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Spatial Equity in the Urban Environment: Assessing Neighbourhood Accessibility to Public Amenities

by

Jared Neil Hewko ©

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*This work is dedicated to Jennifer Tan.*

# Abstract

Neighbourhood spatial accessibility (NSA) refers to the ease with which neighbourhood residents can reach amenities, as well as the quality, quantity and types of activities offered by those amenities. Assessing spatial equity involves comparing NSA with neighbourhood indicators of need for amenities. This thesis, by drawing on public recreational amenity provision in Edmonton, Canada, investigates two shortcomings of existing spatial equity research: the effect of aggregation error on NSA measurement, and the role that amenity quality plays in spatial equity assessments. The analysis demonstrates that aggregation error does adversely affect NSA measures, with the greatest effect occurring when NSA is measured to amenities that have highly localized service areas, and are abundantly located within cities, such as playgrounds. Amenity quality also affects NSA indicators and spatial equity assessments. When differences in playground quality are not accounted for, playgrounds in Edmonton are equitably distributed; however, once quality is considered, playground provision is less equitable.

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Well, two degrees down, and one to go. Zamboni® driving school here I come!!

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# List of Abbreviations

| | |
|---|---|
| **EA** | Enumeration Area |
| **EFCL** | Edmonton Federation of Community Leagues |
| **ESDA** | Exploratory Spatial Data Analysis |
| **GIS** | Geographic Information Systems |
| **LA** | Location-Allocation |
| **LISA** | Local Indicators of Spatial Association |
| **NPDP** | Neighbourhood Park Development Program |
| **NSA** | Neighbourhood Spatial Accessibility |
| **PCPC** | Postal Code Population Counts |
| **PWMC** | Population Weighted Mean Centre |
| **WAPCD** | Weighted Average Postal Code Distance |

# CHAPTER 1

# Introduction

## 1.1 Introduction

The spatial distribution of public amenities and services within the urban environment has been a central focus of much urban and social geographical research. Of primary concern have been issues related to accessibility - the ease with which amenities can be reached, as well as the quality, quantity, and type of activities offered by those amenities (Handy and Niemeier, 1997). "At the very least, the 'quality of life' in a city or region refers to the accessibility of its inhabitants to employment alternatives, educational and medical facilities, essential public social services, and 'nature' or extensive recreational open spaces" (Pred, 1977, p. 10). As accessibility plays a significant role in quality of life, it is imperative to ask whether or not accessibility varies spatially within cities, and whether or not such variation is equitable.

The preceding question has received considerable attention in past research (Knox, 1978; Ottensman, 1994; Pacione, 1989; Truelove; 1993; Talen, 1997, 1998; Talen and Anselin, 1998). Central to all investigations of this type is the notion of equity. Equity is a complex concept, in so far as it can be variously defined and operationalized within geographical research (Hay, 1995). My research focuses on spatial equity, as approached through a needs-based perspective (Lucy, 1981). From this perspective, a distribution of amenities is deemed equitable if it reflects differential need, often measured in terms of socioeconomic characteristics of the underlying population. Approaching spatial equity in this manner typically involves examining associations between accessibility (measured for aggregated units, such as neighbourhoods) and corresponding population characteristics (Ottensmann, 1994; Pacione, 1989; Talen, 1997; 1998; Talen and Anselin, 1998; Truelove, 1993).

This study has two central foci, corresponding to the two papers presented in subsequent chapters. The first paper is a methodological investigation into the potential effects of aggregation error on the measurement of neighbourhood spatial accessibility (NSA). Spatial accessibility measures are based on the distances between aggregated populations (e.g., neighbourhoods) and a particular type of amenity. To facilitate distance measurements, aggregated units are typically represented by a single point. Aggregation error refers to the error in distance measurements that results from the representation of an aggregated unit by a single point (Hodgson et al., 1997). Because spatial equity analyses rely heavily on accessibility measures, it is crucial that problems related to aggregation error be explored. This examination aims to illuminate the problem of aggregation error with respect to measuring accessibility, and hence suggest strategies for reducing such error when calculating NSA measures.

The second paper is on spatial equity and public playground location and quality in Edmonton, Alberta, Canada. While incorporating the methods suggested in the first paper for improving NSA measures, I use various techniques to investigate associations between NSA and neighbourhood socioeconomic conditions. The majority of existing spatial equity research regarding recreational amenities is based on experiences in U.S. and European cities. My analysis of playgrounds in Edmonton allows for spatial equity to be examined within a Canadian urban context. Further, it provides the opportunity for amenity quality to be investigated in relation to spatial equity.

Both analyses are approached through a spatial analytical perspective, and rely heavily on the use of Geographic Information Systems (GIS) and exploratory spatial data analysis (ESDA) (Anselin, 1995) techniques (see Appendix A for a review of ESDA methods). The remainder of this chapter will provide a brief overview of the concepts of spatial accessibility and spatial equity, while drawing reference to relevant literature. I will briefly introduce the two papers contained in this thesis, and outline the objectives of the research.

## 1.2 Spatial Accessibility to Urban Amenities

### *1.2.1 Relevance in Geographic Research*

Accessibility to urban amenities, such as parks, playgrounds, schools, and medical facilities, is important for numerous reasons, as demonstrated by the large amount of interest it has received within geographic research. Several researchers have postulated that access to amenities has implications for quality of life within cities (e.g., Pred, 1977; Knox, 1980). This postulation is consistent with the broader realization that individuals' well being is affected by characteristics of the social, cultural, physical, and built environment. The effects of the environment on one aspect of quality of life – health - have been examined extensively within the realm of health and place, or the geography of health and health care research (for a review of this research see Curtis and Jones, 1998). Individuals' health has been investigated in relation to the characteristics of the areas in which they live (e.g., neighbourhoods) (Duncan et al., 1993; Congdon, 1994; Duncan and Jones, 1995; Ecob, 1996). One neighbourhood characteristic, accessibility to urban amenities, has been identified as a factor that influences the health status of neighbourhood residents (Macintyre et al., 1993).

Macintyre et al. (1993) found that, for different areas in Scotland, a lack of amenities, or 'healthy environments' was associated with poorer health outcomes. In another study, Macintyre and Ellaway (1998) found that, independent of individual characteristics (e.g., income level), residents of areas that lacked health-promoting amenities had poorer health behaviour than individuals who resided in neighbourhoods with accessible amenities. The basic tenet of these types of studies is that access to urban amenities can have consequences for the health of individuals.

In addition to individual well-being, accessibility to amenities affects community well-being. Neighbourhood-based amenities, such as parks and playgrounds, provide spaces in which neighbourhood residents can meet and interact. This interaction helps to build community cohesion within a neighbourhood. Areas with greater levels of community cohesion often have lower levels of other social problems, such as crime and deviance (Bottoms and Wiles, 1992). Further, areas that are highly accessible to amenities may increase a neighbourhood's desirability, thereby influencing the in-migration of families (Jones et al., 1980). This may help prevent problems related to urban desertification, whereby neighbourhoods severely lacking basic amenities and services (e.g., police and fire protection) encourage the out-migration of existing families (except for those families who, often due to financial constraints, are unable to move to different neighbourhoods), and discourages the in-migration of new families. Areas of urban desertification tend to attract transient populations, and are typically plagued by various social problems, such as violence and substance abuse (Wallace, 1990).

Access to urban amenities has implications for individuals' health, community well being, and various other urban problems and processes. It is not surprising, then, that social and urban geographers have been perpetually interested in assessing whether the distribution of public amenities within cities is equitable. The following section provides an overview of the concept of equity when applied to urban amenity provision, and highlights some of the literature that is most relevant to my research.

## 1.3 Spatial Equity

### *1.3.1 Impact on Existing Social Inequalities*

Accessibility to amenities affects various facets of quality of life within the urban environment. Social and urban geographers, within the realm of social justice (Harvey, 1973; Smith, 1994), territorial justice (Boyne and Powell, 1991), and spatial equity (Truelove, 1993; Talen 1997, 1998) research have given great attention to the distribution of amenities and services within cities. The main concern has been assessing whether public amenities are located equitably, or fairly, within cities. Amenities are necessarily located as discrete entities, whereas the populations who they serve are spatially continuous, thereby inevitably resulting in differential accessibility within cities (Dear, 1974). In other words, regardless of where amenities are located, there will always be some persons who are closer to them than others. As noted by Knox, "The crucial question to ask of planned or established facility location patterns is, therefore, *how much* inequality is produced, and *which groups* are most disadvantaged?" (1978:414).

Differential accessibility to urban amenities can act to increase, or decrease existing social inequalities within society (Harvey, 1973). For instance, if poor people, in terms of socioeconomic status, live in areas with poor access to recreational amenities, then the additional burdens (e.g., extra travel costs to reach distant facilities and fewer opportunities to promote health) incurred by not having access to amenities acts to increase existing differences in quality of life between society's 'haves' and 'have-nots'. Spatial equity researchers argue that it is unjust, unfair, or inequitable when such burdens are placed disproportionately on society's poor, or when society's *socially* disadvantaged are also *spatially* disadvantaged. In order to make such an argument, it is necessary to first establish a clear understanding of what is, with respect to amenities, a spatially equitable distribution.

*1.3.2 Conceptual Approaches*

Spatial equity has been variously defined and measured within geographic research [see Truelove (1993) for a review]. Lucy (1981) suggested five conceptions of equity (*equality*, *need*, *demand*, *preferences*, and *willingness to pay*), all of which are relevant for assessing the spatial distribution of urban amenities and services, and will therefore be briefly reviewed. Equity as *equality* implies that resources be distributed equally throughout the population, without regard for the underlying characteristics of the population. Playgrounds, for example, would be equitably distributed if each neighbourhood had precisely the same number of playgrounds. When approached from a *needs-based* perspective, amenities are equitably distributed if the distribution corresponds to underlying population need, which can be represented by socioeconomic indicators. Needs-based equity requires the "unequal treatment of unequals" (Lucy, 1981: 449). From this perspective, equity exists if poorer (as indicated by median income, for example) neighbourhoods have greater access to playgrounds than wealthier neighbourhoods. Needs-based equity is similar to the notion of territorial justice, which requires that service provision is proportional to service need (Davies, 1968).

Equity as *demand* implies that amenity distribution echoes citizens' demand or requests for amenities. In other words, "squeaky wheels" are rewarded with better access to goods and services (Talen, 1998). From this perspective, playgrounds would be equitably distributed if neighbourhoods that have been the 'loudest' or most active in lobbying amenity providers have the greatest access to playgrounds. Somewhat related to demand, is *preference*-based equity. While most demands are based on preferences, not *all* preferences are expressed through demands. Organized groups (e.g., lobby groups) usually orchestrate demands; these demands may not always capture the preferences of the general population. One method of dealing with this is through surveying individuals about their preferences for amenity provision. Goods are equitably distributed if they correspond to the expressed underlying preferences of the citizens. Finally, *willingness to pay* is another basis for evaluating equity. In this case, amenity distribution should correspond to the distribution of those individuals who are willing to pay for their use.

