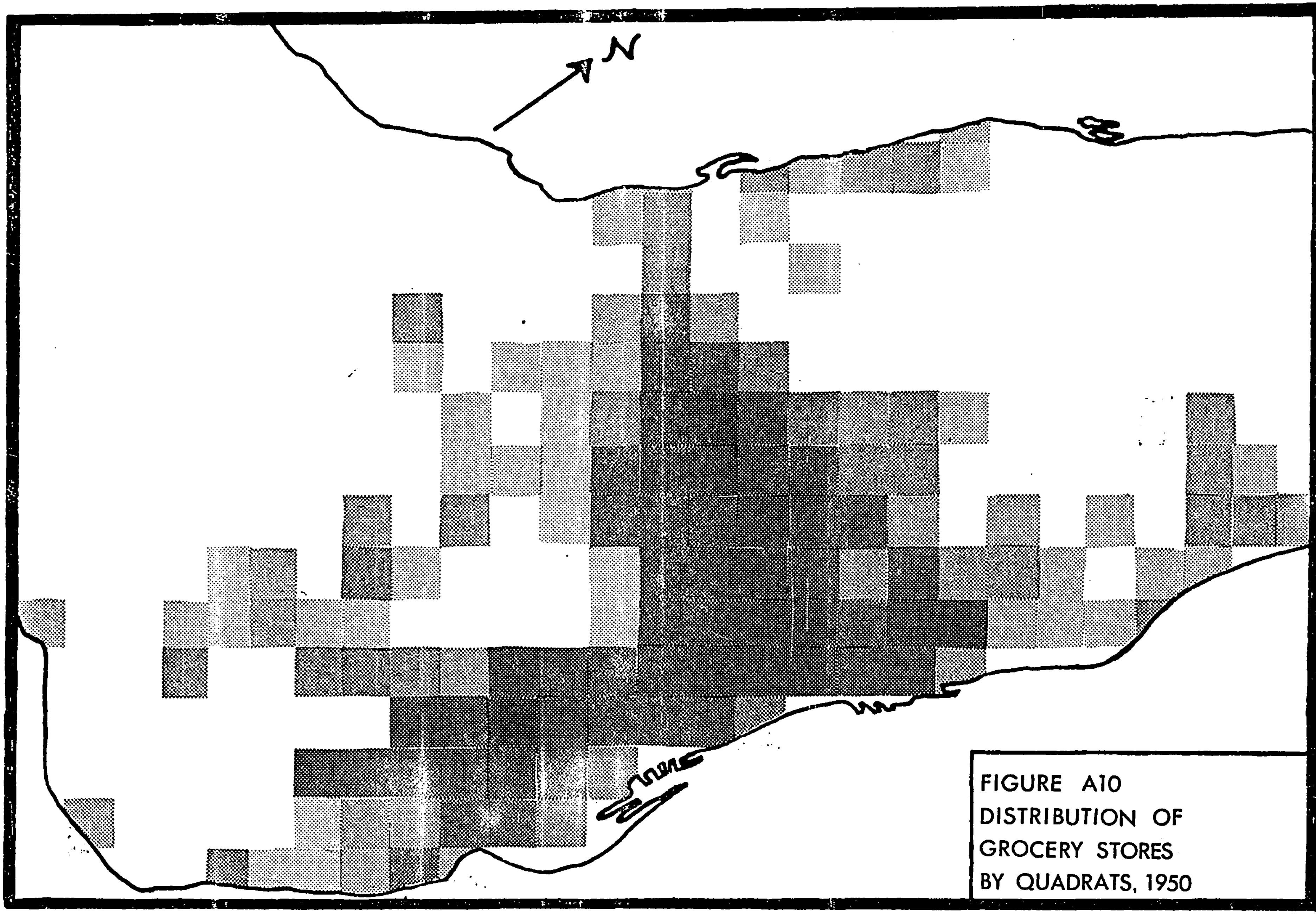


FIGURE A10
DISTRIBUTION OF
GROCERY STORES
BY QUADRATS, 1950

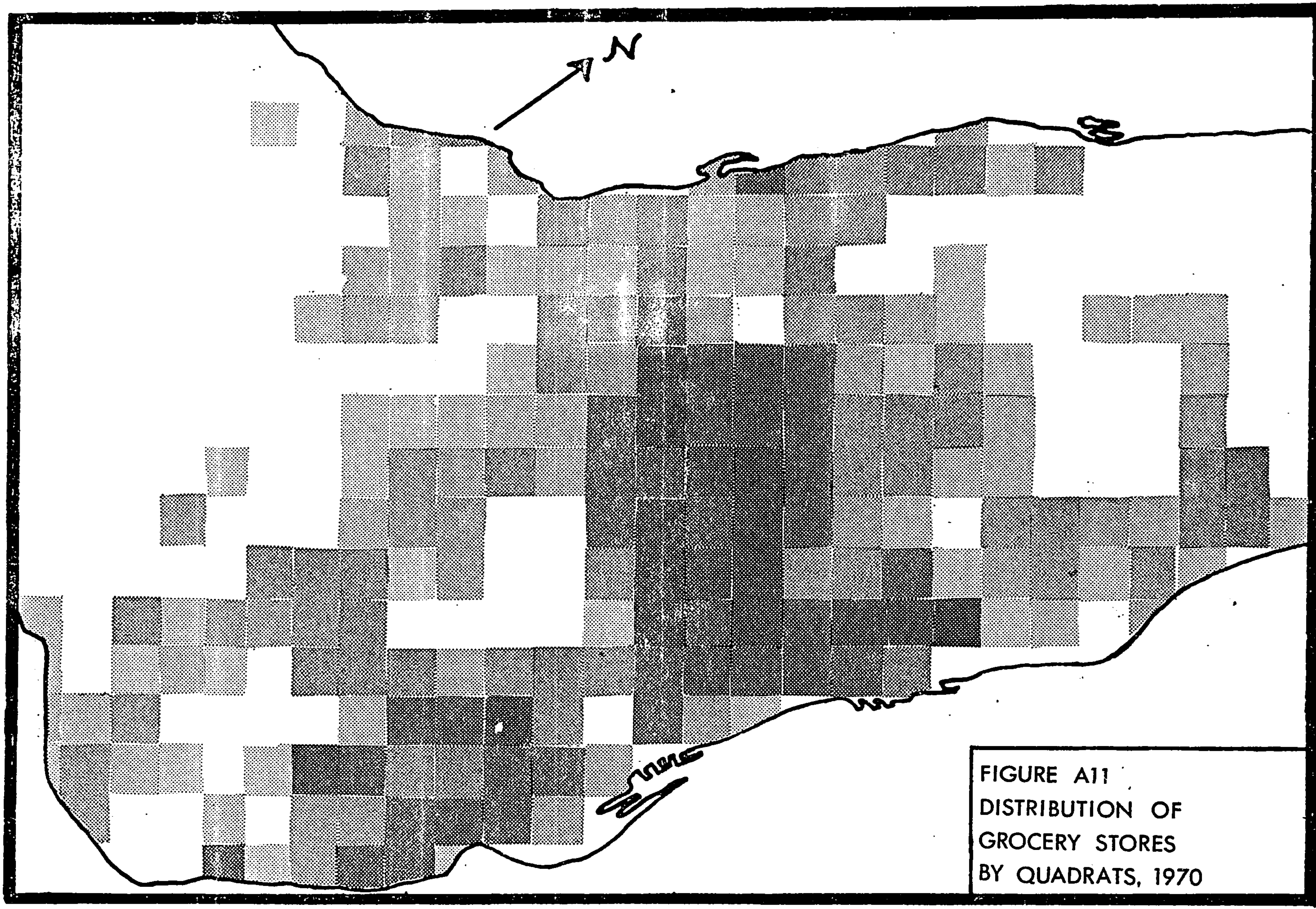


FIGURE A11
DISTRIBUTION OF
GROCERY STORES
BY QUADRATS, 1970

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