THE USE OF DIAGNOSTIC VARIABLES IN URBAN ANALYSIS WITH PARTICULAR REFERENCE TO WINNIPEG

A Thesis
Presented to
the Faculty of Graduate Studies and Research
University of Manitoba

In Partial Fulfillment
of the Requirements for the Degree of
Master of Arts

By

Richard S Baxter, BSc.

1968

ABSTRACT

Urban geography has come a long way since the pioneer efforts of the European school of geography. Techniques have become more refined and the descriptive analysis has become supplanted by the quantitative analysis to a large extent. The discipline now holds a position of academic respectability and practical usefulness. This thesis attempts to extend the quantitative approach to intra urban analysis by the modification of existing statistical models and the development of new computerized analytical processes.

The statistical examination of the urban system is based upon an exhaustive analysis of a data matrix concerning 75 measurable properties in relation to 87 distinct unit areas of the metropolitan sphere of Winnipeg. The properties requiring measurement are termed diagnostic variables, and the data corresponding to areal units come mainly from Census information.

The object of the ensuing analysis is to reduce the fundamental dimensions of the data matrix by associating variables which correlate highly with each other. Factor analysis is a statistical procedure which undertakes this reduction in dimensions by constructing a new

matrix where each factor (aggregate variable) accounts for a diminishing proportion of the total variance. In this study the first factor accounts for over a quarter of the total variance and the first four factors together are responsible for almost three fifths of the variance. Nine factors, amounting to four fifths of the variance, are considered in the subsequent study. Hence, rather than use a 75 x 87 matrix to represent urban structure, it is possible to simplify the system by considering only a 9 x 87 matrix without too much generalization and loss of detail.

The representation of urban structure can use as its criterion the identification of natural areas within the community. It is the expressed opinion that such natural areas exist because of contrasting relationships with adjacent areas rather than location on a gradient within the total urban environment. Accepting this premise, it is necessary to instigate some means of measuring and mapping the degree of contrast between adjacent areal units and evolving a method conducive to computer orientation. The flexibility of such a model is enhanced by specific output techniques which permit the direct mapping of the extrapolated information.

Equipped with the factor design and the mapping technique, it is expedient to analyze the urban structure

of Winnipeg. Two systematic methods are available. Either urban structure with respect to each factor can be examined, or areal unit scores over all nine factors can be assessed. The former approach provides a mosaic of spatially differentiated sub areas and the identification of boundaries for each factor. The second method permits an evaluation of the health or ills of each particular area of Winnipeg by reference to its position on a continuum of scores, for each factor, in the city as a whole.

Whilst the techniques are progressive and practically useful, it is important to realize limitations in the system. Difficulties and restrictions relate to the choice of variables, the unit of area chosen, the meaningful description of the factors, and a few intrinsic weaknesses in the mapping technique. The limitations can be improved, and the analysis made more rigorous, through greater refinement of certain integral processes in the methodology. Computer programs need to be conceptually more complex. The results presented are valid within the limitations of the model used, and it is possible to improve the model with only minor modifications in specific directions.

Acknowledgements.

The pursuit of any idea necessitates both encouragement and advice. Whilst developing the framework of this thesis I was aware of my ignorance concerning Winnipeg as a city. The fact that I was a total stranger in this environment helped in the sense that my statistical conclusions were formulated objectively and without any preconceived ideas. Encouragement was forthcoming through the opinions, from diverse sources, which substantiated particular aspects of the study and motivated further investigation.

The Geography Department provided an atmosphere conducive to the energetic pursuit of this topic. To Dr. M.A.Jarochowska a special debt is due. She both supervised this thesis and helped crystallize some of my views on statistical methodology and philosophy in the field of geography. Her suggestions, at various stages throughout the study, prevented my straying too far from the basic problem, and caused me to rethink certain statements and conclusions.

The facilities afforded me throughout the year allowed this study to proceed; without them I would never have started. In particular, the efficiency of the Computer Department permitted a fast turn around time for jobs, and the advice given by members of the Department aided in the frequent debugging of errors in my ill conceived programs. The many hours spent in learning a new programming language (Fortran IV, as opposed to Algol), and the considerable time involved in punching up data cards and programs constituted the bulk of the effort behind this thesis, but goes unrecorded in the ensuing pages.

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CHAPTER I

INTRODUCTION

A. ORGANIZATION.

The aim of this thesis is to expand upon a method of urban analysis involving the use of diagnostic variables. Having isolated these variables, it is intended to measure the degree of association between them and isolate common causative forces. From this, the urban differentiation into sub areas, in terms of the component variables, is to be attempted using a system of contrast mapping.

This chapter begins with an explanation of the philosophy of urban analysis, particularly the need for research in this field. This is followed by a summary of developments in geographical, sociological, and economic methodology in urban analysis. This is a necessary digression as the subsequent study involves the search for concordant and discordant boundaries based on interdisciplinary criteria. Such a review permits some insight into the forces at work in the community as understood by practitioners in the three disciplines.

Chapter II is concerned with the selection and

measurement of the urban variables. The limitations imposed by the data and their areal extent are explored, and a pilot study is performed to illustrate methods of procedure.

In chapter III the statistical analysis of the variables is presented. Using the resulting component variables, a mapping technique is developed. This technique is discussed in chapter IV. The mapping attempts to isolate sub areas within Winnipeg in terms of contrasts within variables. The geographical interpretation and analysis of these sub areas and their boundaries is undertaken in chapter V. The concluding section, chapter VI, serves as a summary of the more pertinent findings of the study.

B. THE NEED FOR URBAN RESEARCH.

We live in an age of increasing urbanization, and evidently this is a tendency that will continue. Faced with the realization that by the year 2000 a greater percentage, as well as a larger absolute number, of the world's population will live, work, and exercise in urban areas, it is necessary to question our knowledge of this urban environment. To explain the diverse forces operating within an urban region it is necessary to evaluate existing conditions. Any attempt to control and

modify the urban environment for future generations can only be possible if the existing system is fully defined.

The speed with which the urbanization process has proceeded has not allowed the contemporaneous analysis and documentation of urban phenomena. As a result, common urban terminology includes expressions such as congestion, sprawl, blight, slum, renewal, segregation, decentralization, and social friction. These expressions of city malfunction reflect those fields in which cause-effect relationships are least understood. Accepting that a city area embraces a large dynamic system of linkages and forces, it follows, that to understand the city as a whole, it is necessary to try and identify and explain these linkages and forces.

As the city planner is appointed with the task of providing the future generations with better cities[1], it

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[1]The city planner is faced with the problem of defining "better cities". The whole concept of Utopian Planning is basic to his motives and actions in the planning process, and yet the citizen presents no unified opinion as to what constitutes the ideal environment. To identify the issues involved reference should be made to the following articles and texts: "Utopia," Daedalus, Journal of the American Academy of Arts and Sciences (Spring, 1965)., G.A.Jellicoe, Motopia: A Study in the Evolution of Urban Landscape (London, 1961)., K.Lynch, The Image of the City (Cambridge: Massachusetts Press, 1960)., K.Mannheim, Ideology and Utopia: An Introduction to the Sociology of Knowledge (London: Paul, 1936)., Sir Thomas Moore, Utopia, trans. P.K.Marshall (Washington Square Press, 1965)., L.Mumford, The Story of Utopia (New York: Viking, 1962).

is imperative that he is provided with exhaustive and accurate information about the city as it exists today. With this goal in mind, what is the nature of the information that should be supplied to him? If this question could be answered directly then the object of urban research would be clear. Unfortunately, such is the nature of an urban area in terms of complexity, that the question does not permit a straightforward answer.

Instead the research worker must explore the urban field with few preconceived ideas, record observations, and then attempt to explain them. Such research can be aimed in two directions, firstly to acquire information that can be applied to achieve particular social objectives, and secondly to provide information that will contribute to social science theory. Bogue classifies the approach under three headings[2]:

(i) Studies with theoretical implications but with no apparent practical application of the findings,

(ii) Studies with theoretical implications but also capable of providing some of the knowledge needed to achieve immediate practical ends, and

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[2]Donald J.Bogue, ed., Needed Urban and Metropolitan Research (Scripps Foundation for Research in Population Problems, Miami University, 1953), No. 7, p.1.

(iii) Studies with no theoretical implications, or research aimed solely at providing a specific answer to a specific problem, without reference to other considerations.

This conception of urban research can be represented in matrix form as indicated in TABLE I, below.

TABLE I

NATURE OF URBAN RESEARCH

	THEORETICAL IMPLICATIONS	NO THEORETICAL IMPLICATIONS
PRACTICALLY USEFUL	(ii)	(iii)
PRACTICALLY USELESS	(i)	(iv)

Roman numerals (i) to (iii) correspond to Bogue's classification, and the matrix is completed by the insertion of (iv) in the lower right hand cell. In terms of this matrix, urban research may set goals which lie somewhere along the continuum (iv) to (ii), namely useless and not theoretical, to useful and theoretical. The merit of a study will depend upon how close to (ii) it is judged to fall. Assuming that it does not fulfil the condition of being completely useful and rigorously theoretical it has to be judged by balancing its usefulness against its theoretical implications. For this reason urban research

can be assessed as objective if it provides the analytical model required by the planner, and also if it enlarges the urban model of the academician.

Urban research aims at identifying and explaining the forces at work in the community. To achieve this it is necessary to instigate some method of measuring these forces. The need to measure, in order to facilitate comprehension, accounts for the evolution of a vast range of research techniques. Using these techniques, the urban area can be subjected to thorough examination, and the greater the technical refinements, the larger the amount of information that becomes available.

The more information that is known about the urban area, the greater is the probability of constructing an urban model that typifies the city as a whole. It is from such a model that the planner can attempt to build his Utopia by implementing the decision making process and simulating the results on the model.

This practical end to urban research has developed through an academic attempt to measure the forces existing in the urban environment. This problem of measurement has been tackled from different angles by the economist, historian, sociologist, and the geographer. Because the concept of quantification of urban variables is the basis of this study, it is desirable to trace the development

of urban analysis over the last century, to illustrate the aims and changing values of the times.

C. THE GEOGRAPHICAL APPROACH TO URBAN RESEARCH.

Geography has contributed a great deal to the present knowledge of urban structure. The first indication of active geographic research in the urban field can be traced back to the German school of urban geography in the last decade of the 19th. century. Otto Schlüter advocated the need for comparative morphological study of towns, and compared the planned growth of towns in eastern Germany with the uncontrolled growth in western Germany[3]. Dickinson attributes this investigation to the stimulus provided by the researches of Meitzen into village origins[4]. With this beginning the literature was expanded through a series of comparative studies of towns. In 1924, Geisler attempted to classify German towns according to site, plan, and build[5]. This contrasted

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[3]O.Schlüter, "Über den Grundriss der Städte," Zeitschrift der Ges. f. Erdkunde zu Berlin, XXXIV (1899), pp.446-462.
and "Bermerkungen zur Siedlungskunde," Geographische Zeitschrift, V (1899), pp.65-84.

[4]R.E.Dickinson, "The Scope and Status of Urban Geography: An Assessment," Land Economics, XXIV (1948), pp.221-238.

[5]W.Geisler, "Die Deutsche Stadt," Forschungen zu deutschen Lande und Volkskunde (Stuttgart, 1924).

with the views of Hettner who stressed the need for functional classifications of towns two decades earlier[6]. He went further and emphasized the varying effects of location and cultural and economic conditions on the character of cities from epoch to epoch, and from country to country. In effect, Hettner had anticipated the idea of Blanchard who enunciated methods of urban research in 1912. Blanchard itemized four methods of urban study[7]:

(a) The study of physical and cultural conditions in the origins of settlement,

(b) The analysis of the life and organization of individual settlements aerially, as a whole, and in their integral sections,

(c) The analysis of the reaction of the nucleus in functional and morphological development, to the impact of subsequent events, and

(d) The interrelation between the settlement and its territory.

His general theme of "Après l'étude dans le temps, l'étude dans l'espace" typifies the ideology of the French school during this period. It was a theme pursued

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[6]A.Hettner, "Die Lage der menschlichen Ansiedlungen," Geographische Zeitschrift, I (1895), pp.361-375.

[7]R.Blanchard, Grenoble: Etude de geographie urbaine (Grenoble, 1912), reprinted and augmented 1935.

by the notable French geographer Pirenne.

From these early beginnings geographical research pursued lines of enquiry broadly synonymous with those suggested by Blanchard. The inter-war period saw a broadening of concepts concerning the city, and the range of urban research papers reflects a mounting interest. Furthermore, the development of urban geography occurred on both sides of the Atlantic, initially with similar objectives, but later in different directions.

In Britain, for example, there was the work by Patrick Geddes[8] and Dickinson[9], and in America that by Jefferson[10]. Already by 1924 there were sufficient new approaches that Aurousseau felt justified in reviewing these contributions[11]. After 1920 certain distinct approaches to urban research materialized. As these approaches can be recognized up to the 1950's, it is convenient to continue the historical evolution of urban geography within this framework. Basically, urban study

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[8]P.Geddes, Cities in Evolution (London: Williams and Norgate, 1915).

[9]R.E.Dickinson, "The Regional Functions and Zones of Influence of Leeds and Bradford," Geography, XV (1930), pp.548-557.

[10]M.Jefferson, "The Law of the Primate City," Geographical Review, XXIX (1939), pp.226-232.

[11]M.Aurousseau, "Recent Contributions to Urban Geography," Geographical Review, XIV (1924), pp.444-455.

has proceeded along two fronts. The first of these involves relationships between urban areas in terms of functions or spatial relationships. The second involves the study of a single city. Such approaches can be termed inter urban analysis and intra urban analysis respectively.

1. Inter Urban Analysis.

(a) Functional Relationships. Functional classifications of cities date from Aurousseau's work of 1921[12]. He recognized six urban functions: administration, defence, culture, production, communication, and recreation. Attempts to isolate quantitatively, the distinctive functions of towns have since been made by Kneedler[13], Harris[14], Smith[15], Stafford[16], Hart[17], and

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[12]M.Aurousseau, "The Distribution of Population: A Constructive Problem," Geographical Review, XI (1921), pp. 563-592.

[13]G.M.Kneedler, "Functional Types of Cities," Public Management, XXVII (1945), pp. 197-203.

[14]C.D.Harris, "A Functional Classification of Cities in the United States," Geographical Review, XXXIII (1943), pp. 86-99.

[15]R.H.T.Smith, "Method and Purpose in Functional Town Classification," A.A.A.G., LV (1965), pp. 539-548.

[16]H.A.Stafford, "Functional Bases of Small Towns," Economic Geography, XXXIX (1963), pp. 165-175.

[17]J.F.Hart, "Functional and Occupational Structures of Cities in the American South," A.A.A.G., XLV (1955), pp. 269-286.

Pownall[18]. These works utilize a statistical approach to the problem and depend on multivariate techniques. The authors are concerned with the distribution and structure of urban functions, and as Smith states, such functional classifications of urban areas prove to be ends in themselves rather than points of departure for further research into the character of urban settlements.

Harris analyzes 988 United States' cities in terms of percentage employed in particular trades relative to the total employment. From these figures he is able to recognize distinct functional cities: manufacturing (M and M' subtypes), retail, diversified, wholesale, transportation centres, mining, university, resort, and retirement. Stafford, on the other hand, looks at the lower end of the Central Place continuum in southern Illinois. His overall impression is that small Illinois towns exist functionally for the same reason as those examined by Thomas in Iowa[19]. Population changes over time are quickly reflected by changes in the number of establishments, and variations in town size are associated with

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[18]L.L.Pownall, "The Functions of New Zealand Towns," A.A.A.G., XLIII (1953), pp. 332-350.

[19]E.N.Thomas, "The Stability of Distance-Population Size Relationships for Iowa Towns from 1900 to 1950," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 13-30.

disproportionately large variations in the number of functions performed.

Functional analysis of cities has become more refined and specialized. Few cities possess a single unique function, although some have a function which dominates all others. As soon as the urban area becomes multifunctional, the analysis depends on the interpretation of dominance. Kneedler has based her analysis on the number of employed persons in each particular occupation. From a general study of occupational structure in many cities, a degree of dominance can be visualised within a particular area. This concept can be extended by taking into account the entire occupational structure. Alexandersson has achieved this objective for American cities by classifying jobs in the proportion that they exist to supply the needs for goods and services within a specific city compared to the national average[20]. Gillen extended this approach by instigating a scoring system based on the percentage distribution of workers in nine occupational categories[21]. By this means it is

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[20]G.Alexandersson, The Industrial Structure of American Cities: A Geographical Study of Urban Economy in the United States (London: Allen and Unwin, 1956).

[21]P.B.Gillen, The Distribution of Occupations as a City Yardstick (New York: Kings Crown Press, 1951).

possible to classify a city on the basis of its occupational score.

The minimum requirements approach of Ullman and Dacey attempts to identify the minimum percentage of a labour force required in various sectors of the city's economy to maintain the viability of the urban area[22]. This enables a classification of cities to be made based on their degree of specialization. This premise is similar to that adopted by Alexander in his Basic-Nonbasic concept[23]. He analyzes the ties which bind a city to its region, and from this classifies cities in terms of regional function. Clark undertakes a statistical analysis of the primary, secondary, and tertiary industries of cities in relation to their size and concludes that cities remain, and find new functions, when the purpose for which they were established has become partially or completely obsolete[24]. Clark's analysis is based on regional incomes with the object of measuring the numbers engaged in the various industries per million dollars of

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[22]E.L.Ullman and M.F.Dacey, "The Minimum Requirements Approach to the Urban Economic Base," Papers and Proceedings of the Regional Science Association, VI (1960), pp. 175-194.

[23]J.W.Alexander, "The Basic-Nonbasic Concept of Urban Economic Functions," Economic Geography, XXX, No.4 (1954), pp. 246-261.

[24]C.Clark, "The Economic Functions of a City in Relation to its size," Econometrica, XIII (1945), pp. 97-113.

regional income.

This by no means exhausts the literature on functional analysis of urban areas. The tendency to produce results of purely academic interest is matched by the limitations inherent in the use of economic base analysis[25]. Classifications of cities appear to be the goals of any such techniques. Nelson, for example, develops a service classification of American cities[26], and at the other end of the scale Webb analyzes small urban centres in Minnesota[27]. The conceptual framework of urban functions can be seen in the much earlier work of Thorndike and Woodyard[28], and the fact that such approaches to urban analysis will continue, has encouraged Pfouts to document techniques of urban economic analysis[29]. Whilst much of the formative research in these fields was due to the geographer, it is apparent that the economist is

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[25] R.W.Pfouts and E.T.Curtis, "Limitations of the Economic Base Analysis," Social Forces, XXXVI (1958), pp. 303-310.

[26] H.J.Nelson, "A Service Classification of American Cities," Economic Geography, XXXI (1955), pp. 189-210.

[27] J.W.Webb, "Basic Concepts in the Analysis of Small Urban Centers in Minnesota," A.A.A.G., XLIX (1959), pp. 55-72.

[28] E.L.Thorndike and E.Woodyard, "Individual Differences in American Cities," American Journal of Sociology, XLIII (1937), pp. 191-224.

[29] R.W.Pfouts, The Techniques of Urban Economic Analysis (New Jersey: Chandler-Davis, 1960).

now applying his expertise in this field for practical and theoretical ends.

Population as an urban function has encouraged research into city size and threshold population numbers. Auerbach's concept of a Rank-size rule enunciated in 1913[30] has been considerably modified by Zipf[31]. He arrives at an equation $R^n.S_R = M$; where M and n are constants for a given group, S_R stands for the number of people who live in the Rth city in the group, and R is the rank of that city in the group.

Zipf is of the opinion that the rule applies approximately in the United States but is inapplicable in Britain. Hoyt, however, concludes that the rule hardly applies even in the United States[32]. The interest shown in the city Rank-size relationship[33] has served

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[30]F.Auerbach, "Das Gesetz der Bevolkerungskonzentration," Petermann's Geographische Mitteilungen, LIX(1913).

[31]G.K.Zipf, Human Behaviour and the Principle of Least Effort (Cambridge: Addison-Wesley, 1949)., and National Unity and Disunity (Bloomington Ind., 1941).

[32]J.Q.Stewart, "Empirical Mathematical Rules Concerning the Distribution and Equilibrium of Population," Geographical Review, XXXVII (1947), pp. 461-485.

[33]See for example: B.J.L.Berry and W.L.Garrison, "Alternate Explanation of Urban Rank-Size Relationships," A.A.A.G., XLVIII (1958), pp. 83-91., and N.Rashevsky, "Contributions to the Theory of Human Relations: Outline of a Mathematical Theory of the Size of Cities,VII," Psychometrica, VIII (1943), pp. 87-90., C.T.Stewart, "The

to initiate and verify theory. In 1947 Zipf formulated his hypothesis of the "Minimum Equation" as a unifying principle[34]. With the assumption that work is always minimized in human behaviour, he reasons that actual location of persons in the terrain is subject to their dual roles of producer and consumer, the respective economies of which are in conflict. This introduces the second feature of inter urban analysis, namely spatial relationships.

(b) Spatial Relationships. If the development of location theory in geography has to have a beginning, it is Von Thünen's work in Germany which has had a lasting influence. In his Isolated State of 1826, he portrays the economics of location based on rent in an agricultural environment[35]. This book remained unexamined until relatively recently, and its implications in the urban environment are only now being examined in detail. Kohl,

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Size and Spacing of Cities," Geographical Review, XLVIII (1958), pp. 222-245., and B.Shindman, "An Optimum Size for Cities," Canadian Geographer, V (1955), pp. 85-88.

[34]G.K.Zipf, "The Hypothesis of the 'Minimum Equation' as a Unifying Social Principle: with Attempted Synthesis," American Sociological Review, XII (1947), pp. 627-650.

[35]J.H.Von Thünen, Isolated State; an English Edition of Der Isolierte Staat, trans. Carla M. Wartenberg, ed. P.G.Hall (Oxford: Pergamon Press, 1966).

in 1841, indicated the relationship between cities and the natural and cultural environment, paying particular attention to the effect of transport routes on the location of urban centres[36]. In 1894 Cooley emphasized the effect of transport routes on the location and development of trade centres[37]. Then Haig attempted to explain why so many people and manufacturers were to be found in cities[38]. Bobeck's work in 1927 terminated one phase of German geography and heralded a period of contrasting thought within urban geography[39]. The city in the centre of a productive area was the background to Christaller's classic study in southern Germany in 1932[40]. From this the whole concept of 'Central Place' evolved and in particular the logical location of cities as expounded by

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[36]J.G.Kohl, Der Verkehr und die Ansiedlungen der Menschen in ihrer Abhangikeit von der Gestaltung der Erdoberfläche (Leipzig, 1850, 2nd edition).

[37]C.H.Cooley, "The Theory of Transportation," Publications of the American Economic Association, IX (1894), pp. 1-148.

[38]R.M.Haig, "Towards an Understanding of the Metropolis: Some Speculations Regarding the Economic Basis of Urban Concentration," Quarterly Journal of Economics, XL (1926), pp. 179-208.

[39]H.Bobeck, "Grundfragen der Stadt Geographie," Geographischer Anzeiger, XXVIII (1927), pp. 213-224.

[40]W.Christaller, Central Place in Southern Germany, trans. C.W.Baskin (Englewood Cliffs: Prentice Hall, 1966).

Ullman shortly afterwards[41].

There was a noticeable acceleration of research into topics dealing with the city as a Central Place and associated features of urban dominance. In 1940 Bogue studied 67 areas around major cities in the United States and delimited hinterland boundaries midway between adjacent metropolises[42]. Duncan studied 561 United States metropolitan regions in terms of functions and regional relationships, and deduced spheres of influence and industry profiles[43]. In 1930, in England, Dickinson examined the regional functions and zones of influence of Leeds and Bradford[44].

Smailes presented his urban hierarchy of England and Wales in 1944[45]. This was based on an assessment of comparative status and graded order of cities. He evolved a series of indices to measure urban rank, and each town

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[41]E.Ullman, "A Theory of Location for Cities," American Journal of Sociology, XLVI (1941), pp. 853-864.

[42]D.J.Bogue, The Structure of the Metropolitan Community: A Study of Dominance and Subdominance (Ann Arbor: University of Michigan Press, 1949).

[43]O.T.Duncan, et. al., Metropolis and Region (Baltimore: John Hopkins Press, 1960).

[44]Dickinson, Geography.

[45]A.E.Smailes, "The Urban Hierarchy in England and Wales," Geography, XXIX (1944), pp. 41-51.

was coded in terms of these indices. The sphere of influence of central places was measured by means of newspaper circulation by Haughton[46], and by the provision of bus services by Green[47] and Godlund[48]. Taafe carries the idea further by using air passenger numbers as a basis for an urban hierarchy[49]. The association between the nucleus and its umland was discussed by Smailes within the context of his term 'urban field'[50]. Green tidies the picture up by examining the similarities inherent in the classifications provided by Carruthers[51],

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[46] J.P.Haughton, "Local Newspapers and the Regional Geographer," The Advancement of Science, VII, No.25 (1950), pp. 44-45., and "Irish Local Newspapers: A Geographical Study," Irish Geography, II, No.2 (1950), pp. 52-57.

[47] F.H.W.Green, "Urban Hinterlands in England and Wales: An Analysis of Bus Services," Geographical Journal, CXVI (1950), pp. 64-88.

[48] S.Godlund, "Bus Services, Hinterlands and the Location of Urban Settlements in Sweden, Specially in Scania," Lund Studies in Geography, Series B, Human Geography, III (1951), pp. 14-24.

[49] E.J.Taafe, "The Urban Hierarchy: An Air Passenger Definition," Economic Geography, XXXVIII (1962), pp. 1-14.

[50] A.E.Smailes, "The Analysis and Delimitation of Urban Fields," Geography, XXXII (1947), pp. 151-161., and "The Urban Mesh of England and Wales," Transactions and Papers, The Insitute of British Geographers, XI (1946),pp. 85-101.

[51] W.I.Carruthers, "A Classification of Service Centres in England and Wales," Geographical Journal, CXXIII (1957), pp. 371-385.

Smailes, and himself[52].

At the lower end of the continuum, Bracey investigated the rural service centres in southern England[53], and Brush[54] and Webb[55] performed similar tasks in southwest Wisconsin and Minnesota. The comparison in methodology indicates the merit of such a unified approach in areas of contrasting historical and cultural conditions[56]. Evidently this is one of the striking advantages of Central Place studies.

More specific applications of Central Place concepts have involved the analysis into trade relationships within smaller regions. Siddal[57] has adopted

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[52] F.H.W.Green, "Community of Interest Areas - Notes on the Hierarchy of Central Places and their Hinterlands," Economic Geography, XXXIV (1958), pp. 210-226.

[53] H.E.Bracey, "Towns as Rural Service Centres: An Index of Centrality with Specific Reference to Somerset," Transactions and Papers, The Institute of British Geographers, XIX (1953), pp. 95-106., and "English Central Villages: Identification, Distribution, and Functions," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 169-190.

[54] J.E.Brush, "The Hierarchy of Central Places in Southwestern Wisconsin," Geographical Review, XLIII (1953), pp. 380-420.

[55] J.W.Webb, loc. cit.

[56] J.E.Brush, and H.E.Bracey, "Rural Service Centers in Southwestern Wisconsin and Southern England," Geographical Review, XLV (1955), pp. 559-569.

[57] W.R.Siddal, "Wholesale-Retail Trade Ratios as Indices of Urban Centrality," Economic Geography, XXXVII (1961), pp. 124-132.

wholesale-retail trade ratios as indices of urban centrality; Weekley has examined the role of service centres in Nottingham[58], whilst Brown has used centres of retail distribution in the East Midlands[59] and Lomas similarly in the Midlands[60]. Comparisons within a large urban area in terms of service centres has been attempted by Carruthers[61] and Smailes and Hartley[62] in London.

Berry and Barnum give a thorough explanation of the integral factors involved in Central Place systems in the Journal of Regional Science[63]. The distinction between the functional and spatial aspects of urban analysis is at times difficult to identify. Whereas

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[58] I.G.Weekley, "Service Centres in Nottingham," The East Midland Geographer, VI (1956), pp. 41-46.

[59] P.A.Brown, "Centres of Retail Distribution in the East Midlands," The East Midland Geographer, VI (1956), pp. 3-9.

[60] G.M.Lomas, "Population Changes and Functional Regions," Journal of the Town Planning Institute, L (1964), pp. 21-31.

[61] W.I.Carruthers, "Service Facilities in Greater London," Town Planning Review, XXXIII, No.1 (1962), pp. 5-31.

[62] A.E.Smailes and G.Hartley, "Shopping Centres in the Greater London Area," Transactions and Papers, the Institute of British Geographers, XXIX (1961), pp. 201-213.

[63] B.J.L.Berry and H.G.Barnum, "Aggregate Relations and Elemental Components of Central Place Systems," Journal of Regional Science, IV, No.1 (1962), pp. 35-68.

classifications can be devized irrespective of spatial relationships, it is apparent that spatial relationships rely upon the use of some urban functions. Berry and Garrison deal with this issue in their functional bases of the Central Place hierarchy[64]. One of the advantages of spatial relationships between urban areas is that the methodology is applicable irrespective of location. Functional classifications, on the other hand, are subject to the vagaries of location.

Any city classification can only be judged in terms of the premises given by the compiler of the classification. The choice of criteria upon which to score cities may have loaded significance depending on the country in which the cities are to be classified. Hence, a classification which is meaningful and applicable in the United States may be inappropriate in Europe or elsewhere. For this reason different areas of the world need to be analyzed in different systematic fashions. Holzner, Dommisse, and Mueller favour a classification based upon the regionally varying influence of cultures[65]. Such a

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[64] B.J.L.Berry and W.L.Garrison, "Functional Bases of the Central Place Hierarchy," Economic Geography, XXXIV (1958), pp. 145-154.

[65] L.Holzner, E.J.Dommisse, and J.E.Mueller, "Toward a Theory of Cultural-Genetic City Classification," A.A.A.G., LVII (1967), pp. 367-381.

classification, they state, would reveal a pattern of homogeneous world regions of city similarity. They conclude[66]:

> ... it can be stated that any city developed in one distinct culture region, and inhabited by people of that culture region, exhibit urban characteristics distinctive to that culture region only. In other words, all cities express the cultures of the separate regions in which they exist. Therefore it must be possible to establish cultural-genetic city types and to delimit their areal distribution.

This cultural role of cities was recognized by Redfield and Singer in 1954, and they formulate two types of cities[67]:

> 1. Cities of orthogenetic transformation. These are of the moral order ... of culture carried forward.
> 2. Cities of heterogenetic transformation. These are cities of the technical order, where local cultures are disintegrated and new integration of mind and society are developed ....

This is a problem in urban geography which recurs. Hoyt emphasized the issue by writing[68]:

> The principles of city growth and structure, formulated on the basis of experience in cities in the United States prior to 1930, are thus

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[66]Holzner, et.al., p.381.

[67]R.Redfield and M.Singer, "The Cultural Role of Cities," Economic Development and Cultural Change, III (1954), pp. 53-73.

[68]H.Hoyt, "Recent Distortions of the Classical Models of Urban Structure," Land Economics, XL (1964), p.212.

> subject to modifications not only as a result of dynamic changes in the United States in the last few decades but these principles, originating here, are subject to further revisions when it is sought to apply them to foreign cities.

Consequently, inter urban studies have to be evaluated with a great deal of care. Scepticism needs to be balanced by a full comprehension of the terms of reference from which the results are extrapolated. One possibility to overcome this limitation is to make urban research more specific and aim at intra urban research, as opposed to inter urban analysis.

2. Intra Urban Analysis.

> There is nothing intrinsically wrong with functional classifications per se, yet without reference to accessory characteristics ..., they have precious little geographical relevance[69].

This statement by Smith highlights the need to investigate "accessory characteristics". Instead of comparative studies, could this need be satisfied by investigating the forces pertaining to a single urban community? Case studies of single cities were the starting point of urban geography, but they have become more scientific since the second War. Quantitative techniques became an integral part of the research process and a contrast developed between the American and European schools of urban geography. Whilst the former

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[69] Smith, A.A.A.G., p.548.

concentrated on economic aspects and transport problems, the Europeans favoured the morphological approach. At the present time this rift is being closed.

Within the urban area it is evident to the intruder that there are marked areal variations of land use, housing quality, economic function, social characteristics, racial and ethnic groupings. Awareness of these areas which are different and distinct is not sufficiently objective if remedial actions are to be taken to improve conditions. The need is to isolate the factors which account for such marked intra urban differentiation in an objective manner. This will allow a better understanding of the functioning of the city as a whole, and might aid in isolating certain aspects of urban malfunction resulting from the presence of undesirable relationships.

Perloff draws attention to these problems in discussing the role of urban analysis for planning[70]. He maintains that there is a minimum requirement of knowledge necessary for comprehensive planning, and in terms of city planning this incorporates:

(a) What are the people's conceptions of the

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[70] H.S.Perloff, Needed Urban and Metropolitan Research, ed. D.J.Bogue (Scripps Foundation for Research in Population Problems, Miami University, 1953), No. 7, pp. 4-10.

"good life" in the city?

(b) What are the effects of various arrangements of living on personality and on the social and political organization?

(c) What effects do population changes, and of various kinds of "ecological" movements have on the social system, the political structure, and the economic system?

(d) What are the most significant influences of the changes in population structure (age, sex, race, and occupation)?

With these broad objectives the geographer, economist, and sociologist have striven to produce order out of chaos. Mayer emphasizes the geographers' particular role as an attempt to acquire knowledge about the internal structure of cities and metropolitan areas[71]. It is a concern with area; an attempt to measure the degree of homogeneity within areas and the degree of heterogeneity between areas. This measurement can be undertaken using human ecology or population variables, the lines of distinction being tenuous in most cases. Geographical

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[71] H.M.Mayer, "What we need to know about the Internal Structure of Cities and Metropolitan Areas," in Needed Urban and Metropolitan Research, ed. D.J.Bogue (Scripps Foundation for Research in Population Problems, Miami University, 1953), No. 7, pp. 11-27.

research has attempted to attain these goals by explaining the morphology of towns, the functions and linkages within cities, the genesis of cities, and the delimitation and explanation of unique areas such as the Central Business District, industrial zones, residential areas, and communication corridors.

The morphological study of cities has been undertaken mostly by Europeans[72]. The intrinsic quality of these works is that they are exhaustive descriptions of one particular city. Their usefulness is questioned by Bogue[73] who thinks that each study found to merit research should be performed in such a way that nationwide

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[72]See for example: M.R.G.Conzen, "Alnwick, Northumberland; A Study in Town-Plan Analysis," Transactions and Papers, The Institute of British Geographers, XXVII (1960)., and "The Plan Analysis of an English City Centre," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 383-414., H.J.Nelson, "Townscapes of Mexico: An Example of the Regional Variation of Townscapes," Economic Geography, XXXIX (1963), pp. 74-83., P.P.Karan, "The Pattern of Indian Towns: A Study in Urban Morphology," J.A.I.P., XXIII (1957), pp. 70-75., P.J.Smith, "Calgary: A Study in Urban Pattern," Economic Geography, XXXVIII (1962), pp. 315-329., D.Ward, "The Pre-Urban Cadaster and the Urban Pattern of Leeds," A.A.A.G., LII (1962), pp. 150-166., W.William-Olsson, "Stockholm; Its Structure and Development," Geographical Review, XXX (1940), pp. 420-438., E.Kant, "Zur Frage der inneren Gliederung der Stadt," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 321-381.

[73]D.J.Bogue, ed. Needed Urban and Metropolitan Research (Scripps Foundation for Research in Population Problems, Miami University, 1953), No. 7, p.2.

and international comparisons will be possible. For this reason case studies should give way to comparative research.

Differentiation within urban areas is one of the common fields of study. The reason for such differentiation is explained by Kish[74], and the centrifugal and centripetal tendencies are examined by Hoyt[75]. Centrality as a distinct phenomenon has been investigated by Johnson[76]. Beyond mere descriptive analysis of such areal differentiation there are the economic circumstances accounting for this propensity to segregate urban functions. Particular land use functions have been examined in detail, a good example being the C.B.D.[77].

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[74]L.Kish, "Differentiation in Metropolitan Areas," American Sociological Review, XIX (1954), pp. 388-398.

[75]H.Hoyt, "Forces of Urban Centralization and Decentralization," American Journal of Sociology, XLVI (1941), pp. 843-852.

[76]L.J.Johnson, "Centrality within a Metropolis," Economic Geography, XL (1964), pp. 324-336.

[77]See for example: J.E.Bohnert and P.F.Mattingley, "Delimiting the C.B.D.," Economic Geography, XL (1964), pp. 337-347., D.H.Davies, "Hard Core of Cape Town's C.B.D.: An Attempt to Delimitation," Economic Geography, XXXVI (1960), pp. 53-69., H.J.De Blij, "The Functional Structure and C.B.D. of Lourenco Marques, Mozambique," Economic Geography, XXXVIII (1962), pp. 56-77., E.M.Horwood and R.R.Boyce, Studies of the C.B.D. and Urban Freeway Development (Seattle: University of Washington Press, 1959)., R.E.Murphy and J.E.Vance, "Delimiting the C.B.D.," Economic Geography, XXX (1954), pp. 189-222., and P.Scott, "The Australian C.B.D.," Economic Geography, XXXV (1959), pp. 290-315.

The nature and condition of residential areas has been the subject of studies by Davis, Fuchs, Jones, and Hoyt[78]. The increasing interest in the association between residential areas and shopping facilities is reflected in works by Berry, Barnum, and Tennant, Curry, Mabogunje, Pownall, Proudfoot, Thorpe and Rhodes, and a compendium of observations in Economic Geography for 1961[79]. The areal differentiation of the functions of the Baltimore region discovered by Lakshmanan[80]

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[78] J.T.Davis, "Middle Class Housing in the Central City," Economic Geography, XLI (1965), pp. 238-251., R.J.Fuchs, "Intraurban Variations of Residential Quality," Economic Geography, XXXVI (1960), pp. 313-325., R.Jones, "Segregation in Urban Residential Districts: Examples and Research Problems," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 433-446., and H.Hoyt, The Structure and Growth of Residential Neighborhoods in American Cities (Washington Government Printing Office, 1939).

[79] B.J.L.Berry, H.G.Barnum, and R.J.Tennant, "Retail Location and Consumer Behaviour," Papers and Proceedings, The Regional Science Association, IX (1962), pp. 65-106., L.Curry, "The Geography of Service Centres within Towns: The Elements of an Operational Approach," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 31-53., A.L.Mabogunje, "The Evolution and Analysis of the Retail Structure of Lagos, Nigeria," Economic Geography, XL (1964), pp. 304-323., L.L.Pownall, "Retail Potential of Some Representative New Zealand Towns," Economic Geography, XXXIII (1957), pp. 163-170., M.J.Proudfoot, "City Retail Structure," Economic Geography, XIII (1937), pp. 425-428., D.Thorpe and T.C.Rhodes, "Shopping Centres of the Tyneside Region and Large Scale Grocery Retailing," Economic Geography, XLII (1966), pp. 52-73., S.B.Cohen, et.al., Compendium on Retail Structure Studies, Economic Geography, XXXVII (1961), pp. 1-47.

[80] T.R.Lakshmanan, "Approach to the Analysis of Intraurban Location Applied to the Baltimore Region," Economic Geography, XL (1964), pp. 348-370.

indicates the morphological pattern of relationships sought by Pred[81]. The particular case of Chicago investigated by Reinemann[82], and Logan's study of Sydney[83] indicate the importance of industrial location in urban studies.

The pattern of commercial activities in American cities is the subject of an article by Vance[84], in which he establishes the location factors in commercial land use. Brodsky's paper presented to the 63rd Annual Meeting of the Association of American Geographers in 1967 discusses the centrality of employment in American cities in terms of evidence from regression analyses[85]. Whilst location of functions is of major interest, the characteristics of population movements in response to these functions represents a further field of analysis. Nelson

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[81] A.Pred, "The Intrametropolitan Location of American Manufacturing," A.A.A.G., LIV (1964), pp. 165-180.

[82] M.W.Reinemann, "The Pattern and Distribution of Manufacturing in the Chicago Area," Economic Geography, XXXVI (1960), pp. 139-144.

[83] M.I.Logan, "Manufacturing Decentralization in the Sydney Metropolitan Area," Economic Geography, XL (1964), pp. 151-162.

[84] J.E.Vance, "Emerging Patterns of Commercial Structure in American Cities," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 485-518.

[85] H.Brodsky, "Centrality of Employment in American Cities," unpublished paper presented to the 63rd A.G.M. of the Association of American Geographers, 1967.

indicates the relationship between population in similar function cities[86]. Particular reference to diagnostic features of urban population can be found in articles by Clark[87], Berry, Simmons, and Tennant[88], Thomas[89], and Vance[90].

Transport movements and desires have proved to be a profitable field of urban research as a result of the increasing demands made by modern society on the transport system. The understanding of transport networks is beyond the normal specialization of the geographer, but interactions and consequences due to the transport media on the urban area can claim some priority and relevance in the geographer's research. The intimate and intricate relationships which exist have been evaluated only sporadically. Moses has connected the variations in

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[86]Nelson, loc. cit.

[87]C.Clark, "Urban Population Densities," Journal of the Royal Statistical Society, Series A, CXIV (1951), pp. 490-496.

[88]B.J.L.Berry, J.W.Simmons, and R.J.Tennant, "Urban Population Densities: Structure and Change," Geographical Review, LIII (1963), pp. 389-405.

[89]E.N.Thomas, "Areal Associations between Population Growth and Selected Factors in the Chicago Urbanized Area," Economic Geography, XXXVI (1960), pp. 158-170.

[90]J.E.Vance, "Labour-Shed, Employment Field and Dynamic Analysis in Urban Geography," Economic Geography, XXXVI (1960), pp. 189-220.

income within an urban area with traffic problems[91] and Beaver[92], Mayer[93], Taafe[94], and Weigend[95] have studied various aspects of transport geography as they relate to urban areas. Most cities have inaugurated transport studies, and the pressing demands to ease congestion have resulted in the formulation and implementation of plans without due consideration to their effects on the urban environment. Undoubtedly this is a section of urban analysis which remains sadly neglected, yet it is of supreme importance at the present time.

A salient feature in the urban geography of a city is the growth of the built up area through time. Attempts to formulate models for city growth have preoccupied the minds of both sociologists and geographers for some time. As city structure is such an important issue in the

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[91] L.N.Moses, "Toward a Theory of Intra-Urban Wage Differentials and their Influence on Travel Patterns," Papers and Proceedings, The Regional Science Association, IX (1962), pp. 53-63.

[92] S.H.Beaver, "The Railways of Great Cities," Geography, XXII (1937), pp. 116-120.

[93] H.M.Mayer, "Localization of Railway Facilities in Metropolitan Centers as Typified by Chicago," Journal of Land and Public Utility Economics, XX (1944), pp. 299-315.

[94] E.J.Taafe, "Air Transportation and United States Urban Distribution," Geographical Review, XLVI (1956), pp. 219-238.

[95] G.G.Weigend, "Some Elements in the Study of Port Geography," Geographical Review, XLVIII (1958), pp. 185-200.

understanding of the urban area it is desirable to enquire into the development of this concept. Fundamentally it is an issue most discussed by the sociologist, and consequently it is the sociologist's role in urban analysis which needs to be examined.

D. THE SOCIOLOGICAL APPROACH TO URBAN ANALYSIS.

Sociological investigation of urban characteristics is of more recent origin. Aimed at formulating models of generalized urban structure from studies in specific cities, the pattern is one of intra urban analysis. Park sets the scene with a statement in 1926[96]:

> One of the incidents of growth of the community is the social selection and segregation of the population, and the creation, on the one hand of natural social groups, and, on the other, of natural social areas.

Subsequently the intention has been to formulate models of urban growth, and secondly to describe and account for particular social forces at work in the community.

1. Present Concepts of City Structure.

These fall under three headings:

(a) The Gradient Hypothesis, where the pattern of

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[96] R.E.Park, "The Urban Community, A Spatial Pattern and a Moral Order," in The Urban Community, ed. E.W.Burgess (Chicago: University of Chicago Press, 1926), p. 3.

distribution changes continuously in one direction with increasing distance from the centre to the periphery. This is the Concentric Zone Theory of Burgess. The simple model sees a process of succession and expansion with the tendency of each inner zone to extend its area by the invasion of the next outer zone. This is reinforced by the effects of concentration and decentralization. "In the expansion of the city a process of distribution takes place which sifts and sorts and relocates individuals by residence and occupation"[97].

This Concentric Zone Theory reveals a marked similarity to the earlier work by Von Thünen on the Isolated State[98]. In his study of Chicago, Burgess accepts that this ideal situation is subject to divergencies caused by physical barriers and lines of transportation. He supports his conclusions by presenting sociological data in the form of gradients. In passing from the centre of the city to the periphery, delinquent rates, sex ratios and percentage of foreign born persons tend to decrease, whilst home ownership increases.

(b) The Sector Hypothesis postulates radial development pushing out from the centre tending to cause

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[97] R.E.Park and E.W.Burgess, The City (Chicago: University of Chicago Press, 1925, 4th impression 1967), p. 54.

[98] Von Thünen, loc. cit.

certain land uses to reproduce themselves in sectors, particularly along lines of transport. This alternative model was put forward by Homer Hoyt as the Sector Model. He enunciated this theory on the basis of a scrutiny of data provided by real property inventories for 142 American cities[99]. By considering both distance and direction from the city centre, rent levels suggest that the different types of residential areas tend to grow outwards along distinct radii.

(c) The Multiple Nuclei Hypothesis of Harris and Ullman implies that sections of the city tend to specialize, and this causes the city to be organized around several nuclei of various types and functions[100]. The separate functional areas might have existed from the beginning of the city or have evolved during recent times. As Harris and Ullman infer[101]: "Each city is unique in detail but resembles others in function and pattern". This uniqueness implies that no theory of urban growth will apply in its entirety to any one city.

Anderson and Egeland suggest that both Hoyt and

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[99]Hoyt, The Structure and Growth of Residential Neighborhoods in American Cities.