I approach spatial equity through a needs-based perspective. This perspective, which has been adopted by various other researchers, involves examining associations between accessibility and population need (typically represented by census indicators) (Talen, 1997, 1998; Truelove, 1993). The needs-based approach, in comparison to other conceptualizations of equity, is particularly relevant for assessing the distribution of public, no-cost recreational amenities, such as playgrounds. The equality approach ignores differential need in population. For instance, people vary in the amount of private play space (e.g., back yards) available to them, the amount of money that they have available to participate in private leisure activities (e.g., organized sports), and means to overcome distance barriers (Lucy, 1981). All of these factors should be considered when locating public recreational facilities; however, an equality approach fails to do so.

Demand-based equity criteria are also problematic, as demands may primarily reflect the desires of organized groups, and may not be completely representative of the underlying population. Further, wealthy and highly educated citizens are more likely to participate in such groups (Verba and Nie, 1972); this could result in an over-provision of public amenities in the areas where these types of people live. Distributing amenities based on preferences may circumvent problems related to demand approaches; however, it is often costly to interview or survey large portions of the population. Talen (1998) notes that the planning agencies responsible for public recreational amenities often do not have the means necessary to collect data on individuals' preferences. Finally, willingness to pay criterion for determining amenity provision is not applicable to the case of public, no-cost recreational facilities like playgrounds.

Another reason why spatial equity of public recreational amenities should be assessed from a needs-based perspective relates to the purpose of urban planners, or other agencies involved in the distribution of public goods and services. The role of planners is to offset inequalities created by unregulated free market economies (Banerjee, 1993; Talen, 1998). Further, Smith (1994) notes that policies should be evaluated based on how successful they are at decreasing existing geographical and social inequalities. Approaching spatial equity from a needs-based perspective allows for an assessment of the relationship between amenity provision and need. If, for example, it is found that poorer, in terms of socioeconomic condition, areas have worse access to a particular type of amenity, then future amenity provision should aim to reduce or eliminate this relationship.

## 1.4 Literature Review

### *1.4.1 Methodological Approaches*

The common question of most spatial equity research is, do socially disadvantaged populations live in spatially disadvantaged areas? The methodological approaches used to address this question have varied considerably. One important point of variation has been the geographical unit of analysis. Spatial equity research typically involves measuring accessibility for a particular aggregated unit of population, and then comparing accessibility with population characteristics collected at the corresponding unit. Accessibility can be measured at a variety of levels, ranging in size from census blocks (Talen, 1998), to enumeration areas (Truelove, 1993), to census tracts (Ottensman, 1994), or neighbourhoods. I have chosen to focus on neighbourhoods in my research. The neighbourhood is the most appropriate unit of analysis for my research for several reasons. First, the focus of Chapter 3 is playground provision in Edmonton; playgrounds in Edmonton are funded on a neighbourhood basis. Further, focusing on the neighbourhood allows for integration of 1999 Edmonton civic census data, which is disseminated at the neighbourhood level. In addition, because neighbourhoods are typically large, using them provides me with the opportunity to examine aggregation error effects on accessibility measurement, a point that I will return to later in this chapter.

Another point of variation among spatial equity research is the method used to measure accessibility. Approaches range from simple summations of an amenity type within a particular unit of analysis (e.g., the number of playgrounds per neighbourhood), to more complex measures based on distance measurements between populations and amenities. I use two types of accessibility measures in my research, *minimum distance* and *coverage*. The minimum distance approach asks, how far do neighbourhood residents, on average, have to travel to reach the closest amenity of interest? The coverage approach asks, on average, how many amenities are located within a specific distance radius from neighbourhood residents? While these types of measures are relatively simple in comparison to other approaches (see Chapter 2 for more information), Koening (1980) notes that these types of measures converge well with more computationally complex measures. Further, planners and policymakers easily understand these measures, which is crucial when the aim of research is to inform policy.

Finally, studies have varied in terms of the methods used to compare accessibility with population need. Truelove (1993) summarized four common approaches: mapping areas that are beyond the service range of amenities, calculating service-to-needs ratios, correlation analysis, and computing equity indices. Other researchers have used multivariate analysis, such as multiple regression (Jones et al., 1980) and causal path analysis (Cervero et al., 1999). I use two methods to assess spatial equity in Edmonton, traditional correlation analysis and ESDA techniques, such as local indicators of spatial association (LISA) [Anselin, 1995]. These approaches were chosen for several reasons. First, my research is highly exploratory in nature, with the main purpose of looking for general associations between accessibility and population need, without intending to make any claims about causality. Also, as noted by Boyne and Powell (1991), territorial justice (which again is similar to needs-based equity) only requires that there is a positive association between need and amenity provision; need does not have to have an independent, causal influence on provision. Second, univariate and bivariate approaches are the most common methods that have been used to assess spatial equity (Talen and Anselin, 1998), thereby facilitating the comparison of my results with other studies. Finally, the use of ESDA techniques in particular is ideal for the analysis of spatially based data, as they explicitly consider the underlying spatial structure of the study area. Their use allows for the identification and statistical assessment of *spatial* patterns in the data, capabilities that are not typically provided by traditional, non-spatial statistical methods.

Spatial equity analyses have varied considerably in methodological approach. Nonetheless, the common goal of these studies has been to determine whether inequity exists with respect to the distribution of public amenities within cities. The following section reviews the substantive findings of selected spatial equity research.

*1.4.2 Substantive Findings*

In addition to differences in methodological approach, studies have varied in geographical context and the type of amenity under investigation. Some researchers have dismissed the spatial variation in accessibility as "unpatterned inequality", whereby the variation in accessibility is not systematically related to socioeconomic characteristics (Mladenka, 1980; Mladenka and Hill, 1977). Others, however, have found significant associations between accessibility and socioeconomic conditions; in some cases high need areas corresponded with high accessibility (Truelove, 1993) whereas in others the inverse has been found (Knox, 1978; Pacione, 1989). Smale (1999), using GIS to compare the distribution of recreational amenity provision with neighbourhood need in Oakville, Ontario, found that 'under-serviced' neighbourhoods were typified either by high densities of lower income families, or lower densities of higher income families. In another Canadian example, Truelove (1993) analyzed the spatial equity of daycare centres in Toronto using a variety of methods, for different units of analysis. At the enumeration area level, she found that lower than average income families had better access to daycares. When examined for federal electoral districts, which are larger than enumeration areas, she also found positive correlations between population need (measured in terms of the proportion of working females and lone-parent families) and accessibility, suggesting an equitable distribution of daycare facilities.

Spatial equity has also been examined in several European cities. In one of the earliest studies of intra-urban spatial equity, Knox (1978) found that for various Scottish cities, areas that were 'worse-off' (in terms of socioeconomic conditions) also experienced lower accessibility to primary medical care facilities. Pacione (1989) found that the provision of secondary schools in Glasgow, Scotland was lower in 'working class' neighbourhoods, than in 'middle class' and more affluent parts of the city. Further, he noted that schools proposed for closure were located in areas that already had low accessibility to schools.

Recent U.S.-based spatial equity research has made use of various ESDA methods to investigate associations between accessibility to amenities and population need (Talen, 1997; Talen and Anselin, 1998). Specifically, LISA have been used to assess the (dis)similarities between local spatial patterns of accessibility and need. Talen (1997) used such techniques to investigate the spatial equity of public parks in Pueblo, Colorado and Macon, Georgia. She found some evidence for an association between local clusters of low accessibility census blocks and high housing value, as well as low percentages of non-white residents in Macon. In Pueblo, however, the reverse situation arose, in which low accessibility was associated with low housing value and high percentages of Hispanics. In an exploratory analysis of access to public playgrounds in Tulsa, Oklahoma, Talen and Anselin (1998) found no distinctive association between local clusters of accessibility and need.

The inconsistency of the findings reported in the reviewed literature is likely attributable to a variety of factors including geographical setting, geographical unit of analysis (e.g., census block, neighbourhood, etc.), the type of amenity under investigation, the method used to assess spatial equity, and the inherent complexity of intra-urban spatial and social processes. There are two main shortcomings of the reviewed literature. First, spatial equity analyses have not considered potential problems related to aggregation error in accessibility measures. Second, with respect to recreational amenities, spatial equity researchers have given little consideration to the *quality* of recreational amenities. This thesis deals with these shortcomings, with Chapter 2 focusing on aggregation error, and Chapter 3 on spatial equity with respect to playground quality. In the next sections, I further elaborate on these shortcomings; while in the process providing a brief outline of subsequent chapters.

## 1.5 Aggregation Error and Spatial Accessibility

Spatial equity, and hence accessibility, can be assessed for different aggregated units of analysis, ranging in size from small census blocks, to large census tracts or neighbourhoods. Aggregation error occurs when, for the purpose of distance measurements, a single point is used to represent aggregated units, which in turn represent spatially distributed individuals (Hodgson et al., 1997). For example, the typical approach in spatial equity research is to measure distance from the unit's centroid (i.e., geometric centre) to the amenity of interest (Pacione, 1989; Ottensman, 1994; Talen and Anselin, 1998; Cervero et al., 1999). This distance is then used to indicate how far individuals, on average, have to travel to reach that amenity. Using a single point to represent larger areas, such as census tracts or neighbourhoods, can potentially lead to aggregation error, as there is likely considerable variation in the location of individuals living within the unit. Despite this potential, aggregation error has received little attention in spatial equity and accessibility research.

Aggregation error has, however, received considerable attention in location-allocation (LA) research, which is concerned with the optimal locating of systems of facilities based on distance measurements to population demand (Hillsman and Rhoda, 1978; Current and Schilling, 1987; Hodgson et al., 1997). The purpose of Chapter 2 is to draw upon some of the aggregation error-reducing methods used in LA research, and apply them to spatial accessibility measures. Because accessibility measurements are crucial for examining spatial equity, it is necessary to assess whether aggregation error produces erroneous spatial accessibility measures. Such an assessment has not been previously made in spatial equity or accessibility analyses; my research provides one of the primary investigations into aggregation error and spatial accessibility.

### 1.6 Quality of Recreational Amenities

As previously mentioned, accessibility refers to the ease with residents can reach amenities, as well as the quality, quantity, and type of activities offered by those amenities (Handy and Niemeier, 1997). Despite this definition, spatial equity researchers have rarely considered aspects of amenity quality. With respect to recreational amenities, considerations have been given to park size (Talen, 1997; Nicholls, 1999); however, other aspects of amenity quality have not been considered. Differences in amenity quality can affect individuals' desire or ability to use amenities, and hence have implications for accessibility and equity.

Chapter 3 assesses the spatial equity of playground provision in Edmonton, while explicitly considering differences in playground *quality* throughout the city. Playgrounds are of interest for several reasons. First, neighbourhood-based public play spaces provide opportunities for children's social and physical development, as well as provide spaces for social interaction (e.g., families meeting each other). Second, population need for playgrounds is multi-dimensional. Obviously, children are the target population; however, other neighbourhood characteristics that affect children's accessibility to playgrounds like car ownership, dwelling type, and low income are also important in establishing playground need. Thus, examining playgrounds allows for a multi-faceted exploration of need. Further, Edmonton's Community Services department maintains a playground inventory, in which the condition of playground equipment at each play site is recorded. This gives me the unique opportunity to addresses the issue of playground quality and its implications on spatial equity, an aspect that has not been given much consideration in existing research.

### 1.7 Study Objectives

This research has two general foci, corresponding to the two stand-alone papers presented in subsequent chapters. The first paper focuses on aggregation error and the measurement of NSA. The primary objectives of the first paper are:

1. To draw on ideas regarding aggregation error in LA research, and extend them to spatial accessibility measurement.
2. To assess whether aggregation error affects NSA measurements, and whether the effect depends on the type of amenity under investigation
3. To suggest strategies for reducing aggregation error in the measurement of NSA.

The second paper is an exploration of spatial equity, in terms of playground location and quality, in Edmonton. The main objectives are:

1. To measure and map accessibility to playgrounds for Edmonton neighbourhoods.
2. To assess spatial equity by examining associations between NSA and neighbourhood need, as indicated by various socioeconomic characteristics.
3. To determine if playground quality affects underlying spatial equity relationships.
4. To evaluate whether Edmonton's Neighbourhood Park Development Program promotes spatial equity in playground provision.

The first paper has been submitted for publication to *Environment and Planning A*, a journal that has published extensively on both methodological and empirical aspects of spatial accessibility research (for example, Knox, 1978; Bröker, 1989; Martin and Williams, 1992; Frost and Spence, 1995; Handy and Niemeier, 1997; Talen and Anselin, 1998; Cervero et al., 1999). Because of its explicit focus on spatial equity within a Canadian urban context, the second paper will be submitted for publication to the *Canadian Geographer*. Further, I will distribute the findings of the second paper (see Appendix B) to Edmonton's Community Services department, which is responsible for playground provision and maintenance in Edmonton.

The two papers are presented in subsequent chapters, with the first paper in Chapter 2 and the second paper in Chapter 3. Chapter 4 will provide a brief synthesis of the each paper's findings, followed by recommendations for future research.

**1.8 References**

Anselin L, 1995, *Spacestat Version 1.80 User's Guide* Regional Research Institute, West Virginia University, Morgantown, WV

Banerjee T, 1993, "Market planning, market planners, and planned markets" *Journal of the American Planning Association* **59** 353-360

Bottoms A E, Wiles P, 1992, "Explanations of crime and place" in *Crime, Policing, and Place: Essays in Environmental Criminology* Eds D J Evans, N R Fyfe, D T Herbert (Routledge, London) pp 11-35

Boyne G, Powell M, 1991, "Territorial justice: a review of theory and evidence" *Political Geography Quarterly* **10** 263-281

Bröker J, 1989, "How to eliminate certain defects of the potential formula"

*Environment and Planning A* **21** 817-830

Cervero R, Rood T, Appleyard B, 1999, "Tracking accessibility: employment and housing opportunities in the San Francisco Bay Area" *Environment and Planning A* **31** 1259-1278

Congdon P, 1994, "The impact of area context on long term illness and premature mortality: an illustration of multi-level analysis" *Regional Studies* **29** 327-344

Current J R, Schilling D A, 1987, "Elimination of Source A and B errors in *p*-median location problems" *Geographical Analysis* **19** 95-110

Davies B P, 1968, *Social Needs and Resources in Local Services* (Michael Joseph, London)

Dear M, 1974, "A paradigm for public facility location theory" *Antipode* **6** 46-50

Duncan C, Jones K, Moon G, 1993, "Do places matter? A multi-level analysis of regional variation in health related behaviour in Britain" *Social Science and Medicine* **37** 725-733

Duncan C, Jones K, 1995, "Individuals and their ecologies: analyzing the geography of chronic illness within a multi-level modeling framework" *Health and Place* **1** 27-40

Ecob R, 1996, "A multi-level approach to examining the effects of area of residence on health and functioning" *Journal of Royal Statistical Society A* **159** 61-75

Handy S L, Niemeier D A, 1997, "Measuring accessibility: an exploration of issues and alternatives" *Environment and Planning A* **29** 1175-1194

Harvey D, 1973, *Social Justice and the City* (Edward Arnold, London)

Hay A M, 1995, "Concepts of equity, fairness and justice in geographical studies" *Transactions of the Institute of British Geographers* **20** 500-508

Hillsman E L, Rhoda R, 1978, "Errors in measuring distances from populations to service centres" *Annals of Regional Science* **12** 74-88

Hodgson M J, Shmulevitz F, Körkel M, 1997, "Aggregation error effects on the discrete-space *p*-median model: the case of Edmonton, Canada" *The Canadian Geographer* **41** 415-428

Jones B D, Greenberg S, Drew J, 1980, *Service Delivery in the City: Citizen Demand and Bureaucratic Rules* (Longman, New York)

Knox P L, 1978, "The intraurban ecology of primary medical care: patterns of accessibility and their policy implications" *Environment and Planning A* **10** 415-435

Knox P L, 1980, "Measures of accessibility as social indicators: a note" *Social Indicators Research* **7** 367-377

Koenig J G, 1980, "Indicators of urban accessibility: theory and application" *Transportation* **9** 145-172

Lucy W, 1981, "Equity and planning for local services" *Journal of the American Planning Institute* **47** 447-457

Macintyre S, Maciver S, Sooman A, 1993, "Area, class, and health: should we be focusing on places or people?" *Journal of Social Policy* **22** 213-234

Macintyre S, Ellaway A, 1998, "Social and local variations in the use of urban opportunities: a case study in Glasgow" *Health and Place* **4** 91-94

Martin D, Williams H C W L, 1992, "Market area analysis and accessibility to primary health-care centres" *Environment and Planning A* **24** 1009-1019

Mladenka K R, 1980, "The urban bureaucracy and the Chicago political machine: who gets what and the limits to political control" *American Political Science Review* **74** 991-998

Mladenka K R, Hill K Q, 1977, "The distribution of benefits in an urban environment" *Urban Affairs Quarterly* **13** 73-94

Nicholls S, 1999, "Measuring accessibility and equity of public parks: a case study using GIS" paper presented at the *Geographic Information and Society* conference, 20-22 June, University of Minnesota, Minneapolis

Ottensmann J R, 1994, "Evaluating equity in service delivery in library branches" *Journal of Urban Affairs* **16** 109-123

Pacione M, 1989, "Access to urban services – the case of secondary schools in Glasgow" *Scottish Geographical Magazine* **105** 12-18

Pred A, 1977, *City Systems in Advanced Economies* (Hutchinson, London)

Smale B J A, 1999, "Spatial analysis of leisure and recreation" in *Leisure Studies: Prospects for the Twenty-First Century* Eds E L Jackson, T L Burton (Venture Publishing Inc., Pennsylvania) pp 177-197

Smith D, 1994, *Social Justice and Human Geography* (Blackwell, Oxford)

Talen E, 1997, "The social equity of urban service distribution: an exploration of park access in Pueblo, Colorado, and Macon, Georgia" *Urban Geography* **18** 521-541

Talen E, 1998, "Visualizing fairness: equity maps for planners" *Journal of the American Planning Association* **64** 22-39

Talen E, Anselin, L, 1998, "Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds" *Environment and Planning A* **30** 595-613

Truelove M, 1993, "Measurement of spatial equity" *Environment and Planning C* **11** 19-34

Verba S, Nie N, 1972, *Participation in America* (Harper and Row, New York)

Wallace R, 1990, "Urban desertification, public health and public order: 'planned shrinkage', violent death, substance abuse and AIDS in the Bronx" *Social Science and Medicine* **31** 801-813

# CHAPTER 2

# Measuring Neighbourhood Spatial Accessibility to Urban Amenities: Does Aggregation Error Matter?

## 2.1 Introduction

Neighbourhood spatial accessibility (NSA) to amenities broadly refers to the ease with which residents of a given neighbourhood can reach amenities. Spatial accessibility measures have been used in a variety of situations, such as planning housing developments (Geertman and Ritsema Van Eck, 1995), indicating intra-urban variations in quality of life (Knox, 1980), and assessing spatial equity within cities (Knox, 1978; Pacione, 1989; Talen, 1998). Typically, such studies measure spatial accessibility to a particular type of amenity, such as schools (Pacione, 1989), daycare facilities (Truelove, 1993), or public parks (Talen, 1998) for residential areas (e.g., neighbourhoods or census units) within a city. The measurements are then used to inform a variety of urban policy issues, such as identifying areas with low access to amenities or assessing spatial equity. Spatial accessibility measurements at the neighbourhood (or other aggregate level) are, however, susceptible to a variety of methodological problems (Koenig, 1980; Handy and Niemeier, 1997). Failing to consider such problems may result in inaccurate spatial accessibility measures, and hence lead to erroneous recommendations for urban policy.

This paper examines one particular methodological issue, aggregation error, and considers its effects on measuring spatial accessibility. Spatial accessibility is based on the measurement of distance between geo-referenced populations and an amenity. For a variety of reasons (including confidentiality, data dissemination practices, or the research question) populations are aggregated into areal units, such as neighbourhoods or some type of census unit. To facilitate distance measurements, areal units are often represented by a single point, or centroid such as the unweighted geometric centre of a polygon. Aggregation error is the error associated with representing an areal unit, which in turn represents spatially distributed individuals, by a single point (Hodgson et al., 1997). Aggregation error has long been discussed in location-allocation (LA) research, but it has attracted scant attention in the spatial accessibility literature.

This paper adapts ideas from aggregation error research in LA analysis (for example, Hillsman and Rhodda, 1978; Current and Shilling, 1987; Hodgson et al., 1997) and applies them to measuring spatial accessibility. LA models optimally locate systems of facilities and allocate demand, often in the form of population, to those facilities. Many mathematical definitions of optimality are used, but for all, measuring distance from demand points to facilities is critical. Demand points represent the location of spatially distributed individuals living within areal units. LA research, then, is concerned with quantifying the effect that aggregation error has on finding optimal locations for facilities, as well as exploring methods to reduce or eliminate aggregation error.

As in LA modeling, spatial accessibility analyses rely heavily on distance measurements between populations and facilities. Whereas LA uses such measurements to evaluate *potential* facility locations, spatial accessibility research typically uses them to assess *existing* facility locations. Because distance measurements are integral to accessibility-based analyses, it is important to examine potential effects of aggregation error on the measurement of spatial accessibility.