[100]C.D.Harris and E.L.Ullman, "The Nature of Cities," The Annals, of the American Academy of Political and Social Science, CCXLII (1945), pp. 7-17.

[101]Ibid., p. 7.

Burgess patterns exist for different aspects of urban life[102]. From studies in Akron, Dayton, Indianapolis, and Syracuse it was observed that the small families, with the wife at work, who lived in apartment buildings, declined in importance towards the periphery of the city in a concentric zonal fashion. Meanwhile, the prestige areas as measured by education and occupational structures were distributed in sector fashion[103]. The limitations in these classical models have been evaluated by Hoyt[104], but accepting that there are these limitations, the models serve as good starting points for the urban analysis of a specific city.

Urban growth as a topic has pursued similar goals to those of urban structure. Attempting to find a comprehensive model to explain the growth patterns of cities has taken a more practical form of recent. Davie's early work[105] and Griffin's more recent study have been

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[102] T.Anderson and J.Egeland, "Spatial Aspects of Social Area Analysis," American Sociological Review, XXVI (1961), pp. 392-398.

[103] Compare with the results of a Pilot Study based on Winnipeg, pp. 60-73 of this thesis.

[104] Hoyt, Land Economics.

[105] M.R.Davie, "The Pattern of Urban Growth," Studies in the Science of Society, ed. G.P.Murdock (New Haven: Yale University Press, 1937).

basically descriptive[106]. King has also presented a descriptive viewpoint[107], but the methods conceived by Garrison aim at producing computerized models of the urban system[108]. From such models the science of simulation enables the planner to avoid the 'hit and run' policy too frequently adopted. Essentially the effects of planning strategy can be simulated within the computer model rather than on the actual population. As growth of the urban area can be assessed from this model, there is some justification in claiming this as the ultimate theory of urban structure. Possibly this is so, but the model reflects so many parameters (associated only within the computer unit) that it is beyond the conception of the human mind.

2. Social Forces at Work in the Community.

The following statement, lifted from an article by Sheila Harrison[109], conveys the factors requiring

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[106]T.L.C.Griffin, "The Evolution and Duplication of a Pattern of Urban Growth," Economic Geography, XLI (1965), pp. 136-156.

[107]L.J.King, "Discriminatory Analysis of Urban Growth Patterns in Ontario and Quebec 1951-1961," A.A.A.G., LVII (1967), pp. 566-578.

[108]W.L.Garrison, "Toward Simulation Models of Urban Growth and Development," Lund Studies in Geography, Series B, Human Geography, XXIV (1962), pp. 91-108.

[109]S.M.Harrison, The Social Survey (New York: Russell Sage Foundation, 1931), pp. 7-8.

analysis and explanation in the field of sociology:

> The constant rearrangement of elements that make up community life, resulting from new ideas, new opportunities, new interests and energies at work, has taken many forms, among them the transfer of individuals and families to new and different physical environments or the springing up of new environments around their old homes and neighborhoods; the movement of racial, industrial, and agricultural groups away from old associations into new and often difficult ones; a different distribution of people in the various age groupings in many of our largest population centers, and in our rural districts as well, from that obtaining heretofore; the transfer of many of the home industries and functions of a decade or two ago to bakeries, clothing factories, and other shops and agencies outside the home; new forms of transportation and greater general mobility of population; increased leisure time for many people and new forms of recreation facilities, public and private; and a clear tendency, on the one hand, through the great increase in huge multiple dwellings and office buildings, toward the concentration of larger and larger numbers of people on smaller pieces of land, and on the other hand, the apparent tendency toward decentralization in urban regions - toward the removal both of factories and workers' homes from congested central districts to neighboring belts of satellite communities.

The necessity to understand such social forces in terms of associated phenomena focussed attention on methodology. Burgess and Bogue isolated critical issues in this philosophy[110]:

> ... making maps of all types of social problems for which we could get data. From this began to

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[110] E.W.Burgess and D.J.Bogue, eds., Contributions to Urban Sociology (Chicago: University of Chicago Press, 1964), pp. 3-4.

> emerge the realization that there was a definite pattern and structure to the city, and that many types of social problems were correlated with each other.

From this emerged the concept of 'natural areas' and the feasibility of studying these in relation to spatial pattern and cultural life[111]. As mapping must utilize data relevant to variables, it is necessary to identify social variables consistent with urban analytical objectives. The common idea of undertaking Social Area Analysis is to produce a mosaic of distinctive districts. The Shevky and Bell system attempts this exercise with a resulting mosaic through time[112].

This approach to social analysis is still valid, although considerable refinements in technique have since been perfected, mostly due to advances in statistics and computer technology. In their study, Shevky and Bell state[113]:

> ... facts of economic differentiation and of status and power had a significance transcending in importance the significance of relations occurring within the boundaries of the local community.

They conclude that areal differentiation is a response to three factors:

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[111] Burgess and Bogue, p. 7.

[112] E.Shevky and W.Bell, Social Area Analysis (Stanford Sociological Series No. 1, Stanford U.P., 1955).

[113] Ibid., p. 1.

> (a) Distribution of Skills. ... As societies increase in scale, the nature of income-producing property is altered; land gives way to the enterprise, and ownership of the enterprise becomes less significant than position within a given enterprise. At the same time the occupations within a society are regrouped: they become hierarchically organized into levels of skill, income, and prestige[114].
>
> (b) Organization of Productive Activity. ... As societies increase in scale, the structure of productive activity changes. The relationship of the population to its food supply becomes altered. Primary production declines in importance. The range of relations centered in cities increases. The family loses its specific economic, productive functions[115].
>
> (c) Composition of Population. ... As societies increase in scale, mobility increases ... three different concomitants of increased mobility:
>
> (i) Redistribution of population in space.
>
> (ii) Alteration in the age and sex distribution, or changes in the proportion of supporting and dependent populations.
>
> (iii) An increasing diversity ... isolation of subgroups[116].

The aims inherent in this study are closely analogous to the geographers' attempts to isolate spatially differentiated zones. The sociologist is, however, able to manipulate a far greater number and variety of variables, as considerable information is available from census returns.

Moser and Scotts' analysis of British towns[117]

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[114] Shevky and Bell, p. 9.

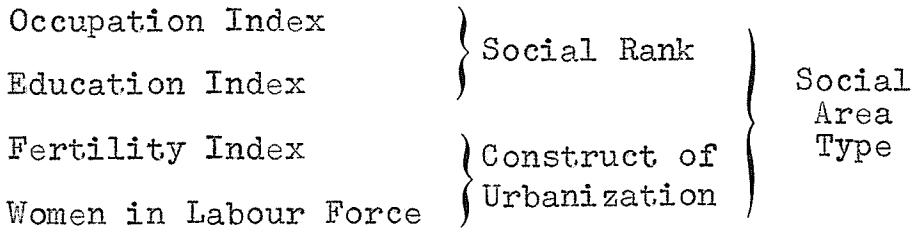
[115] Ibid., p. 10.

[116] Ibid., p. 14.

[117] C.A.Moser and W.Scott, British Towns: A Statistical Study of their Social and Economic Differences (Edinburgh: Oliver and Boyd, 1961).

integrates a number of these variables in arriving at conclusions. Although titled in terms of social and economic differences, the results indicate the tenuous distinction between these disciplines and geography.

Herbert devizes an objective approach to Component Analysis by building up the correlation matrix and assessing the associativity between the variables[118]. Satisfied with the correlation, he uses the component variable because it gives a single expression to several characteristics of the urban structure. His final Social Area Type is constructed as follows:



Interesting points concerning the use of diagnostic variables emerge from Herbert's work. Firstly the occupation index typifies the urban structure well and the fertility index differentiates the urban area with a good degree of accuracy. The percentage of women in the labour force is less successful. The correlation between the two variables in the Construct of Urbanization is very low

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[118]D.T.Herbert, "The Use of Diagnostic Variables in the Analysis of Urban Structure," Tijdschrift, LVIII (1967), pp. 5-10.

in Britain but is high in the United States. Hence such a component variable is more valid in American urban analyses than it is in British counterparts.

The development of factor analysis has aided research in these directions, and it is in the light of these models constructed by Shevky and Bell and Herbert that the ensuing study of Winnipeg is formulated. However, the picture is not yet complete as developments in sociology have been matched by an awareness of the delicate economic forces at work in the urban areas and their effects upon the community as a whole.

E. THE ECONOMIC APPROACH TO URBAN ANALYSIS.

"The city is not, however, merely a geographical and ecological unit, it is at the same time an economic unit. The economic organization of the city is based on the division of labour"[119]. This statement by Park isolates one aspect of an economic analysis of the city - the location of different economic functions. There is a second feature of economic analysis closely associated with the differentiation of functions, namely land values. As McKenzie implies[120]:

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[119] R.E.Park, The City, eds. R.E.Park and E.W.Burgess (Chicago: University of Chicago Press, 1925, 4th impression 1967), p. 2.

[120] R.D.McKenzie, ibid., p. 75.

> Invasions produce successional stages of different qualitative significance, that is, the economic character of the district may rise or fall as the result of certain types of invasion. This qualitative aspect is reflected in the fluctuations of land or rental values.

The first economic interest is in land use characteristics, and stems from the theories of Weber[121] and Isard[122]. By examining location in terms of economic forces they were able to formulate premises from which intra urban distribution of functions became more logical. McCarty, Hook, and Knos have considered the linkages to be found in the industrial complexes[123]. In the case of the urban economic base model, discussion has centred on the work performed by geographers - Alexander in particular. Roterus and Calef examine Alexander's Basic-Nonbasic ratio[124], Hoyt assesses the utility of such studies in measuring urban growth[125], whilst Tiebout tests

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[121] A.Weber, Theory of location of Industries (Chicago: University of Chicago Press, 1929).

[122] W.Isard, Location and Space Economy: A General Theory Relating to Industrial Location, Market Areas, Land Use, Trade, and Urban Structure (New York: Wiley, 1956).

[123] H.H.McCarty, J.C.Hook, and D.S.Knos, The Measurement of Association in Industrial Geography (State University of Iowa, Department of Geography, No.1, 1956).

[124] V.Roterus and W.Calef, "Notes on the Basic-Nonbasic Employment Ratio," Economic Geography, XXXI (1956), pp. 95-99.

[125] H.Hoyt, "The Utility of the Economic Base Method in Calculating Urban Growth," Land Economics, XXXVII (1961), pp. 51-58.

its empirical methods within the general framework of economic analysis.[126]

Secondly, there is the economic interest in land rent. Ratcliff's book Urban Land Economics, covers this wide topic in a systematic fashion[127]. Certain facets of the problem tend to become accentuated. Urban sprawl and fringe settlements are such cases. Sinclair utilizes Von Thünen's model in explaining urban sprawl[128], and Harvey and Clark implement a purely economic enquiry[129]. Preston, on one hand, considers transition zones[130], whilst on the other hand, Yeates takes the full areal extent of Chicago in examining land values[131].

The strictly economic approach in urban research shows the greatest deviation from an interdisciplinary attack on city analysis. Only in the Russian conception

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[126] C.A.Tiebout, "The Urban Economic Base Reconsidered," Land Economics, XXXII (1956), pp. 95-99.

[127] R.U.Ratcliff, Urban Land Economics (New York: McGraw Hill, 1949).

[128] R.Sinclair, "Von Thünen and Urban Sprawl," A.A.A.G., LVII (1967), pp. 72-87.

[129] R.O.Harvey and W.A.V.Clark, "The Nature and Economics of Urban Sprawl," Land Economics, XLI (1965), pp.1-9.

[130] R.E.Preston, "The Zone in Transition: A Study of Urban Land Use Patterns," Economic Geography, XLII (1966), pp. 236-260.

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

of urban geography does it figure as the paramount method of analysis. Elsewhere it acquires a growing stature and will be of increasing usefulness in developing urban methodology.

F. SUMMARY.

The foregoing observations indicate the development of distinctive methods of urban research. They suggest that urban centres imply more than just aggregates of persons. The inter urban geographical studies render some insight into economic functions and spatial disposition, frequently in a hierarchical form, which also exist within one specific urban centre. What applies on a widespread scale is also applicable within the city.

The ideal situation is to identify all the forces at work in the dynamic urban environment. Put simply, the raison d'être of the city is a geographical problem, the human interactions belong to the sociologist, whilst the analysis of location is the field of the economist. A thorough comprehension of the city requires a combined assessment from the point of view of all three disciplines. The choice of variables must reflect this fact and attempt to be as exhaustive as is feasible. The larger the number of variables utilized, the greater will be the probability of formulating a model representing

reality. The magnitude of the task, coupled with an imprecise knowledge as to the limit of the field of forces affecting the urban environment, mitigates against the possibility of ever being able to define the complex urban system completely.

Expressing the situation mathematically, it is possible to postulate three fields of knowledge in urban analysis:

Geographical ≡ Set **G**

Sociological ≡ Set **S**

Economic ≡ Set **E**

The Urban System become the Universal Set I, and assuming that all urban phenomena can be studied in the context of the three sets defined,

$$\mathbf{G} \cup \mathbf{S} \cup \mathbf{E} = I$$ [132]

This situation can be represented in a Venn diagram as shown in Figure 1 (page 47).

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[132] Set Theory in mathematics enables many logical everyday situations to be reduced to a precise algebraic form. In this form they can be subjected to analytical treatment and deductive conclusions drawn from the analysis. Furthermore, situations can be represented diagrammatically by what are called Venn Diagrams. The symbolism in Set Theory is unfamiliar to most, and, therefore, the operations used in the subsequent exposition of ideas are documented here.

Union of two sets is indicated by $\cup$
Intersection of two sets is indicated by $\cap$
Membership of a set is represented by $\in$
Inverse (outside of a set) of **R** is shown as $\mathbf{R}'$

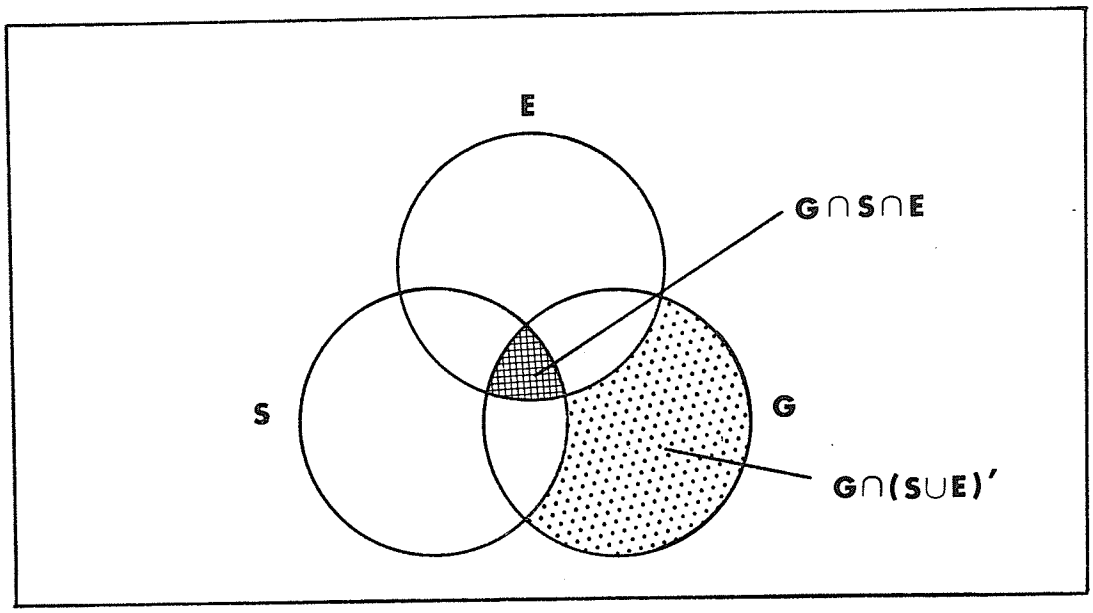

Figure 1. The Urban System.

From this diagram, and using Set algebra, it follows that few studies of the urban area are truly inter-disciplinary - $G \cap S \cap E$, but most are basically within one discipline but using methodology belonging to the others - G or S or E . Only rarely is urban research entirely restricted to one discipline, as would be represented by $G \cap (S \cup E)'$.

The purpose in using this connotation is to state that progressive, useful urban research needs to be within the Set $G \cap S \cap E$, and the maximum utility of such a study will be when this Set defines the complete urban system, namely, when

$$G \cup S \cup E = G \cap S \cap E = I$$

The first object of this thesis is to select

variables pertaining to Winnipeg which lie within the Sets **G**, **S**, and **E**, and attempt to utilize a sufficient number of variables that the Set I has most of its members represented. This choice of variables is presented in the next chapter.

Following this principle, the second objective is to delimit urban sub areas. The traditional criteria in isolating ecological areas include natural boundaries and barriers, prevailing land use and zoning plans, value of dwelling units, and racial segregation[133]. Demographic sub areas are based on enumeration area statistics, by calculating deviations from city ratios, and social sub areas are based on the criteria previously listed. With these sub areas it is then expedient to examine any lack of conformity between boundaries associated with the different variables. As Form, and others, suggest[134]:

> ... some urban sociologists have contended that the distribution of social phenomena may not be directly dependent on variations in land use, natural barriers, and other ecological criteria.

This raises an issue which requires examination. The mapping of sub areas within Winnipeg is the foundation of the second part of this thesis, and the matter of

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[133] W.H.Form, et. al., "The Compatability of Alternative Approaches to the Delimitation of Urban Sub-Areas," American Sociological Review, XIX (1954), p. 435.

[134] Ibid., p. 434.

discordant boundaries will be pursued at that point.

Smith isolates the critical issues at stake in such areal mapping[134]:

> Ideally two conditions should obtain in the resulting scheme:
> (a) the resulting sub-areas must be continuous and contiguous, and exhaust the total space within the corporate limits of the city, and
> (b) the populations contained within the sub-areas should achieve a maximum degree of homogeneity within each sub-area and a maximum degree of heterogeneity among sub-areas.

These two conditions must limit the development of any technique in natural area mapping.

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[134] J. Smith, "A Method for the Classification of Areas on the Basis of Demographically Homogeneous Populations," American Sociological Review, XIX (1954), pp. 201-202.

CHAPTER II

SELECTION AND LIMITATIONS OF DIAGNOSTIC VARIABLES

If one is to accept that there are areal differences existing within the urban area, it is necessary to establish some criteria upon which to measure them. The measurements need to be in the form of data for each unit area based upon relationships with other unit areas within the urban centre. A set of data relates to one particular variable, which is called a 'diagnostic variable' as it has been chosen objectively as an integral component of the urban system.

Clarification is required concerning the two units of measure. A selection must be made as to the unit of area from which to measure the variables, and secondly, the choice of diagnostic variables requires explanation and justification. The first part of this chapter sets out the factors influencing and accounting for the final choices.

Having formulated the structure of the data matrix, it is desirable to test part of it in order to evaluate its limitations. This test is implemented in the form of

a pilot study. This study applies the method of Social Area Analysis, developed by Shevky and Bell[1], to the data matrix of the Winnipeg metropolitan area.

A. SELECTION OF AREAL UNITS.

The largest unit of area is the city itself, and the smallest is that occupied by the individual. Somewhere between these limits a unit of area has to be chosen which proves sufficiently small to ensure a given degree of homogeneity within it, but at the same time not too small that the total number of such units becomes unwieldy or the data prone to error. In electing to use a specific areal unit as a basis for analysis, it is important to ascertain that it is the most desirable unit in terms of the availability and reliability of data. The major source of data is provided by the Census of Canada and the two relevant (for urban areas) units of area are the Census Tract and the Enumeration Area.

The smaller areal unit is the Enumeration Area. It ranges in size from a city block in the central area of Winnipeg, to about 10 blocks in the periphery. The Enumeration Area is the area covered by each enumerator in taking the census. For this reason they "... are primarily

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[1]Shevky and Bell, op. cit.

administrative units for the purpose of conducting the census field operations. As a result, EA's vary from census to census both in number and in size ..."[2].

Changes of boundaries between decennial censuses restrict the usage of Enumeration Areas for comparative study. A second limitation associated with the Enumeration Area is that statistical classifications on this basis are subject to enumerator and respondent biases. These effects are diminished as Enumeration Areas are grouped to give larger units (such as Census Tracts). These biases are more significant for labour force and ethnic groupings, but they approach sizeable proportions for other variables. The exact significance of the response variance for each variable can be found in a Bulletin issued by the Dominion Bureau of Statistics at Ottawa[3].

Because of its small size, the Enumeration Area does provide a more detailed picture of the urban area than larger areal units could supply. It achieves the minuteness and precision that Old considers city block

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[2] Census of Canada, 1961, Bulletin EA/PO/61.

[3] III- Statement on the Nature and Extent of Response Variance Associated with EA Census Statistics, Census of Canada, 1961, Bulletin EA/RV/61.

data could provide for spatial mapping[4]. Enumeration Area data is not, however, in published or readily available form, and this restricts its usefulness.

The second, and larger, areal unit is the Census Tract. The definition delimiting these areas is that, "Census Tracts are designed to be relatively uniform in area and population, and such that each is fairly homogeneous with respect to economic status and living conditions"[5]. The disadvantage in using this areal unit is that their size in fact, varies considerably throughout the metropolitan area[6]. Peripheral tracts are so large that only generalized evaluations of their character are possible. These peripheral areas are, however, the least urbanized, and large contrasts are less likely within the areal unit than for a similar population in the city centre. In spite of this it must be realized that there is a considerable loss of detail inherent in Census Tract data vis à vis Enumeration Area data.

A distinctive advantage accruing to Census Tracts is that their boundaries remain concordant, in the case

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[4]E.B.Old, "The City Block as a Unit for Recording and Analyzing Urban Data," Journal of the American Statistical Association, XLIV, No. 248 (1949), pp. 485-500.

[5]Census of Canada, 1961, Catalogue 95-532, p. 1.

[6]See APPENDIX A, page 207.

of Winnipeg, for the 1951 and 1961 censuses. Comparative studies between years are, therefore, possible.

In Statistical Geography[7] the essentials of Areal Data analysis are formulated. One of the problems in using areal unit data is presented by Duncan[8]:

> Now, an areal unit is being considered here as a "sub population" of the population of items included in the universe of territory which constitutes the field of study. It follows that data on this sub-population - the items "contained in" the areal unit - may be manipulated in any of the ways that population data may be manipulated. The point to bear in mind is that, as a consequence of such manipulations, one obtains a set of data for areal units, or unit data, only some of whose properties resemble those of the data on individual items in the population. ... this areal datum can be handled like an individual datum only if certain of its properties are disregarded. ... Furthermore, an areal datum like the birth rate of the population in the areal unit ... has no close analogy with any individual datum.

The problem to be resolved is whether there is a significant difference in the coefficient of variation for each variable between values for Census Tracts and Enumeration Areas. No statistical measure is possible as data for individuals are not available. In the case of average income it is likely that the standard deviation within a Census Tract is larger than within an Enumeration Area. Assuming an identical mean, this would cause

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[7] O.T.Duncan, et. al., Statistical Geography (The Free Press, Illinois, 1961).

[8] Ibid., pp. 42-43.

its coefficient of variation to be larger also. This is one of the sacrifices that has to be made by generalizing with larger areal units. In no way can either of the two units be considered as random samples, or possessing the same parameters, and hence, normal samplying analysis is inappropriate.

After weighing up the merits of both areal units, the Census Tract was chosen. Due consideration was given to the loss in detail and the potentially inferior homogeneity within the area. The major advantage in choosing the Census Tract is the availability of easily accessible data and the conformity of boundaries over a ten year period. However, the premises and methodology developed would not be altered if the smaller Enumeration Area had been chosen as the unit of area.

Eighty six Census Tracts are listed for the Winnipeg area. Figures for certain peripheral areas - St. Boniface, Assiniboia, Fort Garry, and St. Vital - are not recorded in isolated form. The conterminous urban area includes Windsor Park, which is the unrecorded residential area, comprising the residual of the St. Boniface data. As its population (10,717) was significant, data were extrapolated for this area and given the tract number 87. Fort Garry had a residual population of 2,984 but much of this was not located adjacent to the urban

area. Residual populations for Assiniboia (2,400), Charleswood (707), and St. Vital (1692) were excluded as they comprised mainly rural dwellers.

The location of these 87 areal units is given in MAP 1. The major source of data pertaining to these areas is the Census of Canada[9]. Data from different sources are used in places, but the origin is recorded in appropriate footnotes.

B. SELECTION OF VARIABLES.

The choice of variables is an attempt to give diagnostic measure to the constellation of forces which make up the urban system. Seventy five variables were chosen. Although the number of variables is large, the coverage is by no means full and complete. All that can be hoped is that the number is sufficient to isolate the main factors at work in the community. As would appear from this list of variables[10] an attempt was made to compile as representative and wide ranging set as was feasible. Broadly the variables can be broken down into

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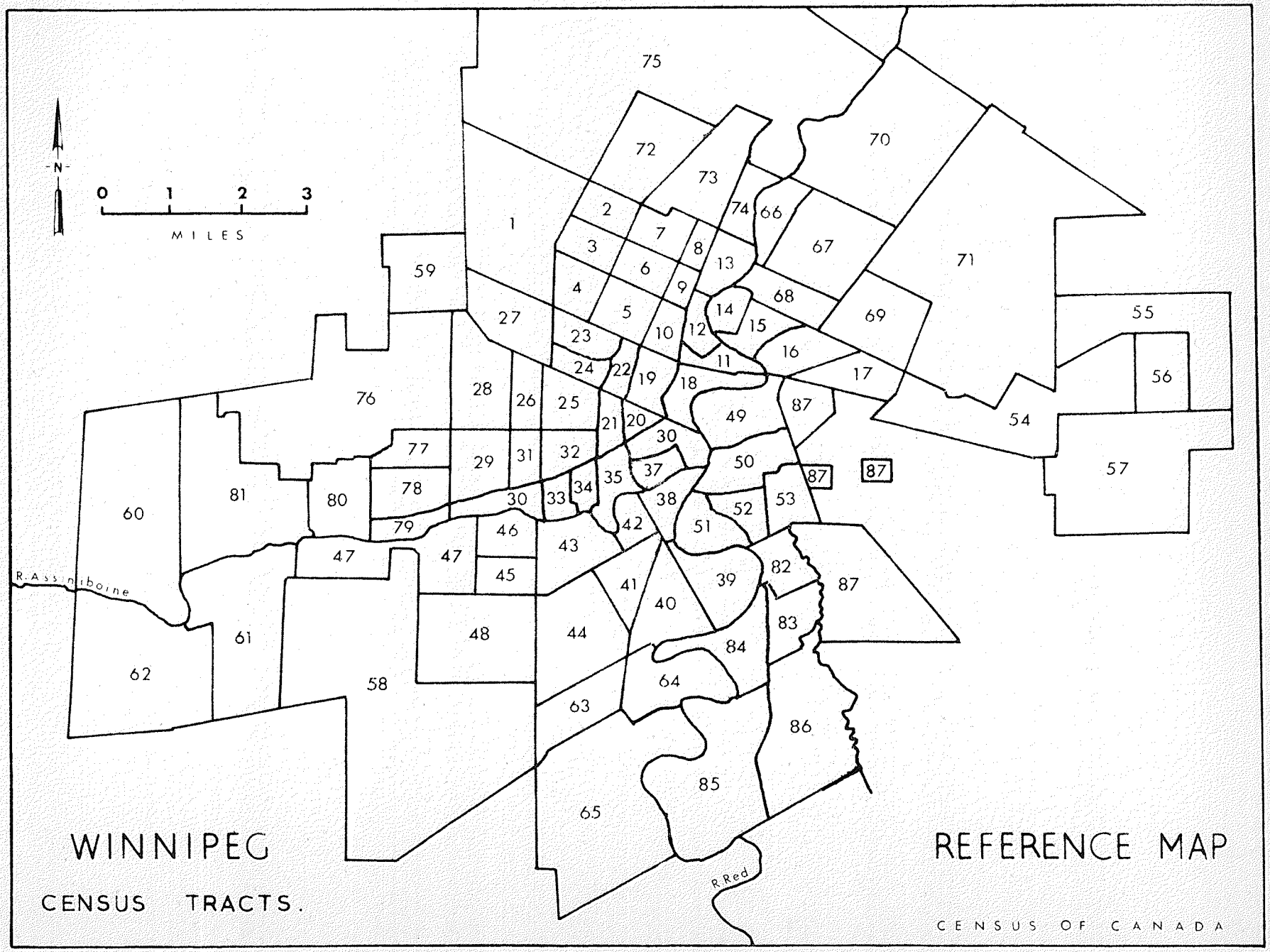
[9]Census of Canada, 1961, Dominion Bureau of Statistics, Ottawa.

[10]The full list of the 75 variables is given in APPENDIX B, page 208. Some of these variables were used to generate further variables for particular purposes (in the pilot study, for example). Explanation of the structure of the less common variables is included in a supplement to APPENDIX B - APPENDIX B (Supplement).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WINNIPEG
CENSUS TRACTS.
REFERENCE MAP
CENSUS OF CANADA

MAP 1

a number of classes:

Population, size and structure (11 variables)

Population mobility (6 variables)

Ethnic composition (12 variables)

Religion (1 variable)

Fertility (3 variables)

Education (2 variables)

Occupational Structure (8 variables)

Income (4 variables)

Household and housing (15 variables)

Social Structure (3 variables)

Retail stores (7 variables)

Physical morphology (3 variables)

C. THE DATA MATRIX.

An item of datum is required for each of the 87 Census Tracts pertaining to each of the 75 variables. The complete supply of data forms a two dimensional array of 87 by 75 unit size. Each unit within the matrix can be denoted by the value x_{ij} (where i takes values from 1 to 87, and j from 1 to 75). This method of nomenclature permits easy access to any item of datum. The areal unit is given by the row number (i value) and the variable by the column number (j value) of the matrix.

The data was punched onto IBM cards and fed into

the University of Manitoba's IBM 360/65 computer. All subsequent statistical manipulations were performed within the computer and the results output in numeric form. The mapping technique was also performed within the computer. The data matrix was operated on by programmed instructions and the mapped results were output by the specific format instructions.

One of the essential requirements in the statistical analysis is that each value x_{ij} in the matrix can be found in the data deck. Some of the census data is obtained from a 20% population sample, and due to sampling variation, estimates of less than 100 are not shown. In such circumstances, estimates for the missing x_{ij} values have to be deduced. The tracts in which this was necessary are listed in APPENDIX B (Supplement).

An added advantage of this method of data storage is that by increasing the dimensions of the array to three, it becomes possible to build a model through time. The three dimensional matrix with unit x_{kij} (where k is a time unit) can be examined through time. With k units of time, the urban system takes on a dynamic context. This dynamism is not examined in this study. Two considerations control the adaption to a time based model. Firstly, the areal unit must remain consistent, and secondly, the computer core storage must be sufficient.

D. PILOT STUDY.

To examine the relationships between some of these variables, this study of Winnipeg is based upon the Social Area Analysis formulated by Shevky and Bell[11]. Inherent in their method is the subjective recognition of certain characteristics of a Social Area. Such an area is identified because it has the same level of living, the same way of life, and the same ethnic background. In order to differentiate the urban centre, it is necessary to measure these three basic dimensions.

A listing of these components, together with the method of compilation follows:

1. ... the same level of living. Social Rank Components.

Two variables are aggregated to form this index.

(a) Occupation Ratio. (Total number of unskilled workers as a percentage of the total labour force for each Census Tract.)[12]

(i) Calculate number of unskilled workers. Add:

Male- Primary. (23)

Craftsmen, production process and related workers. (24)

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[11]Shevky and Bell, op. cit.

[12]Numbers in brackets refer to reference numbers in Table 3 of Catalogue 95-532, 1961, Census of Canada.

Labourers. (25)

Female- Primary. (32)

Craftsmen, production process and related workers. (33)

Labourers. (34)

(ii) Calculate total labour force. Add:

Male labour force. (5)

Female labour force. (6)

(iii) Express unskilled workers as a percentage of the total labour force.

(b) Education Ratio. (The number of persons who have completed no more than grade school as a percentage of total school members for each Census Tract.)

(i) Add: Elementary - 1 or more years. (68)

High School - 1 to 2 years. (69)

(ii) Add: Elementary - 1 or more years. (68)

High School - 1 to 2 years. (69)

High School - 3 to 5 years. (70)

University - 1 or more years. (71)

(iii) Express (i) as a percentage of (ii).

(c) Social Rank Index. The Occupation Ratio and Education Ratio are each scaled between 0 and 100 and then added together. The resulting sum is, itself, scaled between 0 and 100.

2. ... the same way of life. Urbanization Components.

Three variables are aggregated to form this index.

(a) Fertility Ratio. (Number of children under 5 years per 1000 females age 15 through 44 for each Census Tract.)

(i) Record total number of persons 'under 5'.

Add: Males 0-4. (4)[13]

Females 0-4. (16)

(ii) Add number of females in the age range 15 through 44. (19)+(20)+(21)+(22).

(iii) Divide (i) by (ii) and multiply the quotient by 1000.

(b) Women in the labour force Ratio. (The number of females in the labour force per 1000 females 15 years old and over for each Census Tract.)[14]

(i) Record number of females '15 years old and over' employed as 'Wage earners'. (14)

(ii) Record female population '15 years and over'. (3)

(iii) Express (i) as a percentage of (ii).

(b) Single Detached Dwelling Unit Ratio. (The number of single detached dwelling units as a percentage of all dwelling units for each Census Tract.)[15]

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[13]Numbers in brackets refer to reference numbers in Table 1 of Catalogue 95-532, 1961, Census of Canada.

[14]Ibid., Table 3.

[15]Ibid., Table 2.

(i) Record 'single detached occupied dwellings.'

(34)

(ii) Record total 'Households (occupied dwellings).'

(1)

(iii) Express (i) as a percentage of (ii).

(d) Urbanization Index. The Fertility Ratio and the Single detached dwelling unit Ratio are each scaled between 0 and 100. The Women in the labour force Ratio is scaled between 100 and 0. The three are then summed and the resulting Urbanization Index is scaled between 0 and 100.

3. ... the same ethnic background. Segregation Index. In calculating the Segregation Index some deviation is necessary from the method adopted by Shevky and Bell. They were concerned, in particular, with measuring the Negro fraction within American cities. Such an approach is inapplicable in the case of Winnipeg.

Winnipeg is a cosmopolitan city and there are agglomerations of distinct ethnic origin within the urban area[16]. A method of measuring this segregation is to compare the ethnic composition within each Census Tract with the composition of the entire Metropolitan area.

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[16]R.D.Fromson, Acculturation or Assimilation: A Geographical Analysis of Residential Segregation of Selected Ethnic Groups: Metropolitan Winnipeg, 1951-1961., unpublished MA thesis, University of Manitoba, 1965.

A resultant score, indicating ethnic dissimilarity can be calculated as follows:

(i) Calculate the percentage of each of the 12 ethnic groups (British, French, German, Italian, Netherlands, Polish, Russian, Scandinavian, Ukrainian, Other European, Asiatics, and Others- not stated) represented in the total Metropolitan area. This can be represented by the column vector:[17]

$$\begin{vmatrix} xB \\ xF \\ xG \\ xI \\ xN \\ xP \\ xR \\ xS \\ xU \\ xE \\ xA \\ xO \end{vmatrix}$$

xB = Percentage British (34)
xF = Percentage French (35)
xG = Percentage German (36)
xI = Percentage Italian (37)
xN = Percentage Netherlands (38)
xP = Percentage Polish (39)
xR = Percentage Russian (40)
xS = Percentage Scandinavian (41)
xU = Percentage Ukrainian (42)
xE = Percentage Other European (43)
xA = Percentage Asiatic (44)
xO = Percentage Others (45)

Check: $xB+xF+xG+xI+xN+xP+xR+xS+xU+xE+xA+xO = 100$

(ii) For each Census Tract calculate the percentage of each ethnic group. An array of values established at this stage can be represented by the matrix:

$$\begin{vmatrix} 1xB, & 2xB, & 3xB, & \ldots & NxB, & \ldots & 87xB \\ 1xF, & 2xF, & 3xF, & \ldots & NxF, & \ldots & 87xF \\ 1xG, & . & . & \ldots & . & \ldots & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 1xO, & 2xO, & 3xO, & \ldots & NxO, & \ldots & 87xO \end{vmatrix}$$

where N denotes the Census Tract number.

---

[17] Numbers in brackets refer to reference numbers in Table 1 of Catalogue 95-532, 1961, Census of Canada. Percentages calculated from Total population (1).

(iii) Calculate for each Census Tract the difference in each ethnic group between the Metropolitan value and the Census Tract value. This amounts to subtracting the column vector $\begin{vmatrix} xB \\ \cdot \\ \cdot \\ x0 \end{vmatrix}$ from each column of matrix $\begin{vmatrix} 1xB, .. 87xB \\ \cdot \quad\quad \cdot \\ \cdot \quad\quad \cdot \\ 1x0, .. 87x0 \end{vmatrix}$

(iv) For each Census Tract, sum the absolute differences for each ethnic group. For Census Tract N this becomes: $N = \Sigma (|NxB| + |NxF| + \ldots + |Nx0|)$

(v) Complete dissimilarity will be represented by a value 200-2p, where p is the percentage in the total Winnipeg area of the minority ethnic group; and complete similarity will have a value of 0.0.

(vi) The resulting values are scaled between 0 and 100.

The Results

Scaled values were calculated for the three indices Social Rank, Urbanization, and Segregation[18]. In order to analyze the relation between the variables, a series of correlations were computed for component variables of each group. The correlation between Occupation Ratio and Education Ratio is shown in TABLE II, and the correlations between Fertility, Women in the labour force, and Single

[18] See APPENDIX C, pages 215-217.

Detached Dwelling Units are shown in TABLE III.

TABLE II

CORRELATION BETWEEN COMPONENT VARIABLES OF SOCIAL RANK INDEX.

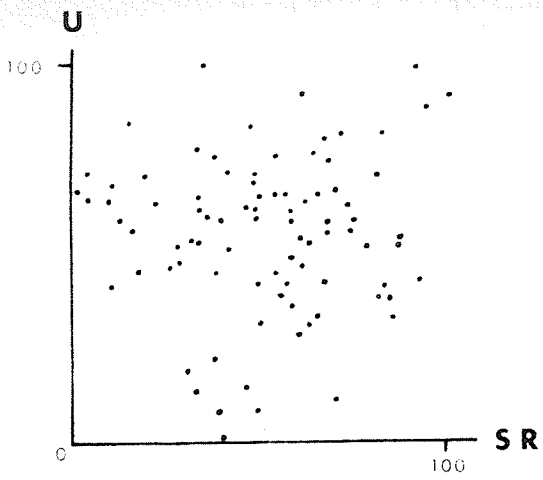
	O.R.	E.R.
O.R.	1.0	
E.R.	0.75	1.0

TABLE III

CORRELATION BETWEEN COMPONENT VARIABLES OF URBANIZATION INDEX.

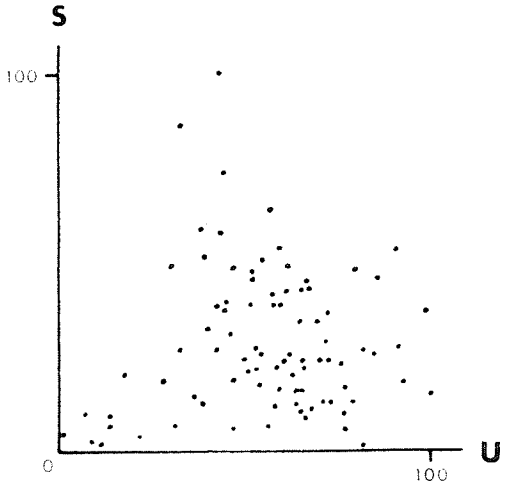
	F.R.	W.L.F.R.	S.D.D.R.
F.R.	1.0		
W.L.F.R.	-0.68	1.0	
S.D.D.R.	0.39	-0.63	1.0

Secondly, a further set of correlations were computed for the three indices. The scaled Index values for each of the 87 Census Tracts are plotted in Figure 2 and the correlation coefficient is recorded. With 85 Degrees of Freedom, a correlation in excess of 0.28 is significant at the 1% level. The between variables correlations infer a substantial (0.40) to high (0.70) relationship, whilst the between indices correlations are



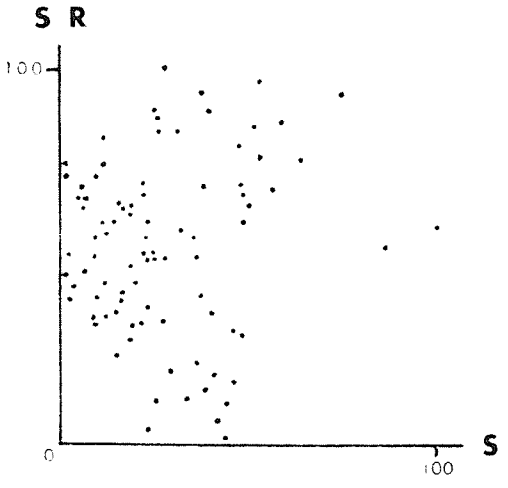
CORRELATION BETWEEN
URBANIZATION INDEX U
AND SOCIAL RANK INDEX SR

r = 0.04



CORRELATION BETWEEN
SEGREGATION INDEX S
AND URBANIZATION INDEX U

r = 0.06



CORRELATION BETWEEN
SOCIAL RANK INDEX SR
AND SEGREGATION INDEX S

r = 0.09

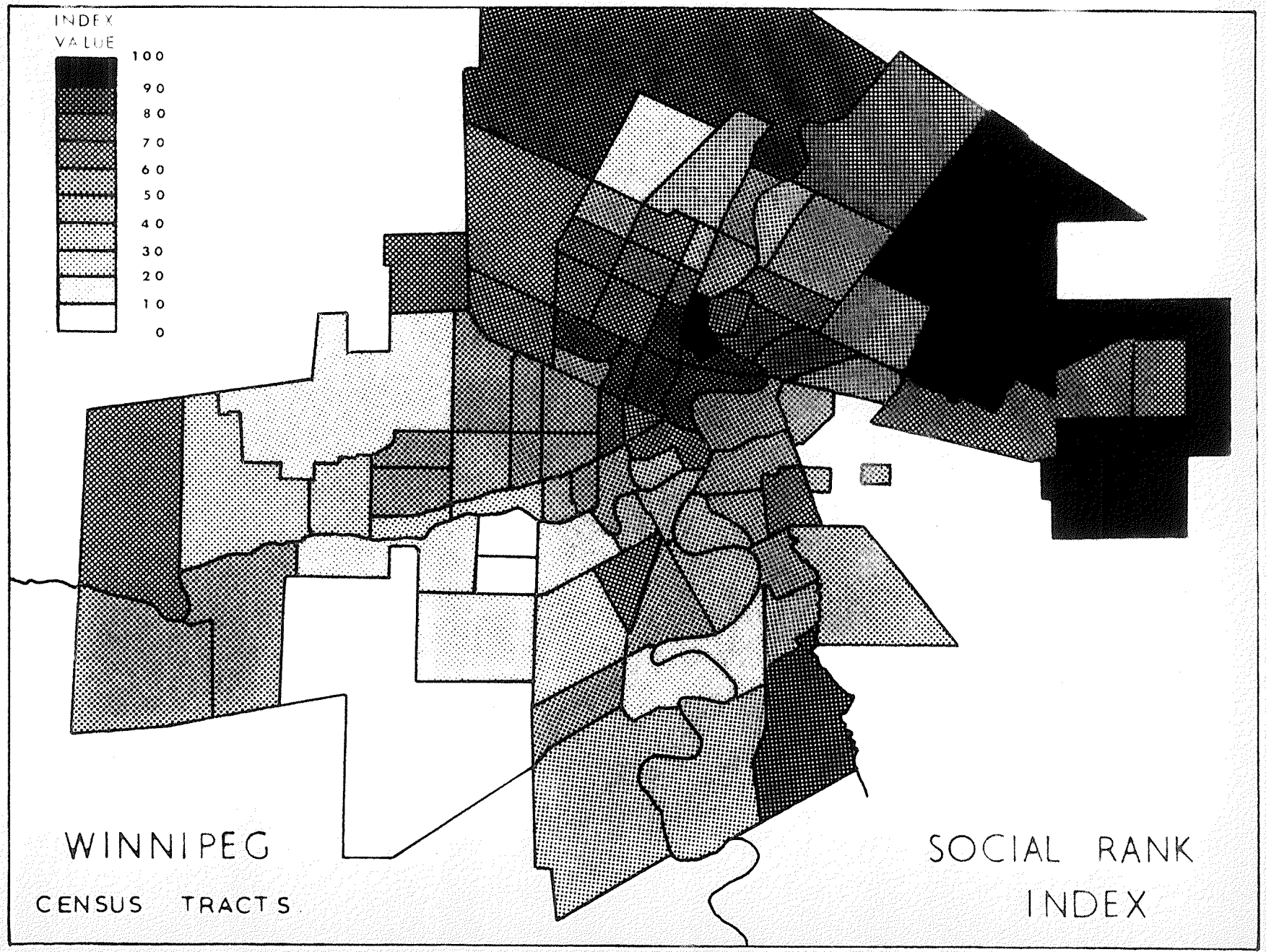
Figure 2
Between Indices Correlation.

indifferent or negligible. The lack of significant correlation between the three indices suggests that Shevky and Bell would have been justified in using them as component factors in the case of Winnipeg.

Extending the study further, it is possible to compare the urban structure of Winnipeg by mapping these three indices. A map of the Metropolitan area is compiled for each index. On these maps each Census Tract is presented by its scaled value for the particular index portrayed by the map. MAP 2 shows the urban structure measured by Social Rank, MAP 3 indicates the Urbanization structure of the city, and MAP 4 represents the city's segregation structure.