One way LA analysts have attempted to reduce aggregation error is by integrating less aggregate (finer resolution) data that better reflect the spatial distribution of individuals (Current and Shilling, 1987). For instance, the standard way to calculate the distance from a particular census tract to a given facility is to measure distance from the unweighted geometric centre of the tract to the facility of interest, and to accept that measurement as representative of the distance that people living within the census tract would have to travel to reach the facility. This approach totally ignores the spatial distribution of individuals within areal units. An alternative approach is to integrate less aggregate data, such as census blocks, which represent the spatial distribution of individuals within the tract. If we seek to make a statement about average distance from that tract, then the census blocks can be used in two basic ways. First, the population weighted mean centre of the block centroids can be calculated, and the distance to the facility measured from this point, which better represents the centre of population within the tract. Alternatively, distance to the facility may be measured from each census block centroid, and the population-weighted average of all the distances calculated to represent the average distance from that tract to the facility. The latter approach results in the least amount of aggregation error, and is therefore considered to be a more reliable method of obtaining distance measurements from aggregated units to facilities (Hillsman and Rhoda, 1978; Current and Schilling, 1987; Hodgson et al., 1997).

This paper investigates the potential effects of aggregation error on the assessment of spatial accessibility, while drawing upon some of the methods and ideas used in LA research. I adopt an approach similar to Talen and Anselin (1998), who used a variety of exploratory spatial data analysis (ESDA) techniques, including local indicators of spatial association (LISA) (Anselin, 1995) to explore the spatial patterns produced by various accessibility measures, and then to determine if different accessibility indicators resulted in differing assessments of spatial equity. Their goal was to demonstrate the sensitivity of equity analyses to the type of accessibility measure used; mine is to examine the sensitivity of accessibility measurements to aggregation error. NSA to three types of publicly funded recreational facilities (playgrounds, community halls, and leisure centres) in Edmonton, Canada provides my case study. The primary task is to assess how (dis)similar the spatial patterns of NSA to each facility type are depending on how aggregation error is combatted. Incorporating three different facility types (in terms of number of facilities and extent of service area) allows me to assess the degree to which aggregation error affects accessibility measures and determine if the effect varies with the type of facility.

## 2.2 Defining and Measuring Spatial Accessibility

Generally, accessibility refers to the ease with which facilities can be reached. NSA refers to the ease with which residents of a given neighbourhood can reach different types of facilities. Spatial accessibility can be measured in many ways; I briefly discuss those considered by Talen and Anselin (1998). *Minimum* distance is simply the distance from an origin (neighbourhood) to the nearest facility of interest (playground); accessibility is inversely related to this measure. *Average travel cost* is the average distance to each facility in the study area; accessibility is also inversely related to this measure. G*ravity potential* is usually the sum of, for all facilities, some function of facility attractiveness mitigated by distance. Talen and Anselin (1998) demonstrate that using different accessibility measures can produce markedly different spatial patterns of accessibility: the choice of the type of indicator to be used is critical. Having said this, however, I have chosen to use the minimum distance method for our analysis. Depending on facility type, other measures may more accurately capture the essence of accessibility, but my purpose is to consider aggregation error problems in accessibility measurement. The choice of a simple, straightforward, easily understood measure, such as minimum distance, is important.

Another methodological issue in spatial accessibility research is the choice of the type (e.g., Euclidean, Manhattan, or shortest network paths) of distance measurement. The most commonly used types of distance measures in accessibility research are shortest network paths (Ottensmann, 1994; Talen, 1997; Talen and Anselin, 1998; Cervero et al., 1999) and to a lesser extent Euclidean (straight-line) distance (Truelove, 1993; Truelove, 2000). Travel to playgrounds is likely on foot, over shorter distance using a combination of network-based travel (sidewalks) and 'short-cuts' or walking trails, and may therefore be reasonably typified by Euclidean distance. On the other hand, the choice to use Euclidean distance might be questionable in the case of leisure centres, to which travel for most persons is limited to the use of roadways. If the primary objective of the analysis were to make substantive claims about accessibility in Edmonton, then more complex measures such as network distance or travel time would have to be considered. For the purpose of this study, a complex distance measurement could complicate the explanation and understanding of aggregation errors. I have chosen to use Euclidean distance in our analysis; my purpose is better served by using this easily understood measure.

## 2.3 Aggregation Error Issues

### *2.3.1 Unit of Analysis*

The spatial unit of analysis used to investigate intra-urban spatial accessibility can vary from small, minimally aggregated units, such as census blocks (Talen, 1997) to larger, highly aggregated units such as census tracts (Ottensmann, 1994; Talen, 1998; Truelove, 2000). Aggregation error arises from the distribution of individuals around the centroid representing them; it is positively related to the breadth of this distribution. The spatial distribution of individuals will vary somewhat around a census block centroid, but because of the block's small size this variation will be much less than that around the centroid of a larger census tract. Thus, analyses using minimally aggregated units are subject to some aggregation error; analyses using larger, more aggregated units, such as census tracts or neighbourhoods have greater potential for aggregation error.

Because finer resolution units are less prone to aggregation error, spatial accessibility research at the finest resolution unit available may be desirable. In many cases, however, larger units such as neighbourhoods may be preferred or required for at least two reasons. First, cities provide certain amenities at the neighbourhood level; community league organizations, operating at the neighbourhood level, may be responsible for administering them. Secondly, detailed socioeconomic data may not be available at less aggregate levels. Compatibility with socioeconomic data is essential if the analysis involves examining accessibility patterns in relation to population characteristics, such as in spatial equity research (Talen and Anselin, 1998). If the research focuses on larger, more aggregate units, then aggregation error must be considered when distance calculations are made from these units.

*2.3.2 Sources of Error: Potential Implications for Measuring Spatial Accessibility*

LA analysts recognize three types of aggregation error, originally identified as *Source A, Source B,* and *Source C* error (Hillsman and Rhoda, 1978). These errors arise when measuring distance from aggregated areal units (e.g., neighbourhoods) to facilities, and result from using a single point to proxy the locations of individuals within the areal units. The precise spatial distribution of individuals within neighbourhoods is typically unknown because of confidentiality restrictions. The location of individuals within neighbourhoods, however, can be reasonably estimated by integrating finer resolution data, such as census blocks or postal codes. Within Canada, postal codes are the least aggregate spatial unit for which reliable total population and dwelling counts are available, and in most major Canadian cities roughly correspond to the size of a city block (Statistics Canada, 1999). In Edmonton, for example, postal codes contain an average of 33 people and 12 dwellings. Small amounts of aggregation error exist within postal code areas, but because they are the least aggregate data available, I treat them as 'error free' in this analysis. The remainder of this section, by using postal code centroids to indicate the distribution of individuals within neighbourhoods, reviews the three types of aggregation error and speculates on how aggregation error affects distance, and hence accessibility measurements.

*Source A* error refers to the misestimation of distance from a neighbourhood to a facility outside of the neighbourhood boundaries (Figure 2.1).

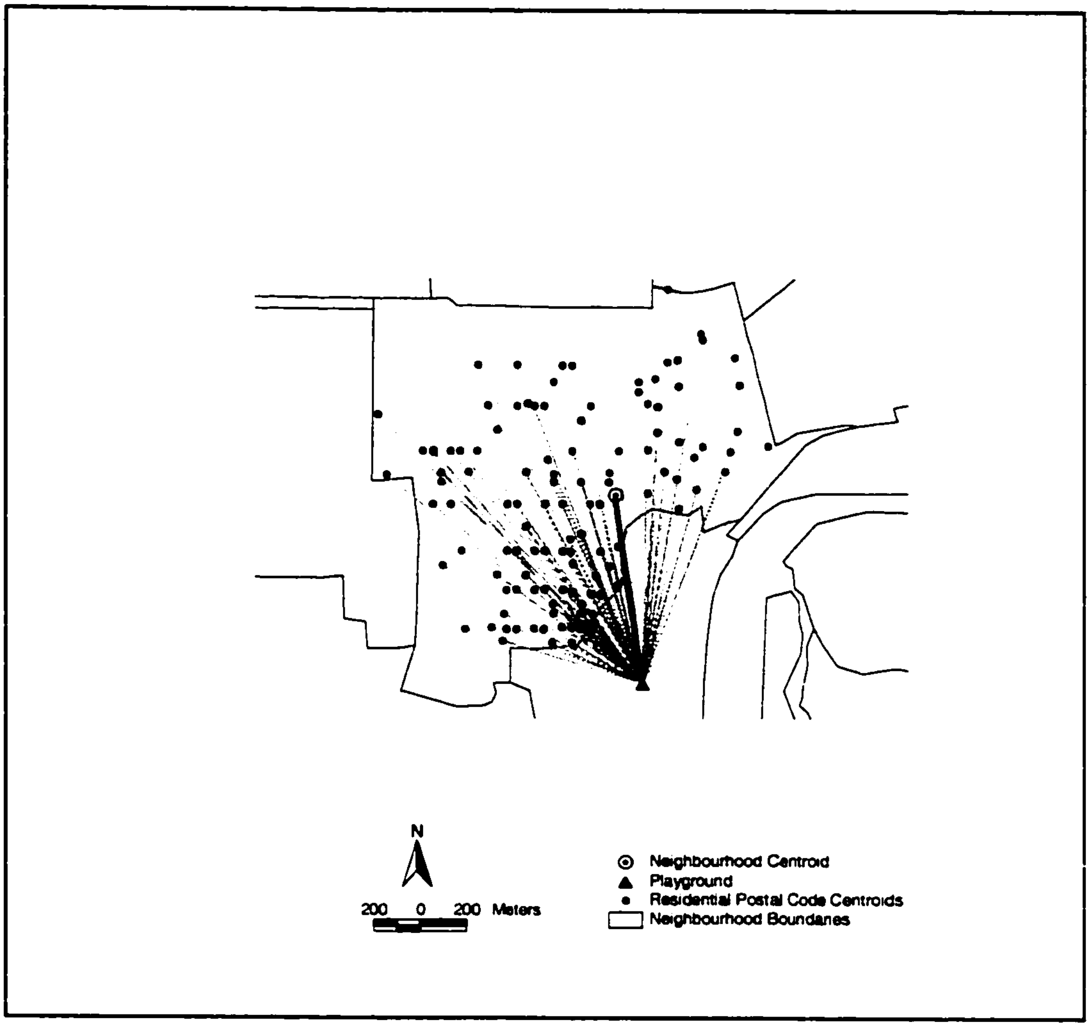


**Figure 2.1.** Source A aggregation error arises when measuring the distance from a neighbourhood centroid to a facility outside of the neighbourhood boundaries.

When measuring accessibility, the traditional approach would be to use the distance from the neighbourhood's centroid to the facility (indicated by the dark bold line) to represent the average distance that neighbourhood residents travel to reach a facility. A more representative measure, however, is the population-weighted average of the distance from each postal code to the facility (indicated by the light dashed lines). Traditionally, *Source B* error (also known as the self-distance problem) occurs when distance is measured from a centroid to itself, resulting in a zero distance measurement.

In the case of accessibility to facilities, the only time a zero distance measurement will result is when a facility location coincides exactly with a neighbourhood centroid. We adopt a less-stringent definition, and consider *Source B* error as the misestimation of distance from a neighbourhood to a facility *within* the neighbourhood (Figure 2.2).

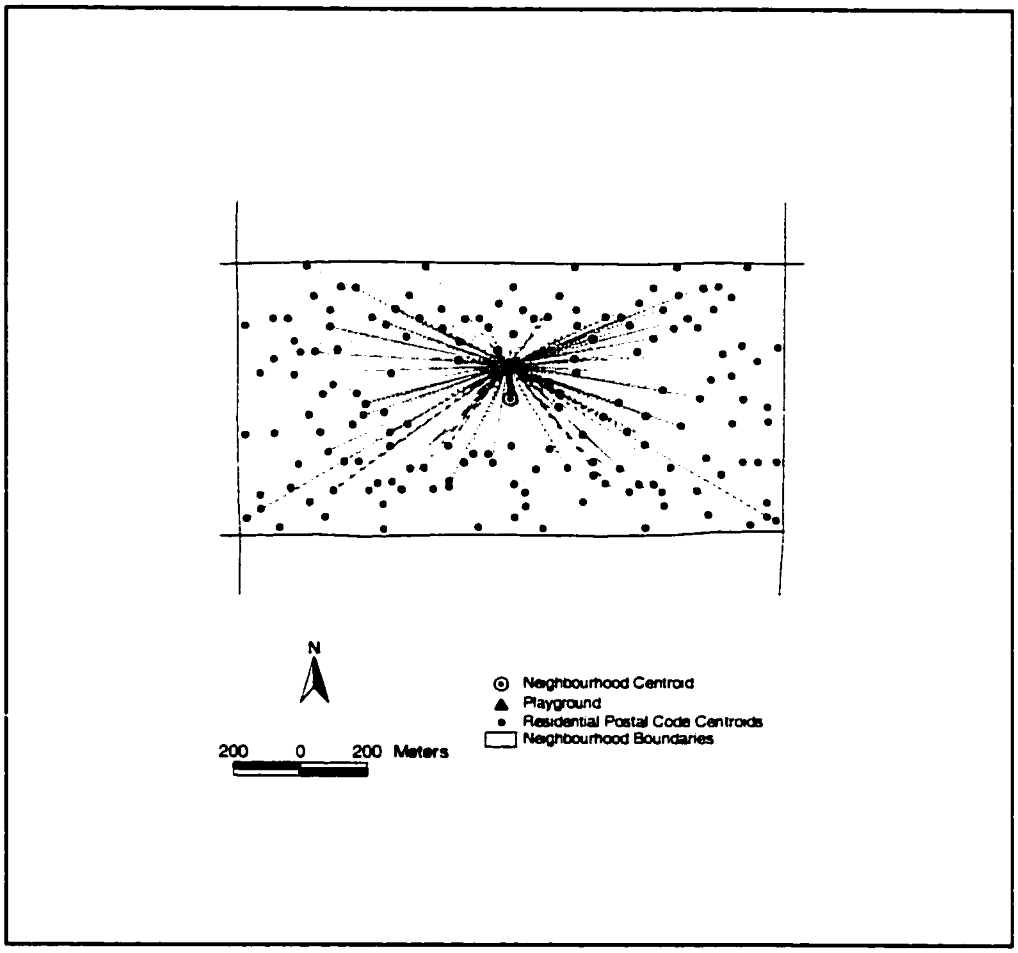


**Figure 2.2.** Source B aggregation error arises when measuring the distance from a neighbourhood centroid to a facility within the neighbourhood.

Because distance is usually measured from the neighbourhood's centroid, an unrealistically low distance measurement will result when a facility is close to the neighbourhood's centroid. *Source C* error results from allocating postal codes to incorrect facilities (Figure 2.3). This occurs because an entire neighbourhood is allocated to the facility nearest to its centroid. Some postal codes within the neighbourhood, however, may be closer to facilities other than the one that is closest to the centroid, and should be allocated accordingly. Failing to consider Source C aggregation error may result in inaccurate estimates of the average distance that neighbourhood residents must travel to reach a facility.

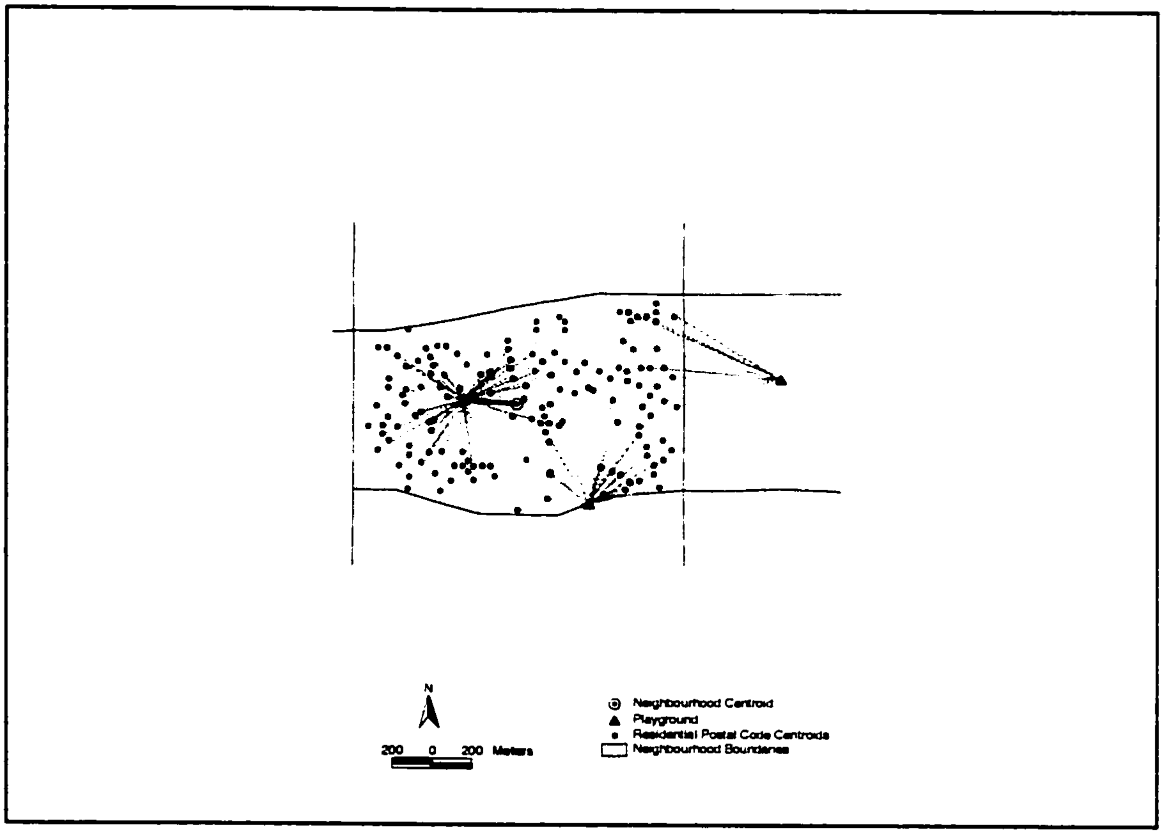


**Figure 2.3.** Source C aggregation error arises when all neighbourhood residents are allocated to the facility closest to the neighbourhood centroid, when in fact some of the residents are closer to alternative facility locations.

### *2.3.3 Reducing Aggregation Error*

Within the spatial accessibility literature, *Source B* error has been given considerable attention. *Source B* error is similar to the commonly noted problem of self-potential that arises with the use of gravity potential models [see Frost and Spence (1995) for a discussion of self-potential]. Accessibility analysts have used several practical approaches to attempt to resolve this issue, such as deriving estimates of intra-zonal distance based on nearest neighbour criteria (Ottensmann, 1994). Geertman and Ritsema van Eck (1995) introduced a raster-based approach for dealing with the self-potential problem. Rather than measure distance to facilities from the centroids of pre-defined spatial units, they transformed their study area into a layer of grid cells and calculated accessibility for each cell. Their approach, while reducing potential aggregation error problems, may not be suitable for estimating the average travel distance to a particular facility for individuals living within larger spatial units. This is because it assumes that individuals are distributed homogeneously within the spatial unit, which is usually not the case. Figure 2.4 shows the spatial distribution of population (as represented by total population counts for postal codes) in a north Edmonton neighbourhood; population is obviously not homogeneously distributed. Such a raster approach calculates distance from each cell within the neighbourhood, when many of the cells do not contain any population. Including these empty cells would likely distort the calculation of average accessibility in the neighbourhood.

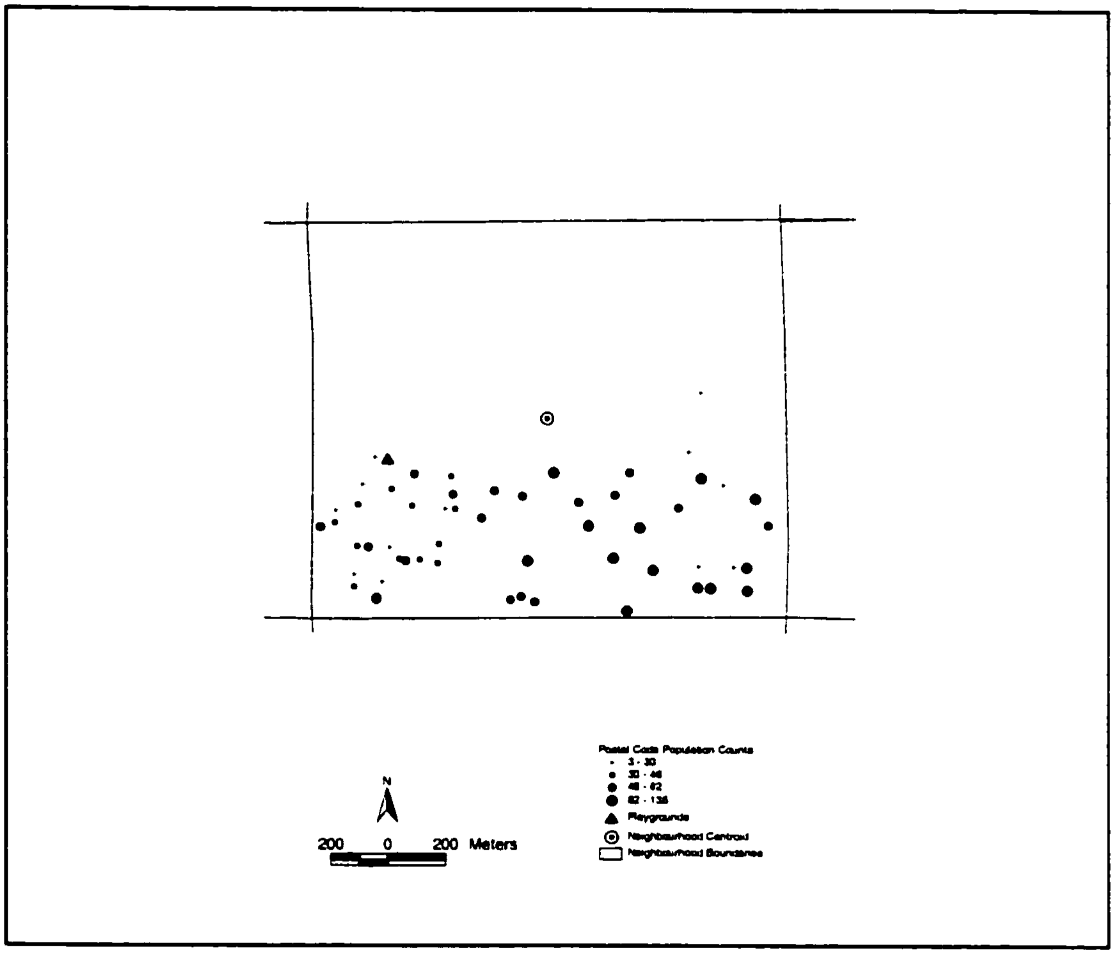


**Figure 2.4.** Incorporation of postal code population counts reveals the non-homogeneous spatial distribution within some neighbourhoods.