The Conclusions

Each of the three maps present different pictures of the urban structure. The Urbanization structure, MAP 3, has the clearest pattern. The method of scaling gives the percentage from complete urbanization. In other words 0 represents total urbanization, whilst 100 indicates the lowest degree of urbanization in the city. The structure corresponds closely with a Burgess Concentric Zone model. A gradual gradient extends in all directions from the Fort James (34 and 35) and Fort Rouge (38) areas. One reason why these two areas have the highest degree of urbanization is that one of the components, number of


INDEX
VALUE
100
90
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10
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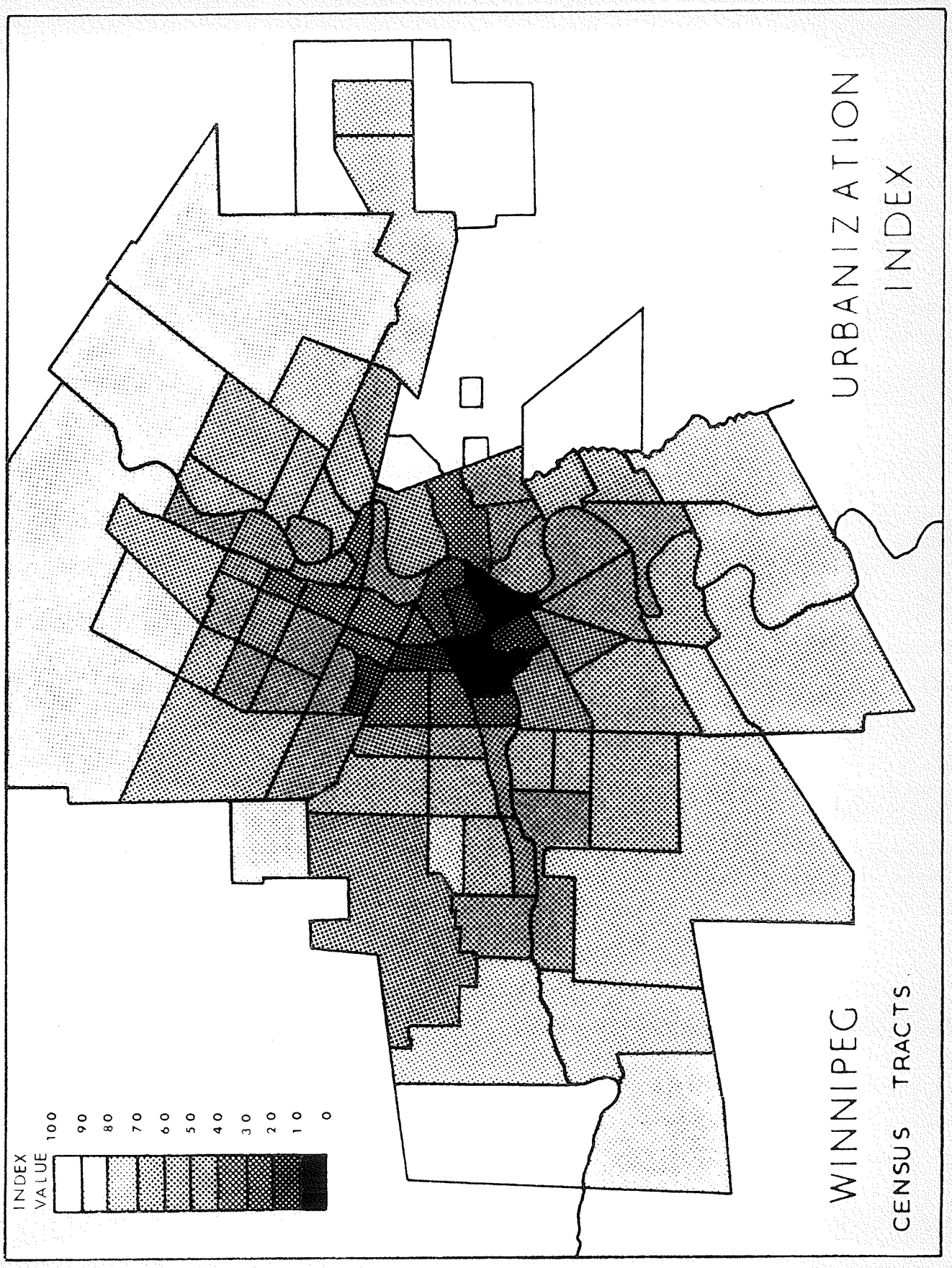
WINNIPEG
CENSUS TRACTS
SOCIAL RANK
INDEX

MAP 2


URBANIZATION
INDEX
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CENSUS TRACTS
INDEX VALUE
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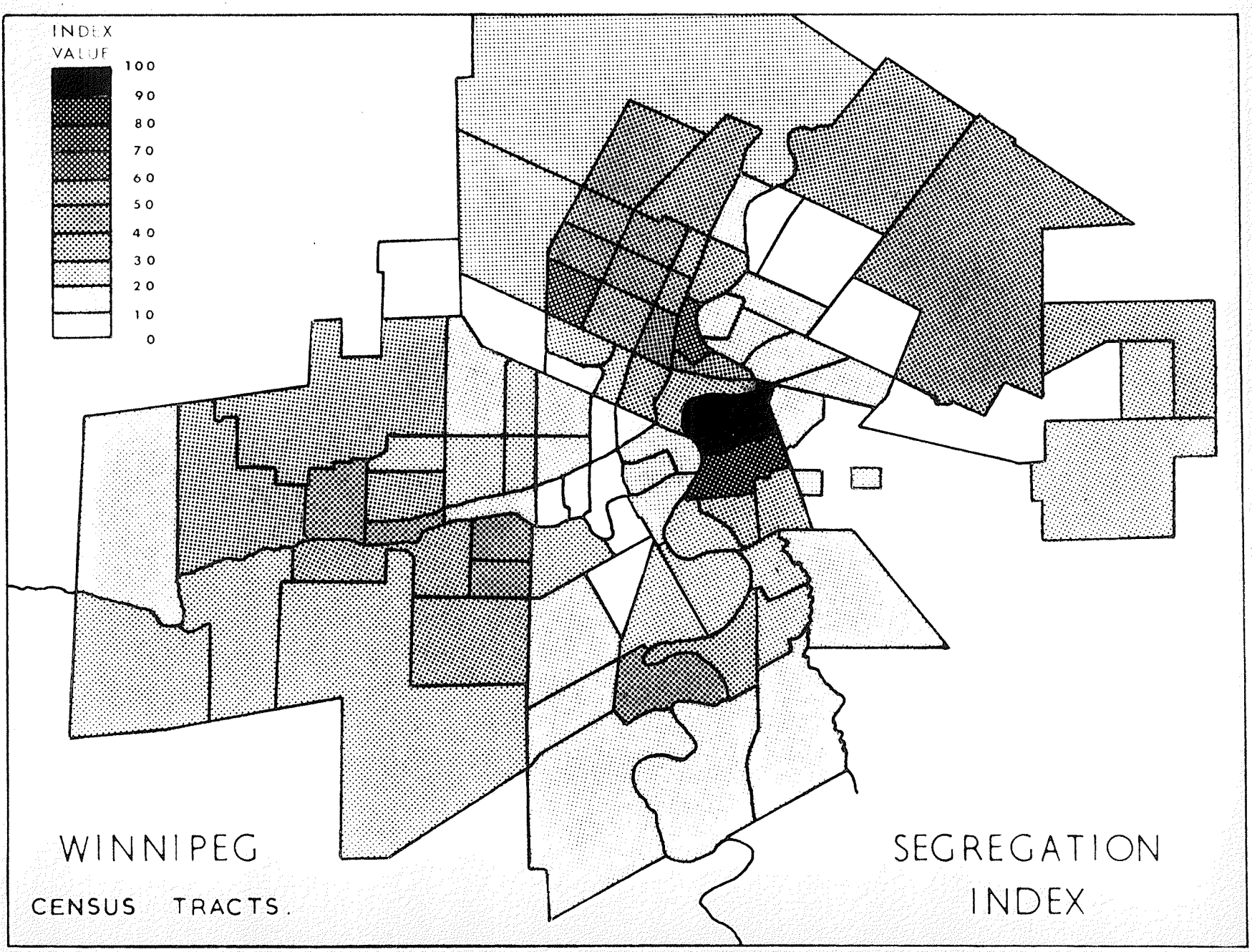
0

MAP 3


INDEX
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0
WINNIPEG
CENSUS TRACTS.
SEGREGATION
INDEX

MAP 4

Single Detached Dwelling Units, has an extreme value in these two areas due to the presence of a large number of apartment buildings. This is partly reflected in the low correlation, 0.39, between the Single Detached Dwelling Ratio and the Fertility Ratio. This suggests one weakness in this method of Social Area Analysis; one component can overwhelm the others.

This fact is reiterated by the Segregation Index in MAP 4. Highest degrees of segregation occur in the French quarter of St. Boniface which is accorded the value of 100. With no clear pattern emerging it is, however, noticeable that large contrasts exist between some adjacent tracts. Moreover, the city centre has the least segregated population structure within the city. This must be almost unique for a city the size of Winnipeg. The typical west European and North American city has a high degree of segregation within the city centre.

The Social Rank Index produces yet a different structure. Expected high values in the city centre are matched by similarly high values in Transcona and the northern areas of the city. The southwestern area of the city, between the Assiniboine and Red rivers, has the lowest values for this index (see MAP 2).

The differences between the three maps can be expected from the results of the correlation. The utility

of this method of analysis is limited by the subjective selection of the components. Furthermore, one variable can dominate the final index if it has extreme values. These limitations apart, this study does indicate the potential use of diagnostic variable analysis. What needs to be done is, rather than select components intuitively, to subject the data matrix to statistical analysis and isolate the factors (similar in concept to the indices of Shevky and Bell) at work in the urban system, and then to map these factors.

CHAPTER III

THE ANALYSIS

The arbitrary choice of variables listed in chapter II is aimed at embracing the controlled and uncontrolled variables that will best test the hypothesis that definite sub areas result from a few fundamental forces at work in the environment. The way adopted by Shevky and Bell of intuitively selecting three such forces is not satisfactory. Factor analysis does not accept a subjective choice of components but determines the degree of association, and picks out the essential wholes among the influences at work.

To perform this analysis it is first necessary to calculate all possible correlations among the 75 variables to see to what extent they covary. This correlation matrix is presented in APPENDIX D[1]. Having produced the correlation matrix, there are a number of

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[1]This requires (75(75-1))/2 coefficients to be calculated. A Factor Analysis can not begin until these 2775 correlations have been calculated. The magnitude of such a task prohibits the analysis without the availability of computer time.

methods of further statistical analysis.

Factor analysis shows how some variables can be grouped together because they behave in the same way, and it proceeds to delineate new independent, underlying factors which may be responsible for these groupings. Until the significant variables, between which regular relationships exist, have been chosen, there is no purpose in formulating precise laws governing the relationships. Factor analysis has as its first goal, the isolation of the real independent factors.

Partial correlation aims at eliminating the effect of one or more contributory influences to a correlation to see to what extent the remainder is due to a particular influence. Factor analysis achieves the same end but, whereas, partial correlation holds variables constant, it holds whole factors constant.

Multiple correlation attempts to obtain a weighted composite of the variables that will give the best possible prediction of the criterion. Factor analysis is more systematic in that it first groups the variables to give estimates of independent functional entities, and then predicts the criterion of these.

The discriminant function tells how to combine a set of variables to give a total which will show the maximum difference between the groups. It is arbitrary in

its combination of variables.

Analysis of variance can handle several independent variables and complex interaction effects at once, but factor analysis can indicate both how many are in action and what the magnitude of their action is.

Although the definite interpretation of a single correlation coefficient is impossible, the sources of variation (factors) which account for the correlations can be made more determinate as more and more variables are taken.

Using the convention that the correlation between any two variables can be represented by the scalar product of their vectors, it is possible to show the relationships between a number of variables diagrammatically. From this diagram it is possible to identify clusters of vectors. A number of problems are associated with this method of identifying clusters. Firstly, clusters may be highly correlated among themselves so that they do not offer independent coordinate axes by which the variables that do not fall into clusters can be brought into a common scheme of representation. Secondly, the level of mean intercorrelation by which a variable can be deemed a member of a cluster is arbitrary. A third restriction on this method is that whilst two factors can be represented in two dimensions, more than three factors necessitates

the use of a hyperspace which can not be committed to visual representation. From this it becomes clear that what factor analysis implies by factors is the dimensions of the space required to contain a certain set of correlations when they are spatially represented.

The method of factor analysis is relatively new in statistics. Initially developed by the psychologists in the study of intelligence, it is only in the last decade that it has been adopted by a few geographers. Berry uses factor analysis in a 1958 paper on regionalization[2], and expands its application in the Atlas of Economic Development published in 1961[3]. In urban geography the 1965 study of Indian cities undertaken by Ahmad relies upon factor analysis[4], as does the more recent work on urban structure by Herbert[5]. The full development of this branch of statistics in geography as a basic research technique is still, however, in its infancy.

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[2]B.J.L.Berry, "A Method for Deriving Multi-Factor Uniform Regions," Przeglad Geograficzny, XXXIII (1961), pp. 263-279.

[3]Norton Ginsburg, Atlas of Economic Development (University of Chicago Press, Chicago, 1961), article by B.J.L.Berry, pp. 110-119.

[4]Qazi Ahmad, Indian Cities: Characteristics and Correlates (University of Chicago, Department of Geography Research Paper No. 102, Chicago, 1965).

[5]Herbert, loc. cit.

Having outlined the main principles and aims of factor analysis in comparison with other analytical methods, indicated some geographical works which utilize the technique, and presented the starting point of the analysis, namely the 75 x 75 correlation matrix, it is now necessary to discuss the subsequent mathematical treatment. Factor analysis, as a multivariate technique, takes two forms. Principal component analysis and pure factor analysis have a distinction which is not always readily apparent, but the mathematical treatment is specific in its application.

Multivariate analysis is concerned with the relationships existing between sets of dependent variables. This relationship can be measured either in terms of dependence or independence. In dependence one, or more, of the variables is selected, and investigation of the way in which it depends on the other variables is undertaken. This is the model of pure factor analysis. Principal component analysis is concerned with independence in which relationships within a set of variables, no one being selected as a special case in the sense of an independent variable, is measured.

With pure factor analysis it is necessary to begin with a model and test it for agreement with a set of data, and thus estimate its parameters. Each variable $\mathbf{x}_i$ (where

i takes values from 1 to p - the total number of variables in the data matrix) can be measured from the equation:

$$x_i = \sum_{k=1}^{p} a_{ik} f_k + b_i s_i + c_i \epsilon_i$$

where f_k are k factors which may appear in more than one x

s_i is a factor specific to x_i

ϵ_i is an error term.

Principal component analysis breaks down a covariance or correlation matrix into a set of orthogonal components or axes equal to the number of variables concerned. These are the eigenvalues (also called latent roots or characteristic roots) and eigenvectors (latent vectors) of the matrix. The correlation matrix is the better starting point as each variable is standardized. This is not the case with a covariance matrix and should the variables not be measured in the same units, certain difficulties occur as the components are not invariant under such changes of scale.

The method of principal component analysis as enunciated by Hotelling[6] is used in this study since the Fortran IV computer language has a number of scientific subroutine packages which permit relatively easy program compilation and running. Eigenvalues are extracted in

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[6]H.Hotelling, "Analysis of a Complex of Statistical Variables into Principal Components," Journal of Educational Psychology, XXIV (1933), pp. 417-441 and 498-520.

descending order of magnitude. The eigenvalues indicate the total variance accounted for by each factor. Cumulative percentages of the total variance in the correlation matrix removed by an increasing number of factors are also calculated. Eigenvectors, which are mutually orthogonal, are derived from uncorrelated factors, and from these vectors and the eigenvalues, the factor matrix is obtained[7]. This factor matrix gives the weights (loadings) for each variable pertaining to the individual factors. The basic equation for this component analysis is:[8]

$$x_i = \sum_{r=1}^{p} w_{ir} z_r$$

where z_r stands for the r^{th} factor

w_{ir} is the weight of the r^{th} factor in the i^{th} variable

This method was applied to the correlation matrix of APPENDIX D. An eigenvalue of 1.0 was chosen, below which no further factors would be extracted. For eigenvalues greater than 1.0, the analysis produced 14 factors. These factors are listed in TABLE IV. From these values it is found that the first factor contributes about 27.7% of the variance, the second factor a further 17.7%, and

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[7]Since the method is an important part of this thesis, the mathematical analysis is presented as an Addendum at the end of this chapter, pages 104-105.

[8]The Fortran IV program effecting this calculation is documented in APPENDIX E, pages 228-230.

the third about 8.1%, making about 52.8% for the three.

TABLE IV

FACTOR ANALYSIS

Factor	Eigenvalue	Percentage of Total Variance[9]	Cumulative Percentage of Total Variance
1	20.797	27.7	27.7
2	12.775	17.0	44.8
3	6.053	8.1	52.8
4	5.085	6.8	59.6
5	3.782	5.0	64.7
6	3.672	4.9	69.6
7	2.661	3.5	73.1
8	2.109	2.8	75.9
9	1.878	2.5	78.4
10	1.441	1.9	80.4
11	1.287	1.7	82.1
12	1.193	1.6	83.6
13	1.093	1.5	85.1
14	1.052	1.4	86.5

Half the variance existing in the correlation matrix can be accounted for by just three factors. This implies that within the urban system three forces exert a pronounced effect on the overall pattern. The first factor itself accounts for over a quarter of the variance and

[9]Errors in last decimal place due to rounding.

would appear to be the most dominant force at work in the Winnipeg urban area. All 14 factors account for over 86% of the total variance but some of the lower factors account for only a small percentage of the whole. It is necessary, therefore, to select a cut off point, below which the factors are of too little significance for this study. Four major factors account for almost three fifths of the total variance, and a further five factors constitute a further one fifth. These nine factors are listed in TABLE V, and the complete situation represented diagrammatically in Figure 3.

TABLE V

SELECTED FACTORS

Major Factors		Minor Factors	
	Cumulative Percentage of Total Variance		Cumulative Percentage of Total Variance
1	27.7	5	64.7
2	44.8	6	69.6
3	52.8	7	73.1
4	59.6	8	75.9
		9	78.4

An examination of the structure of these factors is presented later as the principal components do not have an identifiable separate existence to which a name

can be applied, but rather comprise a weighted mixture of the original 75 variables. For this reason they can only be considered as useful mathematical expressions.

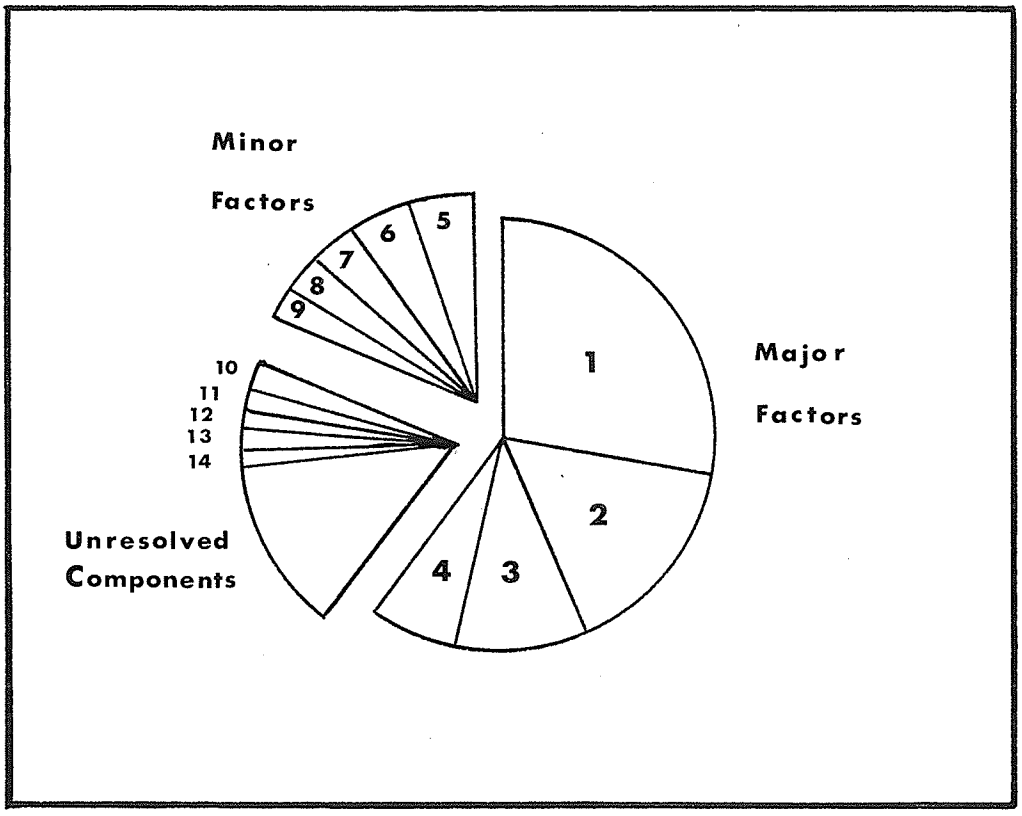

Figure 3. Factor Structure

The next step in the analysis is to examine each of the factors (z_r) in terms of the original 75 variables. This is made possible by the factor matrix (w_{ir}) which records the weightings of each variable for the r^{th} factor. Some variables contribute a positive influence to the factor z_r whilst others have a negative effect. It is the magnitude, rather than the sign, which permits some

conclusions to be made regarding the nature of each of the factors. The weightings applied to each of the 75 variables in reconstituting the factors are given in the factor matrix of APPENDIX F, page 231.

Before examining the structure of each of these factors in detail, it is useful to describe a method of scoring each Census Tract based on these nine factors. This is a necessary corollary as the urban structure is based on spatial diversification whilst the factor analysis has been concerned with the unified situation. The actual spatial pattern within Winnipeg is the basis of chapter V, but some of the source data is compiled at this stage in the analysis.

The basic equation in principal component analysis has been used as a foundation for the extraction of factors. Repeating this equation illustrates that each variable is transformable into a summation of weighted components (the full complement of components which constitute 100% of the total variance):

$$x_i = \sum_{r=1}^{p} w_{ir} z_r$$

Conversely, this equation can be transformed to give a component score in terms of the variable score:

$$z_i = \sum_{r=1}^{p} w_{ir} x_{ir} / \lambda_i$$

where λ_i is the eigenvalue.

and the other parameters remain as already defined earlier in the text.

The next step is to apply this component score to each one of the Census Tracts. Because the variances existing between variables in the original data matrix are not constant, it is necessary to standardize each of the variables. This can be achieved by expressing the Census Tract reading for each variable as a standard deviate and then applying the weightings to these values.

The original 87 x 75 data matrix is transformed to another 87 x 75 matrix in which each a_{ij} value is expressed in standard form. This matrix is then multiplied by the factor matrix w_{ij} (dimension 75 x 9 with nine factors chosen for the study) to give a final matrix with dimensions 87 x 9, in which each column vector gives the factor score for each of the 87 Census Tracts.

As the object of this study is to interpret spatial contrasts in terms of these factors, it is evident that some means of mapping these matrix scores is required. This aspect is pursued in the next chapter and a combination of the mapping technique and the data interpolated in this chapter forms the basis for chapter V. The matrix giving the factor value for each of the 87 Census Tracts forms the basis of an examination of the urban structure of Winnipeg. This matrix is presented in chapter V, although its synthesis is the culmination of the factor analysis undertaken here.

The factor matrix enables an assessment of the structure of the factors to be made. In the case of each factor, those variables with a high weighting (irrespective of sign) in the matrix, have a significant influence within the factor structure. In the case of factors z_1 and z_2 weightings greater than +0.5 and less than -0.5 are isolated, whilst for the remaining factors z_3 to z_9 the corresponding values are $\pm$ 0.25. The variables significant in the structure of each factor can be represented diagrammatically as in Figures 4 and 5.

Adopting these criteria, it is possible to examine the structure of each of the nine factors.

FACTOR 1

This factor accounts for 27.7% of the total variance. From Figure 4 it is apparent that a number of variables are associated beyond the $\pm$ 0.5 limits. These variables are listed in TABLE VI.

The dominant feature of this factor is that it reflects a set of variables closely associated with average income. Increasing average income is associated with increasing car and television ownership. The occupation structure shows increasing percentage of males skilled and a decreasing percentage of males in the labouring category and unemployed. The percentage of females employed, and of these the percentage employed in unskilled trades, is

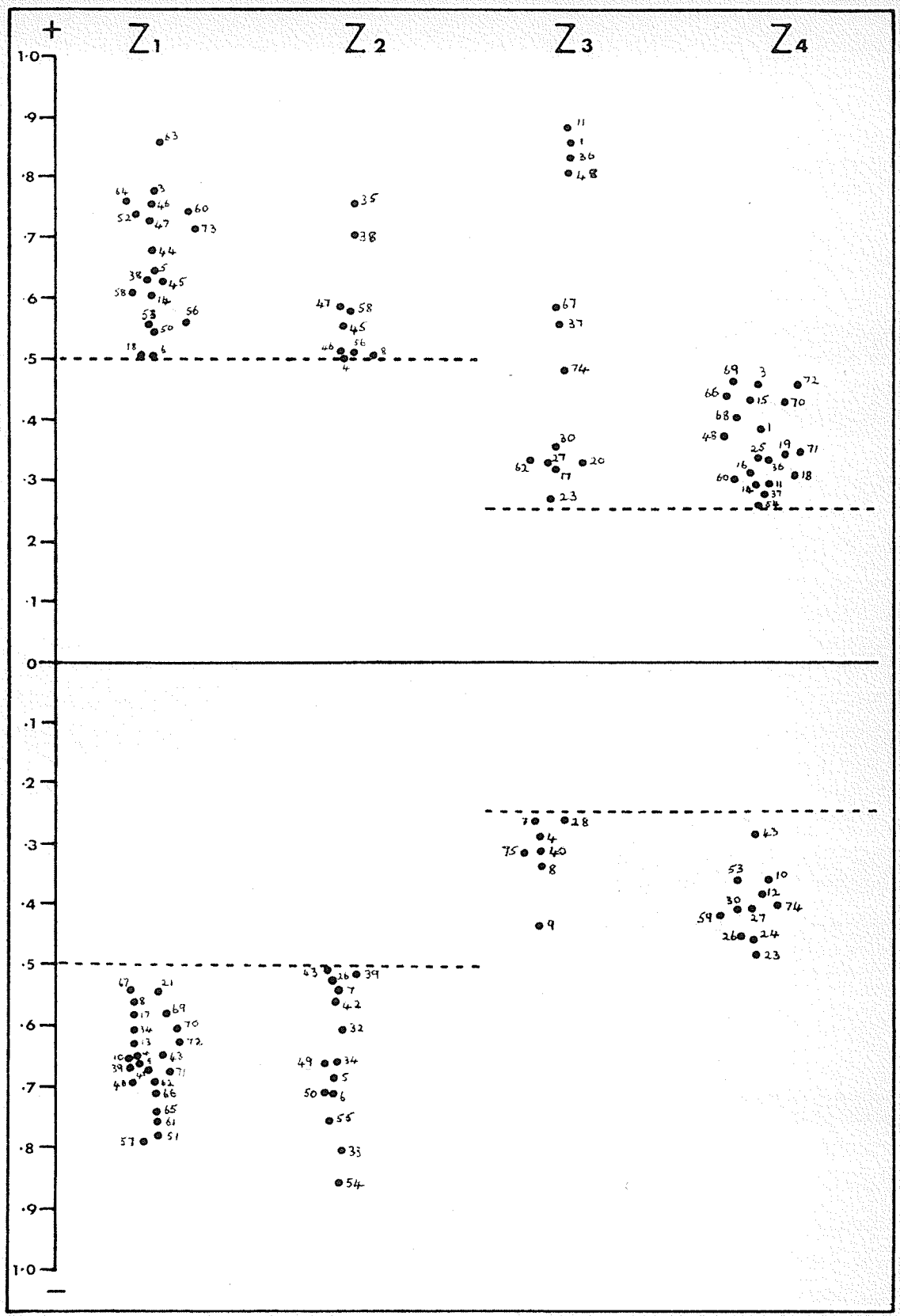

Figure 4. Weightings of Major Factors.

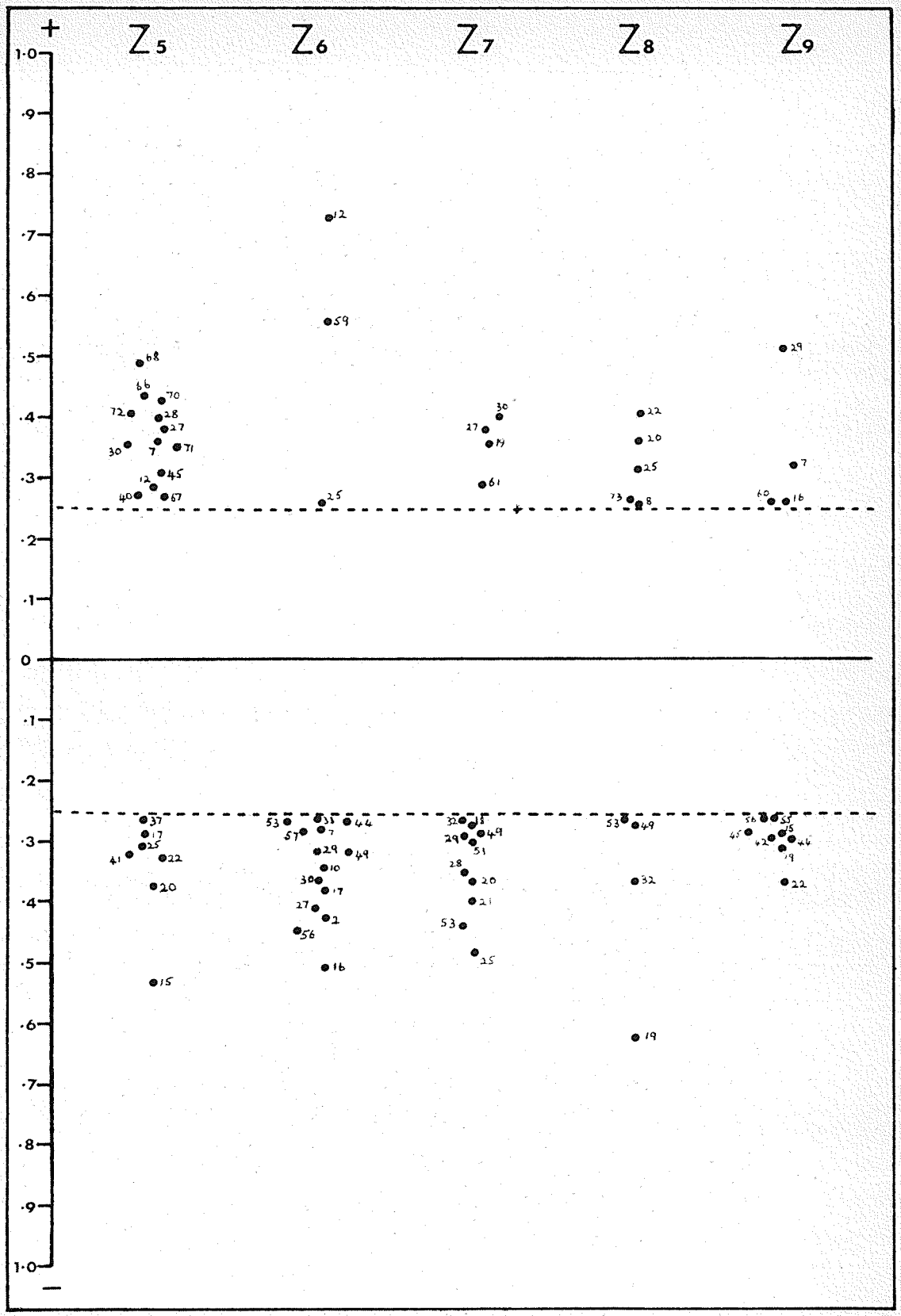

Figure 5. Weightings of Minor Factors.

TABLE VI

STRUCTURE OF FACTOR z_1

x_i	Diagnostic Variable	
3	Percentage born in Canada	POSITIVE
5	Percentage aged 15 or under	
14	Percentage moved from fringe area	
18	Percentage British	
38	Occupation of males - percentage skilled	
44	Average income of head of household	
45	Average family income	
46	Wage and salary income of head of household	
47	Wage and salary income per family	
50	Number of children per household	
52	Percentage of detached dwellings	
53	Number of rooms per dwelling	
56	Median value of property in dollars	
58	Average contract rent in dollars	
60	Number constructed since 1945	
63	Number of automobiles per household	
64	Number of televisions per household	
73	Accessibility	
4	Percentage aged 65 or over	NEGATIVE
8	Index of Aging	
9	Percentage single over 15	
10	Percentage immigrated since 1946	
13	Percentage moved from central city	
17	Percentage from abroad	
21	Percentage Italian	
34	Percentage school dropouts	
39	Occupation of males - percentage labourers	
40	Occupation of males - percentage unemployed	
41	Percentage of female labour force unemployed	
43	Percentage of female workers unskilled	
51	Number of households with lodgers	
57	Number tennant occupied	
61	Number of apartments	
62	Population density	
65	Degree of Social disorder	
66	Total stores	
67	Number of food stores	
69	Number of automobile group stores	
70	Number of apparel and accessories stores	
71	Number of hardware and home furnishing stores	
72	Number of other retail stores	

inversely related to the family income level.

Increased income is reflected in housing characteristics. Greater wealth finds expression in a higher value of property and contract rent, a higher percentage of detached dwellings, and more rooms per dwelling. On the negative side there are less households with lodgers and less tennant occupied dwellings and a lower percentage of apartments. The wealthier areas are characterized by a lower population density and a greater percentage of dwellings constructed since 1946.

This increase in wealth is distributed in peripheral areas where a lower level of accessibility to the downtown area is available. This ties in with the newness of the buildings compared to the city as a whole.

The people involved in this continuum of wealth show an increasing percentage born in Canada of British extraction. Fewer of them have immigrated since 1946. Local mobility indicates that the wealthier groups favour movement within the fringe areas, and a lower percentage have moved out from the city centre.

The increasing wealth is to be found in the married families with children under 15. In these areas there are fewer old people over 65, and the index of aging is low. The percentage of single people over 15 is low also. These facts are associated with the larger percentage of

children to be found in the wealthier groups of the population.

As might be expected, increased wealth is connected with a lower percentage of school dropouts and a lower number of crimes as indicated by the degree of social disorder variable.

The situation with respect to retail outlets is complex. A broad generalization is that in those areas where the higher income groups live, there are fewer shops. This is a feature of this factor as the influence of the C.B.D. controls the balance of the shopping facilities, and the wealthier groups do not live in that area of the city. The implications of this relationship could merit a more rigorous examination.

FACTOR 2

TABLE VII would imply that this factor, which accounts for a further 17% of the variance, is more concerned with the structure of the population in terms of age and education.

Having accounted for the association between youthful sectors of society, and greater wealth in factor 1, it would appear that the situation here is reversed. In the case of this factor, an increasing aging is accompanied by a lower percentage of children, which in turn lowers the percentage of dependents. This is intricately

TABLE VII

STRUCTURE OF FACTOR z_2

x_i	Diagnostic Variable	
4	Percentage aged 65 or over	POSITIVE
8	Index of aging	
18	Percentage British	
35	Percentage population who attended university	
38	Occupation of males - percentage skilled	
45	Average family income	
46	Wage and salary income of head of household	
47	Wage and salary income per family	
56	Median value of property in dollars	
58	Average contract rent in dollars	
5	Percentage aged 15 or under	NEGATIVE
6	Percentage of dependents	
7	Percentage number of males	
32	Fertility of 25-44 age group	
33	Fertility ratio as defined by Shevky and Bell	
34	Percentage school dropouts	
39	Occupation of males - percentage labourers	
42	Number of male workers unskilled (Shevky and Bell)	
43	Number of female workers unskilled (Shevky and Bell)	
50	Number of children per household	
54	Number of persons per room	
55	Percentage of crowded dwellings	

connected with the fertility ratio of the over 25 age group in particular.

The older, more educated and skilled groups occupy the more expensive households, whilst the younger groups , with a higher percentage of school dropouts, and a less skilled male and female labour force, tend to occupy the overcrowded dwellings.

A possible explanation of this factor is that it

reflects the balance between an Anglo-Saxon retirement movement into particular areas, against a less skilled class of labourers of mixed ethnic origin moving into other distinct areas of the metropolitan region. As such it ranks as a force reflecting age and social differentiation within the urban area.

FACTOR 3

This factor is the least satisfactory of the major factors. This is due to the influence portrayed by four variables. Population, number of families, number in the male labour force, and number of households are all measured in absolute units. If each Census Tract were of equal population, covariances between these variables would be meaningful. However, because there is such a wide disparity between population sizes in the Census Tracts, the correlation between these four variables is bound to be high and account for a sizeable amount of the total variance. This highlights one of the problems in factor analysis. If too many variables reflect a single common feature they will give rise to an unreasonably large amount of the total variance and, hence, become upgraded in the position of factor importance.

TABLE VIII suggests that this factor is a good indicator of growth in the urban area. Those areas experiencing the greatest growth of population in the

TABLE VIII

STRUCTURE OF FACTOR z_3

x_i	Diagnostic Variable	
1	Population	POSITIVE
2	Percentage change of population, 1956-61	
10	Percentage immigrated since 1946	
17	Percentage from abroad	
20	Percentage Germans	
23	Percentage Polish	
27	Percentage Other European	
30	Percentage Jewish	
36	Number in male labour force	
37	Number in female labour force	
48	Number of households	
62	Population density	
67	Number of food stores	
74	Land use	
4	Percentage aged 65 or over	NEGATIVE
7	Percentage number of males	
8	Index of aging	
9	Percentage single over 15	
18	Percentage British	
28	Percentage Asiatic	
40	Occupation of males - percentage unemployed	
75	Potential strength of boundary	

period 1956-61 are the large Census Tracts. This indicates the inability of administrative boundaries to keep track with urban expansion. These faster growing areas have a higher percentage of recent immigrants. They also have a higher percentage of German, Polish, and other European inhabitants, possibly as a result of rural depopulation.

These expansions appear to be purely residential and the higher ratio of food shops suggests a tendency

toward neighbourhood development. The negative variables infer that the higher growth rates are associated with younger married people moving into the area. Unemployment is low, as also is the British and Asiatic component of the population.

As the rate of growth in the area increases there is less likelihood of strong physical boundaries restricting the growth. This is a feature of suburban development as a whole. No longer do the physical and cultural restraints manifest themselves as frequently as in the city centre.

FACTOR 4

This factor illustrates the ethnic segregation within Winnipeg. Those areas with a high percentage of British and French occupants tend to be in the larger Census Tract areas where there are a large number of households with fewer rooms and a high ratio of persons per room. These are the newer areas with a high percentage of dwellings constructed since 1946 and few occupied more than 10 years (either due to mobility or age of dwelling). Most of these persons are Canadian born and mobility is quite high with movements into the area from outside the metropolitan area. These tendencies correspond to an increasing factor score for the particular area.

Accompanying a tendency to segregation of the

TABLE IX

STRUCTURE OF FACTOR z_4

x_i	Diagnostic Variable	
1	Population	POSITIVE
3	Percentage born in Canada	
11	Number of families	
14	Percentage moved from fringe area	
15	Percentage from outside the metropolitan area but the same province	
16	Percentage from outside the metropolitan area and a different province	
18	Percentage British	
19	Percentage French	
25	Percentage Scandinavian	
36	Number in male labour force	
37	Number in female labour force	
48	Number of households	
54	Rooms per person	
60	Percentage constructed since 1945	
66	Total stores	
68	Number of general merchandise stores	
69	Number of automobile group stores	
70	Number of apparel and accessories stores	
71	Number of hardware and home furnishing stores	
72	Number of other retail stores	
10	Percentage immigrated since 1946	NEGATIVE
12	Percentage non movers	
23	Percentage Polish	
24	Percentage Russian	
26	Percentage Ukrainian	
27	Percentage other European	
30	Percentage Jewish	
43	Percentage females unskilled (Shevky and Bell)	
53	Rooms per dwelling	
59	Percentage occupied more than 10 years	
74	Land use	

British, French, and Scandinavian is a reduction in the fraction of Polish, Russian, Ukrainian and other European.

The Jewish sector is also diminished in percentage

The increase in the number of all types of retail outlets with the larger size, reflects the tendency for such segregation to be in distinct areas of the city which have their own service centres and autonomy. The city of St. Boniface would seem to epitomize the type of segregation inferred by this factor.

In summary, the four major factors, which account for almost three fifths of the spatial distribution in Winnipeg, combine a number of variables in intricate fashion. Whilst many of the relationships are complex, it is possible to generalize to the extent of saying that four basic forces can be recognized in the environment.

The most important control on spatial differentiation is a difference in income level with its assemblage of associated characteristics. The second influence is in terms of the age and educational standing of various areas. This can be called a social force in the same way as that adopted by Shevky and Bell. Thirdly there is a factor which reflects growth in the urban area. Contrasts are manifested by differences in expansion and decline. Lastly there is a dissociation of the population into ethnic groups, an urban feature of some significance in the case of Winnipeg. It now remains to investigate the form and function of the five minor factors.

FACTOR 5

From TABLE X, this minor factor is difficult to interpret. It presents a relationship between ethnic groups where an increase in Asiatics is accompanied by a decrease in Germans, Netherlanders, and Scandinavians. With increases in Asiatic inhabitants there is a lower mobility. This was a feature of the Chinese sector of Winnipeg at the time of the 1961 census. The Jewish

TABLE X

STRUCTURE OF FACTOR z_5

x_i	Diagnostic Variable	
7	Percentage male	POSITIVE
12	Percentage non movers	
27	Percentage other Europeans	
28	Percentage Asiatic	
30	Percentage Jewish	
40	Occupation of males - percentage unemployed	
45	Average family income	
66	Number all stores	
67	Number of food stores	
68	Number of general merchandise stores	
70	Number of apparel and accessories stores	
71	Number of hardware and home furnishings stores	
72	Number of other retail stores	
15	Percentage from outside the metropolitan area but the same province	
17	Percentage from abroad	NEGATIVE
20	Percentage German	
22	Percentage Netherlands	
25	Percentage Scandinavian	
37	Percentage in female labour force	
41	Percentage of female labour force employed as wage earners	

section of the community has similar prevailing conditions.

These increases are accompanied by a greater number of retail outlets, and this would associate with the Chinese occupation of the downtown area and the Jewish concentration in the North End.

FACTOR 6

TABLE XI

STRUCTURE OF FACTOR z_6

x_i	Diagnostic Variable	
12	Percentage non movers	POSITIVE
25	Percentage Scandinavian	
59	Percentage dwellings occupied more than 10 years	
2	Percentage change of population	NEGATIVE
7	Percentage male	
10	Percentage immigrated since 1946	
16	Percentage from outside the metropolitan area and a different province	
17	Percentage from abroad	
27	Percentage other European	
29	Percentage others and not stated	
30	Percentage Jewish	
33	Fertility ratio by Shevky and Bell	
44	Average income of head of household	
49	Persons per household	
53	Rooms per dwelling	
56	Median value of property in dollars	

The main characteristics exhibited by this factor (see TABLE XI) are the forces of population mobility. It isolates a strong reliance upon non movers. In areas of

higher immobility there are a greater percentage of dwellings which have been occupied over ten years, a smaller change in population as a whole (the older areas of town), fewer newcomers from abroad or outside the province. These areas are associated with lower incomes, fewer persons and rooms per household, and a lower median value of the property. The factor, as a whole, indicates a force of stagnation and possibly of decay in the urban renewal areas of the city.

FACTOR 7

Once again the ramifications of ethnic relationships are apparent in TABLE XII for this factor. Overlooking this aspect, the remaining variables signify the

TABLE XII

STRUCTURE OF FACTOR z_7

x_i	Diagnostic Variable	
19	Percentage French	POSITIVE
27	Percentage other European	
30	Percentage Jewish	
61	Percentage of apartments	
18	Percentage British	NEGATIVE
20	Percentage German	
21	Percentage Italian	
25	Percentage Scandinavian	
28	Percentage Asiatic	
29	Percentage other and not stated	
32	Fertility of 25-44 age group	
49	Persons per household	
51	Percentage households with lodgers	
53	Number of rooms per dwelling	

impact of apartment dwellings in the city. Those areas with a high percentage of apartments have a low fertility in the 25-44 age group, a lower number of persons per household (fewer children), and a lower percentage of lodgers, and fewer rooms per dwelling. This factor is a good indicator of a force controlling a dwelling type preference in Winnipeg.

FACTOR 8

Although this factor constitutes eight basic variables of minor significance, there is a ninth, dominating, variable measuring the French inhabitants in an area. This factor reflects a tendency, exhibited in other factors, for spatial differentiation based on French concentrations. Fertility, aging, and size of dwelling can be interpreted from TABLE XIII.

TABLE XIII

STRUCTURE OF FACTOR z_8

x_i	Diagnostic Variable	
8	Index of aging	POSITIVE
20	Percentage German	
22	Percentage Netherlands	
25	Percentage Scandinavian	
73	Accessibility	
19	Percentage French	NEGATIVE
32	Fertility of 25-44 age group	
49	Persons per household	
53	Rooms per dwelling	

FACTOR 9

As factors account for less total variance, it becomes more difficult to explain the factor structure. This factor involves ethnic relationships and housing characteristics (see TABLE XIV).

The housing characteristic is of greater interest. An increasing number of new houses is associated with occupation by a lower income group. This contrast is particularly difficult to interpret. In association with the lower value of the property and less crowding, it would appear to indicate movement into newly developed areas of uniform, cheaper housing. This is a far from satisfactory factor to explain.

TABLE XIV

STRUCTURE OF FACTOR z_9

x_i	Diagnostic Variable	
7	Percentage of males	POSITIVE
16	Percentage from outside the metropolitan area and a different province	
29	Percentage other and not stated	
60	Percentage constructed since 1945	
15	Percentage from outside the metropolitan area but the same province	
19	Percentage French	NEGATIVE
22	Percentage Netherlands	
42	Percentage males unskilled (Shevky and Bell)	
44	Average income of head of household	
45	Average family income	
55	Percentage of crowded dwellings	
56	Median value of property in dollars	

Unlike the major factors, the minor factors are difficult to interpret. They repeat many trends indicated within the major factor structure and also produce new trends, the forces of which are intricately intertwined and practically impossible to define.