Based on previous LA work, I propose that an ideal way to minimize all types of aggregation error when measuring accessibility for highly aggregated units, such as neighbourhoods, is through integrating less aggregate spatial units. Although it is difficult to obtain locational and attribute data at a completely disaggregate level such as households or individuals, data are often available at slightly more aggregated units such as census blocks in the United States, and postal codes in Canada. The locations of such units, accompanied by population counts, can be used to approximate the spatial distribution of individuals within neighbourhoods. Rather than measure distance from a neighbourhood's unweighted geometric centroid, distance can be calculated from the population-weighted mean centre of the finer resolution points, or preferably, from each finer resolution unit, and then the population-weighted average of these distances used. This avoids (a) estimating intra-zonal distances as substitutes for actual distances to facilities, and (b) assuming a homogeneously distributed population within a neighbourhood. Further, measuring distance from finer resolution units within a neighbourhood allows for the assessment of variation in accessibility within the neighbourhood.

*Source B* aggregation error, in the form of self-potential problems arising in gravity potential models, has been identified as an important methodological issue within spatial accessibility research. The discussion, however, has rarely extended to problems with other types of aggregation error, as well as the effects of aggregation error on other accessibility measures, such as minimum distance. Specifically, questions remain such as: (a) how sensitive are accessibility measurements to aggregation error; and (b) does this sensitivity depend on the type of facility for which accessibility is being measured? My purpose is to address these questions and to determine whether aggregation error should be given greater consideration when using accessibility measures to inform urban policy.

## 2.4 Case Study: Neighbourhood Spatial Accessibility to Recreational Amenities in Edmonton

### *2.4.1 Study Area and Data Sources*

I use Edmonton, Alberta, Canada to investigate the impact of aggregation error on NSA measurement. Edmonton's municipal boundaries contain just over 647 000 people and roughly 663 $km^2$ of land, divided into 299 neighbourhoods (City of Edmonton, 1999). Of these neighbourhoods, 199 are urban-residential and are therefore included in the analysis (Figure 2.5).

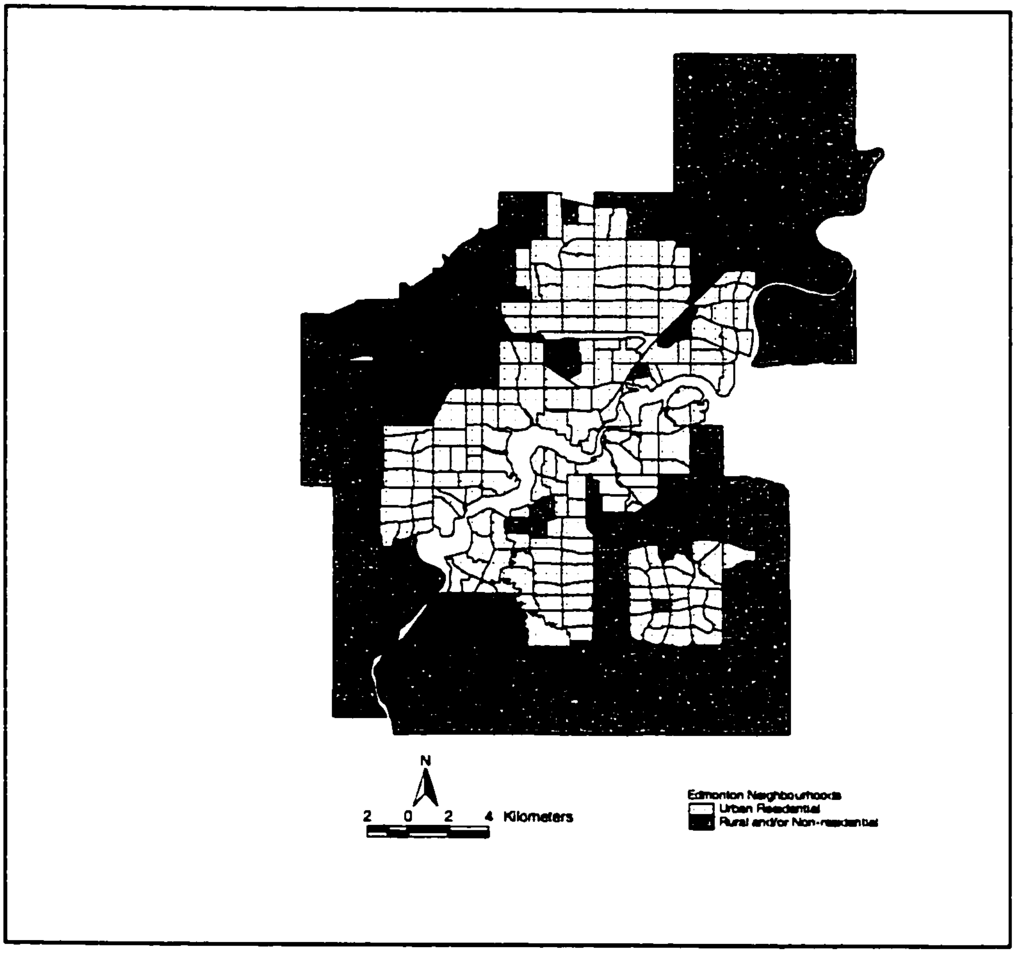


**Figure 2.5.** The city of Edmonton – neighbourhoods by type.

Industrial/commercial neighbourhoods were not included because they lack residential land use; mobile-home parks and rural-residential areas were excluded because of inconsistencies in the locational accuracy of postal code data in such areas. The neighbourhood boundaries are based on the City of Edmonton 2000 Wards and Standard Neighbourhoods map.

To assess possible aggregation error effects, finer resolution data indicating the spatial distribution of individuals within each neighbourhood are required. I obtained postal code locations and postal code population counts (PCPC) from Statistics Canada. The PCPC file consists of total population and dwelling counts for each six-digit postal code in Canada. The most recent PCPC were collected during the 1996 Census of Canada (Statistics Canada, 1997). The PCPC were linked to a postal code conversion file (also available through Statistics Canada), which contains the latitude and longitude co-ordinates of all Canadian postal code centroids. In total, I identified 18 396 Edmonton residential postal codes with population counts of at least one person. In cases where Statistics Canada was unable to precisely locate the co-ordinates of particular postal codes, the agency assigned them to the centroid of their corresponding enumeration area (EA), a census unit that falls between the postal code and census tract in size.

Of the 18 396 postal codes, 874 (4.8%) were assigned the EA co-ordinates instead of the more precise postal code co-ordinates. To rectify this problem, I used the 1999 Select Phone CD-ROM Canadian Edition address and telephone directory, which contains the corresponding address ranges of all Canadian postal codes. In most cases, any given postal code corresponds to a sequential series of addresses along a city block. After extracting the improperly located postal codes from Statistics Canada, the CD-ROM was queried to obtain the address ranges of these postal codes. After retrieving the address ranges, I relocated the postal code centroid to the midpoint of the corresponding address range. I was able to correct 702 of the 874 of the improperly located postal codes, leaving only 172 (roughly 1%) of the original 18 396 postal codes assigned to their EA centroids. Another problem with using 1996 PCPCs is that the neighbourhood boundaries used in the analysis are based on 2000 data. I must assume that while the population may have changed within the four-year period, its spatial distribution has remained relatively constant within each neighbourhood. I trust that the effects on the analysis of some less accurately located postal codes and the assumption of stable spatial distribution of the population between 1996 and 2000 are minimal.

I obtained locational data for the recreational amenities of interest from the City of Edmonton and the Edmonton Federation of Community Leagues (EFCL). Edmonton's Community Services department provided the approximate street address of all publicly funded playgrounds in the city. I chose playgrounds as an example of an abundant amenity that usually serves a highly localized population. I identified 312 playgrounds, of which 11 were eliminated from the analysis because they are located in the city's river valley. Playgrounds in the river valley, an essentially non-residential area that spans the city from east to west, are subject to different funding programs than those within Edmonton neighbourhoods, and hence are located based on a different set of criteria (City of Edmonton Community Services, 1998). The street addresses of 19 publicly funded leisure centres, which offer a variety of fitness activities, were obtained from Edmonton Community Services website.[1] I use leisure centres as an example of spatially dispersed recreational amenities that are few in number and have relatively large service areas. Finally, I chose community halls as a facility type that falls between playgrounds and leisure centres in terms of number, spatial dispersion, and size of

[1] http://www.gov.edmonton.ab.ca/comm_services/rec_facilities/leisure_centers/index.html

intended service area. The street addresses of 132 community halls in Edmonton were posted on the EFCL's website.[1]

### 2.4.2 *Methods for Reducing Aggregation Error*

I performed all geocoding, mapping, and distance calculations with ESRI's ArcView GIS Version 3.2. Following the initial preparation, the data were brought into the GIS environment for subsequent distance measurements and analysis. In all cases, NSA was treated as Euclidean distance, in metres, to the nearest playground, community hall, and leisure centre. To assess potential aggregation error problems, I measured distance to each facility type in three ways. First is the traditional unweighted geometric centroid method, which ignores the spatial distribution of individuals within each neighbourhood, and thus has the greatest potential for aggregation error. This method measures the distance from each neighbourhood centroid to the nearest facility. Mathematically, this method is expressed as:

$$A_i = \min |d_{ij}|, \qquad (1)$$

where $A_i$ is the accessibility of neighbourhood $i$, and $d_{ij}$ is the distance between the unweighted geometric centroid of neighbourhood $i$ and facility $j$.

The second method uses the postal code centroids and corresponding population counts to derive the population-weighted mean centre (PWMC) of each neighbourhood, mathematically defined as:

$$\bar{x}_i = \frac{\sum_{k \in i} x_k w_k}{\sum_{k \in i} w_k}, \qquad \bar{y}_i = \frac{\sum_{k \in i} y_k w_k}{\sum_{k \in i} w_k} \qquad (2)$$

[1] http://www.efcl.org

where $\bar{x}_i$ and $\bar{y}_i$ represent the geographic co-ordinates of the PWMC of neighbourhood $i$, $x_k$ and $y_k$ are the geographic co-ordinates of postal code $k$, and $w_k$ is the total population of postal code $k$. The accessibility measure is calculated from the PWMC of each neighbourhood defined as in (1). Because the spatial distribution of individuals within neighbourhoods is somewhat accounted for, this method is an improvement over the centroid approach, but it is still likely to result in considerable aggregation error, because a single point is being used to represent an entire neighbourhood.