To summarize the structure of these minor factors involves drastic generalization. Factor five implies variance as a result of Asiatic and Jewish segregation, the second minor factor is concerned with mobility of the population in giving rise to regional identity. The seventh factor isolates local differences in terms of dwelling types, with apartment buildings in opposition to single unit dwellings. Factor eight is devoted to French isolation and reinforces tendencies shown in other factors. Lastly, factor nine implies some trend of movement into particular types of housing which are distinct from the area as a whole.

The consequences of this analysis will be taken up at two later stages. Firstly, the mapping of these factors might throw further light onto their structure (see chapter V), and the validity and intrinsic difficulties of the interpretation of factor structure will be discussed in chapter VI, as a conclusion to the entire study.

ADDENDUM

A familiarity with matrix algebra is a prerequisite to understanding the systematic explanation of the linear transformations.

1. The unit matrix $\mathbf{I}$ has elements $a_{ij} = 0$ when $i \neq j$
   and $a_{ij} = 1$ when $i = j$
2. The transpose of matrix $\mathbf{A}$ is $\mathbf{A}'$ where $[a_{ij}] = [a'_{ji}]$
3. An orthogonal matrix $\mathbf{A}$ satisfies $\mathbf{A}\mathbf{A}' = \mathbf{A}'\mathbf{A} = \mathbf{I}$
4. The Inverse of $\mathbf{A}$ is $\mathbf{A}^{-1}$ where $\mathbf{A}^{-1} = [a_{ij}] = A_{ji}\,|\mathbf{A}|$
   The Inverse satisfies the equation $\mathbf{A}^{-1}\mathbf{A} = \mathbf{A}\mathbf{A}^{-1} = \mathbf{I}$
5. The eigenvalues of matrix $\mathbf{A}$ are the values of λ satisfying $|\mathbf{A} - \lambda\mathbf{I}| = 0$
6. The Component Analysis starts with the data matrix of p variables and n observations. The object is to economize in the number of variables needed to describe the inherent relationships within the original data matrix. This is effected by tracing a linear transformation of the type

$$z_i = \sum_{j=1}^{p} w_{ij}\, x_j \qquad (i = 1, 2, \ldots\ldots\ p)$$

where the coefficients of $\mathbf{w}$ are chosen so that the first of the new variates, z_1, has as large a variance as possible.

Then z_2 (uncorrelated with z_1) with the next largest variance is isolated. The process is repeated for z_3, z_4, ... z_n, n being chosen in such a way

that the variance (or cumulative percentage of the variances) reaches a desired level for the whole correlation matrix. In this way a transformation to new variables z_{1-n}, which are uncorrelated and possessing variances $\lambda_1, \lambda_2, \ldots\ldots \lambda_n$, is performed. These variances are the eigenvalues and with the eigenvectors, u'_k, satisfy the relationship

$$u'_k A = \lambda_k u'_k$$

In other words the eigenvector multiplied by the correlation matrix gives the eigenvalue multiplied by the eigenvector. It should be remembered that matrix multiplication is not commutative.

The k^{th} principal component (factor) is obtained from

$$z_k = \lambda_k^{-\frac{1}{2}} u'_k X$$

In order to obtain the factor matrix which represents the weights of each variable under the heading of component z_k, it is necessary to multiply each of the eigenvectors by the scalar $\lambda_k^{\frac{1}{2}} (u'_k u_k)^{-\frac{1}{2}}$

A more rigorous treatment of this subject is available in A Course in Multivariate Analysis by Kendall, and Factor Analysis as a Statistical Method by Lawley and Maxwell.[10]

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[10] M.G.Kendall, A Course in Multivariate Analysis (Charles Griffin: London, 1957).

D.N.Lawley and A.E.Maxwell, Factor Analysis as a Statistical Method (London: Butterworths, 1963).

CHAPTER IV

DEVELOPMENT OF A MAPPING TECHNIQUE FOR THE COMPONENTS

The problem in spatial mapping of a continuous variable results from the necessity to formulate some boundaries within the complete continuous field. The success of the map depends, to a large extent, upon the judicious selection of boundaries. In terms of a bivariate field, the boundaries are usually drawn at some convenient position along the line of regression. In considering the scatter diagram for the **xy** bivariate field (Figure 6) it is apparent that given a significant degree of correlation, the regression equation $y = mx + c$ provides some meaningful measure. A choice of boundaries along the line AB depends upon the number of segments required. Given that the limits of the continuous variable are x_1 and x_2, then the boundary interval is

$(x_2 - x_1)/n$, where n is the required number of divisions of the continuous variable. It follows that each boundary occurs such that its abscissa value is

$x_1 + k(x_2 - x_1)/n$, where k takes values from 0 to n.

This presupposes that the interval remains constant. In using this method there is no reason to assume otherwise, and this property must restrict the utility of such a model.

The limitations of this method can be illustrated by the case of the concentric zone theory of Burgess. One of the criticisms of such a model is that the boundaries mark particular values along a gradient[1], and the line in the model is nowhere as abrupt in reality. For this reason lines can be drawn arbitrarily at any radius from the centre to correspond to any value along the gradient. Why have just five rings in the Burgess model rather than twenty-five?

The questionable validity in basing value judgements upon such a subjective approach invites an examination of alternative techniques. The regression line fulfils the condition that the points are distributed about it such that the sum of their distances (residuals or deviates) from the line squared, reaches a minimum. In the case of the y on x regression, with y as the dependent variable, $\sum_{i=1}^{k} (y_i - y_r)^2$ takes a minimum value. The y_r

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[1]E.W.Burgess, "The Determination of Gradients in the Growth of the City," Publications of the American Sociological Society, XXI (1927).

value is the point on the regression line with the same abscissa value as y_i, and k is the number of points. The line of best fit can, thus, be determined in the form of least squares[2]. A straight line will frequently prove to be a less satisfactory fit than a curve. A curve is a general expression for the designation of both linear and non-linear functions. Moreover, correlation is the tendency for two observed variables to be related in the form of a single-valued mathematical function. A curve frequently satisfies the least squares condition more adequately, but the difficulty of curve fitting and the

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[2]This can be deduced mathematically. To find the limit when $\sum(y_i - y_r)^2$ is at its minimum:

$$\sum(y_i - y_r)^2 = \sum y_i^2 - 2\sum y_i y_r + \sum y_r^2$$

Since $y_r = mx_i$

$$= \sum y_i^2 - 2m\sum y_i x_i + m^2\sum x_i^2$$

But $r = \sum xy/N\sigma_x\sigma_y$

$$= \sum xy/\sqrt{\sum x^2 \sum y^2}$$

And

$$\sigma_x = \sqrt{\sum x^2/k}$$

$$\sigma_y = \sqrt{\sum y^2/k}$$

$$= k\sigma_y^2 - 2kmr\sigma_x\sigma_y + km^2\sigma_x^2$$

$$= A \text{ (say)}$$

Using the calculus: $\frac{dA}{dm} = -2r\sigma_x\sigma_y + 2m\sigma_x^2$

$= 0$ for minimum values of A

$\therefore m = (2r\sigma_x\sigma_y)/(2\sigma_x^2) = r(\sigma_y/\sigma_x)$

$\therefore y = r(\sigma_y/\sigma_x)x$; which is the regression coefficient.

subsequent algebraic analysis restricts its usage.

The superimposition of a series of regression straight lines can sometimes satisfy the least squares condition better than one straight line. To demarcate separate fields within the overall $x_i y_i$ scatter diagram demands an initial identification of boundaries to these fields. Once this has been done a series of regression lines can be drawn to fit the points in each field. This has been undertaken for the same points shown in Figure 6, and the resulting lines possess different gradients and, therefore, intersect each other (Figure 7). At these intersections boundaries can be drawn. The advantage of such a method is that the sum of the residuals squared is lower than for a single regression line. With the change in gradient giving rise to the distinct boundaries, the intervals are unlikely to be of equal magnitude.

One disadvantage that results from this subdivision within the scatter diagram is that the number of points in each subdivision is fewer than for the whole field. This means that the degrees of freedom for each measure of correlation are reduced and a higher correlation coefficient is required to maintain the same level of significance. There is thus a limit to the number of subdivisions possible to remain within a desired level of significance. This level is prescribed by the nature of the analysis.

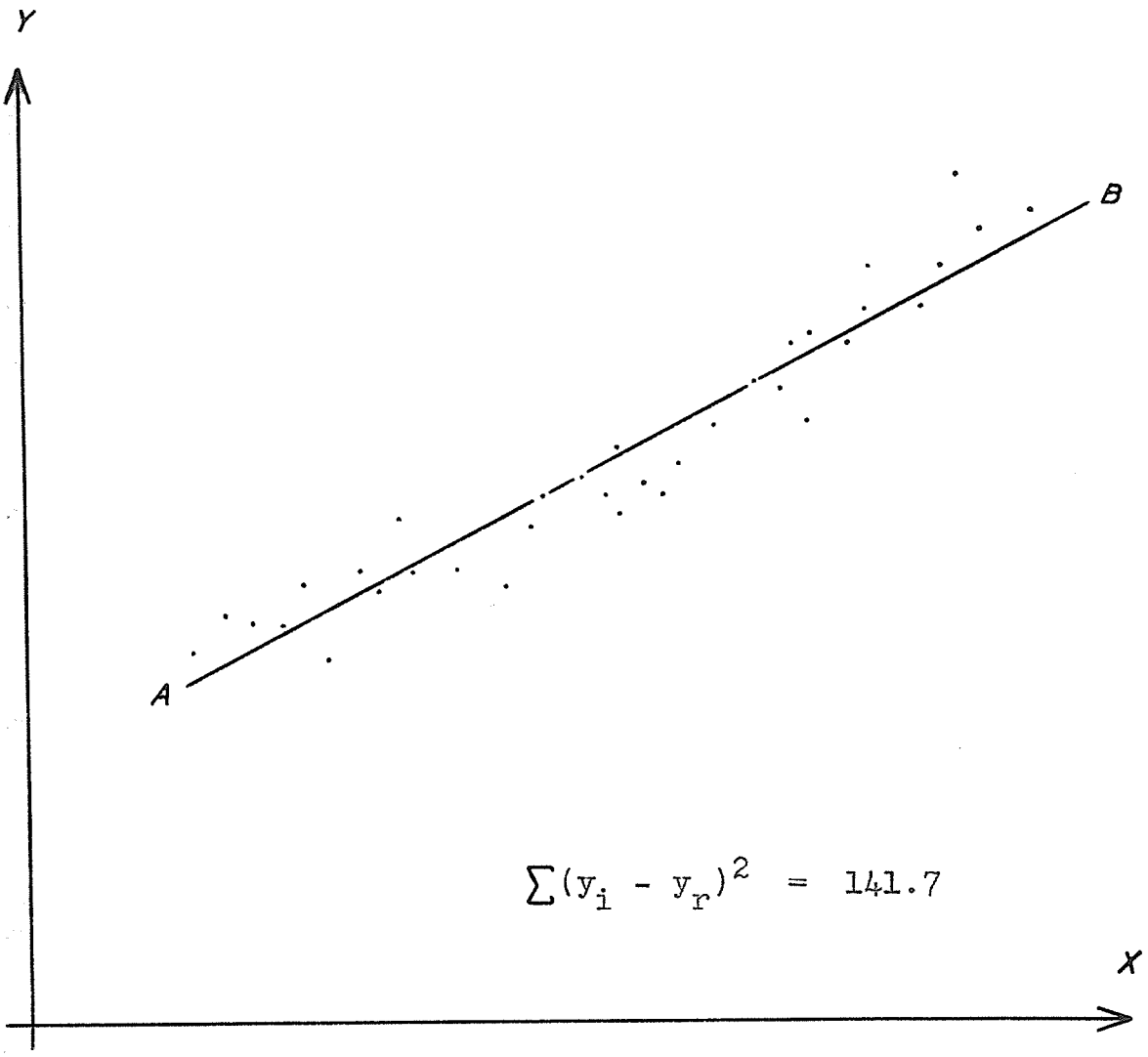


Figure 6

Sum of Residuals Squared for a Single Regression Line in the Bivariate Field

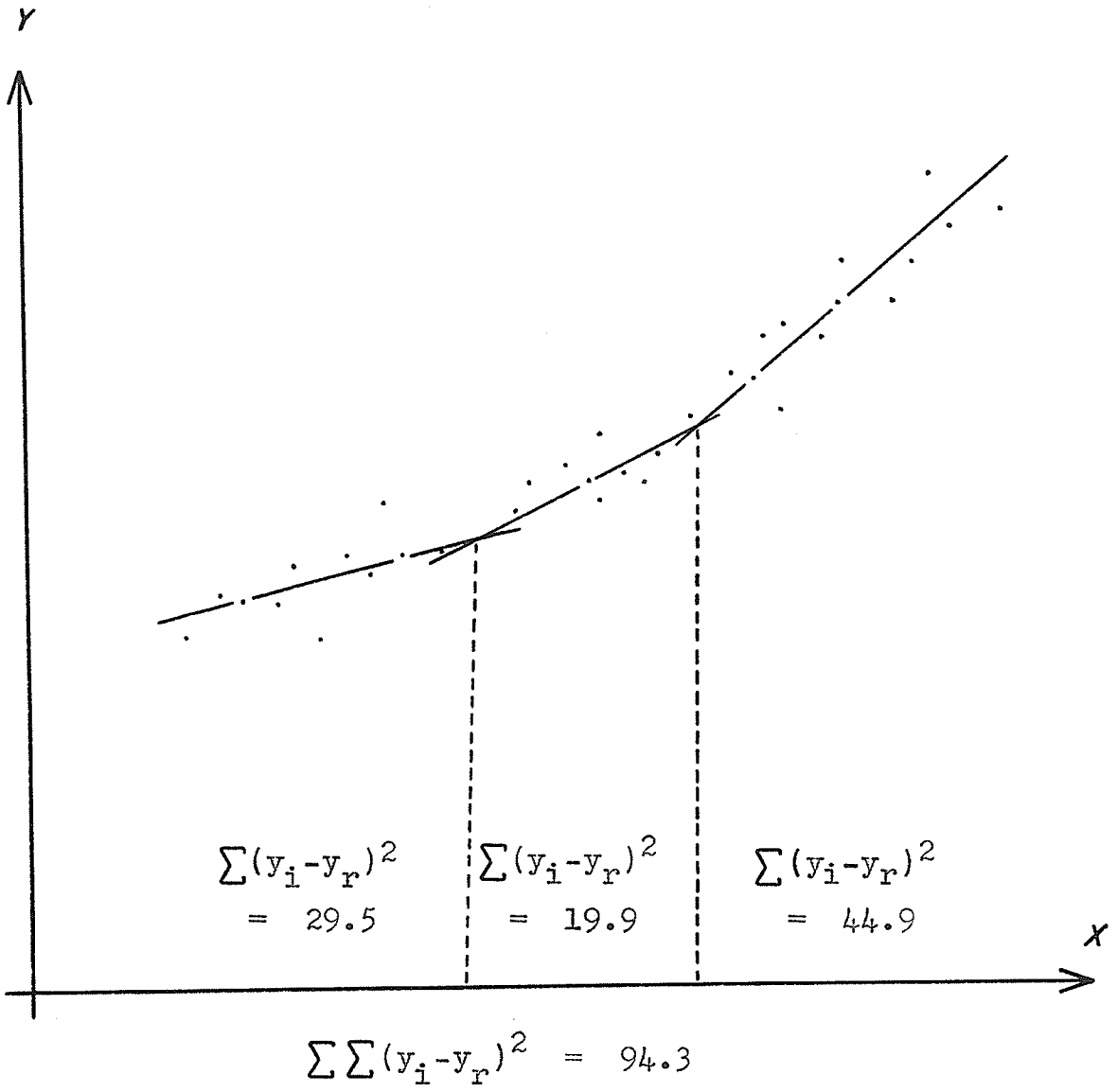


Figure 7

Sum of the Residuals Squared
for Three Regression Lines
in the same Bivariate Field

These difficulties inherent in selecting boundaries are problematic. It is pertinent to question the whole validity of such an approach to mapping urban phenomena if the objective is to isolate sub areas in the city. The pilot study based on the Social Area Analysis of Shevky and Bell maps areas which fall within certain segments of a continuum for the whole city (with index values from 0 to 100). Hence, each area falls within one of a possible ten classes relative to the city as a whole. Is this an ideal way of identifying sub areas in a city? A social sub area exists as a distinct entity by virtue of a contrast with its neighbouring areas. If this is the case it is desirable to isolate these contrasts and formulate a completely new method of mapping them.

The immediate consequences in accepting this premise can be illustrated by a simple example. Assume that 30 areas are measured with respect to one variable, and that the resulting areal measures are plotted on an increasing scale (Figure 8).

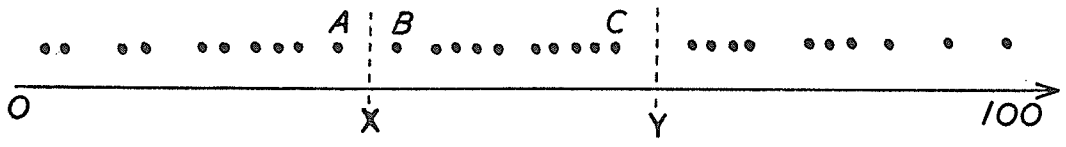


Figure 8
The Areal Unit Measure with Respect to One Variable

Should it be desirable to divide the continuum into three separate classes, boundaries might be erected at X and Y (visual breaks in the continuum occur at these points, and ten areas then constitute each class). Extending the example further, assume that three areas A, B, and C meet at a point. B and C will be mapped in the same class whilst A will be within a different class (Figure 9). A greater contrast exists, however, between C and A or B than between A and B. For this reason C should be mapped as distinct from either A or B.

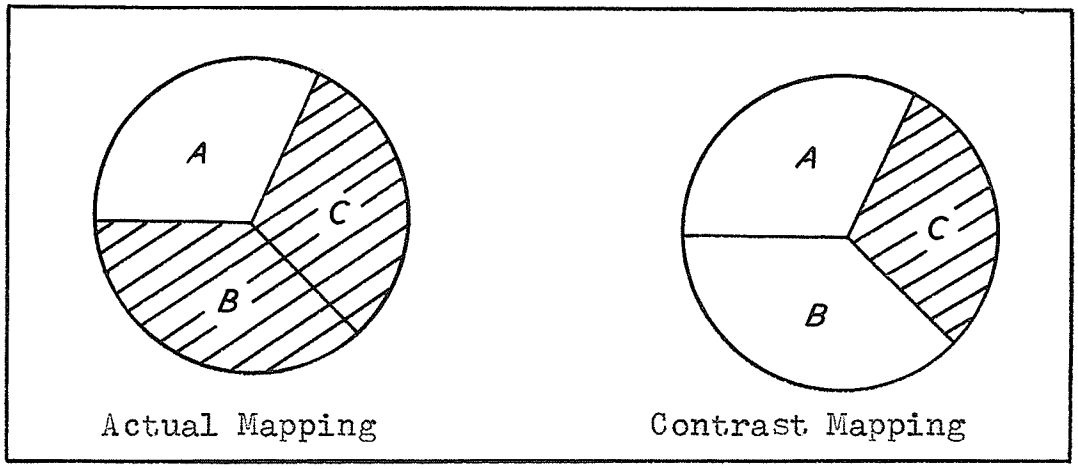


Figure 9. Mapping of Three Neighbouring Areal Units

The conclusion to be drawn from this example is that rather than identify areal differentiation within the city by comparing each unit area with the city as a whole, it is necessary to develop a systematic method of identifying contrasts between adjacent areas.

In this example, it is probable that in other locations within the urban area contrasts between adjacent areas will exist at different values. Consider the case of a transect through eight Census Tracts (75, 1, 4, 5, 10, 11, 18, and 49) in metropolitan Winnipeg for which the median salary is measured (Figure 10). The measure of median salary can be plotted on a frequency polygon, and

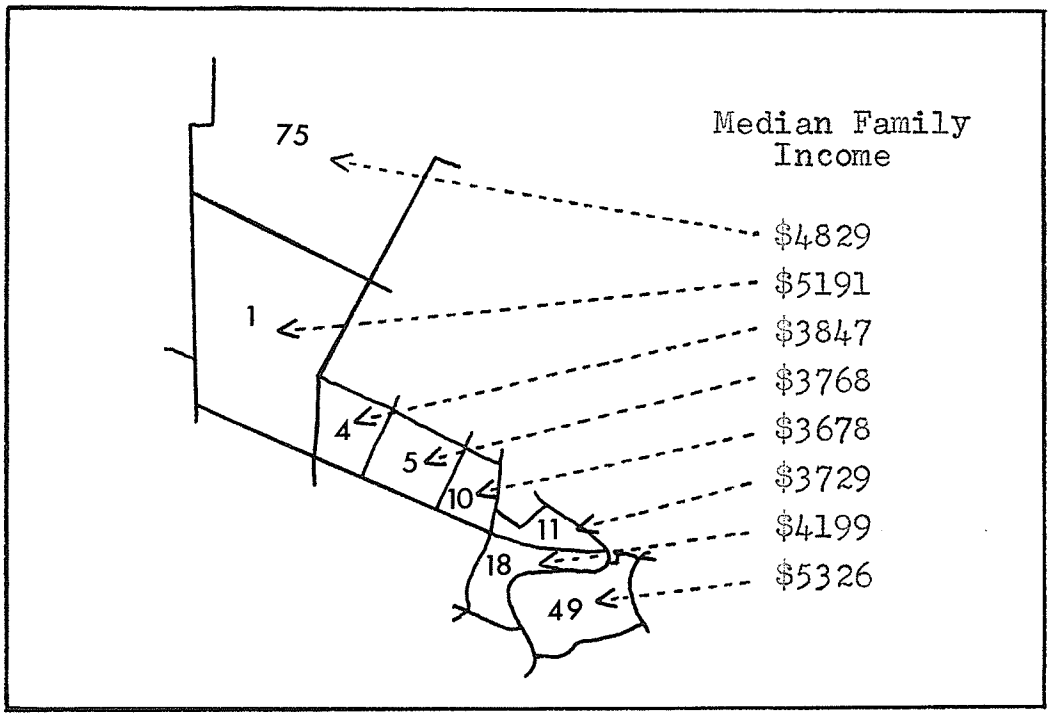


Figure 10. Median Family Salary for 8 Census Tracts.

from this, two extreme changes in gradient are visible (Figure 11). Although the contrast exists in two different places, it is appreciated that they are at different levels in each case. By isolating the actual contrast, irrespective of the actual range in which it occurs, it

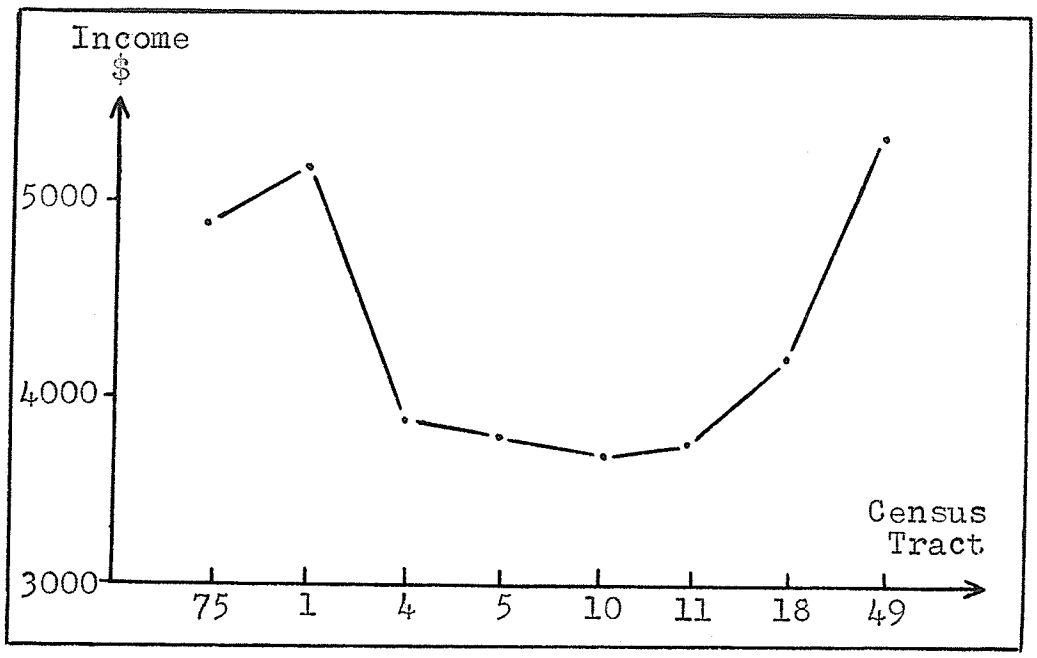


Figure 11. Average Family Income of Census Tracts

is possible to plot the positive or negative deviation between each successive areal measure (Figure 12). In this way the two pronounced contrasts along the transect are readily visible. If this process is repeated for a much larger number of areas it is necessary to specify some limits beyond which the contrast assumes significance. A pair of parallel lines, at a distance of x standard deviates from the zero contrast axis, indicate the limits beyond which the contrast is sufficiently large to be considered as a natural boundary for the particular variable (in this particular instance the two significant boundaries coincide with McPhillips Street and the Red River, both strong physical divides). The main problem is

in ascribing a particular value to x, that is, in deciding when a contrast reaches a level to justify calling it a boundary between natural areas.

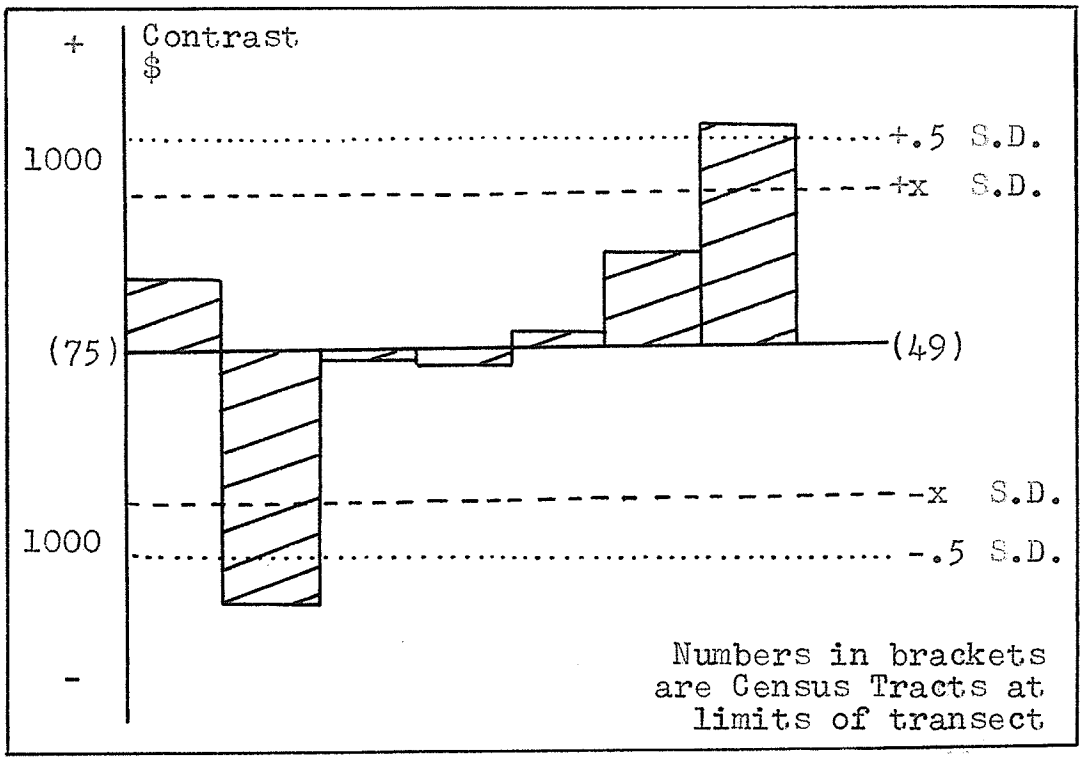


Figure 12. Contrasts in Average Family Income.

This principal can be applied over a wide area if certain modifications are made. Assume that areal contrasts pertinent to one variable need to be located in the Winnipeg area. Further assume that values for the 87 Census Tracts are normally distributed. By calculating the mean and standard deviation for the variable it is possible to represent each of the Census Tract measures in the form of standard deviates. Any one Census Tract can be isolated and the deviate contrast with all other Census Tracts calculated.

This process would be laborious and time consuming, so the methodology is reworded to permit fast computer analysis. Essentially the process is to scan the normal distribution field, stopping at a series of values and calculating and mapping the deviation of every Census Tract value from this arbitrarily chosen standard. In detail the process is as follows:

(a) Erect an arbitrary pivot at the value "mean - 2 standard deviations" for the particular variable.

(b) Calculate the deviation (in standard deviates) of each of the 87 Census Tracts from this pivot.

(c) Code these deviations by the following numerals:

$< \pm$ 0.1	standard deviate	= 0
$< \pm$ 0.2		= 1
$< \pm$ 0.3		= 2
$< \pm$ 0.4		= 3
$< \pm$ 0.5		= 4
$< \pm$ 0.6		= 5
$\geq \pm$ 0.6		= 9

This means that any area with the value 9 is at least 0.6 standard deviates away from the pivot and at least 0.5 standard deviates away from any area with the value 0. This situation is shown in Figure 13.

(d) Map the calculated values for each Census Tract.

(e) The pivot is then moved along the normal distribution by a step of 0.2 standard deviates and the calculation and mapping is repeated at each such position.

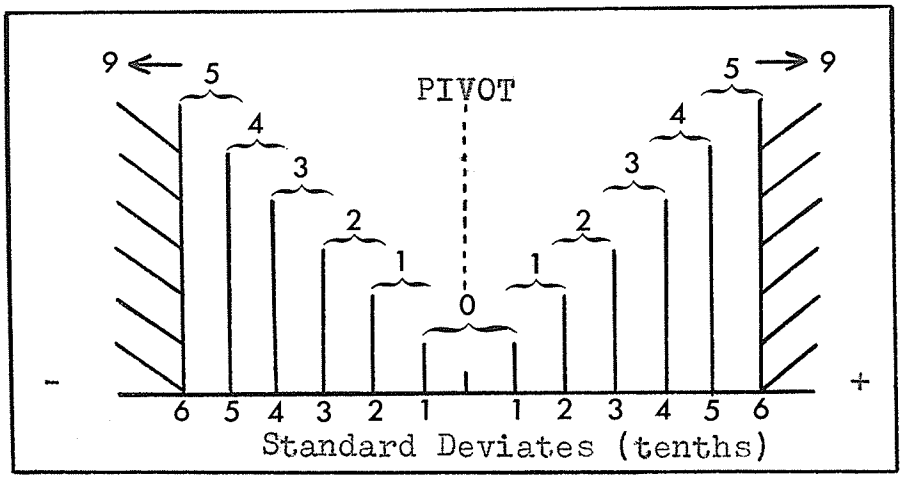


Figure 13. Deviation about Pivot

A movement of 0.2 standard deviates causes each Census Tract value to fall into the 0 category (± 0.1 S.D.) once, and only once, during the scan of the distribution. (f) The process continues until the pivot reaches a value of "mean + 2 standard deviations". A series of 21 maps results, and covers values from -2.6 S.D. to +2.6 S.D..

If the original measures for each of the 87 Census Tracts are normally distributed, the range covers 99+% of the cases and only occasionally will a Census Tract value lie outside this range (see Figure 14), and such exclusions will simply indicate a non-normal distribution for the particular variable under consideration. In fact the following example possesses this property at the positive end of the distribution (where Tuxedo averages too high a family income to be included in the normal distribution curve for the city as a whole).

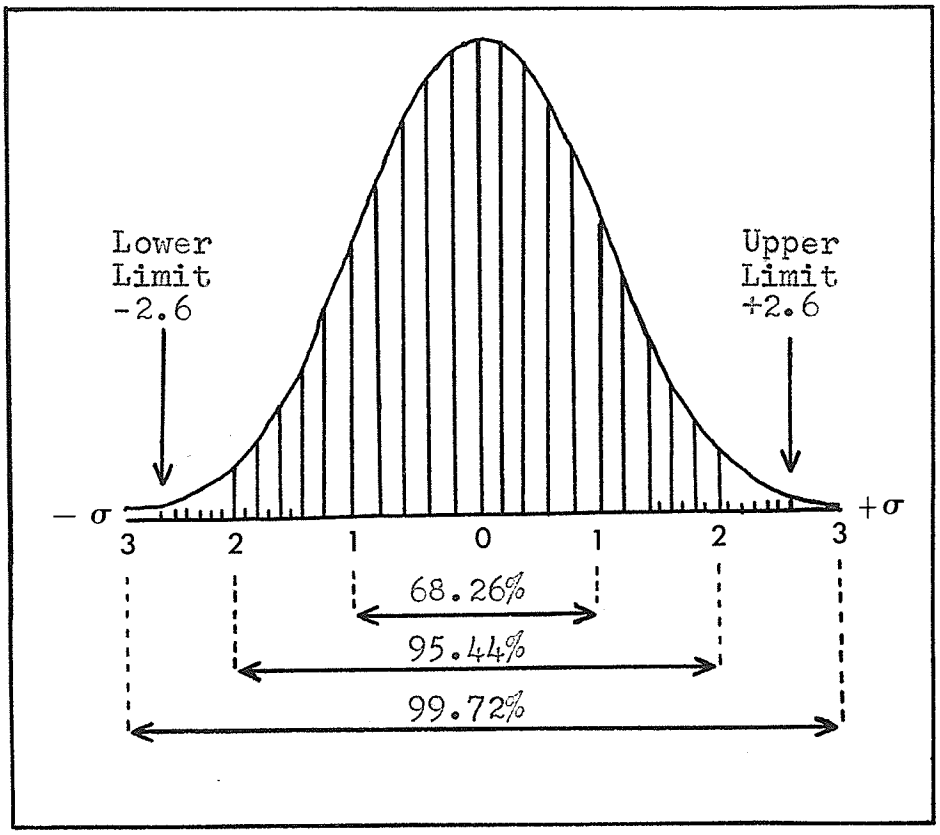


Figure 14. Location of Pivot Points and Limits of Scan.

(g) Using these maps it is possible to draw in the boundaries between areas which differ by at least 0.5 S.D., by locating areas where 9's are adjacent to 0's. These boundaries can then be transferred to a master map which shows the full quota of such boundaries throughout the range (5.2 S.D.) of the particular variable.

(h) To give an illustration of the results from this process, the variable 'average family income' (which was used in the previous example) is chosen. The series of 21 computer maps are reproduced (MAPS 5-25) with the pivot

value recorded and the 0.5 S.D. contrast boundaries drawn in. A final map (MAP 26) collects these boundaries onto one map and this serves to identify the sub areas (referred to average family income) in the metropolitan area of Winnipeg.

One important premise adopted in the development of this technique is the choice of the value 0.5 as the critical deviation necessary to signify a distinct contrast between two adjacent areas. There is no statistical reason why this particular value has been adopted, and the computer program could be rewritten with any other chosen value.

However, if the individuals within each Census Tract are normally distributed about their mean (the value of which is the datum measure for the whole area), then it is likely that there will be some overlap between the two normal curves separated by a distance of 0.5 standard deviations. The exact amount of the overlap depends on the coefficient of variation of each of the areal units. If homogeneity is dominant in a Census Tract (as the Census definition implies) there will be considerably less overlap than for a randomly chosen sample as a measure of the Census Tract area (see Figure 15). Without a measure of the coefficient of variation relevant to each variable, for each Census Tract, it is impossible to give a mathematical expression for the area

MAP 5

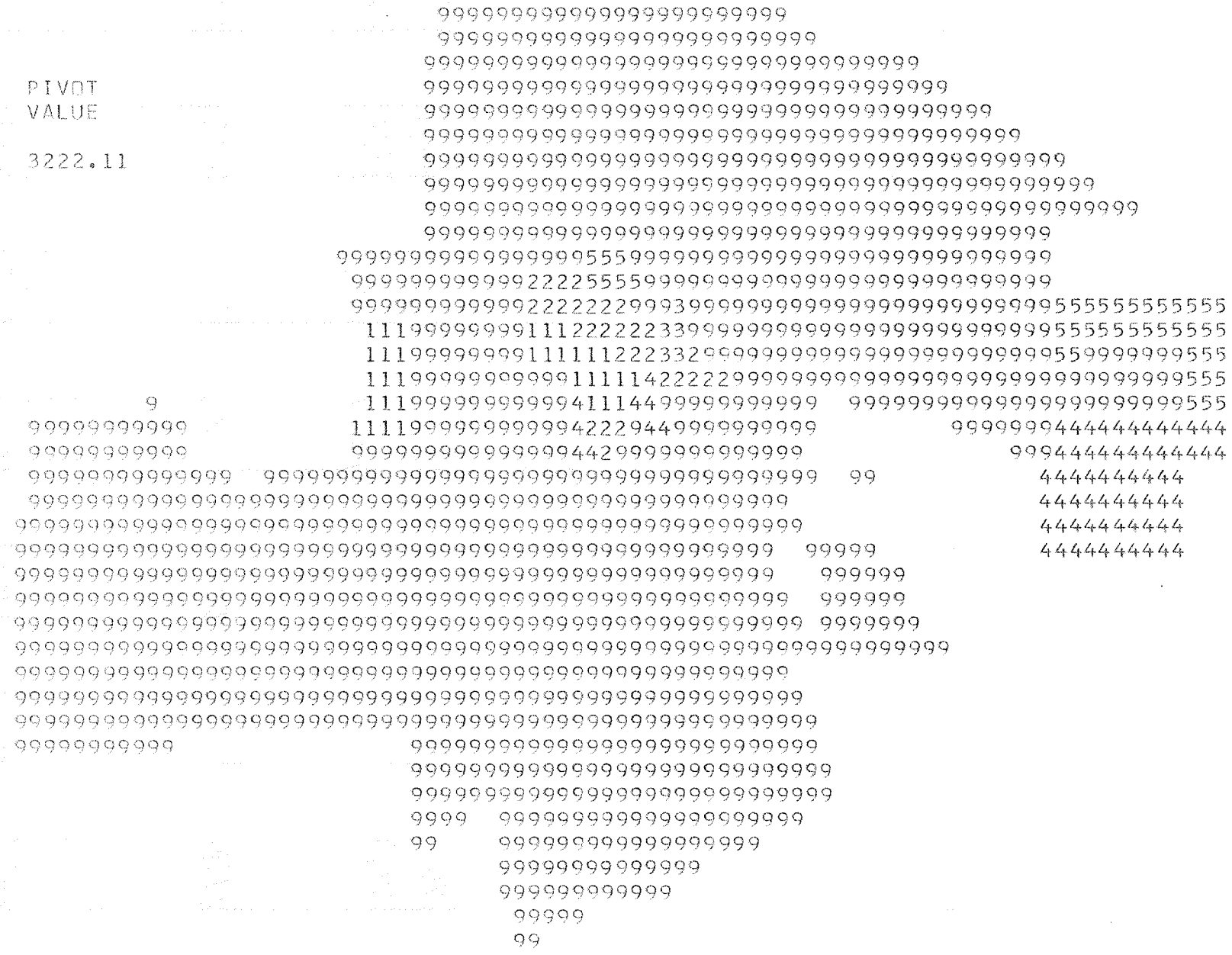
MAP 6

PIVOT
VALUE

2367.43

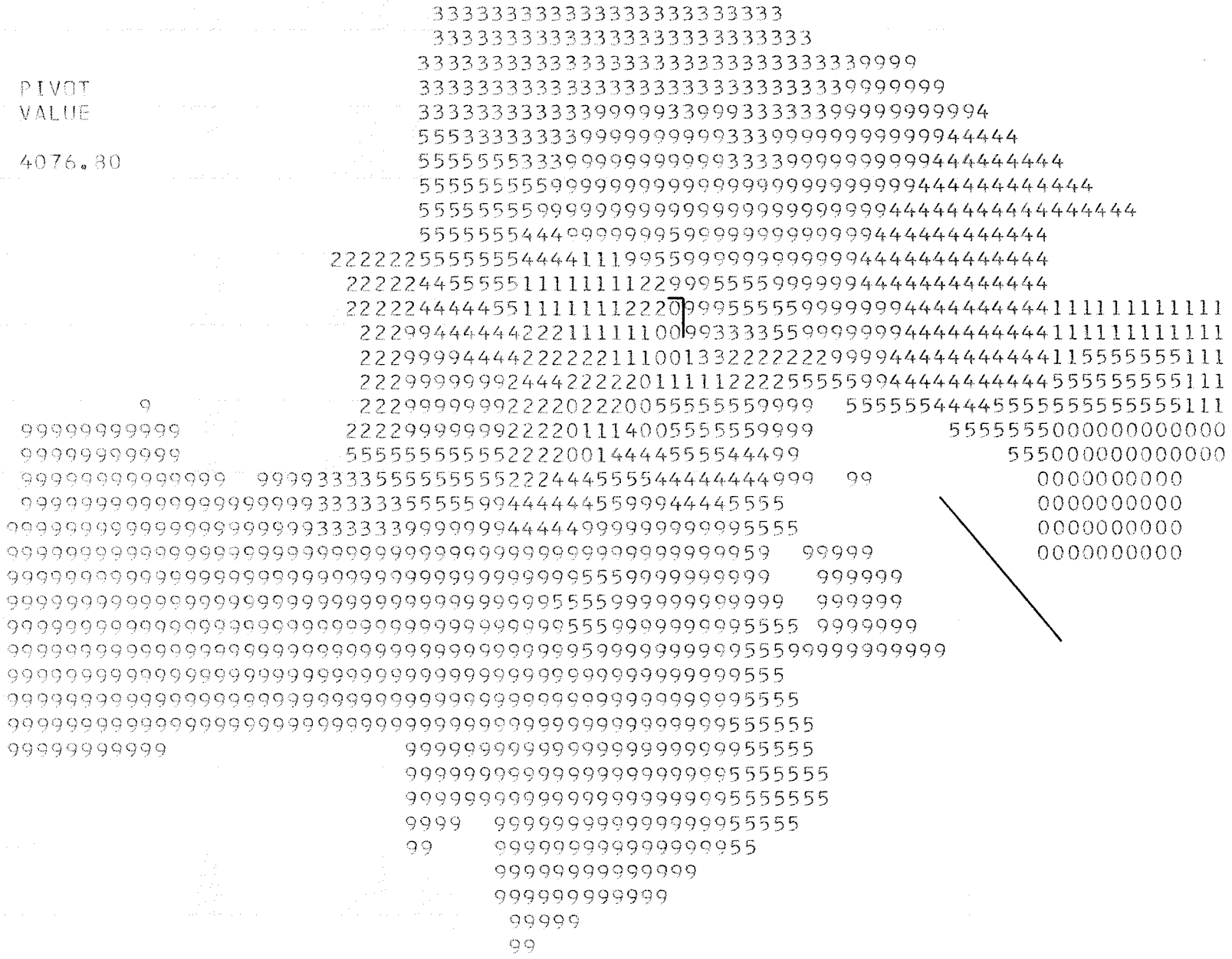
MAP 7

MAP 8



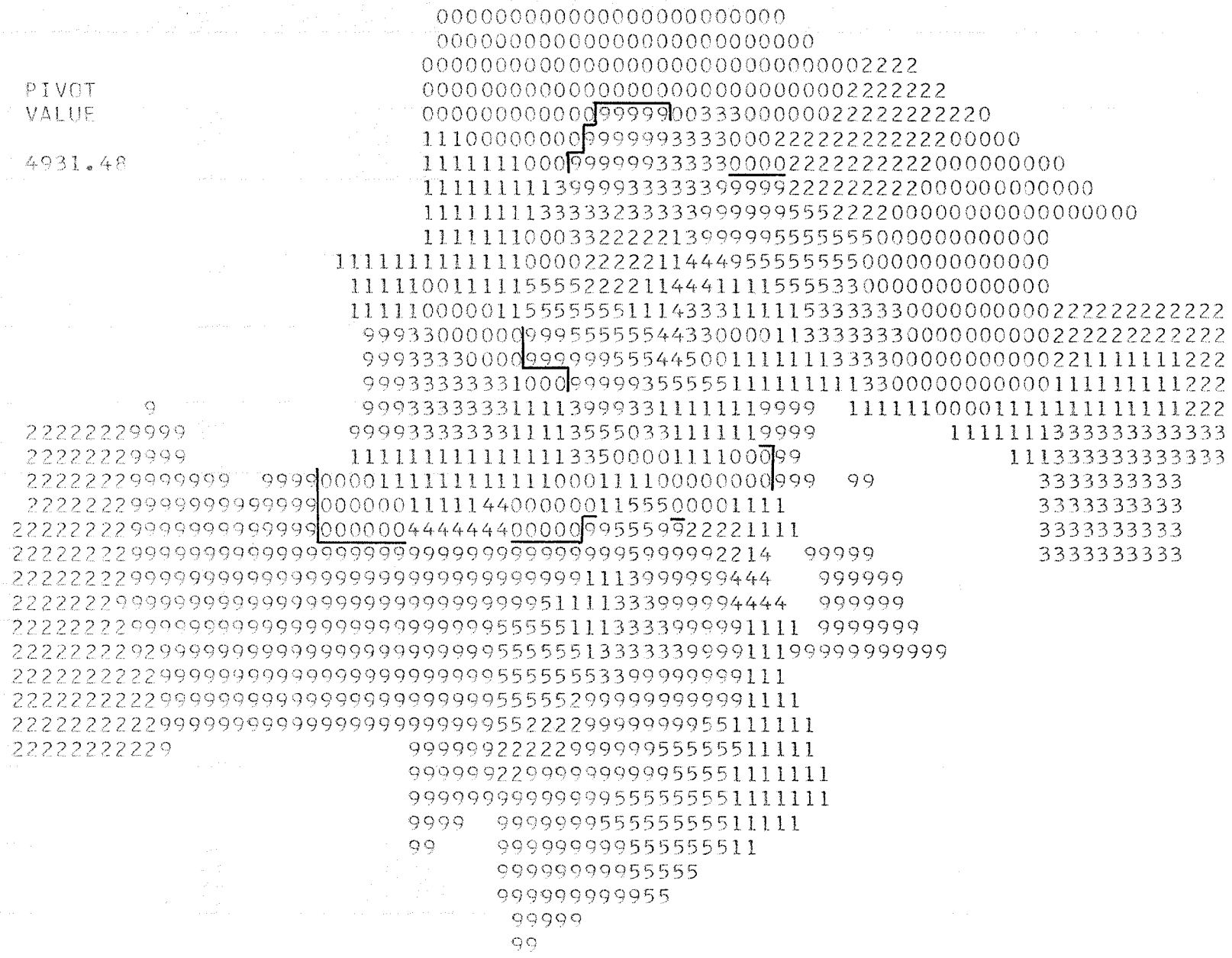
MAP 9

MAP 10



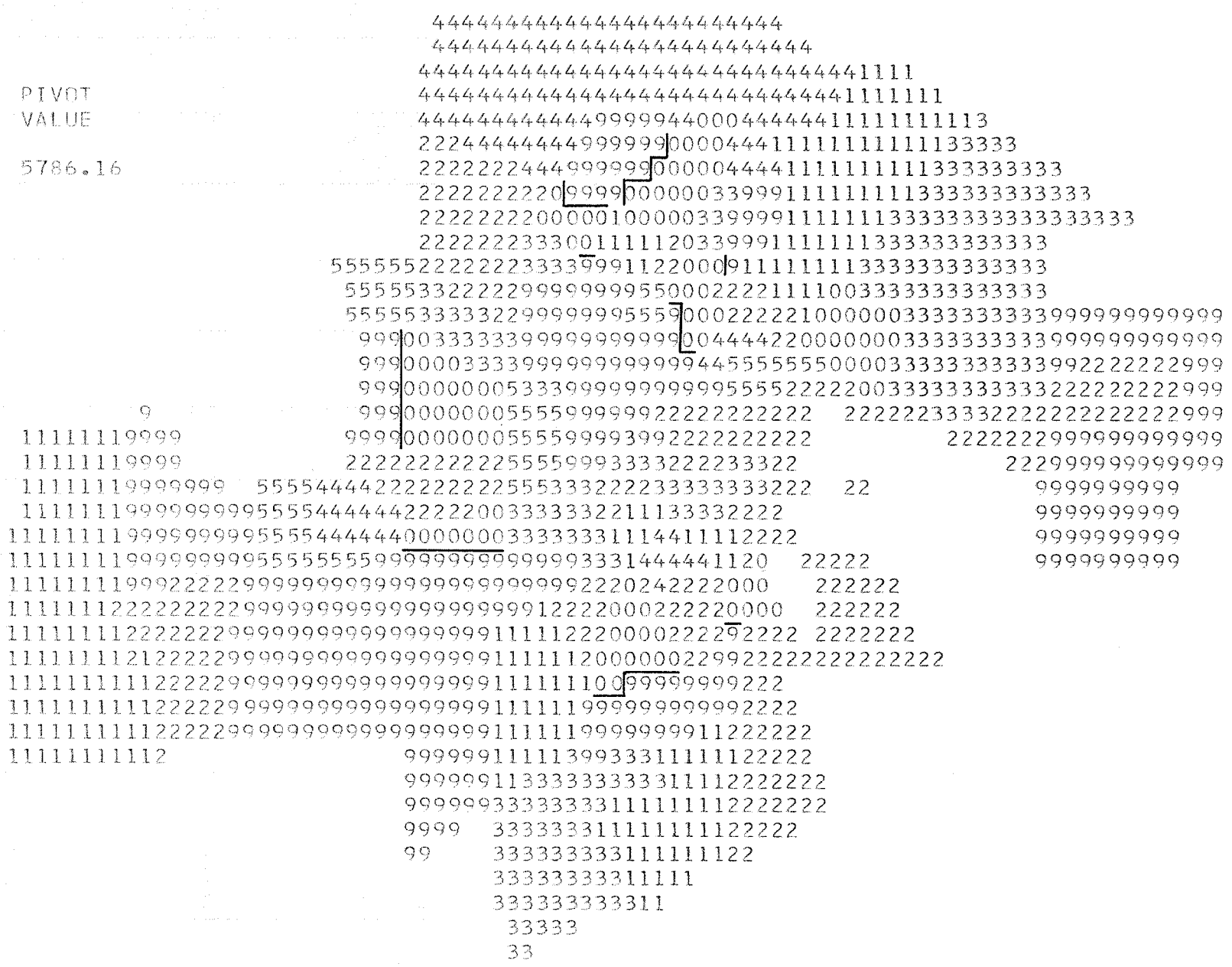
MAP 11

MAP 12



MAP 13

MAP 14



MAP 15

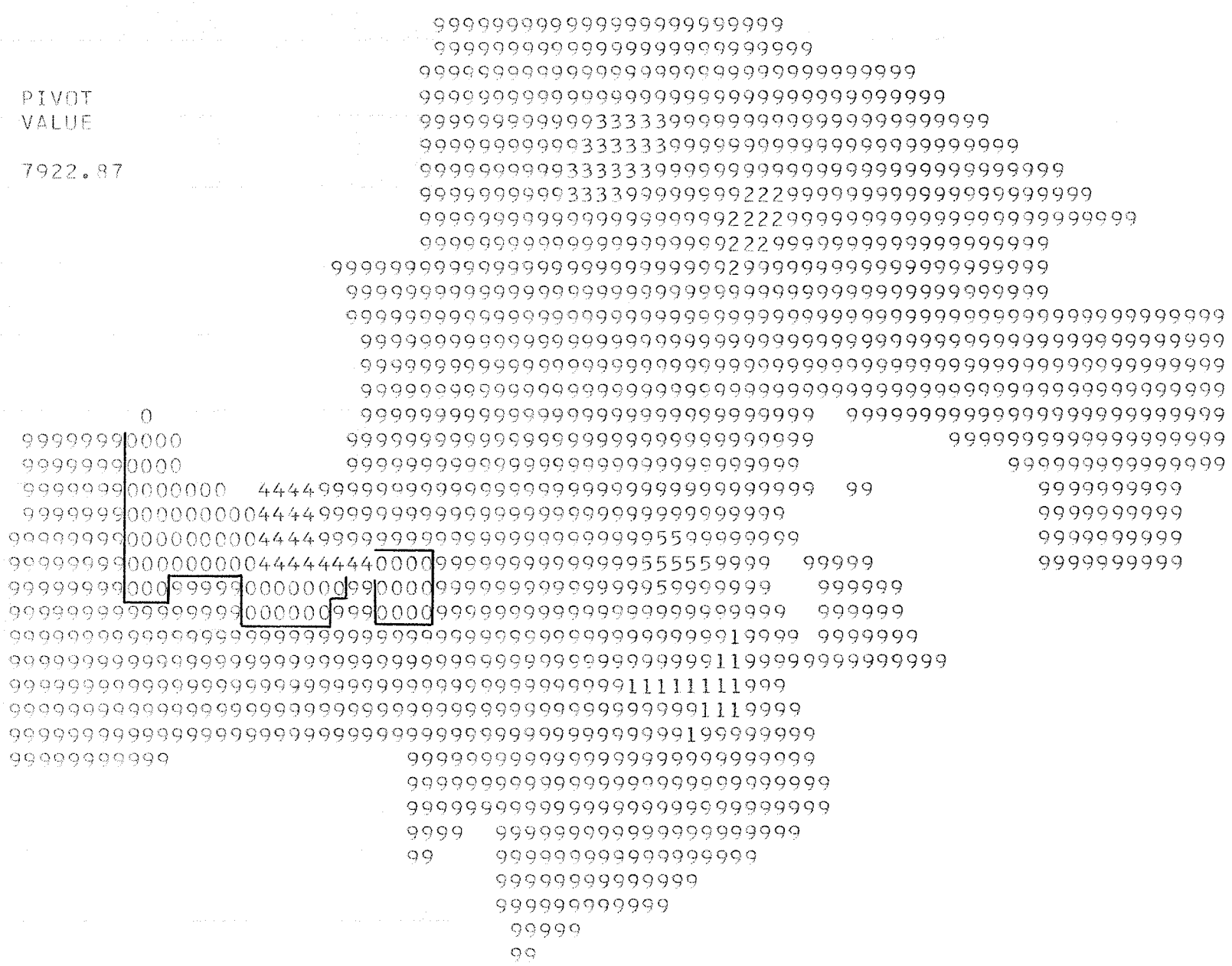
MAP 16

PIVOT
VALUE

6640.84

MAP 18

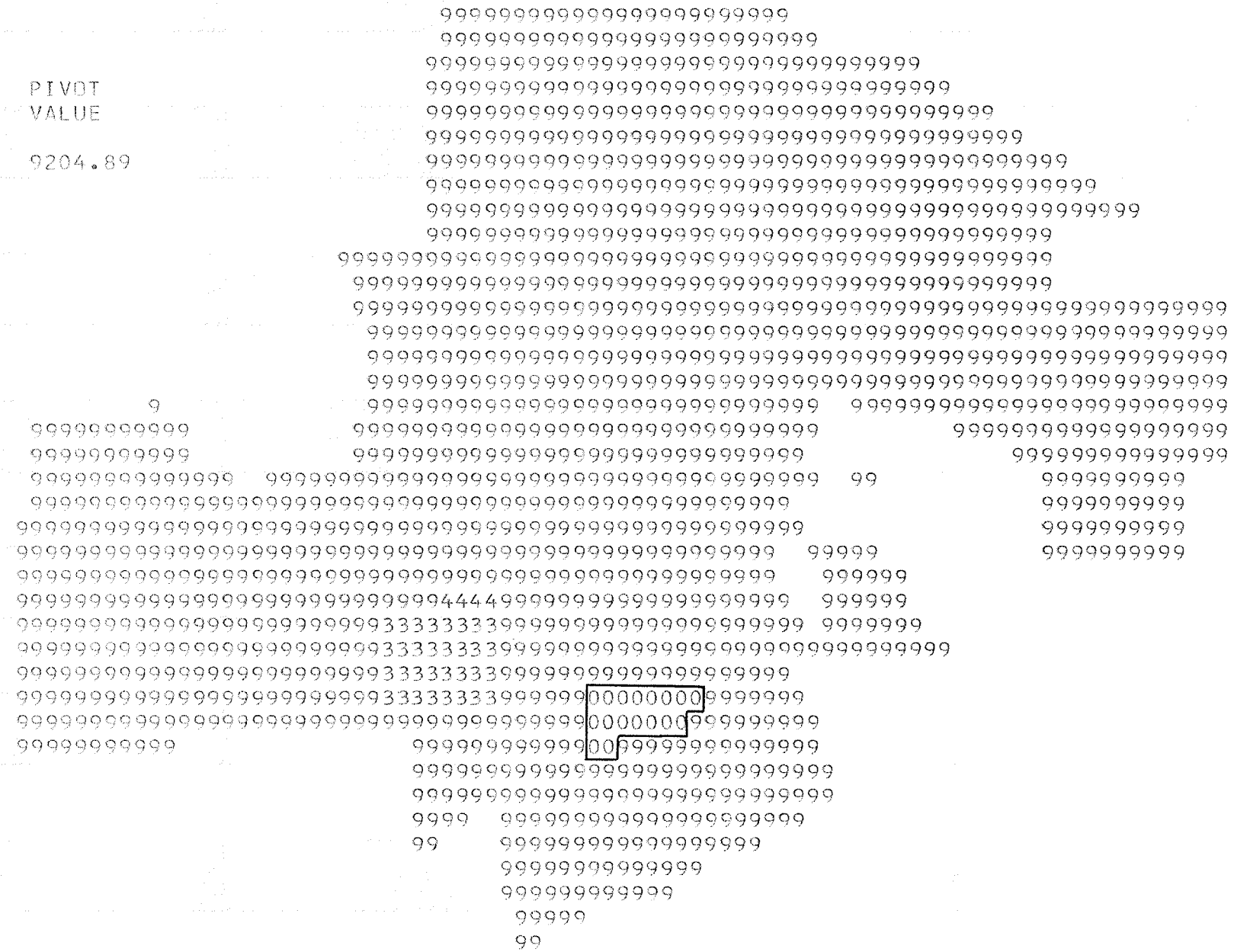
MAP 19



MAP 20

MAP 21

MAP 22

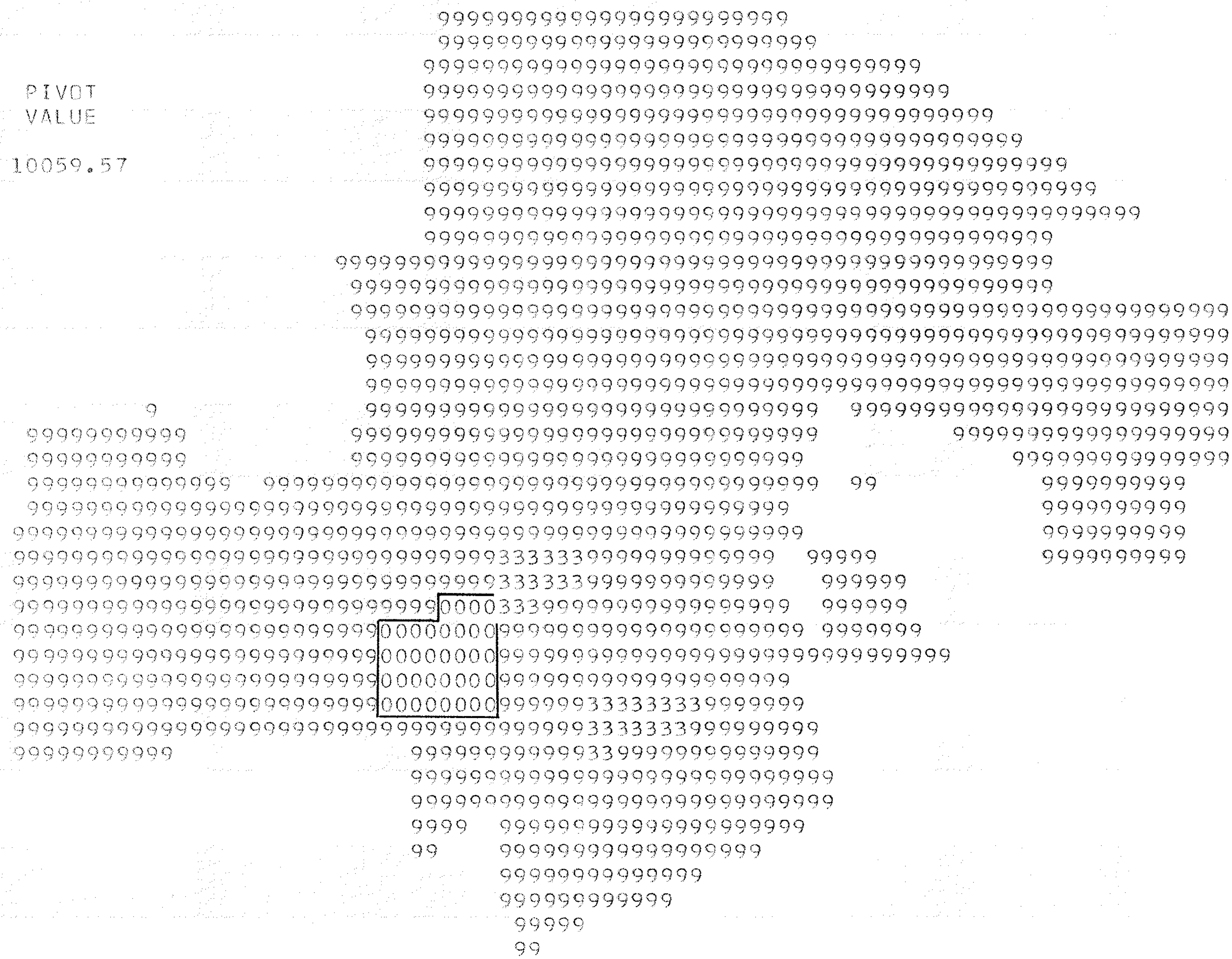


MAP 23

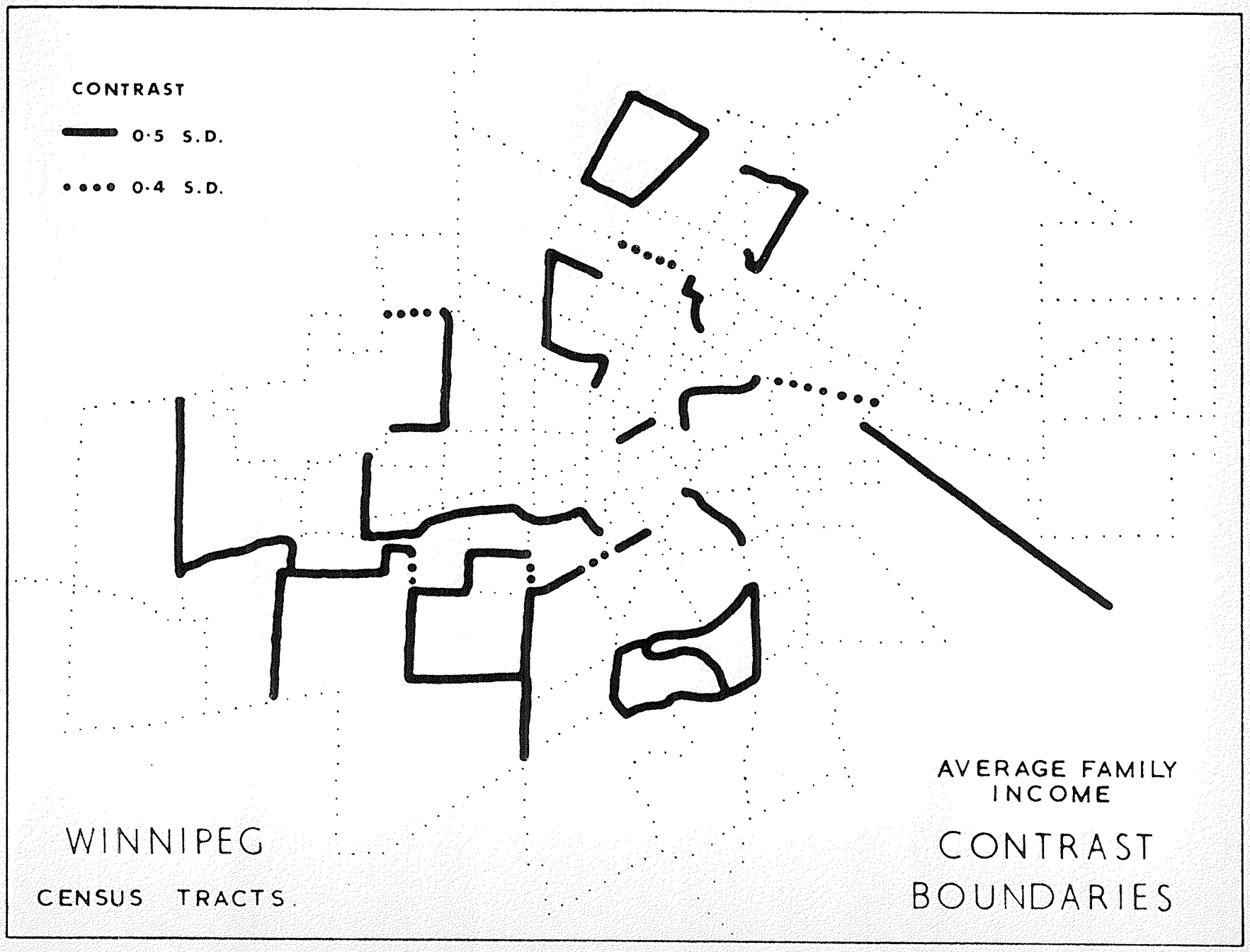
MAP 24

PIVOT
VALUE

10059.57



MAP 25


CONTRAST
0·5 S.D.
0·4 S.D.
AVERAGE FAMILY INCOME
CONTRAST BOUNDARIES
WINNIPEG
CENSUS TRACTS

MAP 26

common to both curves.

Hence, it is necessary to ascribe some arbitrary value as a level, above which a significant contrast exists. The difficulty is analogous to that of defining the x value in Figure 12. A value of 0.5 has been chosen for the purpose of this study. Furthermore, in this

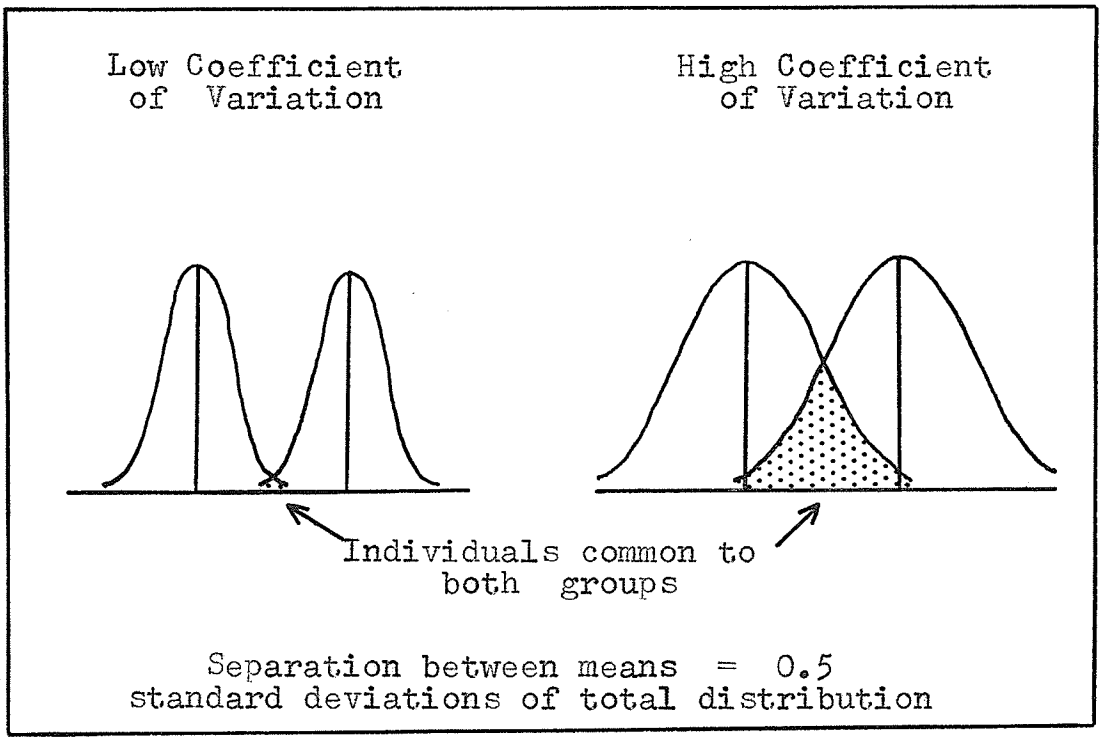


Figure 15. Individuals Common to Adjacent Distributions.

example, as the standard deviation for average family incomes is $2149 (mean of $5786), a deviation of 0.5 standard deviations implies a contrast between median salaries of areas amounting to at least $1074.

This method of mapping embraces the entire urban area for which source data is available. The spatial limits are immaterial and only control the initial development of the computer output map. Because every Census Tract value is considered at each stage in the analysis, the resulting contrast boundaries reflect the overall picture for the city area.

The results satisfy the conditions laid down by Smith in outlining prerequisites of areal mapping[2]. The sub areas are continuous in the sense that they grade up to a contrast boundary. Should the continuum of values for the 87 Census Tracts have few marked contrasts, then the resulting sub areas might be extensive and permeate throughout the urban area and even continue to the city limits. This is acceptable if the postulate concerning the role of a contrast boundary is valid. The sub areas exhaust the total space within the city's corporate limits.

Inherent in the statistical analysis is the condition that Census Tracts common to a sub area possess a desired degree of homogeneity. The basic premise adopted in the extraction of boundaries between sub areas ensures that there is a large degree of heterogeneity among the sub areas. For these reasons the mapping technique fulfils the necessary prerequisites of areal mapping.

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[2]J. Smith, loc. cit.

The object in developing this mapping technique is to analyze the spatial structure of urban Winnipeg. This could be undertaken for each of the 75 variables selected and the resulting contrast boundaries compared. However, the relationships between these 75 variables have been examined in chapter III and certain dominant factors have been extracted which express these relationships. Rather than produce contrast maps for each variable, it is more desirable to map contrasts for each of the nine selected factors. This will indicate the diversification of Winnipeg in terms of the major forces influencing the metropolitan area. Such an examination of the urban structure is attempted in the next chapter.

CHAPTER V

THE URBAN STRUCTURE OF WINNIPEG

With the aid of the factor matrix it is possible to compile a new matrix which gives the Census Tract scores for each factor, scaled between 0 and 100. This stage was the culmination of the analysis undertaken in chapter III. These scores form the basis of any subsequent study into the urban structure of Winnipeg. Such a study can have two objectives. The first path is to apply the mapping technique and produce a mosaic of sub areas as dictated by the factor structure. In terms of each factor it becomes feasible to identify areas of low score, and isolate boundaries which provide natural breaks between atypical areas. Problem areas can be sought and their limits demarcated.

The second direction in which the analysis might proceed is by assessing the nature of each unit area in terms of its score for each of the factors under consideration. The Census Tract areas hold a particular position on a continuum of scores for each factor. Some areal units have a low position on many factors whilst other units are in the upper quartile for most factors. Each

situation poses distinctive problems to the planner who intends to unravel the complex interaction within the urban environment.

Before embarking on such an analysis for the Winnipeg metropolitan area it is essential to record the fact that the analysis is not comprehensive. The information associated with the factor design and mapped results is vast and the implications intricate. Therefore, the ensuing observations can only be regarded as cursory, and systematic only to the extent of documenting methodology. Much further analysis is pertinent but falls outside the scope of this particular thesis. Specific extensions to the analysis are likely in two directions. Firstly, a more exact understanding of one particular sub area in the city might be required. Alternatively, a more exact interpretation of the relationships inherent in a factor structure might be wanted. To cover both contingencies all numerical outputs are included in annotated Table form or as referenced Appendices in this thesis.

The first factor, which represents the dominant force in the city, has a distinctive pattern. Individual Census Tract scores are tabulated in TABLE XV and plotted in Figure 16. Areas characterized by low scores are located in the downtown area of the city with Census Tracts 3 - 13, 18 - 22, and 36 having below average scores.

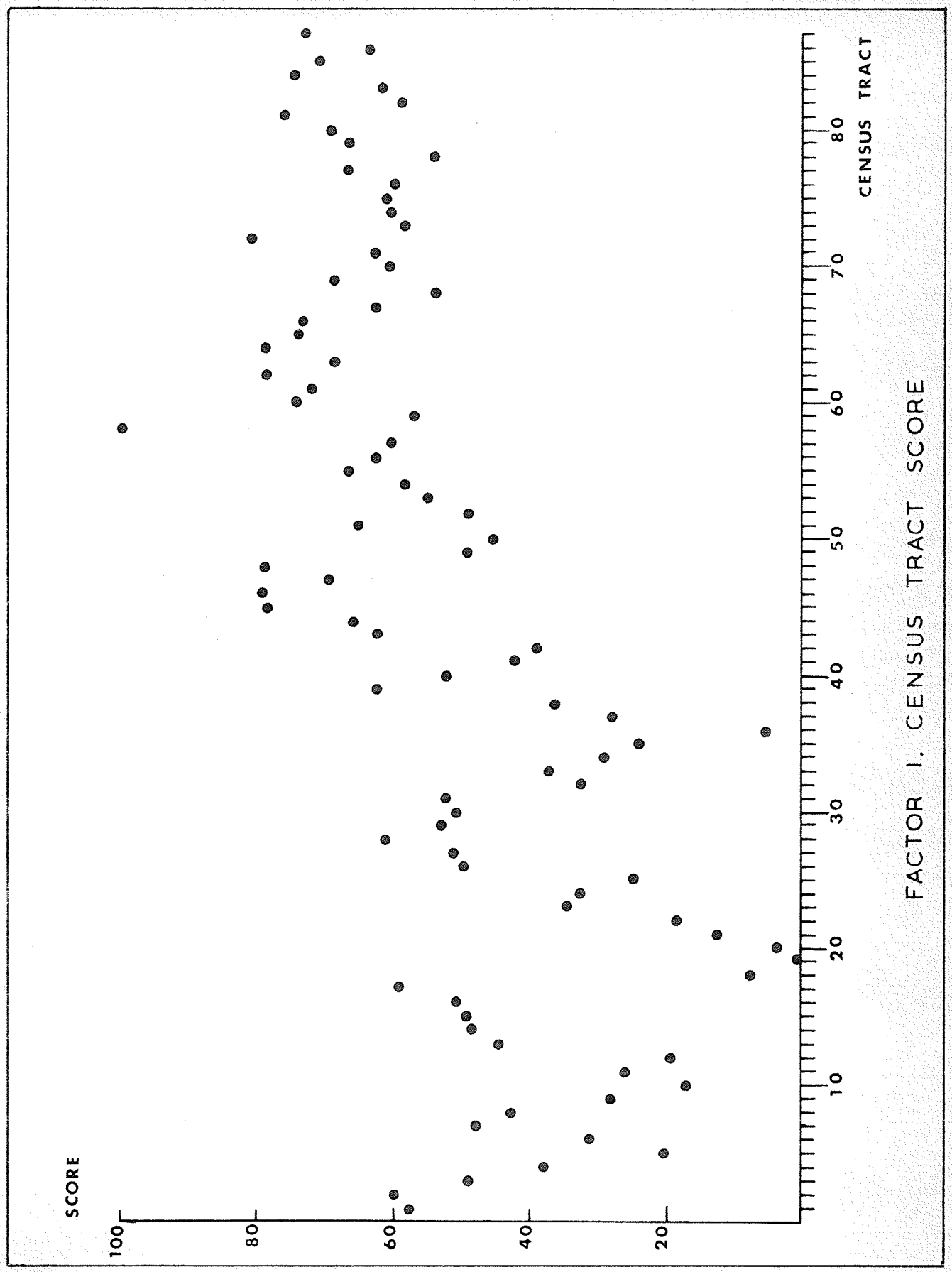
TABLE XV

CENSUS TRACT SCORES ON FACTOR 1
(Wealth in the Urban Area)

Census Tract	1	2	3	4	5	6	7	8	9	0
	58	60	49	38	20	31	48	42	28	17
1-	26	19	45	49	49	51	60	9	0	4
2-	13	18	35	33	25	50	52	61	53	51
3-	53	33	38	29	24	5	29	36	62	58
4-	43	39	63	66	78	79	70	79	50	46
5-	65	50	55	59	67	63	60	100	57	74
6-	72	79	69	79	74	74	64	54	70	61
7-	63	81	59	60	61	60	67	55	67	69
8-	76	60	62	75	72	64	74			

All these areas are in the older part of the city. Lowest values are to be found in the zone centred on the Portage and Main intersection. Some of these low wealth areas (11, 19, 20, and 22) have been redeveloped in recent years, or are now subject to redevelopment schemes. A sector of below average scores is found in the area between the Assiniboine river and Portage Avenue (Tracts 33-37). Once again this area has been subjected to some rejuvenation with the development of apartment dwellings in recent years.

Figure 16 indicates that above average scores are common to the higher numbered Census Tracts. These suburban areas are more affluent than the downtown core.


SCORE
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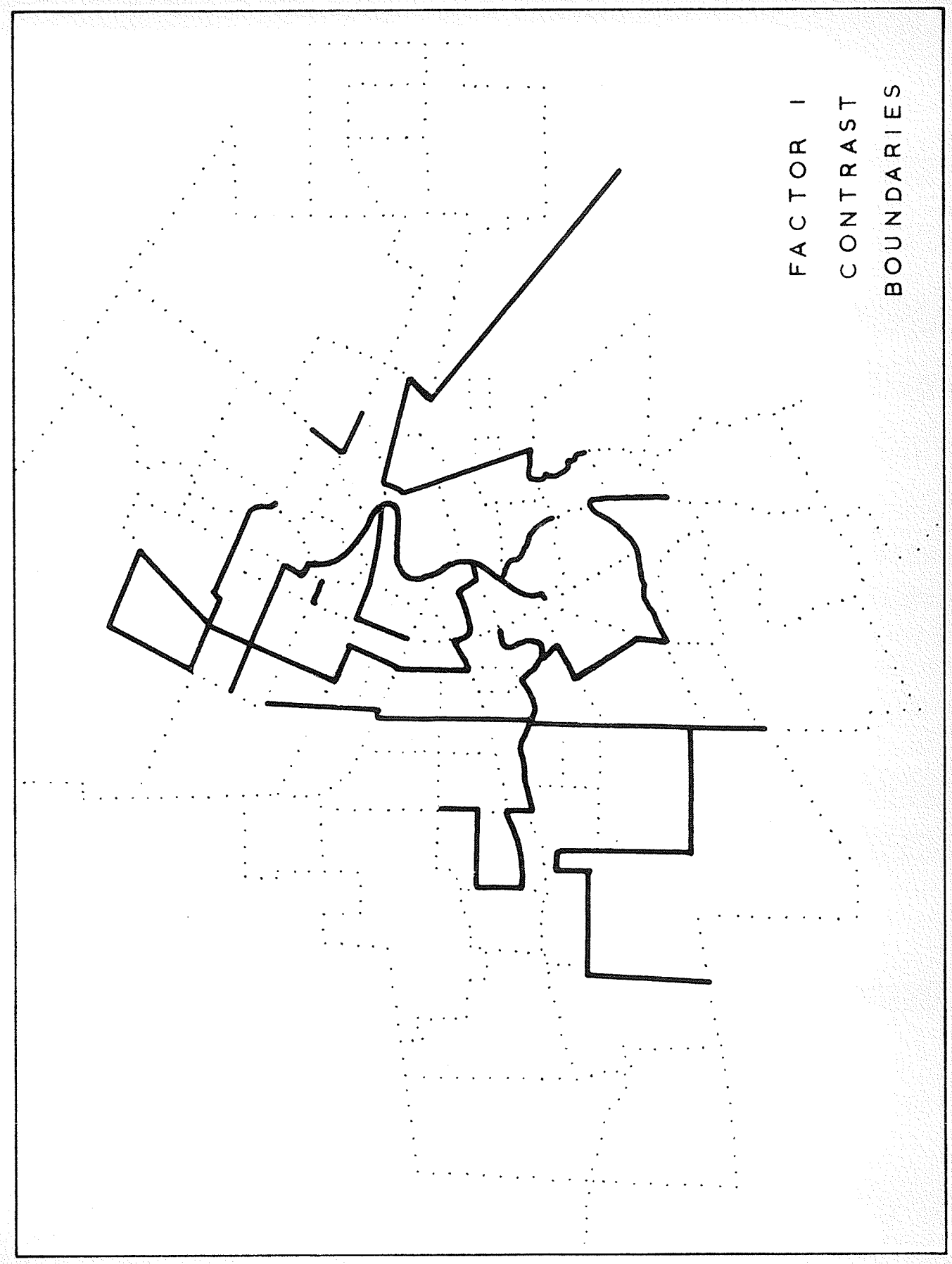
70
80
CENSUS TRACT
FACTOR 1. CENSUS TRACT SCORE

Figure 16



MAP 27

With one exception there is no great variation in values between the peripheral zones. The exception is Tuxedo (58) which heads the list of scores by a wide margin. This residential area is unique in the Winnipeg metropolis, representing a high class, new development catering for the higher income groups of the population.

Turning to the actual sub areas associated with this factor, certain basic features are displayed in MAP 27. Transitions in factor values occur with a movement away from the city centre (Portage and Main). A typical concentric zone pattern is manifested. Low values exist in the centre with increasing values as the suburbs are approached. Certain anomalies exist. In the older part of the city the Red and Assiniboine rivers form distinct contrast boundaries, but in the peripheral areas they exert little influence.

Based on these boundaries, certain sub areas can be isolated. North of Portage Avenue including the North End as far as Church Avenue, bounded in the west by Arlington Street and in the east by the Red river, is the first such area. Low scoring, it represents the poorer central core of the city. A second ring surrounds this. Its limits are McPhillips Street and Ingersoll Street in the west, the Assiniboine river, Stafford Street, and the Red river in the south, the Canadian Pacific Railway line

in the east, and the boundary with the City of West Kildonan in the north.

Beyond this ring are the suburbs. Little contrast is to be found in this peripheral belt with the exception of Waverley Street which provides a sharp break between River Heights (45, 46, and 48) and Crescentwood (43 and 44). Two small sub areas stand out. Tuxedo, in the south west has already been mentioned, but in the north is the new development of Garden City (72) which is atypical in relation to the surrounding areas.

In summary, the dominant feature of factor one is its simplicity. Gradation of scores away from the city centre is matched by the lack of marked contrasts throughout the city as a whole. Distinctive areas can be isolated and explained, and the entire picture fits in with the customary explanation of city structure.

The second factor controls the social structure of the environment. Census Tract scores are recorded in TABLE XVI and plotted in Figure 17. Unlike factor one, the distribution of values is not regular. A sector of high values to the south west exists between Broadway (37 and 35), through Fort Rouge (38, 42, and 43), into River Heights (45, 46, 47, and 48), and terminating at Tuxedo (58). This sector is counterbalanced by one of low values to the north east of the city starting from the central

TABLE XVI

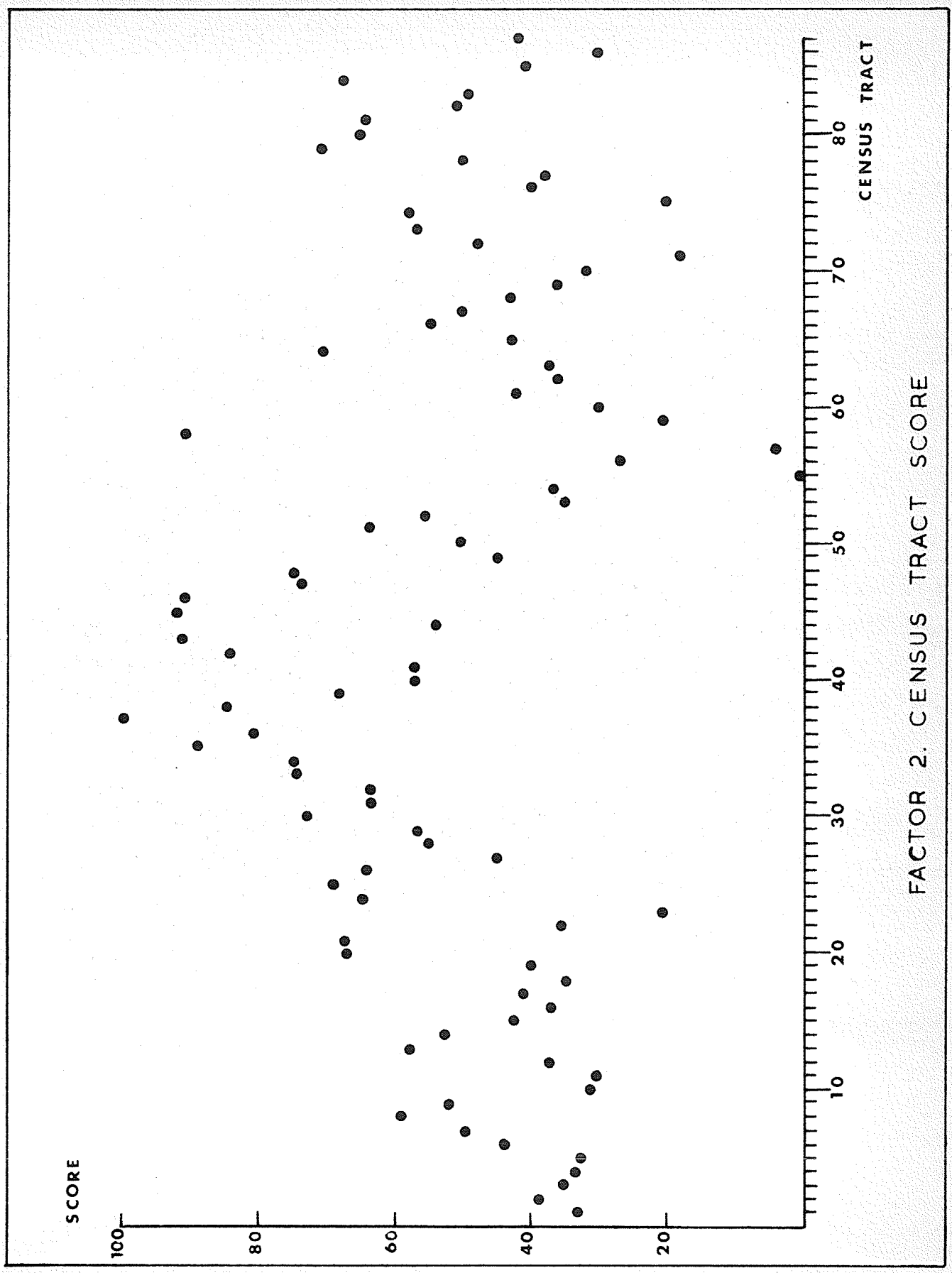
CENSUS TRACT SCORES ON FACTOR 2
(Social Structure and Age)

Census Tract	1	2	3	4	5	6	7	8	9	0
	33	39	35	34	33	44	50	59	52	32
1-	31	37	58	53	43	37	41	35	40	67
2-	67	36	21	64	69	64	45	55	57	73
3-	63	63	75	75	89	71	100	85	69	58
4-	57	85	92	54	92	91	74	75	45	51
5-	64	56	35	37	0	28	4	92	21	30
6-	43	36	38	71	44	56	51	44	36	32
7-	18	49	58	58	20	41	39	50	72	65
8-	65	51	50	69	42	30	42			

business district and passing through Tracts 18, 11, 15, 16, 69, 71, 54, 55, 56, and 57. The lowest values are at the extremity, in the City of Transcona. This is a residential area established around the Canadian National Railway yards and serving a specific social class of the population.

The suburbs do not score highly in this factor. Most of the city core has below average scores and moving away from the centre sees an initial rise in the factor scores which in turn gives way to a subsequent decline in the peripheral areas.

The subdivision of the city in response to this


FACTOR 2. CENSUS TRACT SCORE
SCORE
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CENSUS TRACT
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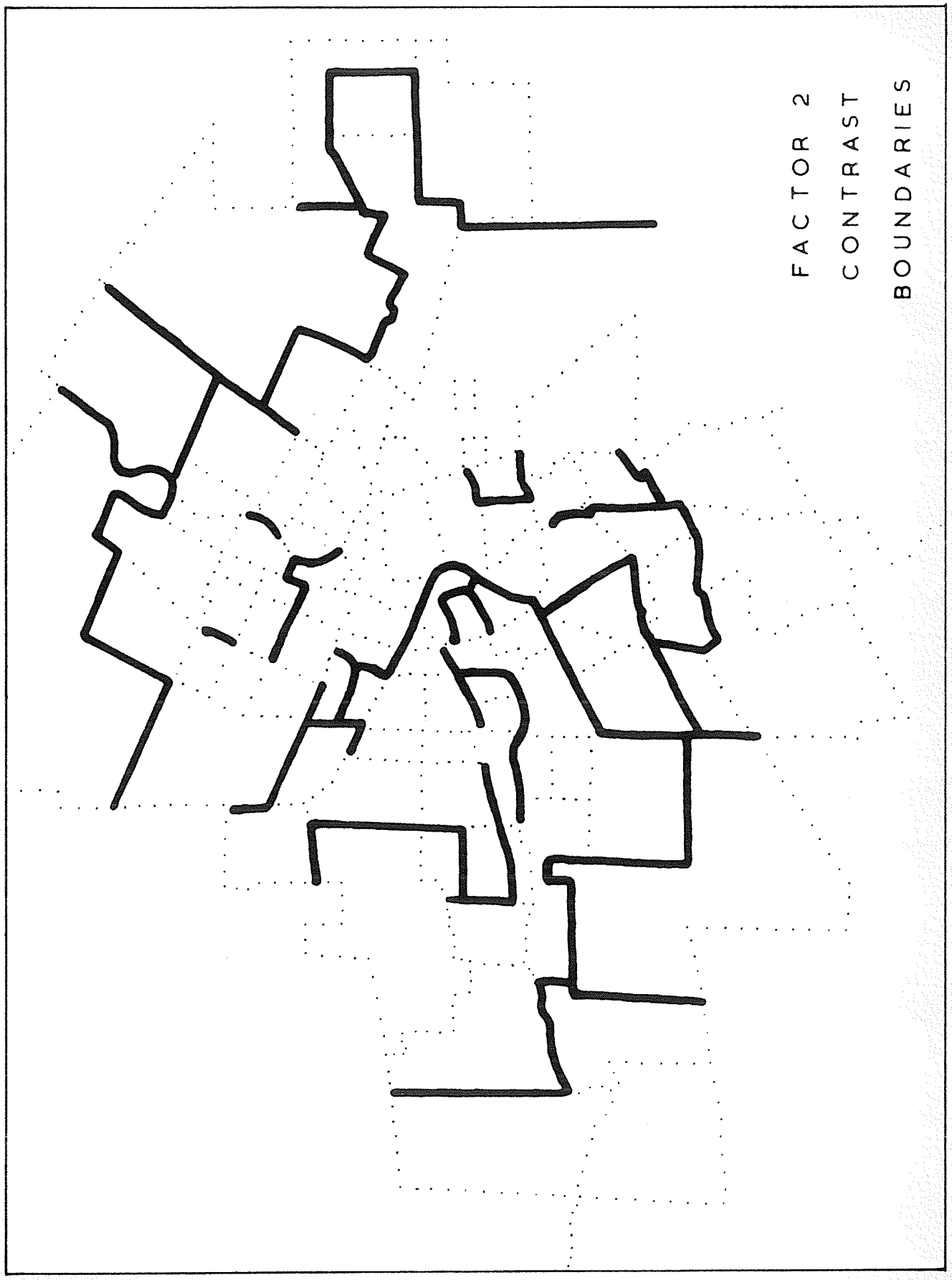
Figure 17



MAP 28

factor is illustrated in MAP 28. An immediate contrast exists with the factor structure previously examined. The social structure is fairly homogeneous in the downtown sectors of the city and presents its greatest contrasts in the suburbs. The north eastern city limits are subject to considerable variation (Transcona and North Kildonan). Crescentwood (44 and 41) together with part of Riverview (40) form a distinct sub area. The high scoring wedge, mentioned earlier, is delimited by the Crescentwood area to the south east, Tuxedo to the south west, and the Assiniboine river to the north. Tuxedo forms a distinct natural area. The West End, between Portage Avenue and Notre Dame (20, 21, 24, 25, 26, 27, 28, 29, 78, 31, and 32), forms an above average scoring island in the central area. Further west, St. James (80, 81, 77, and 79) and Assiniboia (60) combined with Charleswood (61 and 62) form separate groupings.