The third approach, which I refer to as the weighted average postal code distance (WAPCD) method, considers the spatial arrangement of individuals within each neighbourhood and measures distance from each postal code to the nearest facility. To calculate accessibility for a particular neighbourhood, I use the population weighted average distance of all the postal codes within the neighbourhood's boundaries. Formally, this method is defined as:

$$A_i = \frac{\sum_{k \in i} w_k (\min |d_{kj}|)}{\sum_{k \in i} w_k} \quad (3)$$

This method is considered by LA analysts to result in the least amount of aggregation error and hence to give the best estimate of average distance from a spatial unit to a facility (Hillsman and Rhoda, 1978; Current and Schilling, 1987; Hodgson et al., 1997). I therefore adopt it as our 'gold standard' or 'benchmark' solution for evaluating the quality of the other two procedures.

My primary goal is to determine whether the measurement of NSA is subject to aggregation error. Assuming that the WAPCD method represents the most accurate estimation of average accessibility of a neighbourhood, I wish to know if the PWMC or the commonly used centroid method produces similar accessibility measurements for each neighbourhood. If they do not, then I conclude that aggregation error does affect the measurement of NSA. The remaining sections use a variety of techniques to examine whether the centroid, PWMC, and WAPCD methods result in different levels and spatial patterning of NSA.

*2.4.3 Descriptive Statistics and Correlation Analysis*

Descriptive statistics for the three sets of neighbourhood accessibility values demonstrate some interesting patterns (Table 2.1). For all facility types the standard deviation is highest for the centroid approach and lowest for the WAPCD method. Assuming the WAPCD to be the most representative measure of average NSA,

**Table 2.1.** Descriptive statistics for neighbourhood spatial accessibility (metres to nearest facility) by measurement method and facility type (n = 199).

| Method | Mean | Stand. Dev. | Median | Minimum | Maximum |
|---|---|---|---|---|---|
| Playgrounds | | | | | |
| Centroid | 311.12 | 239.15 | 260.41 | 5.16 | 1412.11 |
| PWMC | 285.29 | 209.11 | 228.77 | 11.05 | 1296.06 |
| WAPCD | 408.34 | 146.92 | 376.91 | 174.95 | 1306.80 |
| | | | | | |
| Community Halls | | | | | |
| Centroid | 531.70 | 408.33 | 379.50 | 12.19 | 1680.84 |
| PWMC | 507.50 | 385.57 | 358.59 | 46.05 | 1815.07 |
| WAPCD | 628.63 | 291.15 | 509.37 | 214.05 | 1815.35 |
| | | | | | |
| Leisure Centres | | | | | |
| Centroid | 2001.46 | 1170.58 | 1708.39 | 103.93 | 5452.22 |
| PWMC | 1978.14 | 1150.21 | 1682.30 | 165.42 | 5245.81 |
| WAPCD | 1991.88 | 1129.43 | 1631.90 | 296.37 | 5263.45 |

then the centroid and PWMC approaches consistently inflate the variation of accessibility among neighbourhoods. For all facility types, the centroid and PWMC approaches both produce unrealistically low estimates of 'average' neighbourhood accessibility for the neighbourhoods with the highest accessibility (i.e., the lowest distance to the nearest facility). The centroid approach claims that the distance to the nearest playground for the neighbourhood with the highest accessibility (i.e., the minimum value as reported in Table 2.2) is about five metres; the WAPCD method reports that this figure is 175 metres. This misestimation of distance reflects *Source B* aggregation error, and is in line with the self-potential problems often noted within the accessibility literature. Thus, the summary statistics indicate that aggregation error may impact the measurement of NSA.

Dalvi and Martin (1976) noted that when examining accessibility for residential zones, interest typically lies in a given zone's accessibility *relative* to other zones in the study area, rather than its *absolute* accessibility level. Because a neighbourhood's relative position is especially relevant for accessibility analyses, it is crucial to examine whether aggregation error affects the accessibility rank of neighbourhoods. In other words, do the relative positions, or ranks, of neighbourhoods change depending on the measurement method used? To address this question, I calculated Spearman Rank correlation coefficients between the various measurement methods for each facility type (Table 2.2).

**Table 2.2.** Spearman Rank correlations[1] of neighbourhood spatial accessibility by measurement method and facility type (n = 199).

| | Centroid | PWMC | WAPCD |
|---|---|---|---|
| **Playgrounds** | | | |
| Centroid | *1.000* | | |
| PWMC | *0.745* | *1.000* | |
| WAPCD | *0.526* | *0.553* | *1.00* |
| **Community Halls** | | | |
| Centroid | *1.000* | | |
| PWMC | *0.906* | *1.000* | |
| WAPCD | *0.859* | *0.881* | *1.000* |
| **Leisure Centres** | | | |
| Centroid | *1.000* | | |
| PWMC | 0.989 | 1.000 | |
| WAPCD | 0.989 | 0.998 | 1.000 |

[1] All coefficients significant at $p < 0.05$.

For playgrounds, the correlation between the WAPCD and centroid method is relatively low (0.526) suggesting that there is considerable difference in the ranks of neighbourhoods under each measurement method. The PWMC approach does not fare much better than the standard centroid method, yielding a correlation of only 0.553 with the WAPCD approach. These relatively low correlations suggest that aggregation error does affect NSA to playgrounds, as there is substantial change in the ranks of neighbourhoods depending on the measurement method used.

For community halls, the correlation between the WAPCD approach and both the centroid (0.859) and PWMC (0.881) methods are much higher than for the playgrounds. Although slight rank changes result from the different measurement methods, the magnitude of the coefficients suggest that the centroid and PWMC approach better approximate the WAPCD for the community halls than for the playgrounds. This indicates that aggregation error only slightly affects NSA to community halls. In the case of NSA to leisure centres, there are essentially no differences in the ranks of neighbourhoods under each measurement method. This is indicated by the high (almost perfect) correlations between the three methods. For leisure centres, aggregation error has little, if any, effect on the ranking of NSA.

### *2.4.4 Exploratory Spatial Data Analysis*

I also used various exploratory spatial data analysis (ESDA) techniques to assess the impact of aggregation error on the measurement of NSA. These techniques were incorporated because they explicitly address the spatial nature of the data, and their use is becoming more prevalent in studies that examine intra-urban patterns of spatial accessibility (e.g., Talen, 1997; Talen and Anselin, 1998). All spatial statistical analyses were performed using *Spacestat Version 1.90* (Anselin, 1998). First, Moran's *I* (using the randomization approach) was calculated for the NSA values (i.e., metres to nearest facility) under each measurement method for each facility type to assess whether the different methods result in varying degrees of global spatial autocorrelation (for a review of Moran's *I* see Appendix A). Edmonton's spatial structure makes some urban-residential neighbourhoods into 'islands' – residential areas bordered only by non-residential neighbors; we were thus obliged to use distance-based contiguity to define each neighbourhood's set of spatial neighbors. To test the sensitivity of Moran's *I* to different sets of spatial neighbors, we defined three different row-standardized distance-based matrices with distance cut-offs of 1.6, 2.0, and 2.5 kilometres.

**Table 2.3.** Global Moran's *I* [1] for neighbourhood spatial accessibility by measurement method and facility type (n = 199).

| Method | 1.6 km | | 2.0 km | | 2.5 km | |
|---|---|---|---|---|---|---|
| | *I* | *z* | *I* | *z* | *I* | *z* |
| Playgrounds | | | | | | |
| Centroid | **0.132** | **2.741** | **0.112** | **3.144** | **0.089** | **3.205** |
| PWMC | **0.132** | **2.727** | **0.075** | **2.153** | **0.064** | **2.325** |
| WAPCD | **0.253** | **5.185** | **0.161** | **4.509** | **0.151** | **5.356** |
| Community Halls | | | | | | |
| Centroid | -0.054 | -0.954 | -0.023 | -0.473 | 0.006 | 0.369 |
| PWMC | -0.018 | -0.264 | 0.003 | 0.205 | 0.022 | 0.894 |
| WAPCD | -0.026 | -0.413 | -0.005 | 0.005 | 0.008 | 0.424 |
| Leisure Centres | | | | | | |
| Centroid | 0.052 | 1.138 | -0.011 | -0.170 | -0.017 | -0.415 |
| PWMC | 0.037 | 0.824 | -0.027 | -0.591 | -0.032 | -0.912 |
| WAPCD | 0.0328 | 0.744 | -0.029 | -0.648 | -0.035 | -1.008 |

[1] Bold values indicate significant spatial autocorrelation ($p < 0.05$).

For playgrounds, all measurement methods resulted in significant ($p<0.05$) positive global spatial autocorrelation (Table 2.3). In all cases, though, the magnitude of spatial association is strongest using the WAPCD method, with both the PWMC and centroid approach under-reporting the extent of autocorrelation. The relative differences in the strength of autocorrelation between the measurement methods remain more or less consistent regardless of the contiguity matrix used. For neither the community halls nor the leisure centres does NSA show significant global spatial autocorrelation in any situation.

Global spatial autocorrelation measures assess the *general* spatial patterning of phenomena over a study area. These measures can mask important *local* spatial patterns in the data (Talen and Anselin, 1998). Anselin (1995) defines a LISA as any statistic that can be used to identify significant spatial patterns around an individual location, and to decompose measures of global spatial association based on the contribution of each individual observation to the strength of the global measure. Global measures of spatial autocorrelation, such as Moran's *I*, report a single value to indicate the degree of spatial clustering for an entire study area, whereas LISA provide a measure of the strength and type of spatial patterning around each individual location within the study area. This is particularly useful for assessments of spatial accessibility, because the aim of such analyses is not only to detect the *general* spatial pattern of accessibility within a city, but more usefully to identify *specific* areas within the city that display significant patterns of low or high accessibility.

To assess the degree to which aggregation error affects the local patterning of NSA, I used the local counterpart of Moran's *I*, mathematically defined as

$$I_i = z_i \sum_j w_{ij} z_j \text{ ,} \tag{4}$$

where $z_i$ and $z_j$ represent the variables in standardized form (mean = 0, standard deviation = 1), and the summation over $j$ pertains to all contiguous values of $i$ according to the spatial weights $w_{ij}$. The spatial weights for the calculation of all LISA were defined based on a row-standardized 2.0 kilometres distance-based matrix. Global spatial autocorrelation was not particularly sensitive to the variously defined distance-based matrices. As a result, the 2.0-kilometre cut-off criterion, representing a mid-point between the two extremes of 1.6 and 2.5 kilometres, was the only one used for the local spatial association analysis.