The factor as a whole fails to portray any distinct urban pattern but comes nearest to characterizing a sector structure. Areal values tend to reflect the social structure of the occuping persons with interesting relations especially noticeable in the peripheral areas of the metropolitan area.

An urban analysis of Winnipeg for factor 3 is fraught with danger. The domination of Census Tract size has been alluded to in chapter III. Unfortunately, so

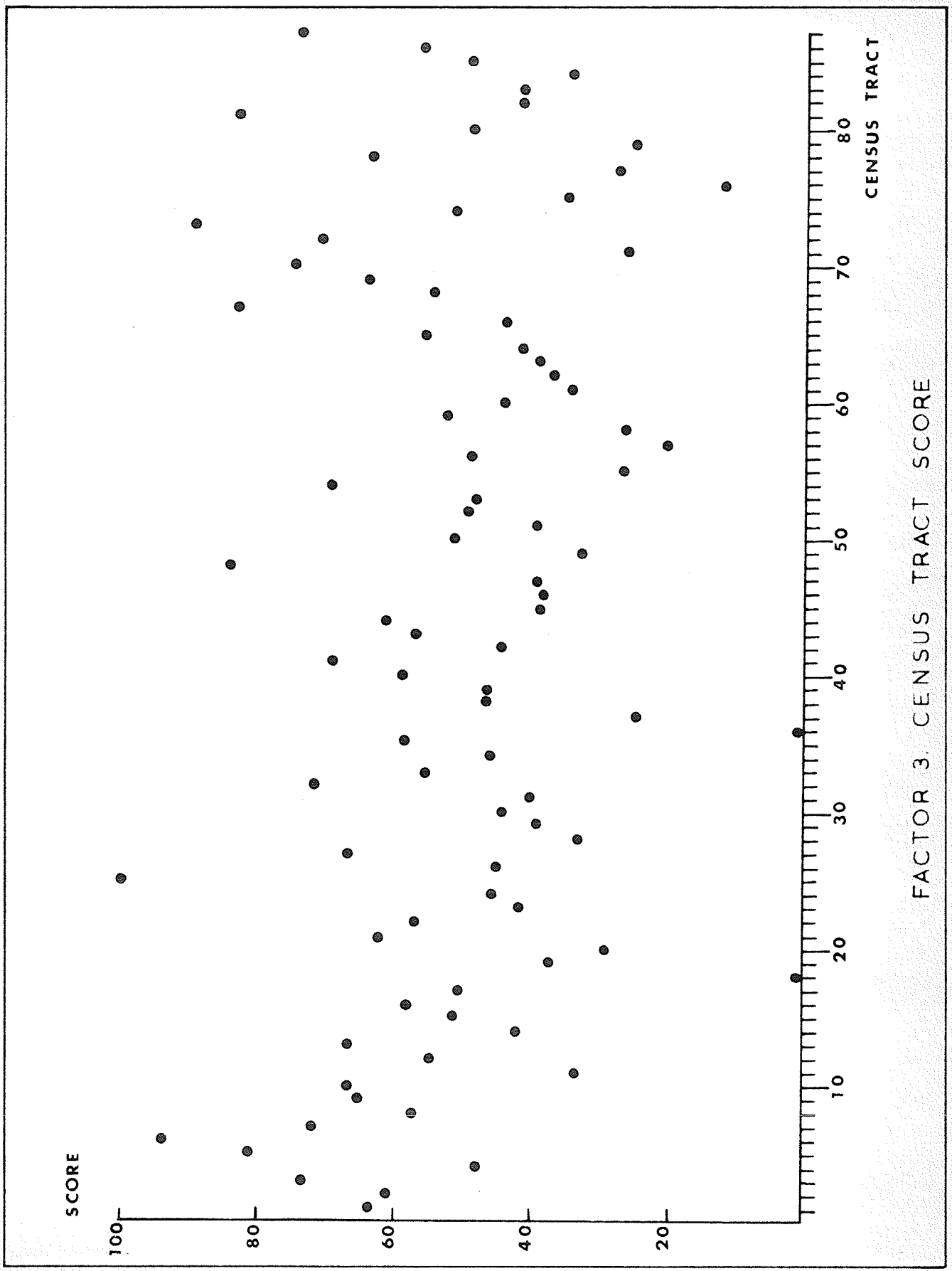
TABLE XVII

CENSUS TRACT SCORES ON FACTOR 3
(Growth and Mobility)

Census Tract	1	2	3	4	5	6	7	8	9	0
	64	61	74	49	81	94	72	58	66	66
1-	33	55	66	43	51	58	51	0	38	29
2-	62	57	42	46	100	45	68	34	40	44
3-	40	72	56	47	59	0	24	47	46	59
4-	69	44	57	61	39	39	40	85	33	51
5-	40	49	49	70	27	50	20	27	53	44
6-	35	38	39	42	55	44	84	55	64	75
7-	27	71	90	52	36	12	28	64	25	49
8-	83	42	42	35	49	56	74			

severe is this domination that other variables represented in the factor structure are hidden. The analytical results attest to the limitations of the Census definition relating to the concordant size of the Census Tract unit.

TABLE XVII records the appropriate scores which are presented diagrammatically in Figure 18. The heavily populated areas occur in the North End of the metropolitan area. Gross densities increase in the larger populated units. The extreme peripheral areas have lower densities and smaller populations per unit area. Some indication of the extent to which population size dominates gross densities is given by Windsor Park (87) where low densities are offset by a numerically large population.


FACTOR 3. CENSUS TRACT SCORE
SCORE
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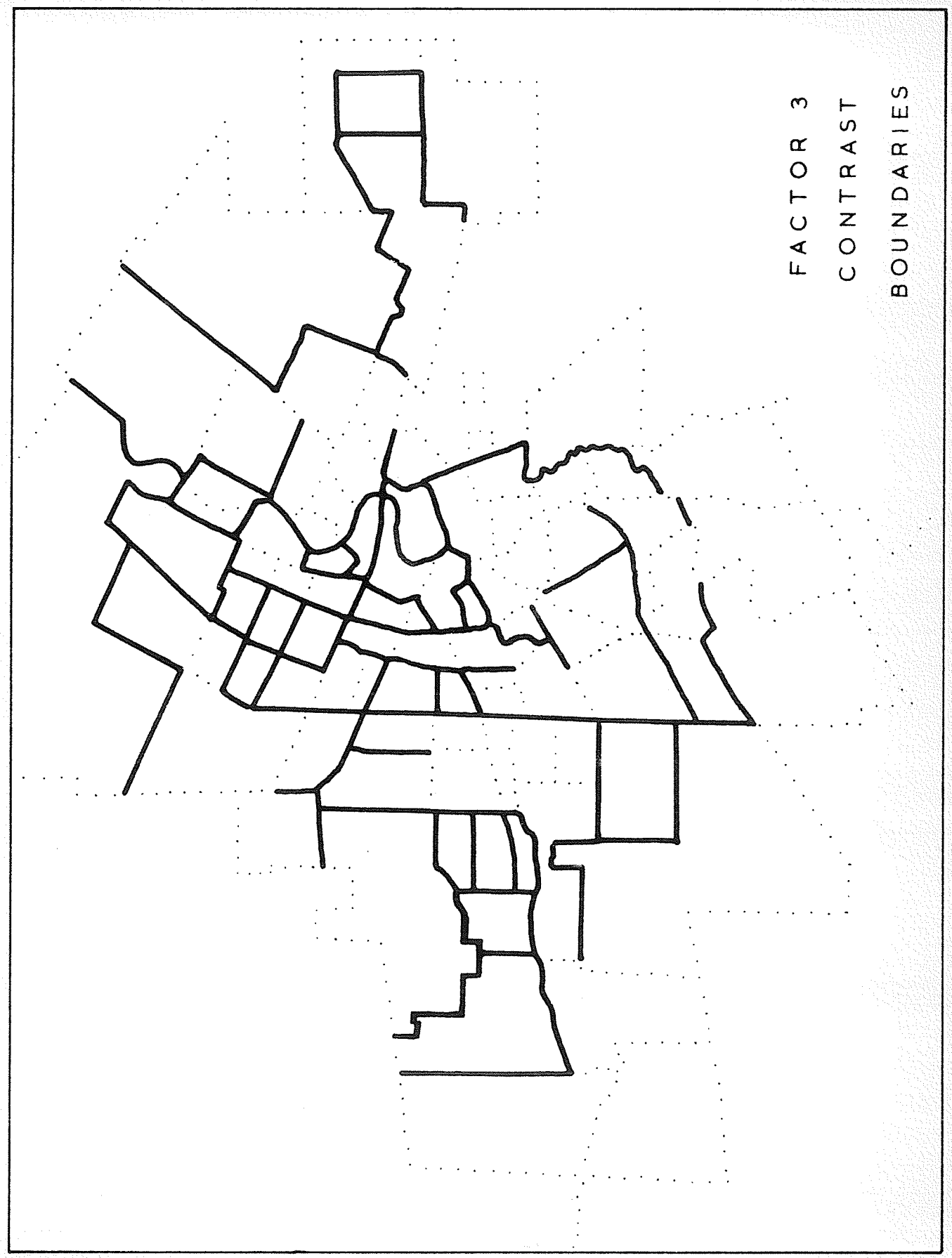
80
CENSUS TRACT

Figure 18



MAP 29

It is interesting to note that most autonomous Cities within the metropolitan area have at least one Tract which is large and possessing a high density. St. Boniface has Windsor Park (87), St. James has an area to the west of Silver Heights (81), West Kildonan has the predominantly non-British areas (72 and 73), North Kildonan has Springfield Heights (71), in East Kildonan it is Tract 84. Conceivably this is connected with the location of suburban retail service centres. Densely developed areas appear to cluster around these local centres.

It is possible to say something about other features of the factor structure. The larger areas are associated with greater mobility and fewer elderly people. This is a reflection of city location (central) rather than unit area size. The index of aging upholds the assertion that a greater percentage of elderly people live in the low scoring areas where mobility is also less.

The contrast boundaries (MAP 29) are not very significant. The main impression is of frequent contrasts in all areas of the city. Peripheral zones in the south are more akin to each other, but this has no useful connotation as the exact property being measured is open to dispute. This factor is controlled to too large an extent by mere population size. A more thorough examination could relate these features to the historic development in the city.

Factor four represents two characteristics. Firstly there is the nature of ethnic segregation, and secondly the pattern of mobility. The scores of TABLE XVIII and Figure 19 receive the following interpretation.

High scores correlate with above average representation of British, French, or Scandinavian groups and below average representation by Polish, Russian, Ukrainian, and other European, and Jewish groups. For this reason the North End (Tracts 2 - 13) has below average scores, whilst St. James (81) with its large British component, and St. Boniface (49 and 50) with its large French component have high scores.

High scores also imply a larger number of Canadian born inhabitants, fewer recent (since 1946) immigrants, and fewer non movers. The greater mobility associated with high scores is connected with a larger movement of new inhabitants from outside the metropolitan area who fall into the more skilled group of the occupational category. Figure 19 produces no distinctive trait except to identify the low scores made by the central areas of the city.

Because the ethnic mix is so diverse, the contrasts might be expected to be large throughout the area. MAP 30 supports this postulate. A mosaic of sub areas connects small groups of Census Tracts together to provide fewer total units. The effect of the Red river in the old centre

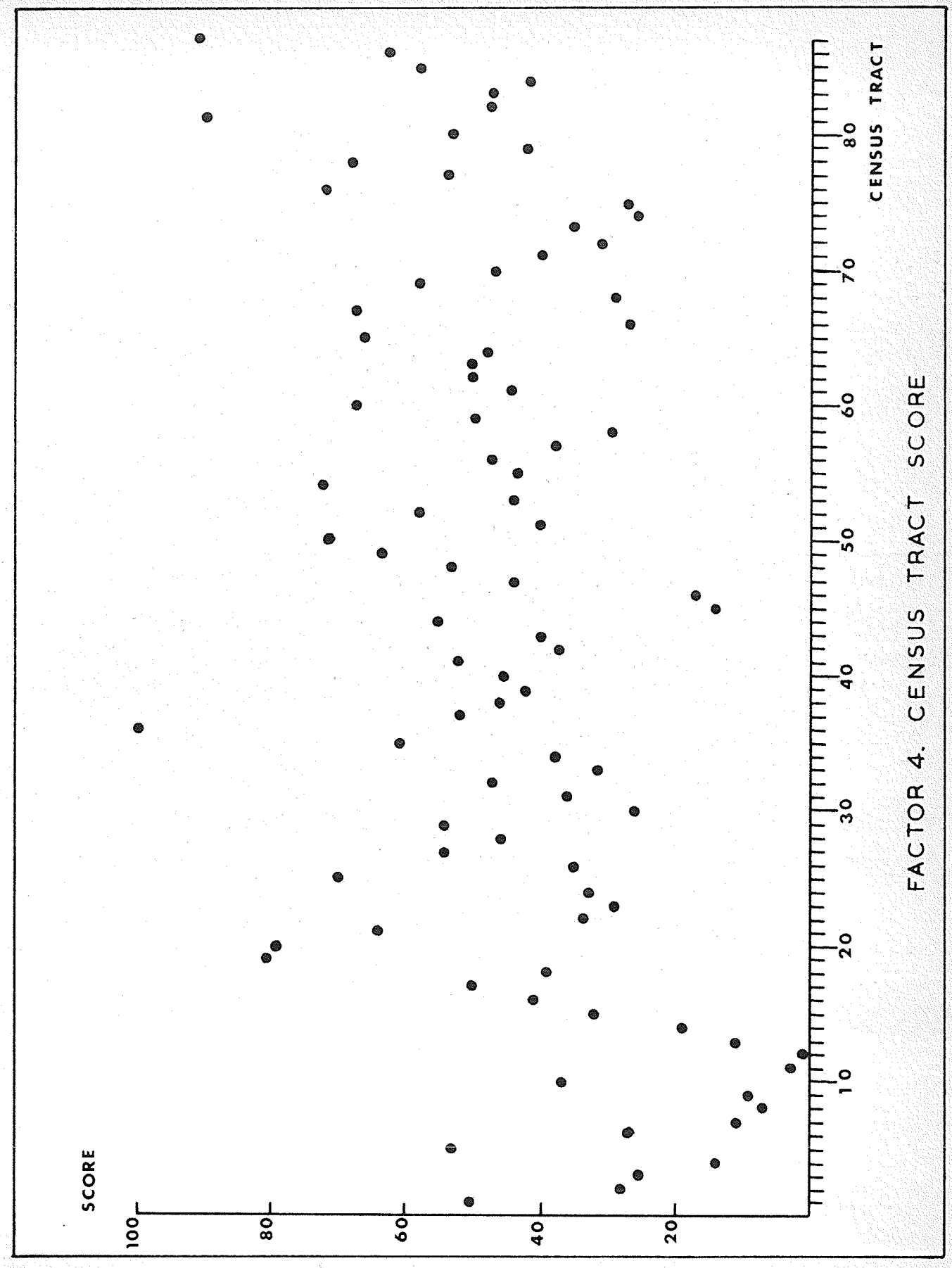
TABLE XVIII

CENSUS TRACT SCORES ON FACTOR 4
(Ethnic Segregation and Mobility)

Census Tract	1	2	3	4	5	6	7	8	9	0
	50	29	26	14	53	27	11	7	9	37
1-	3	0	11	20	33	41	50	40	81	79
2-	64	34	29	34	71	35	54	46	54	27
3-	36	48	31	38	61	100	52	46	43	46
4-	53	37	41	56	14	18	45	54	64	72
5-	40	59	44	72	44	47	39	30	50	67
6-	45	51	51	49	66	27	68	29	58	48
7-	40	32	35	27	28	73	54	69	43	54
8-	90	48	48	42	59	63	90			

of the city focuses attention on the early segregation of the French into St. Boniface. The southern half of the city presents greater homogeneity, whilst it is the central area that constitutes the bounded, low scoring sub areas.

Suburban growth accounts for the lack of peripheral contrasts. Lacking the segregation reserved for the older areas, they possess similar mobility characteristics. The fast growing areas, such as Windsor Park (87), score highly on account of the influx of new residents. Census Tract 36 owes its highest score to the combination of all the ethnic features typical of this factor.


FACTOR 4. CENSUS TRACT SCORE
SCORE
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CENSUS TRACT
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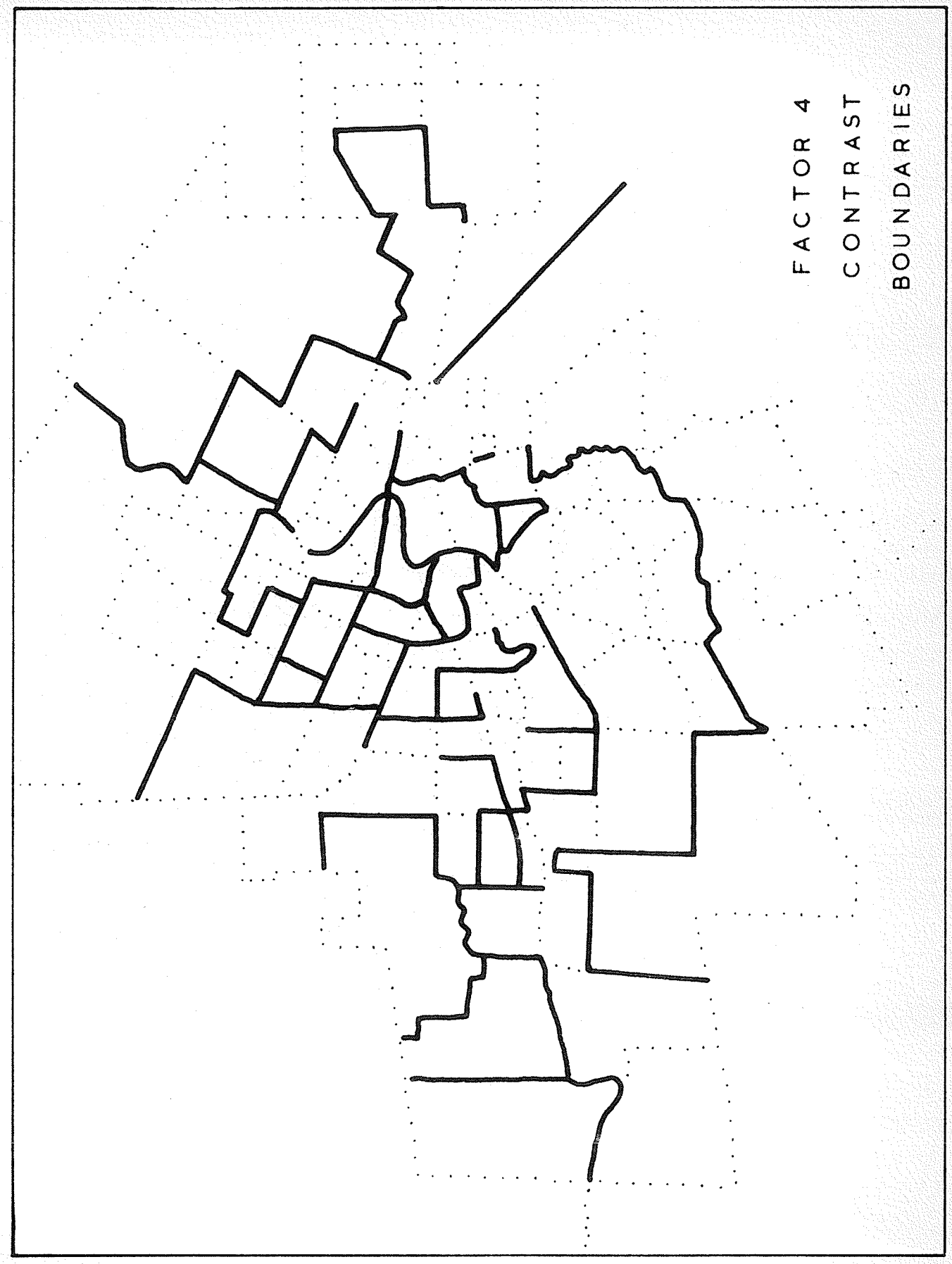
Figure 19



MAP 30

TABLE XIX gives the Census Tract scores for factor five. The factor structure indicates that the high scores are associated with a number of causes. The weightings of a certain group of retail outlets, especially those concentrated in a downtown location (merchandising, apparel, hardware, and furnishings), cause high central area scores. High scores also reflect the longevity of the buildings and the immobility of the inhabitants. Much of the North End can ascribe its high score to this cause. The high percentage of Asiatics just north of Portage and Main is instrumental in bolstering scores in that area.

Low scores between Portage Avenue and the river Assiniboine are connected with the high percentage of females in the area who are employed as wage earners. Low scores in suburban areas might be expected, but Tuxedo (58) and South River Heights (48) contradict this generality. This anomaly is due to the high income in these areas, and income is a significant variable in the constitution of this factor structure.

Figure 20 portrays the entire situation. Above average scores in the city centre with peaks in the downtown shopping core, low localized scores along the northern banks of the Assiniboine river, and average scores in the peripheral segments of the city.

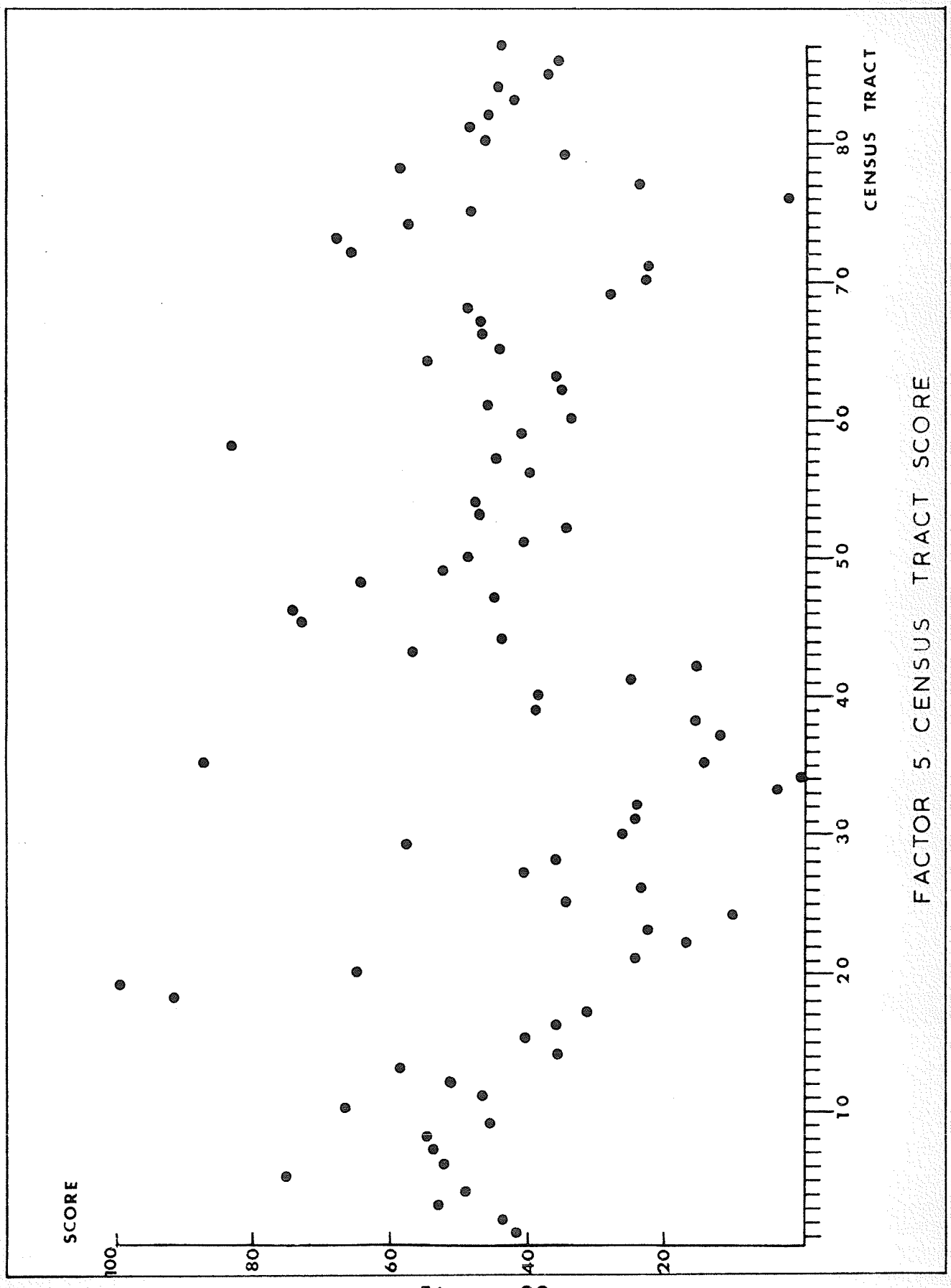
In MAP 31 the central area is shown bounded on

TABLE XIX

CENSUS TRACT SCORES ON FACTOR 5
(Retail Location and Asiatic Occupation)

Census Tract	1	2	3	4	5	6	7	8	9	0
	42	44	54	50	76	53	55	55	46	67
1-	47	52	59	36	41	37	32	92	100	65
2-	25	18	23	11	35	24	42	37	59	28
3-	25	24	5	0	16	88	13	17	40	39
4-	25	16	58	44	74	75	46	65	54	50
5-	42	36	48	48	24	41	46	84	42	34
6-	47	36	37	56	46	48	48	50	29	23
7-	23	67	69	59	50	4	25	60	36	47
8-	49	47	43	46	38	37	45			

all sides. The retail area around Portage and Main contrasts with the isolated commercial core between the two roads (20). Bounding this core there is the twilight zone of low scoring areas, most pronounced in the south and west, and limited by the Red river in the east. To the west of the city, high scores isolate the Polo Park area (29 and 75). These scores reflect the high incidence of centralized shopping in the area with provision of those groups fundamental to the factor structure. This is the reason why high scores isolate parts of West Kildonan (72 and 73) in the northern sector of the city. The physical boundaries (rivers and railways) exert only local influences in isolating sub areas for this factor.


FACTOR 5. CENSUS TRACT SCORE
SCORE
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CENSUS TRACT
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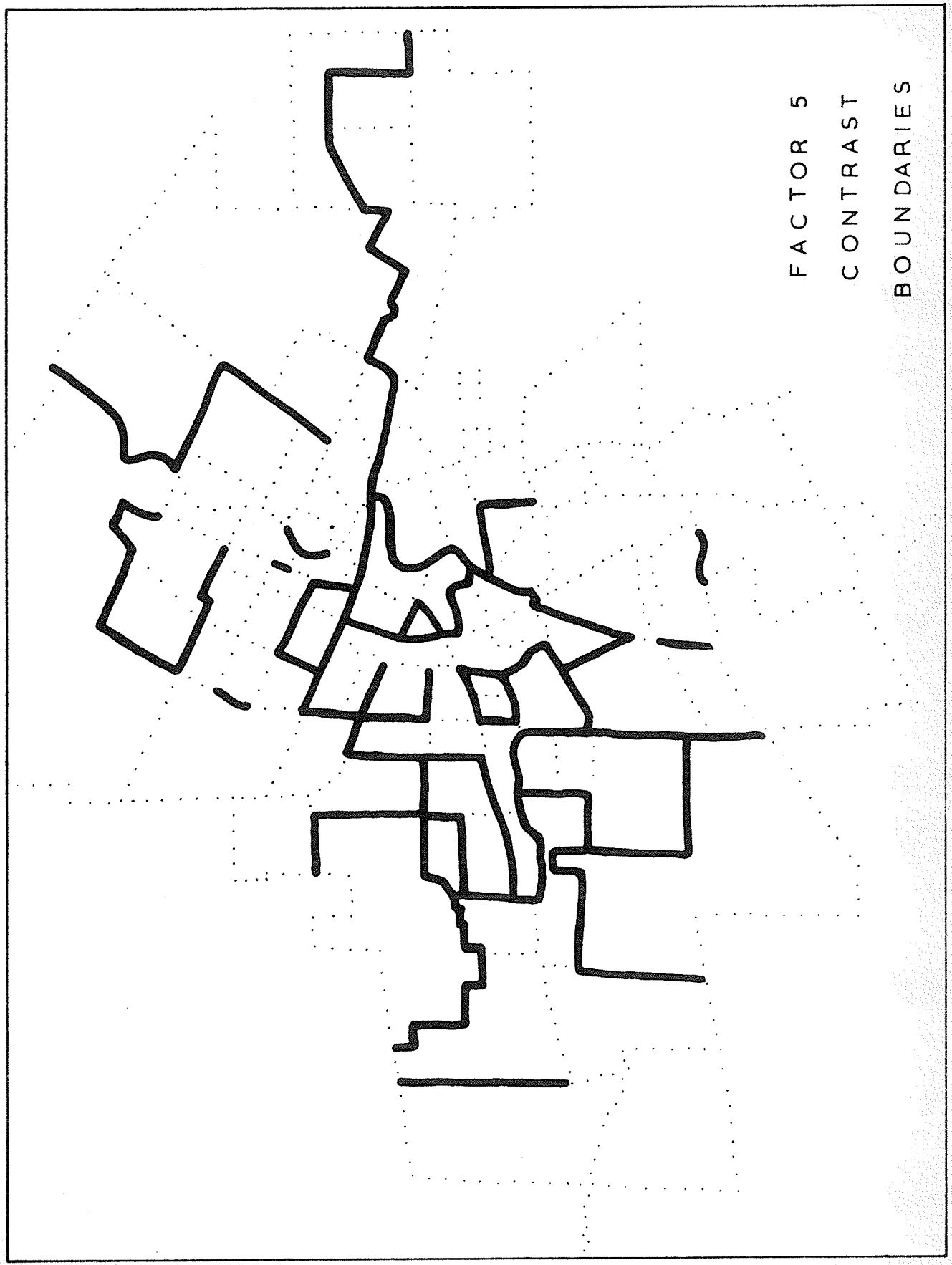
Figure 20



MAP 31

Domicile inertia is the major feature of factor six. High scores in TABLE XX correspond to those areas of a low rate of population increase between 1956 and 1961. Such areas are characterized by a high level of immobility with below average percentages of recent immigrants and people who have moved into the area from outside the province, or from abroad. A stage of stability, through equilibrium, would describe these areas.

Figure 21 shows the wide disparity between areas, with no apparent trend for the city as a whole. Four areas stand out because of their extremely low scores. Tuxedo (58), South River Heights (48), Garden City (72), and areas adjacent to the airport (76) in St. James are new, developing regions receiving an influx of new inhabitants. These circumstances favour low scores. Newly developed Springfield Heights (70), Windsor Park (87), and North Transcona (55) display similar characteristics.

All these areas are identified on MAP 32. They are distinguished by being bounded by contrast boundaries which exist as evidence of the differential growth rates and mobilities in relation to neighbouring areas. Areas of marked homogeneity are discernible in the city fabric. The core of the city is typified by large tracts having similar factor scores. Settlements along the Red river show remarkable similarities in growth and mobility

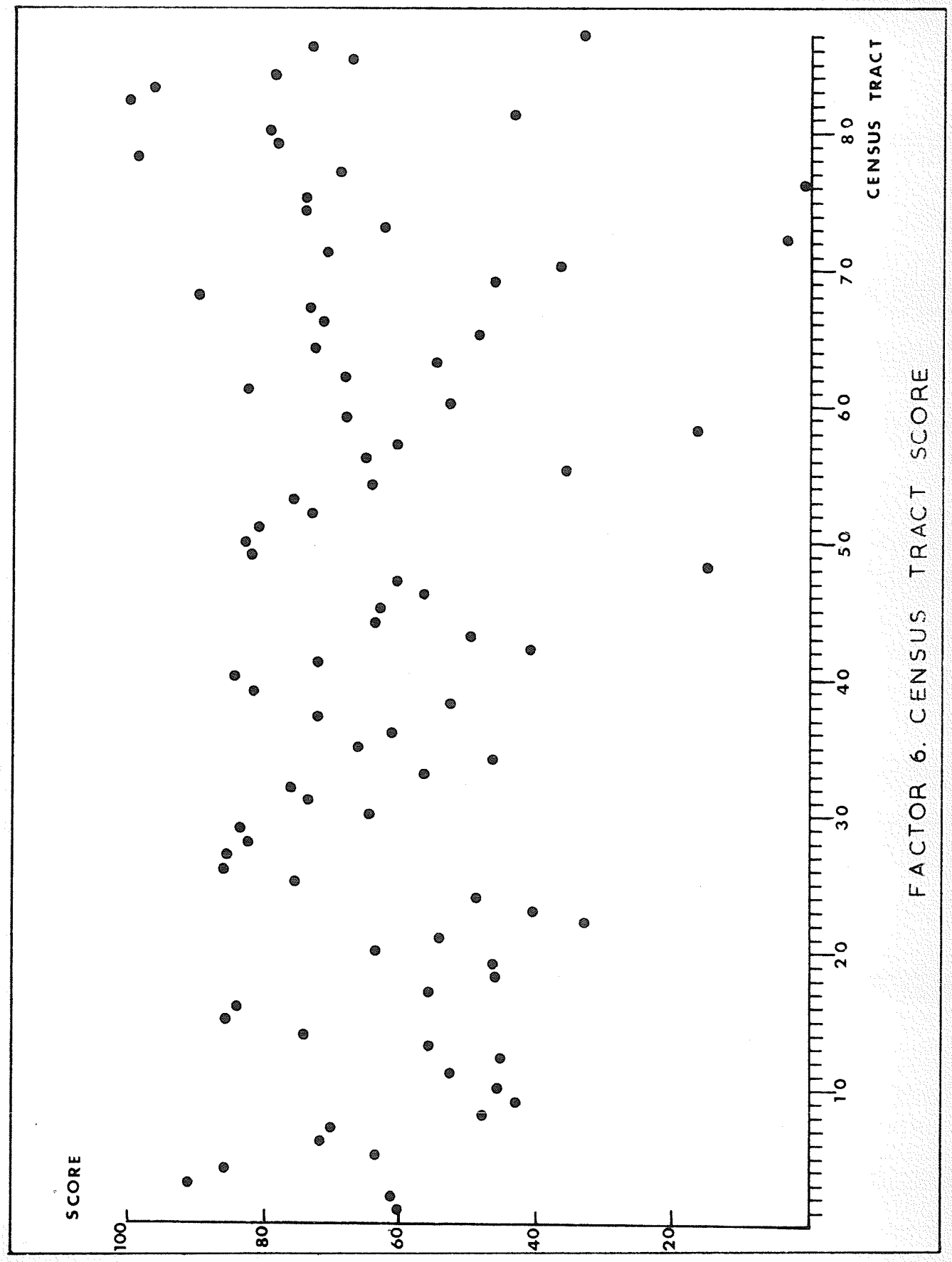
TABLE XX

CENSUS TRACT SCORES ON FACTOR 6
(Domicile Inertia)

Census Tract	1	2	3	4	5	6	7	8	9	0
	61	62	92	86	65	73	71	48	43	46
1-	53	45	56	75	86	85	56	46	46	64
2-	55	33	41	49	76	87	86	83	84	65
3-	74	77	57	46	68	61	73	53	81	84
4-	72	41	50	65	63	57	61	15	82	83
5-	82	74	76	65	36	66	61	18	69	53
6-	83	69	55	73	50	72	74	90	47	37
7-	71	4	63	75	74	0	70	99	80	80
8-	45	100	97	79	68	75	34			

values. The West End of the city presents few contrasts and appears to be in a state of equilibrium with respect to human mobility. The large sub areas are those with high Census Tract scores. This would suggest that stability comes when the inhabitants cease to move around and the area is not subject to rapid changes of population. Such areas are fully developed and not liable to future expansion, unless through comprehensive redevelopment.

The propensity towards apartment living and the ethnic mix are the two characteristics of factor seven. High scores in TABLE XXI are a response to a high incidence of apartment dwellings and the attendant, associated


FACTOR 6. CENSUS TRACT SCORE
SCORE
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CENSUS TRACT
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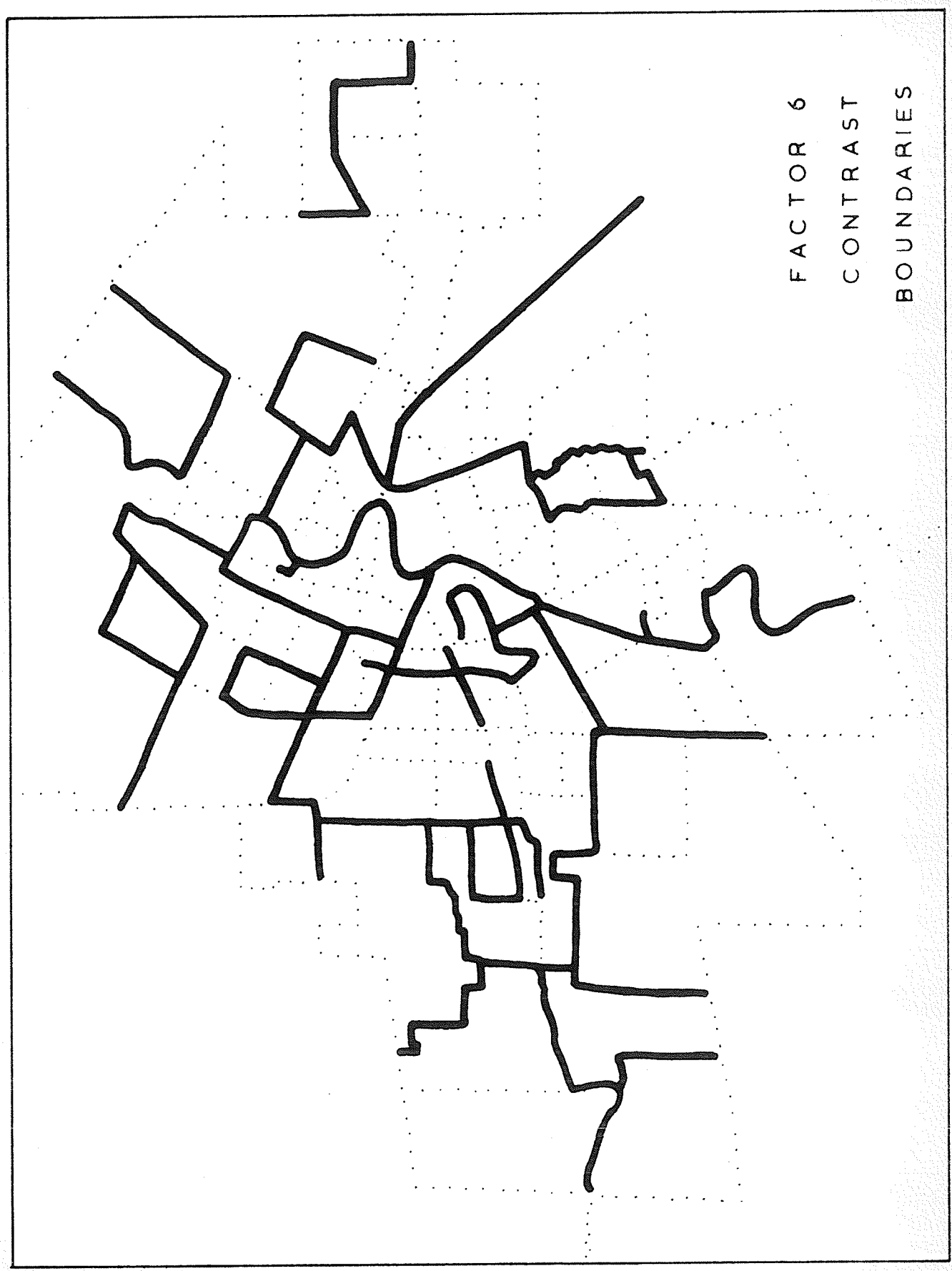
Figure 21



MAP 32

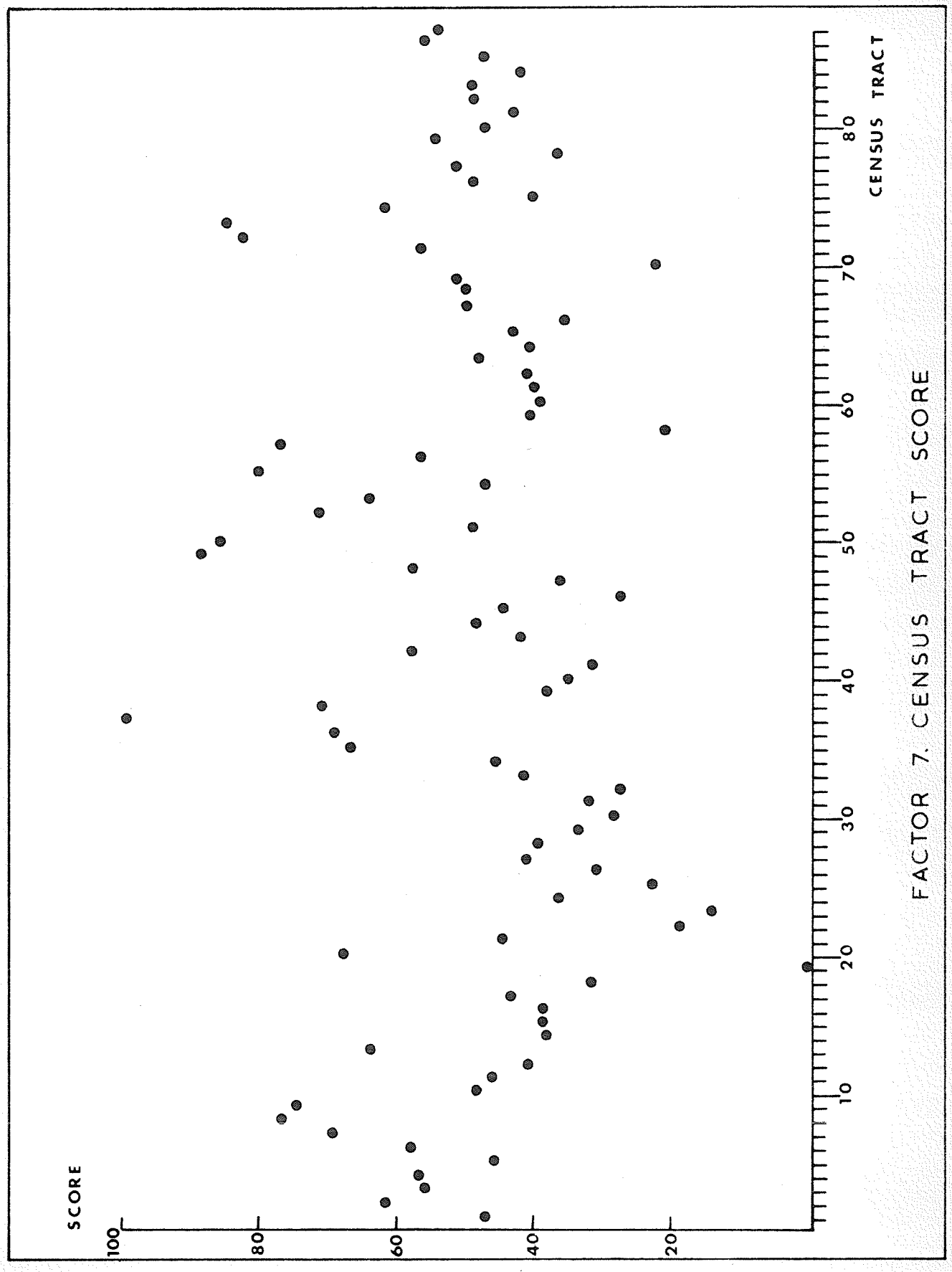
TABLE XXI

CENSUS TRACT SCORES ON FACTOR 7
(Apartment Living and Ethnic Mix)

Census Tract	1	2	3	4	5	6	7	8	9	0
	48	62	56	57	47	59	69	78	77	49
1-	47	41	64	38	39	39	44	32	0	68
2-	46	19	15	37	23	32	43	40	35	29
3-	33	28	42	46	68	69	100	72	39	36
4-	34	59	43	50	45	28	37	59	89	87
5-	49	73	66	49	81	57	78	22	41	40
6-	40	41	50	40	43	37	50	50	52	24
7-	57	84	86	62	41	49	52	37	56	48
8-	43	49	50	43	49	57	56			

variables, or can be the result of particular ethnic groupings. High ethnic scores indicate Jewish, French and other European concentrations, whilst low scores reflect the occurrence of Asiatic, German, Italian, Scandinavian, and British groups. The irregular pattern caused by this dual factor control is exhibited in Figure 22.

High scores in the central areas (Census Tracts 20, 21, 35, 37, 38, and 42) result from the very high density of apartment dwellings. The high scores in St. Boniface (49 and 50) are due to the French proportion of the inhabitants, and similar values in the North End are a result of Jewish occupation. The distinctive zero value


FACTOR 7. CENSUS TRACT SCORE
SCORE
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CENSUS TRACT
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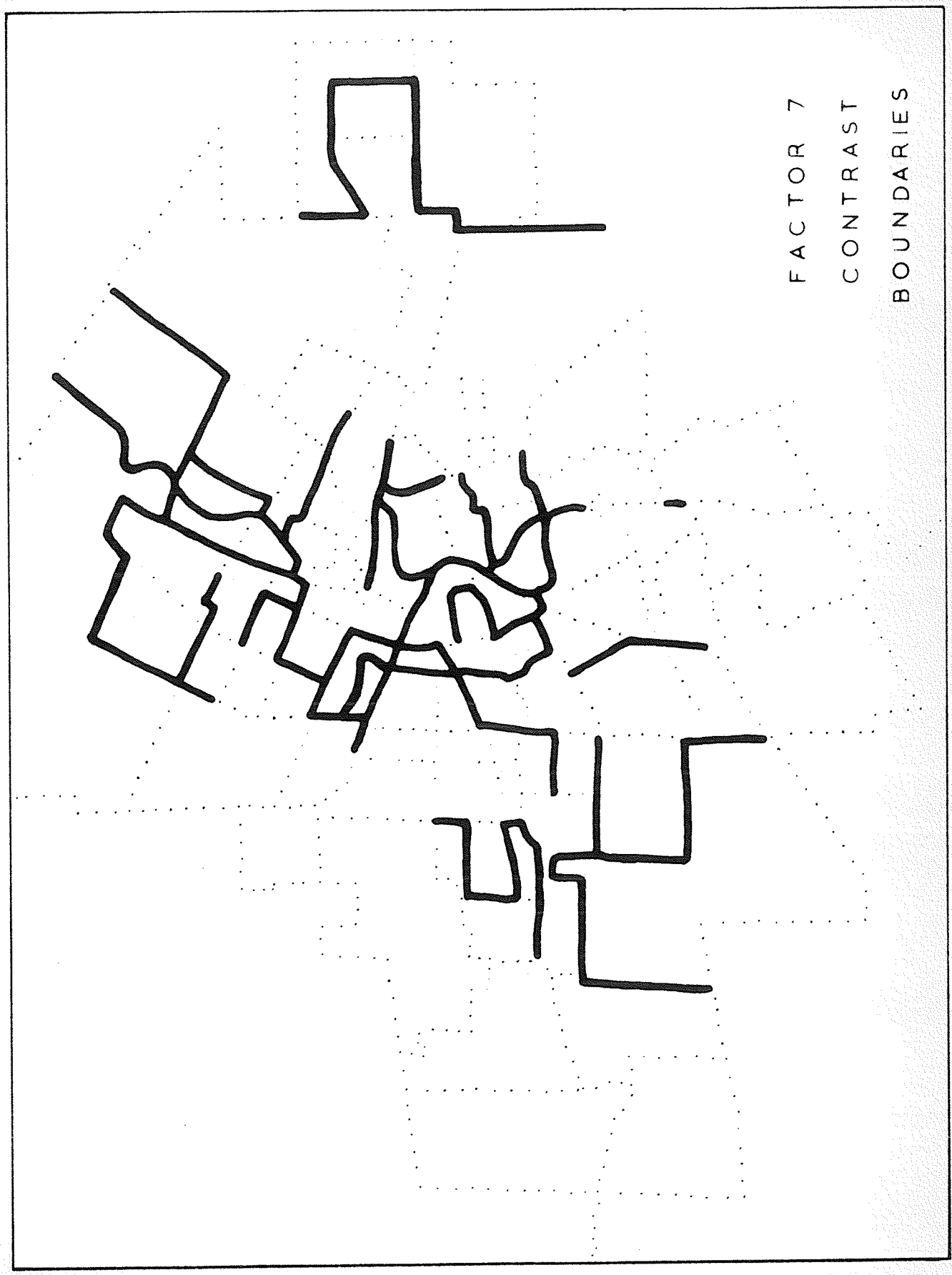
Figure 22



MAP 33

of Census Tract 19 can be accounted to the high level of Asiatic occupation. This area is the Chinatown in the city of Winnipeg.

MAP 33 gives visual expression to the downtown variations resulting from the two aggregate components of ethnic origin and apartment living. They both present their greatest fluidity in this central area. The apartment living area is identified around the Assiniboine river at its confluence with the Red river (20, 21, 35, 37, 38, and 42). The North End of the town unfolds a mosaic of sub areas caused by ethnic groupings. Census Tract 70 has a low score because of the concentration of Germans in the area; St. Boniface remains distinct due to the French occupation; Tracts 72, 73, 8, and 9 contain the dominant areas of other European concentration. The suburbs remain undifferentiated. This is on account of the general usage of single unit detached dwelling units as opposed to apartment units, and due to a less heterogeneous ethnic cross section.

The dominant feature of factor eight is the large factor matrix value for variable 19, the number of French people in each Census Tract. Low scores refer to those areas of French concentration. TABLE XXII emphasizes this fact. St. Boniface has extremely low values for Census Tracts 49 and 50, and below average scores for Census Tracts 51, 52, and 53. Figure 23 shows that most

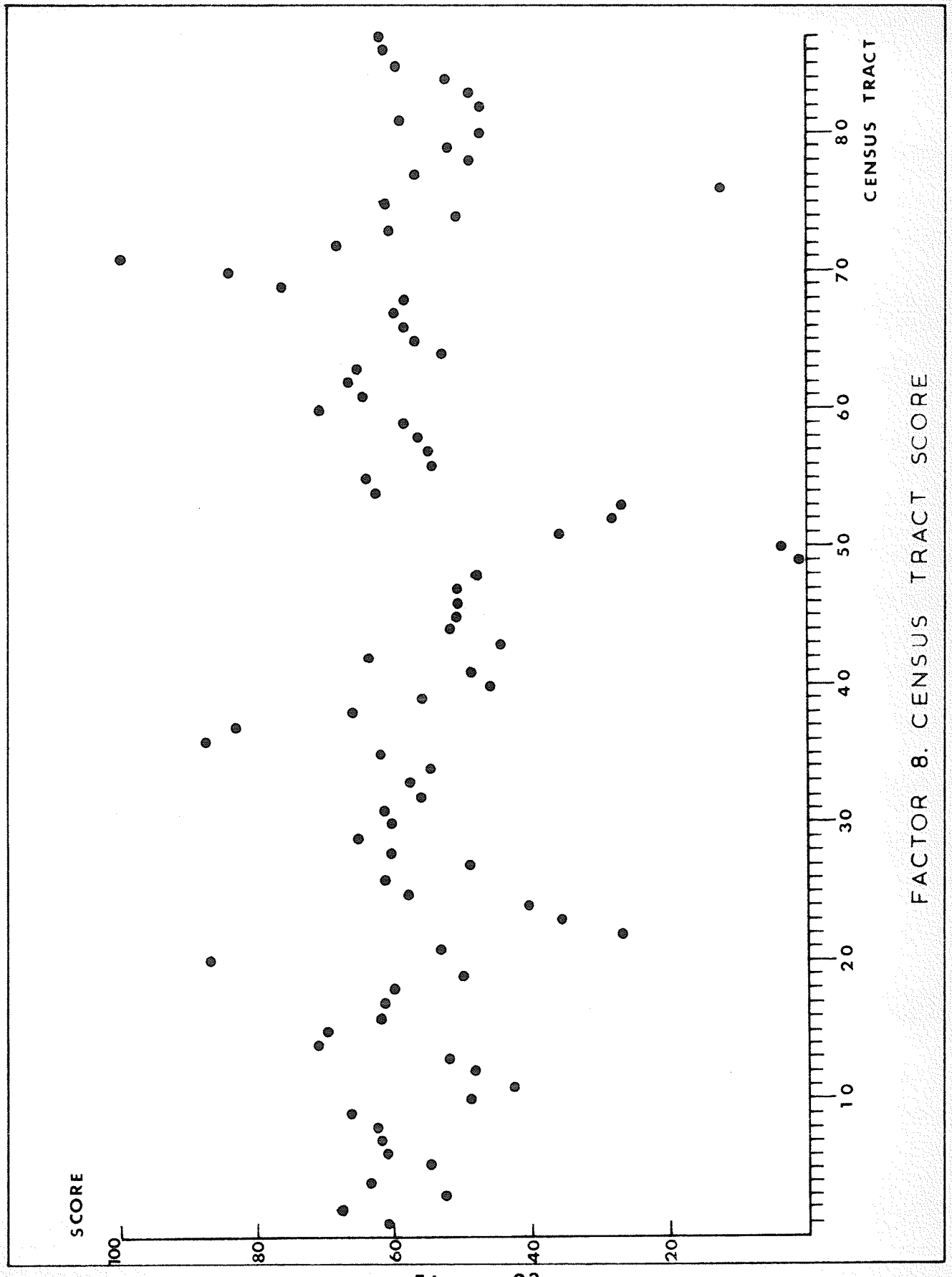
TABLE XXII

CENSUS TRACT SCORES FOR FACTOR 8
(French Domination)

Census Tract	1	2	3	4	5	6	7	8	9	0
	61	68	53	64	55	62	62	63	67	49
1-	43	48	52	71	70	62	62	60	51	87
2-	54	27	39	41	60	63	49	62	67	62
3-	63	57	58	54	62	88	84	68	56	46
4-	50	64	45	53	52	51	51	48	0	4
5-	37	29	27	64	64	55	55	57	59	72
6-	66	68	66	54	58	59	60	59	78	85
7-	100	68	61	52	62	12	57	49	53	48
8-	60	48	49	54	60	62	63			

areas lie just above the average score and disperse to only a small extent. Noticeable deviations are the St. Boniface areas and Census Tract 76 in St. James. The last area owes its low score to high values of persons per household and rooms per dwelling, variables which also have a significant negative effect in the factor structure. At the other end of the scale, Census Tract 71 in North Kildonan receives its high ranking because of its high proportion of persons of Netherlands extraction, a group which has a positive influence in the factor structure.

MAP 34 identifies the grouping of the St. Boniface areas, but elsewhere the boundaries are of miscellaneous


FACTOR 8. CENSUS TRACT SCORE
SCORE
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CENSUS TRACT
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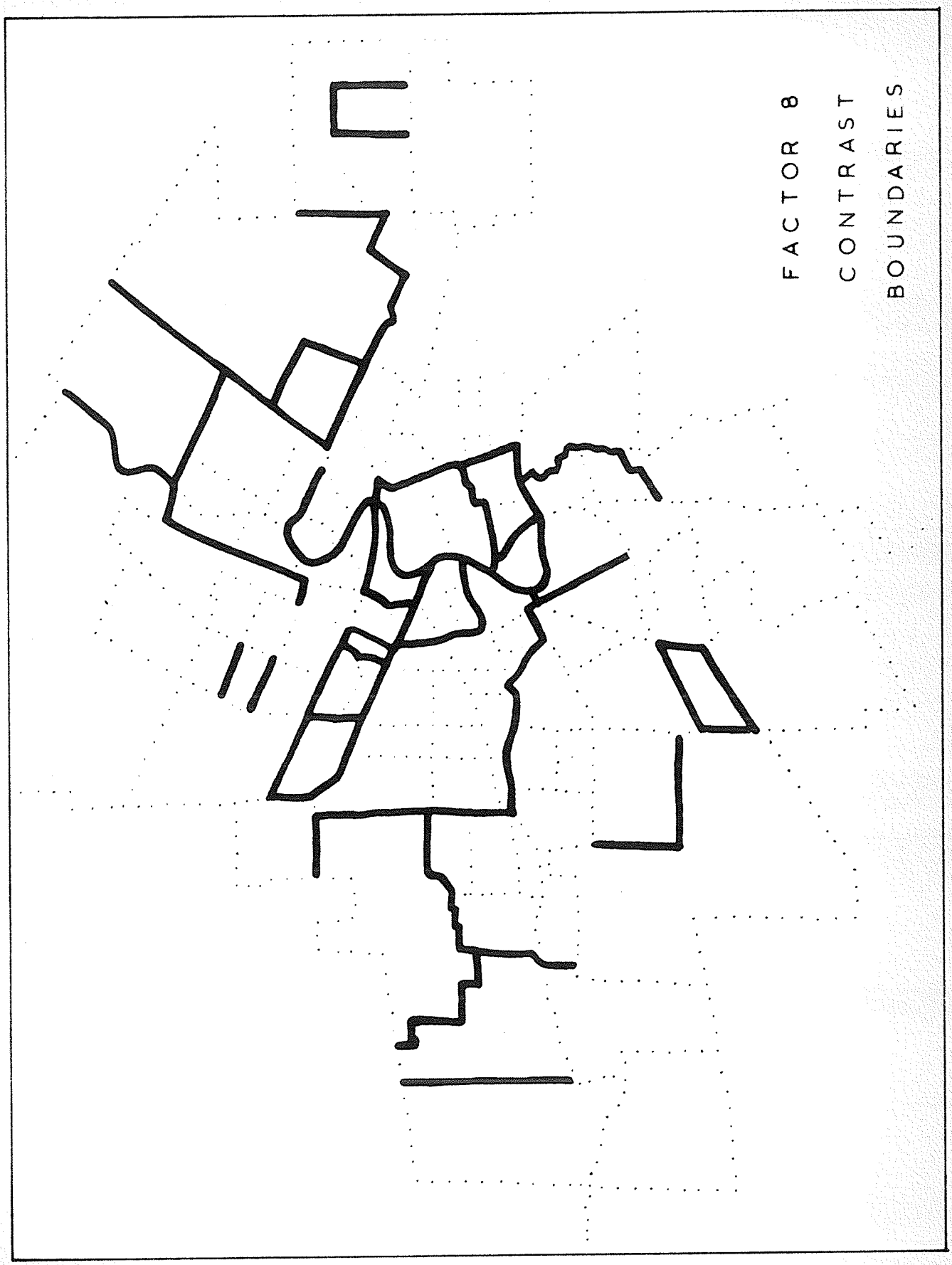
Figure 23



MAP 34

interest only. That there are so many contrast boundaries, when the scores are so close together, is due to the small standard deviation in the Census Tract scores, which in turn causes small differences in Census Tract scores to have quite large deviation differences.

The structure of factor nine includes two diametrically opposed forces. Negative weightings apply to variables 44, 45, and 56, implying a close connection between income and value of property. The factor also renders a strong relationship between unskilled workers and age and condition of crowding of dwellings. Both these relationships are in the same direction but are clearly unrelated. Resulting from this, the low score attached to Tuxedo (58) in TABLE XXIII is due to the income characteristic, whilst the low score of North Transcona (55) arises from the high ratio of unskilled workers. The exceptionally high score of Census Tract 76 in St. James is a result of the large number of persons whose ethnic origin is not stated (variable 29), a variable with a high positive loading in this factor.

The remaining areas have a small dispersion in score and like the preceeding factor's sub areas map, the contrast boundaries (MAP 35) are too frequent considering the small dispersion of the scores. Naturally the extreme values mentioned are confined within strong contrast

TABLE XXIII

CENSUS TRACT SCORES ON FACTOR 9
(Income and Level of Skill)

Census Tract	1	2	3	4	5	6	7	8	9	0
	56	54	50	51	42	41	53	53	50	47
1-	53	42	55	45	46	46	62	57	46	49
2-	38	35	42	44	35	57	53	62	48	40
3-	50	36	38	23	34	44	55	46	50	50
4-	40	39	31	52	44	32	59	54	29	25
5-	43	29	41	41	4	36	29	0	43	47
6-	48	51	49	42	43	47	47	48	45	44
7-	22	59	60	54	47	100	58	50	54	51
8-	49	48	55	51	39	29	46			

boundaries, but there are many other areas which receive similar treatment on account of the interplay between other component variables and the small standard deviation for the factor as a whole (see Figure 24).

A brief survey of the urban structure with respect to each of the nine factors has isolated certain advantages and limitations in the methodology. Whilst these will be discussed at some length in chapter VI, it is pertinent to observe that whilst each Census Tract score for the major factors is significant, and the sub areas isolated are meaningful and useful, these scores are less valid for the minor factors. In the case of the minor factors

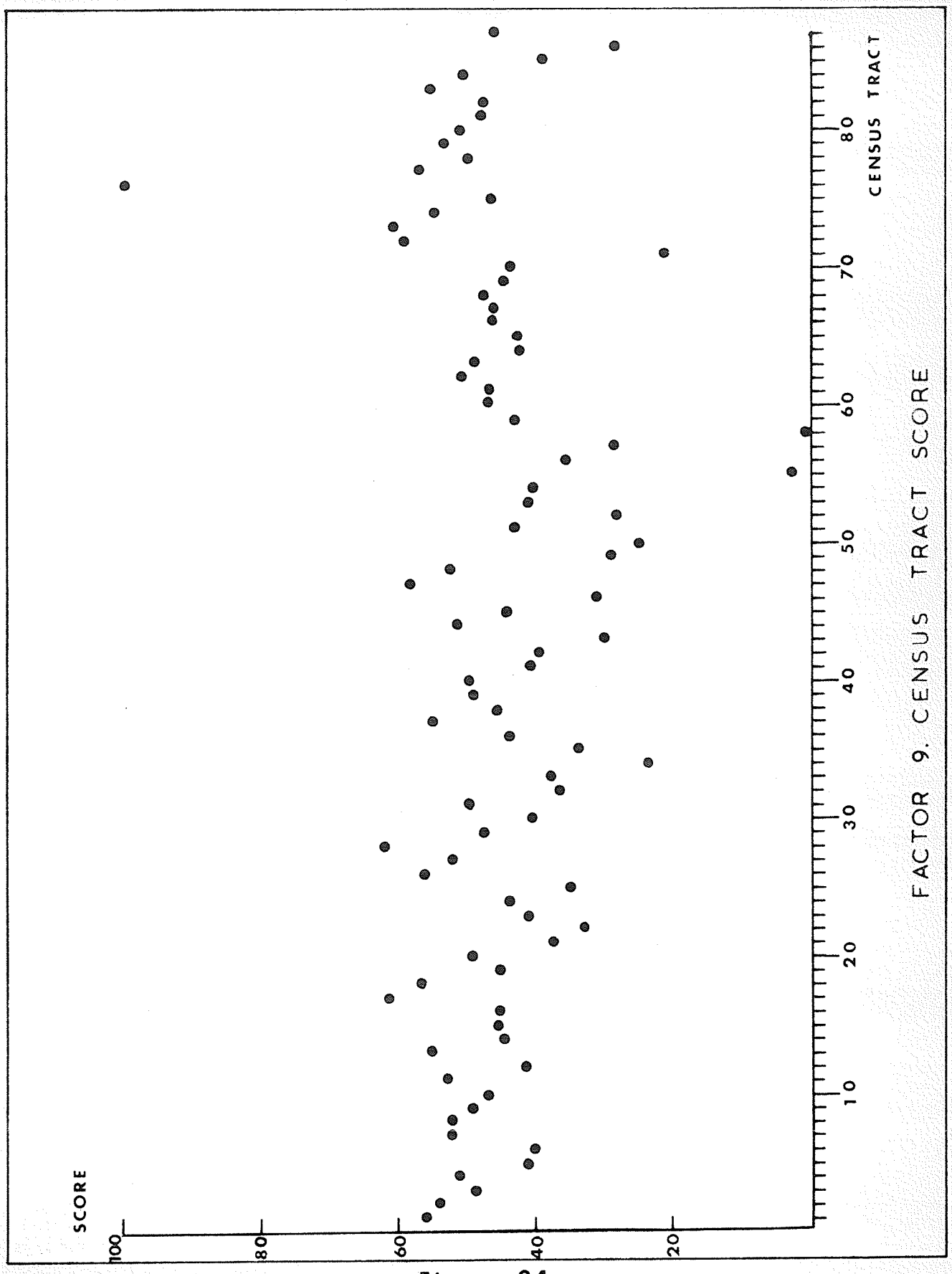
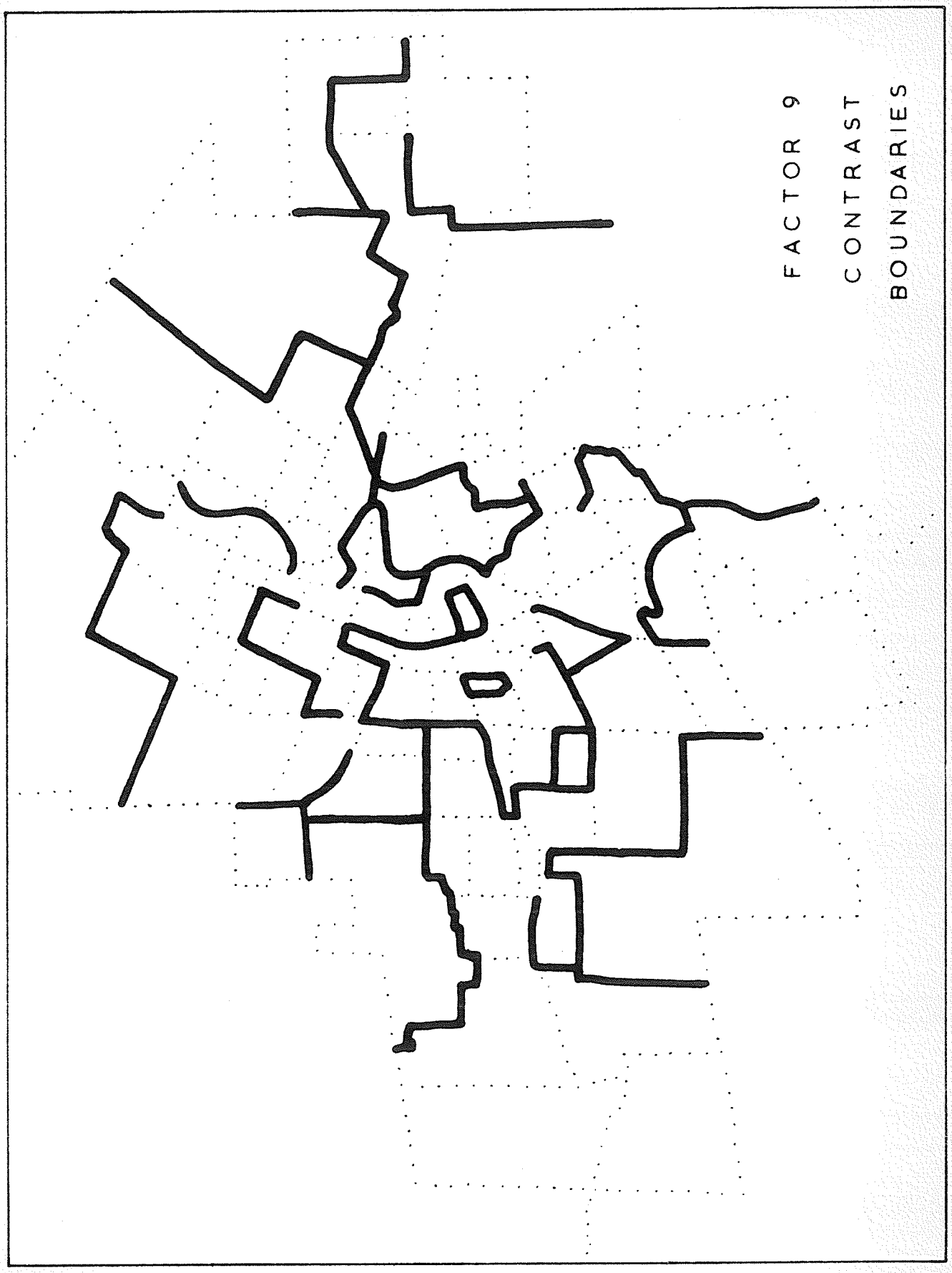

FACTOR 9. CENSUS TRACT SCORE
SCORE
100
80
60
40
20
CENSUS TRACT
10
20
30
40
50
60
70
80

Figure 24



MAP 35

there is an increasing tendency for successive factors to select only anomalies from the whole area. Whilst the bulk of the scores cluster around a mean value, it is the few widely dispersed Census Tracts which incite attention. Unfortunately, the small deviation of the scores as a whole, gives rise to a contrast map which identifies both the areas of marked difference from the normal, and also those areas distinguished by only slight differences.

The second method of studying the urban area is to review a single areal unit. Its stresses and strains can be understood from its scores on each of the factors selected for the study. To give an example of this type of analysis consider the comparison between Tuxedo (58), a first class residential area, the downtown area (19) which is part of the old wholesale industrial area adjacent to the C.B.D., and part of an area reviewed for urban renewal, and thirdly, part of the city of Transcona (56) which owes its origin to the Canadian National Railway yards and workshops there. At the outset it is evident that strong differences exist between the chosen areas, but how are these differences reflected in the factor scores?

In Figure 25 the scores for each of these Census Tracts on the nine factors are graphed. On factor one, which is a measure of income and wealth, Tuxedo heads the

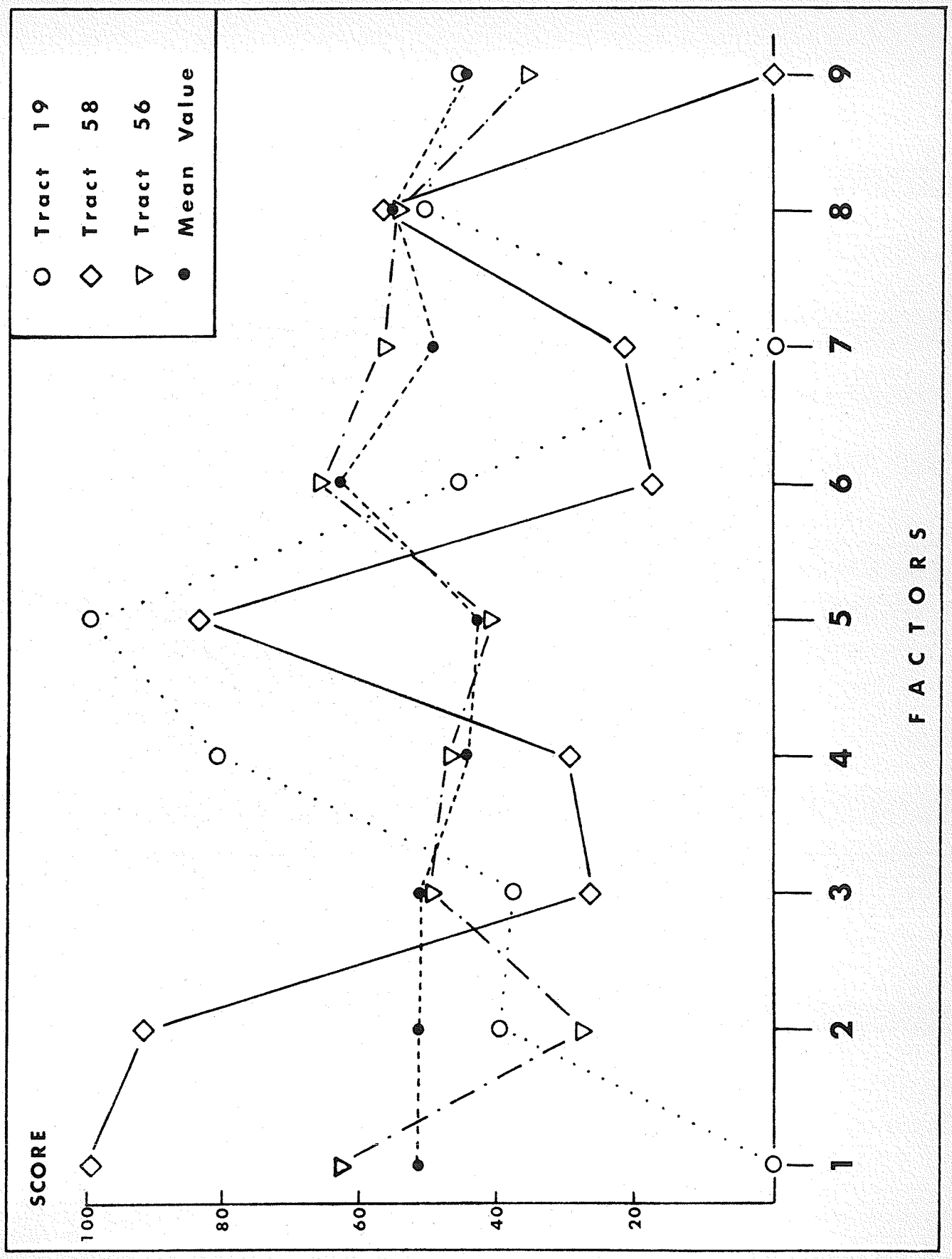

Tract 19
Tract 58
Tract 56
Mean Value
SCORE
100
80
60
40
20
1
2
3
4
5
6
7
8
9
FACTORS

Figure 25

list for the whole city whilst the downtown Tract supports the column. Transcona occupies a position above the city average. Tuxedo maintains its high score on factor two which is a measure of social structure. Transcona in this case falls below the downtown area, but both lie below the city average. The poor social structure score of the City of Transcona has been mentioned earlier in this study.

There is no marked difference on factor three, but the difference in mobility is reflected in factor four. The extremely high value for the downtown area reflects the transient nature of many of its inhabitants. On factor five, the high income level provides Tuxedo with its high score, and the incidence of central area shopping facilities is the cause of the downtown's very high rank on this factor. These were the two areas selected to illustrate the twofold nature of the factor's structure.

Tuxedo has a very low score on factor six, a sign of housing and population expansion. Whereas Transcona approximates to the mean value, the downtown area falls below it in spite of suffering a small population decrease in the period 1956-61. The downtown area occupies bottom position for factor seven because of the concentration of Asiatics in the area. Meanwhile, Tuxedo fails to score much higher but this is due to its ethnic mix, where a low percentage of French occupants is matched by a high percentage of British inhabitants.

No marked differences exist in factor eight where the pattern is similar to the city normal. The high income of Tuxedo once again differentiates it in factor nine. The low level of skill in Transcona causes its score to be below the city average.

This type of analysis can be performed for any area of the city, but the task is made difficult because of the complex structure of the factors (especially the minor factors). Census Tract scores can only be understood if reference is made back to the original data matrix, and variables which have a high factor weighting are examined. This is especially the case where factor structures possess two distinct and unrelated associations of variables.

This brief exposition only serves to pave the way for more rigorous analyses. It provides an exact presentation of methodology but reserves the right to delve into the results with infinite exactitude. The facts are presented and a few deductions drawn, but the vast amount of incorporated information necessitates analysis along a narrow front. Its benefits are more readily visible if the objectives of the study are clearcut and simple in design. Because this study is more concerned with method, a limit to enquiry has to be established and, therefore, much must remain as purely numerical data.

CHAPTER VI

CONCLUSIONS

What lessons can be learnt from the preceeding analysis? Accepting that the component analysis is more objective in its approach than the method of Social Area Analysis formulated by Shevky and Bell, it is interesting to compare the results. The three indices (Social Rank, Urbanization, and Segregation) they use as indicative of urban structure are analogous to three of the factors derived by the component analysis. Whilst the presentation of the data is different, similarities exist in the areal distribution of values. Factor one, the distribution of wealth in the community, has the same concentric zone structure in the urban area as the Urbanization Index in the Social Area Analysis. Factor two compares favourably with the Social Rank Index. The mapping of the Social Rank Index in chapter II produces the same strong visual contrasts as shown in the contrast boundaries for factor two. The Segregation Index devized from concepts propounded by Shevky and Bell is comparable with factor four of the component analysis. The two maps and Table of Census Tract scores have noticeable

similarities, but because factor four also includes mobility in its structure there are some deviations.

Because the factor structure is based upon the linear transformation of all 75 of the original variables, it is inappropriate to picture the urban structure in the same way as portrayed by the three maps resulting from the Social Area Analysis. In the latter case the components are well defined and comprehendable, and the relative shading has tangible meaning. In the factor structure there is a good case for using contrast boundaries as the Census Tract scores are values based on a complex mixture of 75 variables. Reference to individual Census Tracts is possible by investigating the actual basis upon which these scores are compiled.

An important difference is that factor analysis is general in its application but specific in its results. Whereas the method is equally applicable to any urban area, given the original source data, the factor structure and amount of variance accounted for by each factor is unique for each urban area. Social Area Analysis is based on fixed components which enforce the same rigidity on each urban area to which the method is applied, yet the components may have a different significance in each of the study areas. Generalities are sought by using such a method, but if more precise knowledge is required about

the forces at work in the community, it is necessary to use more sophisticated techniques.

Although it has been suggested that factor analysis is a move in the right direction as far as urban analysis is concerned, it is important to appreciate certain limitations in the procedure adopted in this thesis. These limitations are of two types, those accountable to the theory of factor analysis, and secondly those resulting from specific applications of this analysis in the preceeding study. Systematically these limitations can be discussed in the order in which they are encountered in the major part of the study:

(i) Choice of units of area

(ii) Choice of variables

(iii) Factor analysis as a method

(iv) Restrictions in the computer mapping

(v) Inadequate interpretation of the urban structure of Winnipeg from the results.

In order to formulate some criteria upon which subsequent studies can be made, it is worthwhile expanding upon each of these five recognized limitations.

The choice of areal units was based upon the rival merits of the Census Tract and the Enumeration Area. For a number of reasons the Census Tract was adopted but evidently its large size mitigates against its usefulness

in some areas of the city. Because it assumes homogeneity within its boundaries it is inevitable that a large amount of detail is lost. This is especially true in those Census Tracts with a large population and areal extent. The Enumeration Area overcomes this limitation as it is based on an administrative unit of area which has a reasonably constant population size. Furthermore, as its size is so much smaller it does not generalize to the same extent as the Census Tract does, and for this reason might satisfy the requirements of a workable unit better.

Further studies along these lines might well be devized in terms of the Enumeration Area figures if they are available. Once adopted they cause changes in the technical level of the analysis. The data matrix becomes too large for computer storage and the use of some transitory form of storage (other than core) during computer runs is necessary. This is best provided by a scratch tape and the program rewritten to assimilate this refinement. Also a number of the variables which rely upon inter census comparisons have to be excluded as the Enumeration Areas do not retain concordant boundaries over the ten years, 1951-1961.

Certainly, as more and more census material becomes available in computer tape form, it is desirable to use the smaller Enumeration Area statistics stored in this

manner. With data for the 1966 sample census becoming available, it should be possible to reconstruct the model so that the type of results produced in this thesis can be upgraded in a matter of minutes. Evidently it is a matter of convenience in deciding which unit area is to be adopted.

Probably, first stage analysis of an urban area should be undertaken at the Census Tract level to obtain a general picture of the urban dynamics, then, if more precise and specific results are required, the Enumeration Area can be used as the areal unit. With the likelihood of collecting census material based on grid coordinates in the future, a better method of storing data will become available. Grid coordinates map into matrix structures easily, and these can be used flexibly by computer storage systems.

The subject of choosing variables is more disputable. In retrospect, the list used in this study is considered comprehensive in the socio-economic fields. Perhaps arguments can be put forward for including some of the following variables: birth and death rates, age pyramids for each area, infant deaths, welfare, illegitimate births, mental illness, library book circulation, differential property insurance rates, retail purchasing power, and retail trade in monetary value. The reason

they have not been included is due to lack of numerical data and the need to maintain some simplicity in the model. The index of aging adopted as a variable, for example, is a good replacement for the eleven variables necessary if the age pyramid of the population is to be used.

The major limitation is the lack of sufficient geographical variables. There are certain difficulties in representing qualitative characteristics (such as land use) in numerical terms, with the major problem of reducing geographical characteristics of the townscape to meaningful numerical representation. Land use, accessibility, potential strength of boundary, and gross densities have been incorporated, but features of site, situation, plan and morphology, communications, building types, and traffic and pedestrian flows, have a significant role to play in intra urban dynamics. Such manifestations in the townscape have been ignored. Assessment of these influences involves the sort of time consuming fieldwork alien to the speed and objectivity critical to factor analytical methods in urban geography.

In other urban areas the list of variables could be pruned. The ethnic mix of Winnipeg is conducive to the incorporation of twelve variables denoting ethnic composition. In other American and Canadian cities the

ethnic composition is not so important and in the case of European cities is of only minimal significance. Evidently the choice of variables will depend, to a large extent, on the particular city under investigation.

The actual analysis is convincing but two properties require closer examination. Firstly, the use of principal components analysis can be questioned. Is it more suitable than a pure factor analysis? In retrospect the components analysis and its study of relationships within a set of variables proves highly satisfactory. Although a pure factor analysis has greater noise reducing capabilities, its isolation of single variables and the measurement of other variables' dependence on them, is not ideal for this particular study.

Certain aspects of principal components analysis prove the close interplay between the analytical theory and the data matrix structure. As is evidenced by factor three, growth and mobility, it is possible to generate factors because of certain properties in the original correlation matrix. The criticism does not concern the factor analysis of the covariance existing in the correlation matrix, but rather the selection of units (absolute or percentage values) in which the variables are measured. If too many variables representing a similar relationship are included, it is inevitable that

this relationship will produce a high percentage of the total trace. Whilst this is the object of the exercise, it is necessary to select variables with care so that certain relationships are not overemphasized. The correlations between absolute values in each Census Tract (for households, population, and labour force numbers, for example) are likely to be very high and they will reflect a significant amount of the total variance.

Hence any criticism concerning the factor analysis is directed towards its implementation rather than towards its theory. The structure of the data matrix and the choice of variables and the units of measurement assume a real importance in the use of this analytical technique. Given these satisfactory conditions, the methodology would appear to be ideally suited to the type of analysis undertaken in this study.

The development of a mapping technique to isolate areal contrasts proved satisfactory. The concepts involved in the output are straightforward, but there are a number of ways in which the output can produce inconsistent results. Throughout the mathematical analysis there is no spatial configuration given to the 87 Census Tract areas. As a result, the contrasts exist within the 87 cells of a dimensioned array. The actual spatial location of these cells is not apparent until the results are

output under specific format instructions to give the final contrast maps.

It is conceivable that the identification of contrast boundaries could be output as one computer map rather than 21 maps showing the contrasts at particular positions throughout the distribution curve of the entire variable. This would save some time in interpretation but would necessitate identifying the spatial disposition of the Census Tracts in the computer model. This would make the method too specific in its application.

Furthermore, as the contrast boundaries are measurements between groups into which areal values fall, they vary to a small extent between individual items. Consider the example where A has a value 17.0 and B has a value 19.0 and both lie in the group whose boundaries are 15.0 and 20.0. Both X and Y with respective values of 31.0 and 34.0 lie in the group bounded by values 30.0 and 35.0. Assuming the contrast between the two groups exceeds the 0.5 standard deviations used in the study, it is clear that the contrast between A and Y is greater than that between B and X. Deviations of this form are observable in the mapping technique but detract to only a small degree from the practicality and precision of the method as a whole.

A further refinement in such a technique is the

opportunity to change the standard deviation value selected as identifying a contrast boundary. Moreover, this change can be effected during the computer analysis of the data and based upon some specific instructions concerning the level of differentiation required. In order to produce a simpler mosaic of sub areas, this deviation value could be increased until the required degree of generalization is achieved in the output maps. As a method of structural analysis based on contrasts, the process offers extensive flexibility and is easily manipulated to the requirements of the operator.

The use of the factor analysis and the urban mapping is illustrated by the exposition of the urban structure of Winnipeg. The use of Winnipeg as an urban area on which to test the methodology has not been elucidated. Other than its complex ethnic structure, it presents no characteristics which favour it over any other urban area[1]. The benefits lie in the fact that it is convenient to undertake research in an area where values and judgements can be easily verified. Results deduced in this work are enhanced by personal satisfaction in their value, either by conversation with local inhabitants or by direct observations of the city. To study an area in an

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[1]Fromson, loc. cit.

empirical fashion benefits from being within the environmental climate of that area. An added reason for studying Winnipeg is that, apart from the current program of the Social Audit, little has been undertaken in urban work in the city or its surroundings[2].

The actual results extrapolated in the analysis of Winnipeg have been listed in the preceeding chapter. It is pertinent to reiterate the fact that the exposition is brief because the inferences are numerous and complex. The actual urban analysis could form the basis of a separate thesis, and as this was not the objective accepted at the outset, only broad generalizations have been suggested. In attempting to develop methodology, it is inevitable that descriptions and results are precise and not encumbered with unnecessary asides. Geographical description is kept to a reasonably low level when it fails to conform to the integrated mathematical description of circumstances. In summary, the looseness and brevity inherent in the urban analysis is intentional but at the same time the core of the problem has been solved and presented, and extended research is easily undertaken from this established pattern.

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[2]An initial stage in this study is presented in the unpublished booklet Social Audit: Socio-Economic Study of Metropolitan Winnipeg, Department of Welfare, 1967.

Having evaluated the actual analytical processes and results, it is desirable to consider the overall implications of the study. In the introductory chapter a wide background to urban analysis was reviewed. How does this analysis fit into the context of accepted patterns of investigation? To what extent does this work help to solve the dilemna of a universal set theory for all urban research? Whereabouts in the matrix of practically useful and theoretically useful can this type of analytical approach to the urban environment be placed? These are vital questions which need answering if the usefulness of the method is not to be vitiated.

This study fills a particular role in the geographical appraisal of cities. As a method it satisfies the second of Blanchard's objectives, namely, the analysis of the life and organization of individual settlements aerially, as a whole, and in their integrated sections[3]. From the inter urban viewpoint it offers little. However, the use of factor analysis as a geographical method is to be found in functional classifications by Ahmad[4] and Moser and Scott[5]. Many of the functions utilized in this

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[3]Blanchard, loc. cit., see page 8 in this thesis.

[4]Ahmad, loc. cit.

[5]Moser and Scott, loc. cit.

study of Winnipeg (occupation for example) are used in the many city classifications based on the criteria of functional importance and dominance.

Population size in cities has assumed a separate importance. The absolute population of Winnipeg could be examined in relation to other Canadian or American cities. Nowhere in this particular work is this relationship examined, yet population of areal units within the city figures very highly as a controlling force in the environment. Stability of population reflected in immobility, appears to be a particular feature of some areas. Since the areal units are conterminous, and the Census Tract boundaries do not separate distinct urban entities, there is no merit in postulating intricate relationships between the population sizes of the individual areas.

The spatial aspect within the city is of paramount importance. Urban geography has considered spatial relationships as relationships existing between cities but there is evidence to conclude that similar hierarchical arrangements exist within a city. The provision of retail outlets is a good example. The sphere of influence of the C.B.D. and suburban shopping centres gives rise to concepts of urban centrality and this is recognizable as a distinct characteristic of the city. The importance of retail pattern is brought out in factors one, four, and

five, and the close interplay with other variables in the factor structure is clearly visible.

One advantage of this approach to urban analysis is that it satisfies many of the criteria raised by Holzner et al. in considering relationships between cities of different cultures[6]. Factor analytical methods are applicable in any continent with the one provision that the choice of initial variables must reflect the cultural forces pertinent to the urban environment of each specific city. If this condition is satisfied, it answers the rhetorical question raised by Hoyt about dynamic and cultural change[7].

In its concern for just one city, Winnipeg in this case, the preceeding study should compare with the intra urban approach to urban geography. Perloff assesses particular usages for urban analysis in the planning field[8]. The building of a descriptive model of the urban system helps to answer some of the enquiries he makes of the urban environment as a prerequisite to comprehensive planning. Certainly the model is geared towards explaining the internal structure of cities and metropolitan areas

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[6]Holzner, Dommisse, and Mueller, loc. cit.

[7]Hoyt, Land Economics, see page 23 of this thesis.

[8]Perloff, loc. cit.

cited by Mayer as the role of the urban geographer[9]. Furthermore, because of its adaptability to any city, factor analytical methods overcome Bogue's criticism of case studies[10]. Although unique in its application, the method of application is universal.

Like the sociologist, the geographer is interested in differentiation within the city. Contrast boundaries produce differentiation and although each particular zone for each factor has not been examined, such a study is not impossible. In the case of factor one, for example, the gradation of scores away from the centre of the city is associated with roughly concentric contrast boundaries. Because these boundaries exist, it is implied that there is a sharp break at particular points along the gradient, which find visual representation on the ground. In this way factor one gives rise to three zones in the city of Winnipeg. Firstly there is the inner core, then an extended frame area, and finally a suburban zone. A general picture is accompanied by this overlying pattern of similar zones. A similar investigation is possible for the other factors isolated in the analysis, but such a simple pattern fails to emerge.

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[9]Mayer, loc. cit.

[10]Bogue, loc. cit.

In totality the thesis typifies the objectives found in sociological analyses of urban areas. It uses the Social Area Analysis of Shevky and Bell as a starting point and involves a complex of sociological variables in the actual factor analysis. Park's aim in isolating and explaining natural sub areas is fundamental to this particular study[11]. The concepts of city structure are explored and some analogy to Burgess' concentric zone structure has been observed for factor one[12] and traces of a sector structure for factor two[13]. The lack of any unified structure to explain all features of the city is in accord with the observations of Anderson and Egeland[14].

The whole pattern of urban forces found in Winnipeg, reduced to factor structures, is associated with spatial differentiation. As Burgess and Bogue implied, "... began to emerge the realization that there was a definite pattern and structure to the city, ..."[15]. The early part of this study, based on the Social Area Analysis of Shevky and Bell, validifies this statement and reinforces the remarks they make about the distribution of skills, the

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[11]Park, The Urban Community, p. 3.

[12]Park and Burgess, The City, p. 54.

[13]Hoyt, The Structure and Growth of Residential Neighborhoods in American Cities.

[14]Anderson and Egeland, loc. cit.

[15]Burgess and Bogue, loc. cit., p. 7.

organization of productive activity, and the composition of the population within the urban community[16].

The economic variables included in the data matrix provide a strong economic framework to the study. The fact that the first factor depends upon wealth in the community is a sure indication that economic forces assume a supreme importance in urban structure. Building values and rents are closely connected with urban location and it would be interesting to examine the trends in these values over a 50 year period to see to what extent declines in the city core and increases in peripheral areas are manifested. There are many economic and historical aspects of a city structure which remain unexplored by the method of factor analysis.

Inherent in this type of analysis is a desire to identify all the forces at work in the dynamic urban environment. The choice of variables embraces the geographic, sociological, and economic fields, and aims at being as exhaustive as is practically feasible. The degree to which the research is directed along an interdisciplinary path is subject to opinion, but the data matrix itself can make some claim to embracing a mixture of interdisciplinary relationships. The methodology is

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[16] Shevky and Bell, loc. cit., see page 40 in this thesis.

mathematical but the results are framed in socio-economic terms with the geographical influence represented.

If the variables, x_i , belong to one of the three sets **G** (geographical), **S** (sociological), or **E** (economic), then the factors, z_i , transformed from these 75 variables must lie in the set formed by the intersection of these three sets. In set terminology this means:

$$x_i \in \mathbf{G} \text{ or } \mathbf{S} \text{ or } \mathbf{E}$$

$$\in (\mathbf{G} \cup \mathbf{S} \cup \mathbf{E})'$$

but $$z_i \in \mathbf{G} \cap \mathbf{S} \cap \mathbf{E}$$

If the entire urban system is accurately represented by the model constructed from the 75 variables (an improbable situation) then:

$$\mathbf{G} \cap \mathbf{S} \cap \mathbf{E} = \mathbf{G} \cup \mathbf{S} \cup \mathbf{E} = I$$

and $$z_i \in I$$

In this case the factors are measurements of the overall character of the community, and the desired goal of achieving urban research on a broad interdisciplinary front has been achieved.

The complete impact of such analytical procedures in geographical analyses is difficult to ascertain. Moving further away from the customary morphological approach, they achieve a greater degree of utility in their results. The theoretical usefulness of factor analytical methods rests in the usefulness of the whole

method and a case has been given to justify its merits on this account. Subsequent uses of a method do not, in general, advance the theoretical usefulness or understanding of the method itself, but help in isolating advantages and disadvantages in particular applications of the method. With respect to practical usefulness it is beyond doubt that factor analysis is a progressive technique. It gives to the city planner and urban analyst a method that, once understood, is flexible and objective in its application. By its use, the research worker is able to reduce the complexity of urban interactions to more basic and meaningful patterns. From this platform he can extend the analysis in a more rigorous deductive fashion, or break away and use the results to furnish the starting point of a predictive model for the urban system. The whole field of statistical interpretation of human behaviour is new and exciting, and this example of its application to the human environment of a city is but one of its possible outlets.

APPENDIX A

POPULATION OF CENSUS TRACTS[1]

Tract		Tract		Tract		Tract	
1	6972	23	2145	45	3819	67	11660
2	4291	24	4215	46	3967	68	5365
3	7399	25	13147	47	4505	69	6387
4	3495	26	4496	48	11485	70	8206
5	8904	27	8495	49	4415	71	682
6	9200	28	3154	50	7812	72	4894
7	6466	29	4117	51	4524	73	10969
8	3262	30	4242	52	5272	74	4214
9	4218	31	3651	53	4860	75	1327
10	5796	32	8308	54	9143	76	1039
11	1688	33	5981	55	125	77	1434
12	3857	34	4613	56	4489	78	8349
13	5364	35	8664	57	491	79	2371
14	3216	36	1576	58	1627	80	6832
15	4788	37	4447	59	4369	81	13952
16	6088	38	5669	60	3688	82	4381
17	4714	39	5863	61	2710	83	4338
18	1554	40	7651	62	2826	84	4046
19	5927	41	8189	63	2545	85	4537
20	3925	42	4459	64	5019	86	8275
21	7490	43	7595	65	6980	87	10717
22	4576	44	7786	66	3893		

[1]For location of Census Tracts see MAP 1, page 57.

APPENDIX B

THE DIAGNOSTIC VARIABLES

Population size and structure

1 Population
2 Percentage change of population, 1956-1961
3 Percentage born in Canada
4 Percentage aged 65 or over
5 Percentage aged 15 or under
6 Percentage of dependents
7 Percentage number of males
8 Index of aging
9 Percentage single over 15
10 Percentage immigrated since 1946
11 Number of families

Population mobility

12 Percentage non movers
13 Percentage moved from central city
14 Percentage moved from fringe area
15 Percentage from outside the metropolitan area but the same province
16 Percentage from outside the metropolitan area and a different province
17 Percentage from abroad

Ethnic composition

18 Percentage British
19 Percentage French
20 Percentage German
21 Percentage Italian

22 Percentage Netherlands
23 Percentage Polish
24 Percentage Russian
25 Percentage Scandinavian
26 Percentage Ukrainian
27 Percentage other European
28 Percentage Asiatic
29 Percentage others and not stated

Religion

30 Percentage Jewish

Fertility

31 Fertility of 15 - 24 age group
32 Fertility of 25 - 44 age group
33 Fertility ratio as defined by Shevky and Bell

Education

34 Percentage school dropouts
35 Percentage of population who attended university

Occupational structure

36 Number in male labour force
37 Number in female labour force
38 Occupation of males - percentage skilled
39 Occupation of males - percentage labourers
40 Occupation of males - percentage unemployed
41 Percentage of female labour force employed as wage earners
42 Percentage of male workers unskilled as defined by Shevky and Bell
43 Percentage of female workers unskilled as defined by Shevky and Bell

Income

44 Average income of head of household
45 Average family income
46 Wage and salary income of head of household
47 Wage and salary income per family

Household and housing

48 Number of households
49 Persons per household
50 Children per household
51 Percentage of households with lodgers
52 Percentage of detached dwellings
53 Rooms per dwelling
54 Persons per room
55 Percentage of crowded dwellings
56 Median value of property in dollars
57 Percentage tennant occupied
58 Average contract rent in dollars
59 Percentage occupied for more than 10 years
60 Percentage constructed since 1945
61 Percentage of apartments
62 Population density

Social structure

63 Number of households with automobiles
64 Number of households with televisions
65 Degree of social disorder

Retail stores

66 Total number of stores
67 Number of food stores
68 Number of general merchandise stores

69 Number of automobile group stores
70 Number of apparel and accessories stores
71 Number of hardware and home furnishing stores
72 Number of other retail stores

Physical morphology

73 Accessibility
74 Land use
75 Potential strength of boundary

APPENDIX B (SUPPLEMENT)

COMPILATION OF DATA FOR VARIABLES

Unless listed below, the data for each variable is derived from the same heading in the Census. Numbers are changed to percentages within the computer. Those tracts in which estimates had to be made are listed against the appropriate tract number for each variable.

6 Number 65 and over plus number 15 and under as a percentage of the total population.

8 Number over 65 divided by number under 15 x 100.

12-17 Estimates for tract 55.

31 and 32 Estimates for tracts 18, 55, 57, 71, and 76.

33 Shevky and Bell Fertility ratio. See page 62.

34 School dropouts. See page 61, Education Ratio.

38 Managerial + professional and technical + clerical as a percentage of the total male labour force.

39 Labourers as a percentage of the male labour force.

42 and 43 See page 60-61, Occupation Ratio.

44 and 45 20% sample. Estimates for 55, 57, 71, 76, and in the case of variable 45, 18 also.

52 Estimates for 18, 20, 36, 37, 55, and 76.

55 Estimates for 8, 11, 14, 18, 26, 29, 30, 31, 33, 36, 39, 42, 43, 45, 46, 47, 51, 55, 57, 58, 61, 64, 66, 71, 72, 75, 76, 77, 79, and 84. It is questionable whether this is a valid variable in the light of the large number of tracts which have to be estimated. The number of missing units accounted for by the above tracts is small, however, in relation to the whole metropolitan area.

56 Estimates for 18, 20, 36, 37, 55, 57, and 76.

57 Estimates for 28, 45, 55, 57, 58, 60, 61, 62, 63, 66, 69, 71, 72, 75, 77, and 85.

58 Estimates for 28, 45, 55, 57, 58, 60, 61, 62, 63, 66, 69, 71, 72, 75, 77, and 85. Median contract rent may be based on only a few of the dwellings in the Census Tract and, therefore, may be quite atypical of the rest of the dwellings in the tract.

59 Estimates for 38, 45, 55, 57, 58, 60, 61, 62, 63, 66, 69, 71, 72, 75, 77, and 85.

60 Estimates for 8, 10, 11, 12, 19, 20, 22, and 23.

61 Estimates for 2, 3, 4, 23, 28, 29, 45, 46, 55, 57, 58, 59, 60, 61, 62, 63, 64, 66, 69, 70, 71, 72, 75, 76, 77, 78, 82, 83, 84, and 85.

62 Population density. Number of persons per gross unit area, major enclosed areas of open space excluded[1].

63 Estimates for 55 and 71.

64 Estimates for 55.

65 Social disorder. Number of juvenile delinquents, liquor offences, and adult crimes per 1000 persons[2].

66-72 Estimates for 58, 59, and 75.

73 Accessibility. Distance by road from the centroid of the Census Tract to the junction of Portage and Main in the C.B.D.[3].

74 Land Use. Social sub areas were compared with a land use map. For the statistical analysis an artificial scale was devized. Three divisions were used as weightings: C.B.D. (2), Industrial (0), and Residential (10). These weights were multiplied by the percentage of each land use in the Census Tract[4].

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[1]Data calculated by planimetric measurements.

[2]Data from Socio-Economic study of Winnipeg by the Department of Welfare, 1967.

[3]Data from direct measurement.

[4]Data compiled from land use map in the Economic Atlas of Manitoba (Plate 36), Department of Industry and Commerce.

75 The potential of Census Tract boundaries to form physical boundaries was measured as follows:
(a) Each tract was isolated in turn and its adjacent tracts were ascribed a score:

10 if separated by a river
6 if separated by a railway line
3 if separated by a main road or open space
1 if separated by a minor road
(these scores are purely subjective).

The sum of these scores was found for each tract and divided by the number of tracts adjacent to the tract in question.
This raises the issue of weighting Census Tracts but as this variable was so imprecise, no mathematical adjustment, beyond that explained, was performed[5].

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[5]The problem of weighting values is well documented in A.H.Robinson, "The Necessity of Weighting Values in Correlation Analysis of Areal Data," A.A.A.G., XLVI (1956), pp. 233-236.

APPENDIX C

(i)

SCALED VALUES FOR SOCIAL RANK INDEX

Tract	Value	Tract	Value	Tract	Value	Tract	Value
1	66.48	23	88.23	45	0.0	67	49.68
2	58.79	24	46.41	46	5.27	68	63.26
3	76.49	25	59.13	47	16.87	69	54.90
4	75.03	26	59.24	48	11.14	70	67.71
5	79.32	27	67.84	49	57.12	71	95.59
6	67.66	28	46.99	50	51.08	72	15.88
7	63.46	29	35.52	51	32.41	73	34.89
8	38.64	30	27.02	52	50.44	74	40.22
9	66.03	31	41.85	53	68.26	75	83.29
10	83.92	32	56.37	54	64.83	76	18.66
11	85.44	33	38.89	55	92.60	77	49.14
12	92,15	34	49.68	56	68.51	78	57.22
13	55.32	35	40.66	57	100.0	79	28.24
14	63.22	36	60.99	58	3.92	80	28.68
15	71.32	37	31.31	59	71.64	81	20.63
16	73.97	38	39.45	60	61.09	82	55.41
17	58.78	39	33.41	61	48.67	83	48.67
18	87.38	40	49.02	62	49.31	84	14.30
19	82.86	41	61.95	63	42.56	85	33.98
20	63.71	42	33.12	64	10.84	86	82.16
21	71.07	43	11.07	65	39.13	87	34.87
22	85.64	44	22.95	66	33.63		

APPENDIX C

(ii)

SCALED VALUES FOR URBANIZATION INDEX

Tract	Value	Tract	Value	Tract	Value	Tract	Value
1	65.76	23	53.89	45	66.33	67	64.57
2	60.65	24	14.25	46	64.93	68	63.89
3	58.95	25	35.87	47	57.19	69	75.91
4	56.71	26	49.42	48	69.40	70	80.44
5	51.98	27	56.42	49	41.64	71	89.51
6	43.20	28	62.24	50	32.24	72	84.88
7	53.66	29	60.46	51	53.14	73	60.61
8	44.59	30	47.29	52	42.27	74	58.51
9	32.72	31	50.73	53	58.09	75	82.36
10	39.46	32	38.33	54	75.71	76	45.66
11	37.78	33	21.71	55	99.11	77	70.10
12	43.61	34	8.71	56	75.48	78	65.46
13	44.94	35	0.0	57	91.10	79	46.67
14	53.58	36	27.96	58	71.49	80	52.09
15	66.70	37	17.91	59	80.72	81	71.28
16	62.60	38	7.82	60	92.15	82	64.58
17	58.49	39	53.32	61	71.39	83	61.29
18	52.19	40	59.25	62	84.10	84	59.42
19	39.50	41	47.26	63	71.85	85	77.78
20	30.92	42	14.07	64	65.08	86	71.04
21	11.45	43	41.58	65	76.37	87	100.0
22	33.05	44	63.62	66	65.48		

APPENDIX C

(iii)

SCALED VALUES FOR SEGREGATION INDEX

Tract	Value	Tract	Value	Tract	Value	Tract	Value
1	21.89	23	24.87	45	44.23	67	8.70
2	49.32	24	6.07	46	41.83	68	14.77
3	53.22	25	14.14	47	39.73	69	9.28
4	64.42	26	22.74	48	33.94	70	48.22
5	46.85	27	5.83	49	100.0	71	53.10
6	56.90	28	18.52	50	86.13	72	46.03
7	50.18	29	23.39	51	21.02	73	41.13
8	38.25	30	18.00	52	36.99	74	15.63
9	49.23	31	20.45	53	37.71	75	25.69
10	51.49	32	11.72	54	5.30	76	30.28
11	59.34	33	2.75	55	36.94	77	22.96
12	74.38	34	1.78	56	22.17	78	32.30
13	35.75	35	2.92	57	26.88	79	47.86
14	16.88	36	18.06	58	23.06	80	45.73
15	10.44	37	18.96	59	0.0	81	36.15
16	10.61	38	10.30	60	18.12	82	23.22
17	10.86	39	27.83	61	28.31	83	23.53
18	37.70	40	21.77	62	25.47	84	38.03
19	30.94	41	5.59	63	12.44	85	12.08
20	6.40	42	9.14	64	42.40	86	11.63
21	0.75	43	26.13	65	16.44	87	14.74
22	25.51	44	14.70	66	9.19		

APPENDIX D

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10	11
1											
2	17										
3	05	27									
4	-13	-43	-64								
5	08	41	58	-89							
6	02	31	39	-60	89						
7	-23	03	-13	-13	24	30					
8	-12	-26	-42	82	-81	-63	-19				
9	-21	-36	-41	70	-82	-77	06	74			
10	06	-08	-85	29	-29	-24	06	16	25		
11	99	15	05	-15	10	02	-25	-16	-28	05	
12	-10	-44	06	08	-01	07	-08	-19	-28	-36	-01
13	13	-14	-61	48	-53	-47	-20	48	39	59	12
14	-03	49	59	-57	63	56	07	-42	-49	-43	-04
15	04	-01	01	10	-19	-24	-18	24	30	15	-01
16	12	19	32	-09	-05	-17	-06	03	19	-18	09
17	22	-08	-58	21	-32	-36	-07	17	32	78	18
18	03	-06	51	00	-05	-09	-29	07	-07	-56	05
19	-03	-05	26	-03	04	04	03	-02	21	-19	-09
20	13	10	-28	-17	09	-01	-12	-14	-14	51	15
21	12	-15	-41	26	-31	-29	05	13	29	51	09
22	-23	04	12	-29	37	37	10	-20	-22	03	-23
23	-04	-06	-58	06	02	09	24	-05	-05	54	-03
24	-05	-13	-39	28	-19	-06	03	13	07	34	-04
25	02	-08	25	-01	-04	-08	-16	07	-07	-24	03
26	-09	-01	-47	03	08	18	30	-06	-10	37	-08
27	12	25	-40	08	-11	-12	04	03	02	34	13
28	-08	-10	-36	37	-30	-18	53	30	42	21	-14
29	-11	-14	-16	08	-18	-25	39	12	44	22	-16
30	14	29	-23	-01	-04	-09	-07	-04	-10	17	17
31	-06	10	08	-30	44	48	22	-34	-37	01	-06
32	-04	09	40	-51	68	71	35	-59	-47	-29	-06
33	-02	42	30	-68	87	87	47	-63	-62	-05	-04
34	-16	-25	-44	13	03	17	37	06	11	42	-19
35	05	08	20	18	-27	-30	-38	17	10	-25	07

(Correct to 2 decimal places)

	1	2	3	4	5	6	7	8	9	10	11
36	96	14	-04	-06	-02	-09	-21	-06	-12	13	95
37	71	-06	-15	24	-36	-39	-47	27	25	21	67
38	13	17	41	-02	-07	-15	-46	00	-18	-47	17
39	-24	-21	-55	24	-12	02	54	14	35	50	-29
40	-22	-22	-55	51	-40	-20	46	44	55	36	-28
41	09	-29	-37	52	-73	-77	-20	57	74	33	04
42	-01	-09	-21	-07	18	26	16	-11	-13	27	-02
43	00	-09	-67	16	-04	08	38	02	03	65	-01
44	02	20	44	-19	12	03	-26	-17	-22	-41	04
45	02	13	37	-06	02	-03	-26	-08	-16	-41	05
46	07	21	51	-20	15	07	-26	-17	-30	-52	11
47	09	19	49	-13	07	00	-33	-11	-26	-52	13
48	97	10	-01	01	-07	-11	-32	05	-11	06	96
49	-07	25	33	-75	79	65	33	-77	-50	01	-07
50	-09	29	56	-81	90	79	45	-72	-53	-30	-10
51	00	-26	-69	59	-65	-56	-05	45	63	68	-05
52	-10	29	57	-50	58	54	15	-39	-59	-60	-05
53	-05	11	20	-23	19	11	-10	-41	-23	-08	-01
54	-01	11	08	-47	58	57	43	-37	-28	10	-04
55	-30	-04	06	-32	45	49	37	-26	-14	07	-32
56	03	26	37	-18	04	-11	-21	-10	-04	-30	02
57	-04	-29	-49	60	-68	-61	04	67	83	41	-12
58	09	16	40	-14	02	-10	-30	-08	-13	-38	13
59	-17	-22	-25	34	-23	-08	-07	01	02	02	-11
60	15	47	70	-74	66	45	11	-47	-53	-52	15
61	05	-26	-49	66	-74	-66	-22	74	74	41	-02
62	30	-25	-59	53	-69	-70	-38	47	51	57	29
63	00	29	72	-40	35	22	-19	-22	-36	-67	03
64	13	25	66	-61	52	33	-31	-55	-62	-51	20
65	-14	-19	-59	41	-39	-29	20	39	50	58	-20
66	27	-17	-43	48	-41	-26	15	39	43	30	21
67	56	-16	-42	22	-16	-06	00	07	08	40	54
68	09	-08	-25	32	-20	-04	28	26	27	10	05
69	27	-08	-30	36	-32	-21	13	36	39	26	20
70	05	-15	-32	47	-43	-30	15	43	47	17	00
71	22	-19	-44	41	-37	-26	22	28	38	34	16
72	08	-15	-34	51	-47	-33	14	47	51	18	02
73	-08	28	54	-63	74	70	10	-52	-65	-39	-06
74	28	09	-02	-15	14	11	-25	-34	-38	07	33
75	-14	-03	04	20	-12	-02	-05	16	10	-12	-15

(Correct to 2 decimal places)

	12	13	14	15	16	17	18	19	20	21	22
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13	-28										
14	-11	-83									
15	-49	18	-04								
16	-46	01	-02	21							
17	-46	51	-41	25	10						
18	17	-21	09	01	49	-27					
19	-10	-25	22	16	-11	-10	-31				
20	-17	24	-06	12	-21	32	-24	-33			
21	-22	36	-35	27	-10	59	-15	06	09		
22	-10	-23	32	32	-12	-26	-10	-05	21	-14	
23	01	35	-28	-14	-43	27	-76	-16	19	08	-04
24	01	28	-28	-17	02	23	-16	-22	09	14	-18
25	05	-04	-02	24	15	-04	66	-35	13	09	01
26	09	21	-18	-13	-46	05	-72	-19	14	-04	10
27	-11	23	-09	-30	-04	27	-45	-07	-07	01	-27
28	-15	18	-22	01	-10	09	-14	03	01	32	-15
29	-31	14	-26	10	34	34	03	-07	02	22	-11
30	-03	18	-06	-33	07	11	-26	-20	-07	-16	-21
31	-07	-12	21	-16	-07	-12	-17	-04	14	-11	15
32	17	-46	37	-31	-17	-26	-09	34	-08	-11	10
33	-23	-40	59	-07	-09	-22	-24	07	12	-14	48
34	-07	18	-16	17	-56	25	-61	19	22	33	24
35	08	02	-04	-20	48	-14	51	-18	-23	-23	-23

(Correct to 2 decimal places)

	12	13	14	15	16	17	18	19	20	21	22
36	-11	20	-11	03	13	28	03	-09	14	18	-28
37	-17	32	-24	29	05	35	02	04	17	27	-19
38	25	-17	16	-31	38	-32	66	-22	-21	-31	-22
39	-17	22	-23	07	-36	34	-66	18	02	33	01
40	-16	27	-27	06	-28	21	-41	16	-07	35	-08
41	-28	48	-51	36	09	52	-07	11	11	42	-43
42	03	00	05	15	-50	05	-49	16	21	11	29
43	-07	40	-32	01	-53	41	-76	-03	30	33	-04
44	11	-26	28	-19	38	-29	50	-19	-16	-30	-06
45	18	-22	21	-27	36	-30	51	-17	-21	-29	-12
46	21	-29	27	-31	40	-38	62	-21	-21	-35	-09
47	24	-26	23	-30	39	-37	64	-21	-20	-34	-14
48	-07	21	-11	07	11	22	08	-07	09	11	-26
49	-08	-39	39	-10	-02	-05	-19	06	23	-02	34
50	-09	-57	58	-17	06	-32	-09	18	-03	-29	40
51	-25	57	-58	38	-11	64	-27	01	22	66	-22
52	35	-56	51	-34	-03	-61	33	-19	02	-55	19
53	19	-22	12	-27	28	-10	28	-20	10	-09	-02
54	-19	-15	26	06	-36	-02	-48	26	18	03	33
55	-07	-20	25	03	-30	-08	-36	24	02	-03	44
56	-11	-22	30	-09	46	-16	42	-14	-10	-21	-07
57	-47	55	-50	35	17	50	-24	22	-19	39	-24
58	04	-14	12	-09	50	-21	56	-27	-09	-28	-04
59	57	-05	-22	-35	-32	-07	-04	-01	-03	05	-21
60	-11	-50	58	-15	30	-37	29	-12	-02	-40	17
61	-43	62	-47	42	09	47	-16	16	-09	39	-21
62	-13	60	-58	30	-06	66	-17	-04	18	52	-33
63	11	-52	50	-24	43	-51	62	-11	-16	-53	04
64	25	-36	32	-20	24	-36	37	-09	-09	-41	-03
65	-28	49	-45	10	-18	52	-39	06	11	53	-22
66	-20	38	-33	22	-09	31	-22	17	-07	31	-25
67	-01	32	-29	00	-26	38	-39	09	10	29	-26
68	-12	16	-14	12	-04	04	-13	14	-15	07	-16
69	-29	30	-25	34	-02	32	-15	20	-04	39	-22
70	-20	32	-26	23	00	18	-09	14	-12	18	-17
71	-11	33	-32	17	-14	31	-21	11	-03	41	-21
72	-22	34	-28	26	04	20	-07	14	-11	22	-18
73	06	-55	62	-15	07	-47	21	-19	-02	-40	46
74	25	-08	08	-26	00	-03	03	-28	14	-08	07
75	08	-15	08	-11	06	-13	32	-01	-04	-06	05

(Correct to 2 decimal places)

	23	24	25	26	27	28	29	30	31	32	33
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24	31										
25	-54	-15									
26	89	17	-47								
27	29	24	-49	19							
28	03	06	06	00	05						
29	02	05	10	-09	-11	28					
30	16	19	-38	10	94	-09	-17				
31	20	05	-12	23	-05	03	-08	-07			
32	01	-13	-10	02	-23	01	-09	-26	38		
33	15	-09	-13	20	-08	-01	-08	-09	49	62	
34	56	-02	-18	54	-12	27	10	-31	15	22	26
35	-46	20	09	-46	17	-15	-15	32	-20	-31	-40

(Correct to 2 decimal places)

	23	24	25	26	27	28	29	30	31	32	33
36	-02	-04	03	-08	17	-02	-08	18	-10	-14	-10
37	-07	-05	12	-14	01	-04	-01	-01	-24	-41	-39
38	-56	06	23	-54	06	-24	-26	24	-19	-16	-33
39	63	17	-43	58	12	32	27	-10	12	07	18
40	29	12	-26	29	15	61	13	-07	-01	-13	-05
41	05	09	08	-08	-02	24	39	-13	-31	-49	-68
42	40	06	-20	40	-03	03	-11	-14	20	20	30
43	77	29	-29	71	26	28	10	07	22	09	17
44	-44	03	14	-38	03	-20	-24	17	-03	02	-08
45	-45	05	12	-39	05	-15	-24	19	-04	-02	-17
46	-53	05	22	-45	-03	-24	-23	15	-02	05	-08
47	-54	04	23	-47	-04	-25	-26	15	-08	-02	-18
48	-05	-03	05	-11	12	-10	-12	16	-11	-18	-16
49	11	-11	-14	14	-10	-16	02	-09	32	58	74
50	-01	-24	-15	05	-15	-15	03	-10	39	70	85
51	23	24	00	10	07	40	24	-11	-23	-39	-43
52	-29	-22	25	-08	-20	-24	-27	-04	27	41	39
53	-24	10	01	-22	01	-19	-09	11	03	14	05
54	32	-14	-17	33	-06	08	03	-17	32	49	68
55	29	-16	-32	30	-12	00	-04	-20	19	35	61
56	-41	-07	11	-37	05	-13	-07	15	-07	-12	-11
57	20	17	-21	05	14	35	43	-03	-25	-46	-43
58	-53	-09	27	-46	06	-23	00	25	-22	-18	-22
59	07	14	03	11	03	-01	-07	03	-02	14	-28
60	-29	-24	17	-17	-09	-21	-07	04	14	30	44
61	12	12	-12	-03	16	29	20	03	-32	-56	-53
62	20	14	-01	06	18	08	10	06	-29	-56	-63
63	-61	-13	30	-49	-15	-34	-17	06	-07	12	11
64	-26	-22	09	-23	-04	-59	-26	16	01	20	19
65	37	17	-12	27	11	55	27	-09	05	-08	-15
66	16	-01	-06	09	08	54	18	-06	-01	-11	-19
67	40	06	-19	32	17	16	03	07	08	05	-07
68	12	-04	-06	04	05	56	14	-03	-01	06	-01
69	04	-02	10	-02	-02	55	15	-17	-13	-09	-10
70	02	-02	-01	-01	04	48	17	-07	00	-17	-22
71	16	02	-03	10	04	57	22	-13	01	-09	-15
72	00	-05	-01	-06	04	53	19	-07	-04	-21	-26
73	-14	-23	10	01	-18	-33	-31	-02	35	38	66
74	10	20	-16	05	20	-32	-22	29	09	-01	01
75	-31	00	15	-28	-26	-01	12	-25	-11	-02	-11

(Correct to 2 decimal places)

	34	35	36	37	38	39	40	41	42	43	44
35	-86										
36	-14	06									
37	-07	06	71								
38	-86	86	13	03							
39	72	-54	-21	-13	-77						
40	54	-31	-17	-03	-51	70					
41	14	-09	15	52	-22	18	27				
42	52	-51	-20	-03	-56	43	28	-05			
43	71	-59	03	-06	-71	72	46	15	48		
44	-72	78	01	-13	82	-56	-45	-36	-43	-59	
45	-73	83	02	-11	86	-56	-40	-33	-46	-58	97
46	-80	81	06	-13	92	-67	-52	-43	-50	-66	93
47	-81	84	08	-07	95	-70	-53	-36	-51	-68	92
48	-17	10	95	76	16	-26	-19	17	-05	-02	-01
49	12	-27	-13	-32	-24	14	-20	-48	21	05	06
50	07	-27	-18	-44	-18	06	-21	-64	15	-09	06
51	34	-14	07	37	-37	46	50	69	14	42	-36
52	-26	08	-16	-44	31	-41	-38	-63	-08	-31	34
53	-53	57	-05	-17	53	-31	-39	-33	-28	-37	71
54	63	-76	-09	-20	-70	44	25	-24	54	43	-53
55	50	-49	-34	-34	-55	56	34	-39	43	21	-31
56	-70	73	03	-02	73	-47	-37	-20	-45	-58	90
57	27	-07	02	30	-35	49	56	70	01	24	-39
58	-74	71	08	03	75	-65	-54	-19	-45	-65	80
59	10	-01	-13	-07	00	-03	-01	06	-02	15	-13
60	-38	10	08	-21	35	-51	-49	-45	-18	-44	39
61	20	00	11	44	-20	29	49	71	-01	17	-32
62	16	-03	39	64	-16	17	22	70	01	28	-30
63	-69	54	-04	-19	72	-73	-61	-43	-42	-78	65
64	-48	23	08	-13	43	-54	-75	-41	-22	-49	40
65	47	-27	-09	06	-47	60	63	45	21	55	-45
66	35	-21	32	32	-35	39	52	40	10	40	-36
67	33	-26	57	49	-36	34	19	23	19	54	-34
68	22	-18	07	01	-26	30	37	16	17	25	-24
69	31	-18	29	33	-31	34	44	38	12	32	-28
70	24	-13	10	15	-23	29	52	35	02	23	-27
71	38	-26	28	28	-36	37	49	36	11	42	-36
72	24	-10	14	20	-23	29	54	39	00	22	-27
73	-15	01	-16	-36	15	-27	-37	-74	05	-34	32
74	-26	26	27	14	35	-38	-39	-23	-10	-06	28
75	-08	13	-16	-07	23	-17	-05	04	-15	-24	08

(Correct to 2 decimal places)

	45	46	47	48	49	50	51	52	53	54	55
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46	95										
47	94	99									
48	02	06	10								
49	-07	00	-08	-26							
50	-03	08	-02	-24	84						
51	-36	-49	-45	01	-20	-57					
52	31	45	42	-17	32	48	-71				
53	67	66	64	-14	46	20	-06	26			
54	-62	-57	-63	-12	54	61	-12	12	-41		
55	-38	-37	-43	-36	56	61	-11	05	-13	71	
56	88	82	81	01	05	04	-24	17	64	-52	-29
57	-33	-46	-44	06	-48	-46	61	-80	-47	-08	00
58	80	79	80	10	-04	-02	-33	26	56	-54	-42
59	-04	-06	-03	-13	-18	-26	10	08	12	-24	-30
60	31	45	41	05	41	60	-68	60	15	19	-01
61	-25	-40	-35	18	-64	-63	60	-82	-52	-18	-14
62	-27	-36	-29	40	-49	-74	72	-69	-23	-28	-29
63	63	75	75	-01	10	29	-69	58	40	-30	-24
64	33	47	47	07	39	39	-59	49	44	-06	-01
65	-41	-51	-51	-13	-12	-27	68	-52	-28	16	12
66	-29	-40	-40	32	-44	-35	41	-42	-49	07	-08
67	-30	-38	-37	58	-16	-21	30	-41	-28	14	-03
68	-19	-26	-27	07	-22	-11	25	-17	-29	11	00
69	-24	-33	-33	26	-24	-27	52	-40	-30	08	-09
70	-21	-30	-30	13	-49	-34	30	-28	-48	02	-07
71	-31	-40	-41	26	-36	-33	43	-42	-42	09	-04
72	-19	-30	-29	15	-52	-37	36	-33	-48	-02	-11
73	24	34	27	-16	53	68	-66	61	25	25	36
74	28	31	31	25	10	-01	-17	07	37	-26	-26
75	10	13	16	-13	-12	-12	02	06	11	-26	-23

(Correct to 2 decimal places)

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58	80	-28									
59	-28	-16	-12								
60	41	-54	41	-42							
61	-16	91	-22	-17	-54						
62	-22	57	-21	12	-64	66					
63	59	-53	68	-13	69	-48	-54				
64	28	-61	44	-04	50	-61	-38	60			
65	-33	59	-48	07	-49	52	42	-70	-66		
66	-31	55	-40	01	-47	57	42	-61	-61	50	
67	-36	28	-37	17	-45	29	51	-57	-31	35	67
68	-22	31	-27	-04	-23	29	02	-36	-38	35	71
69	-21	46	-31	-09	-30	45	32	-47	-46	45	73
70	-22	53	-31	-02	-39	55	29	-47	-59	42	91
71	-29	48	-41	07	-46	47	48	-59	-59	48	87
72	-21	56	-29	-04	-39	59	31	-48	-58	42	91
73	27	-64	23	-25	63	-63	-68	54	48	-49	-50
74	17	-37	24	20	10	-27	09	19	28	-40	-29
75	05	-05	08	13	03	-04	-18	20	-05	-07	-16

(Correct to 2 decimal places)

	67	68	69	70	71	72	73	74	75
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68	35								
69	41	63							
70	39	61	53						
71	59	48	58	80					
72	36	71	65	94	77				
73	-36	-26	-43	-41	-46	-45			
74	07	-32	-31	-38	-19	-35	15		
75	-30	-03	-05	-11	-19	-08	-05	02	

(Correct to 2 decimal places)

APPENDIX E

FORTRAN IV PROGRAM FOR FACTOR ANALYSIS

```
    DIMENSION X(87,75),XBAR(75),S(75),V(5625),R(3000),
   1B(75),TV(75),D(75),T(75)
    CALL CORRE(87,75,0,X,XBAR,S,V,R,D,B,T)
    WRITE(3,2)(XBAR(J),J=1,75)
  2 FORMAT(6HOMEANS/(8F15.5))
    WRITE(3,3)(S(J),J=1,75)
  3 FORMAT(20HOSTANDARD DEVIATIONS/(8F15.5))
    DO 120 I=1,75
    DO 110 J=1,75
    IF(I-J)102,104,104
102 L=I+(J*J-J)/2
    GO TO 110
104 L=J+(I*I-I)/2
110 D(J)=R(L)
120 WRITE(3,5)I,(D(J),J=1,75)
  5 FORMAT(4HOROWI3/(10F12.5))
    CON=1.0 (This is the lowest value of eigenvalue
             required in the extraction of roots)
    MV=0
    CALL EIGEN(R,V,75,MV)
    CALL TRACE(75,R,CON,K,D)
    DO 130 I=1,K
    L=I+(I*I-I)/2
130 S(I)=R(L)
    WRITE(3,6)(S(J),J=1,K)
  6 FORMAT(1HO/12H EIGENVALUES/(10F12.5))
    WRITE(3,7)(D(J),J=1,K)
  7 FORMAT(37HOCUMULATIVE PERCENTAGE OF EIGENVALUE/
                                (10F12.5))
    WRITE(3,8)
  8 FORMAT(1HO/13H EIGENVECTORS)
    L=0
    DO 150 J=1,K
    DO 140 I=1,75
    L=L+1
140 D(I)=V(L)
150 WRITE(3,9)J,(D(I),I=1,75)
  9 FORMAT(7HOVECTORI3/(10F12.5))
    CALL LOAD(75,K,R,V)
    WRITE(3,10)K
 10 FORMAT(1HO/16H FACTOR MATRIX (,I3,9H FACTORS))
    DO 180 I=1,75
    DO 170 J=1,K
    L=75. *(J-1)+I
```

```
170 D(J)=V(L)
180 WRITE(3,11)I,(D(J),J=1,K)
 11 FØRMAT(9HOVARIABLEI3/(10F12.5))
    IF(K-1)185,185,188
185 WRITE(3,19)K
 19 FØRMAT(5HOONLY,I2,30H FACTOR RETAINED NO ROTATION    )
    GO TO 100
188 CALL VARMX(75,K,V,NC,TV,B,T,D)
    NV=NC+1
    WRITE(3,12)
 12 FØRMAT(1HO/10H ITERATION,7X,9HVARIANCES/8H CYCLE   )
    DO 190 I=1,NV
    NC=I-1
190 WRITE(3,13)NC,TV(I)
 13 FØRMAT(I6,F20.6)
    WRITE(3,14)K
 14 FØRMAT(1HO/24H ROTATED FACTOR MATRIX (I3,9H FACTORS))
    DO 220 I=1,75
    DO 310 J=1,K
    L=75. *(J-1)+I
310 S(J)=V(L)
220 WRITE(3,15)I,(S(J),J=1,K)
 15 FØRMAT(9HOVARIABLEI3/(10F12.5))
    WRITE(3,16)
 16 FØRMAT(1HO,/23H CHECK ON COMMUNALITIES//9H VARIABLE,
                                7X,8HORIGINAL
   1,12X,5HFINAL,10X,10HDIFFERENCE)
    DO 230 I=1,75
230 WRITE(3,17)I,B(I),T(I),D(I)
 17 FØRMAT(I6,3F18.5)
100 CALL EXIT
    END
```

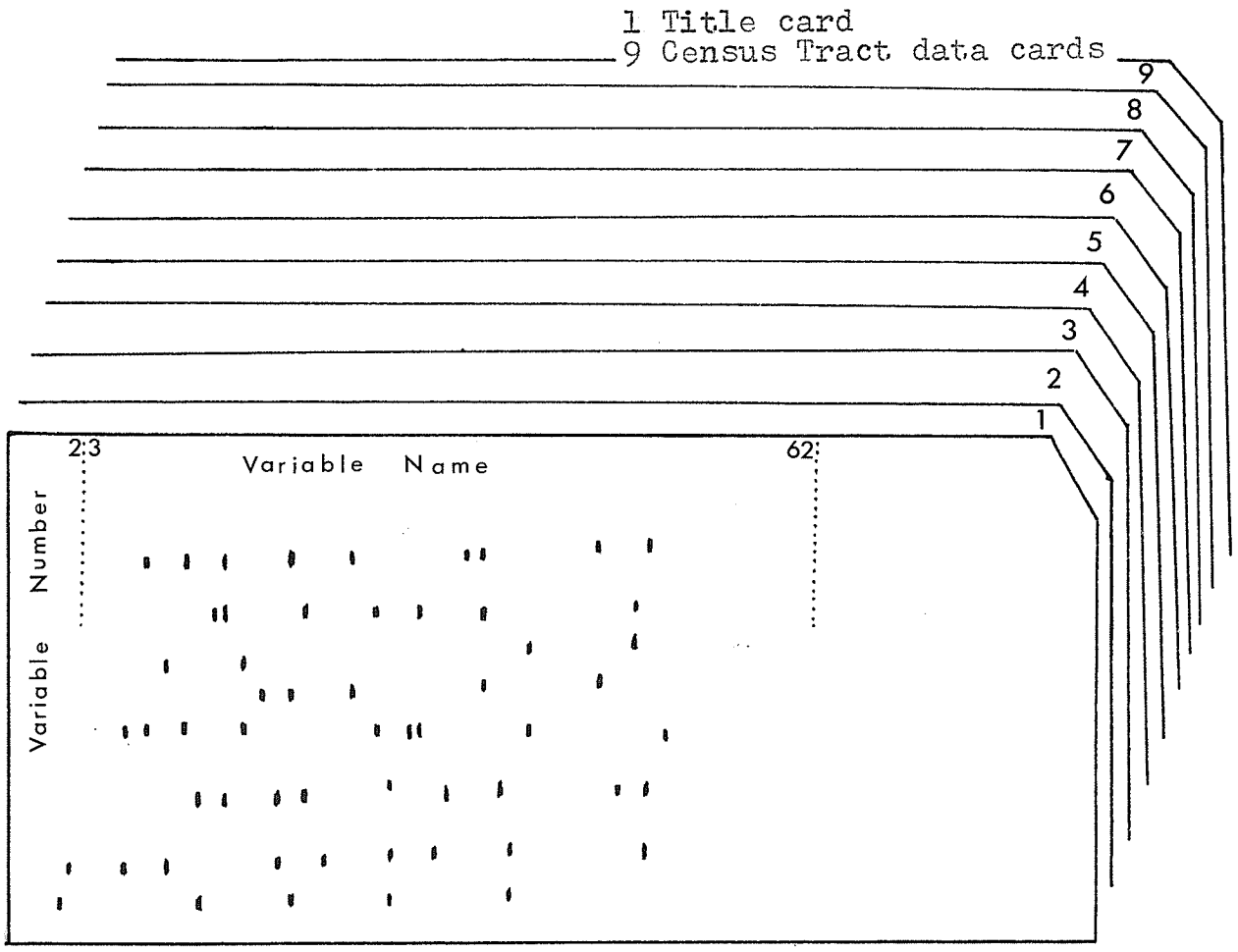
CORRE calls upon the Subroutine DATA in order to perform the correlation. The data matrix must be read into store X. The following program was used

---

```
    SUBROUTINE DATA
    DO 200 K=1,75
    READ(1,202)N,(T(I),I=1,15)
202 FØRMAT(I2,15A4)
    WRITE(3,203)N,(T(I),I=1,15)
203 FØRMAT(1HO,'VARIABLE',I3,5X,15A4)
    READ(1,204)(X(J,K),J=1,87)
204 FØRMAT(10F8.0)
200 WRITE(3,205)(X(J,K)J=1,87)
205 FØRMAT(' ',10F10.2)
    RETURN
    END
```

LAYOUT OF DATA CARDS

10 cards for each Variable:



Data for10 Census Tracts on each card
Arranged in blocks of eight columns.

APPENDIX F

FACTOR MATRIX

x_i	z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	z_9
1	-026	214	856	377	062	070	-028	-061	006
2	344	-117	265	142	062	-422	158	190	096
3	781	-033	-106	469	-113	088	144	-191	008
4	-649	500	-287	-178	181	205	003	094	-107
5	641	-680	238	161	001	-108	-056	-017	019
6	497	-713	140	111	182	013	-097	063	-072
7	-129	-544	-269	096	360	-270	-230	-062	322
8	-565	510	-336	040	007	057	226	253	-008
9	-661	423	-433	075	-073	-168	090	-166	018
10	-666	-109	294	-357	-169	-341	-227	125	-093
11	027	218	879	299	061	129	-034	-037	027
12	246	021	-060	-377	287	737	-109	-141	-022
13	-630	289	196	-209	-091	-170	-043	231	080
14	608	-337	-029	294	043	-089	188	029	-207
15	-306	067	-066	421	-533	-131	082	200	-288
16	262	452	-064	304	-136	-501	-027	-084	259
17	-585	121	322	-098	-294	-371	-228	-127	060
18	500	555	-235	315	-123	189	-271	095	118
19	-122	-183	-175	341	033	077	363	-621	-301
20	-112	-166	332	-179	-372	-073	-360	374	-049
21	-544	047	115	040	-219	-130	-393	-237	-143
22	207	-429	-150	046	-309	-043	045	406	-363
23	-458	-473	271	-481	127	-077	112	080	061
24	-188	108	068	-462	139	-163	-172	046	048
25	184	283	-140	336	-304	269	-476	320	153
26	-331	-521	184	-452	165	014	137	198	026
27	-155	084	332	-404	387	-403	384	-047	162
28	-474	-020	-259	243	403	-185	-351	061	076
29	-295	032	-224	155	-181	-316	-286	-198	520
30	061	176	355	-408	360	-344	404	048	216
31	139	-449	086	-007	208	-081	-203	153	-044
32	346	-601	-015	177	246	119	-264	-367	-042
33	354	-803	115	197	069	-265	-098	099	-066
34	-606	-655	-054	003	-088	177	-060	049	-073
35	410	759	-059	-169	215	-224	000	-024	-153
36	-097	282	836	331	074	037	-054	-053	066
37	-331	432	568	275	-252	139	065	-052	-144
38	632	705	015	-081	187	-007	-017	025	-064

(Correct to 3 decimal places)

x_i	z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	z_9
39	-665	-518	-157	-136	115	-196	-007	-153	-075
40	-694	-196	-317	026	274	-130	021	028	-114
41	-682	429	-042	091	-327	023	016	-174	189
42	-277	-564	089	-056	-077	145	058	100	-294
43	-650	-503	236	-281	160	-017	-138	093	046
44	678	482	-036	-082	221	-261	-132	-002	-293
45	622	555	-060	-106	314	-196	-129	-008	-277
46	756	511	-020	-046	250	-132	-140	011	-151
47	726	582	-012	-065	220	-070	-112	009	-148
48	-098	331	811	352	053	142	057	011	013
49	418	-661	125	-046	-192	-315	-278	-269	-078
50	543	-709	-011	215	019	-245	-036	-187	042
51	-785	203	-015	-131	-225	-141	-287	-111	-175
52	736	-239	-094	061	206	233	-100	248	171
53	556	225	038	-355	031	-265	-438	-260	-245
54	-114	-865	090	253	-083	-038	087	-004	048
55	-031	-751	-188	042	-083	-146	151	-086	-263
56	560	505	-052	003	108	-448	-077	-016	-262
57	-787	263	-197	135	-080	-280	231	-137	031
58	614	580	011	-028	-005	-232	-052	047	-012
59	-097	065	-065	-420	208	565	-231	-221	106
60	739	-149	105	299	-040	-216	067	136	268
61	-761	401	-089	141	-110	-166	295	044	-109
62	-694	431	328	-120	-248	076	007	-078	-099
63	863	281	-107	118	-038	-022	088	045	137
64	760	012	236	-048	-168	108	133	-187	150
65	-743	-097	-137	-053	068	-217	-232	-073	-021
66	-717	085	098	440	441	033	-067	072	-070
67	-541	-062	584	120	274	165	-085	-145	-095
68	-433	-045	-097	397	493	-023	-075	086	005
69	-586	079	063	467	202	-073	-190	-019	-119
70	-602	133	-140	436	426	006	013	196	-033
71	-680	036	095	347	361	058	-179	030	-061
72	-626	179	-137	466	414	-017	-003	179	-042
73	720	-402	007	082	-013	-078	025	258	-116
74	309	134	485	-394	027	081	-084	004	-103
75	120	185	-316	002	-119	175	-196	008	075

(Correct to 3 decimal places)

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