To assess the significance of the local Moran statistics, a conditional permutation approach was used [for a detailed review of this approach see Anselin (1995)]. Basically, this consists of assessing the 'extremeness' of the observed local Moran statistic by generating a number of random permutations (in this case 9 999) of the values of each observation's neighbouring values, and recalculating the local Moran statistic under each permutation. The local patterning around an observation would be considered significant at the 0.05 level, for example, if of the roughly 10 000 permutations, only 5% of the calculated statistics were more extreme than the observed local statistic. Because of potential problems associated with multiple comparisons and correlated tests, there is debate over what the appropriate significance level for LISA should be [for detailed discussions see Anselin (1995) and Ord and Getis (1995)]. I adopt the rationalization of Talen and Anselin (1998) and use a standard 0.05 significance level to detect significant local spatial patterning. My main tenet is that the various methods (i.e., centroid, PWMC, and WAPCD) of measuring NSA will result in different local spatial patterning. Choosing a non-stringent level of 0.05 increases the reporting of significant spatial clusters under all measurement methods, and hence increases the chance of finding similarities in spatial patterning among the methods.

The observed local Moran statistics can be used in conjunction with a Moran Scatterplot (see Appendix A) to identify the type of spatial clustering around each observation (Anselin, 1995; Anselin 1995a). For each observation with a significant local Moran value, it is possible to identify the nature of the spatial patterning around each observation. The Moran Scatterplot allows for the identification of four types of local spatial association. The first two types, which are indicative of positive spatial association (i.e., local clustering of like values), are (a) high values (above the mean) surrounded by high neighbouring values, and (b) low values (below the mean) surrounded by low neighbouring values. The remaining two types indicate spatial outliers, and are either a high value surrounded by low neighbouring values, or a low value surrounded by high neighbouring values (Talen and Anselin, 1998). The *Spacestat* extension for ArcView allows for the creation of LISA significance maps, which are maps indicating significant LISA as well as the type of spatial patterning around the significant observations (Anselin, 1999).

Figure 2.6 (see following page) shows neighbourhoods with significant local Moran statistics for distance to the nearest playground, as measured with the WAPCD (6a), PWMC (6b), and centroid (6c) methods. The legend terms, "high" and "low" refer to neighbourhood accessibility, and not to the original variable, distance to the nearest facility. As such, high accessibility values correspond to low distance measurements, and low accessibility levels indicate high distance measurements. The WAPCD approach identifies 36 neighbourhoods with significant Moran indicators; the PWMC and the centroid approach identify 18 and 23 neighbourhoods respectively. All three approaches identify a general cluster of low accessibility (i.e., low-low) neighbourhoods in the extreme northwest corner of the city. The WAPCD method identifies significant clusters of high accessibility in the west and central parts of Edmonton; the PWMC and centroid methods do not. Visual comparisons give a general idea of the differences in local spatial patterns; Table 2.4 shows more concisely how the PWMC and centroid methods deviate from the WAPCD standard for each type of spatial association. The method used to compare the (dis)similarities among the approaches involves the following process. Using the case of neighbourhoods that are clusters of low accessibility to playgrounds as an example, under all three approaches the low-low

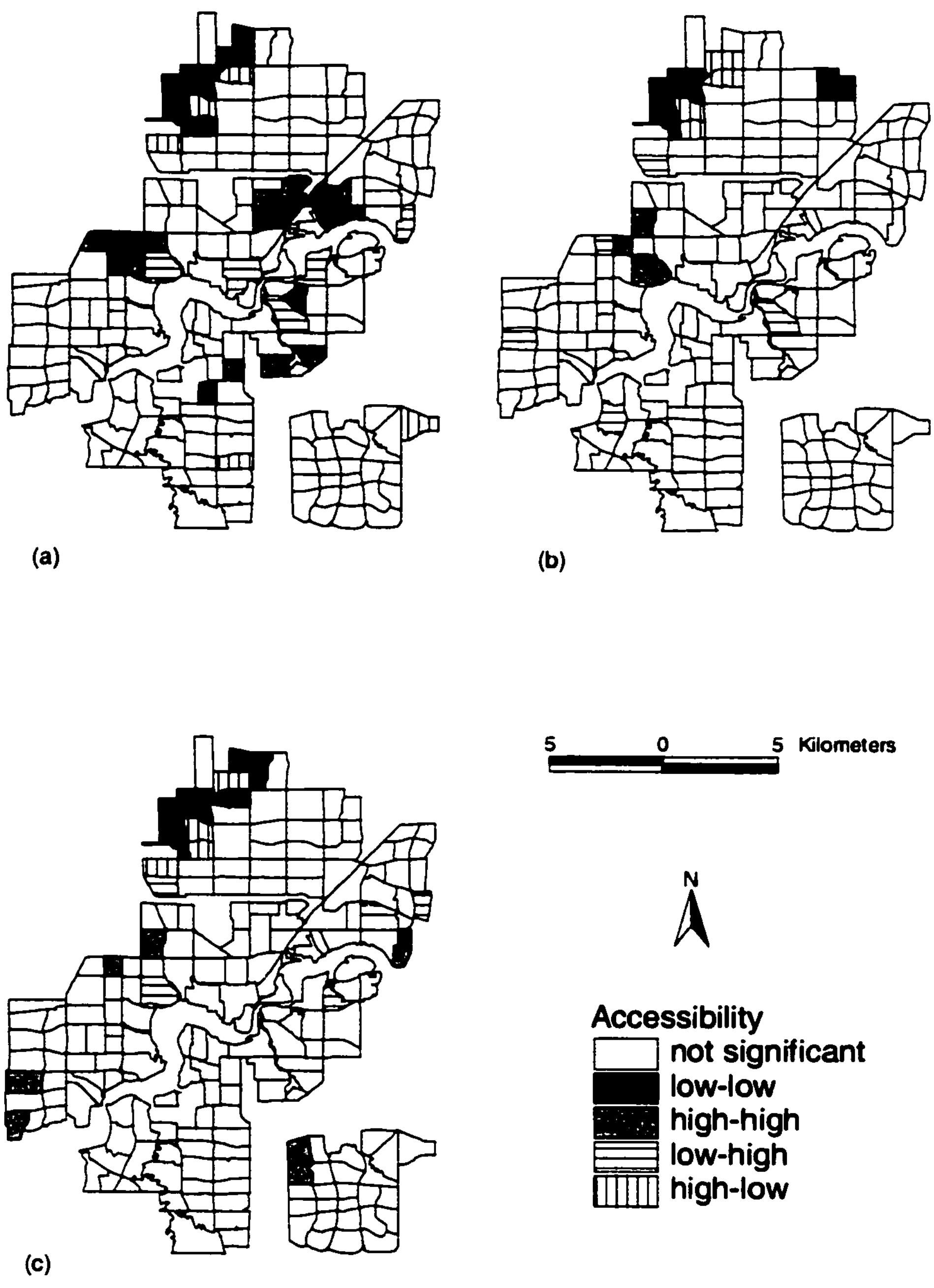


**Figure 2.6.** Playground Accessibility: LISA map for (a) WAPCD, (b) PWMC, and (c) Centroid method. Classification refers to accessibility, and not to the original variable, distance to the nearest facility (i.e., low accessibility corresponds to high distance to the nearest facility).

neighbourhoods are assigned a value of one, and all other neighbourhoods a zero. Because the WAPCD is our 'gold standard', the PWMC and centroid values are each individually subtracted from the WAPCD values. For instance, to determine the difference between the WAPCD and PWMC methods, neighbourhoods that were assigned a one under each method would receive a zero value upon subtraction. If a neighbourhood was assigned a zero using the WAPCD approach, but became a one under the PWMC method, a value of negative one would result from subtraction. After making all subtractions, the sum of the squared resultant values is used to assess which methods are best at approximating the same local spatial patterns as the WAPCD approach. The summed value can be interpreted as the number of times a particular method deviated from the WAPCD method. The deviations are of three types: an approach failed to detect a neighbourhood with a significant local Moran value, an approach produced a significant observation that was not indicated by the WAPCD method, or an approach produced a significant observation that differed in *type* of spatial association from that indicated using the WAPCD method.

**Table 2.4.** Differences in local spatial patterning compared to the WAPCD method.

| Type of Spatial | Playgrounds | | Community Halls | | Leisure Centres | |
|---|---|---|---|---|---|---|
| Association | Centroid | PWMC | Centroid | PWMC | Centroid | PWMC |
| Low-Low | 4 | 5 | 4 | 6 | 2 | 0 |
| High-High | 23 | 19 | 4 | 2 | 2 | 0 |
| Low-High | 9 | 9 | 2 | 0 | 1 | 0 |
| High-Low | 5 | 5 | 6 | 5 | 0 | 0 |

With the playgrounds, both the PWMC and centroid methods deviate from the WAPCD method for all types of local spatial association. Note, however, that similar values in the table do not necessarily mean that the deviations occurred at the same location – the maps (Figures 2.6a-c) are required to see where the deviations occur. The centroid and PWMC methods deviate the most when it comes to identifying local clusters of high accessibility. In no case was a high-high neighbourhood commonly identified under all three methods. The bulk of the difference in this category is due to the failure of the centroid and PWMC methods to detect the high accessibility cluster of neighbourhoods in the north-central part of the city. I suspect that this is attributable to Source C aggregation error (i.e., the allocation of postal codes to incorrect facilities under the centroid and PWMC approach). In this particular area of the city, there is a relatively high density of playgrounds (in many cases more than one playground per neighbourhood) and if the centroid or PWMC methods are used, the entire neighbourhood is assigned to the playground closest to that neighbourhood's single point. In these cases, the distances from both the PWMC and the centroid to the nearest playground under-estimate average accessibility, because many postal codes within a neighbourhood may actually be closer to playgrounds other than the one that is closest to the centroid or PWMC.

The number of deviations from the WAPCD method for other types of local spatial patterning was not as great as for the high-high pattern. The clusters of low accessibility did show a few differences; however, four neighbourhoods were commonly identified as clusters of low accessibility under all measurement methods. There was a slightly higher number (nine for both the PWMC and centroid method) of differences for the low-high pattern (low accessibility neighbourhood surrounded by high accessibility neighbourhoods) of local spatial association, and in no case was a neighbourhood commonly identified by the three measurement approaches as exhibiting low-high patterning. Finally, both the centroid and PWMC approaches yielded five differences in the high-low type of spatial patterning (high accessibility neighbourhoods surrounded by low accessibility neighbourhoods), and only one neighbourhood was commonly identified by all three approaches as having a high-low pattern.

The differences in patterns of local spatial association are less evident for NSA to community halls than they are for playgrounds (Figures 2.7a-c). In total, the WAPCD method identified 25 neighbourhoods with significant LISA, the PWMC 24, and the centroid 25. Despite the similarity in total number, there are some differences in the location of significant neighbourhoods, as well as the type of patterning around the neighbourhoods. The least number of differences are found in the low-high (low accessibility outliers) category, with the WAPCD approach producing only one significant observation with low-high patterning, the PWMC mimicking that result, and the centroid method failing to recognize the same observation, but identifying a different neighbourhood (refer back to Table 2.4). There are substantially fewer differences in the high accessibility clusters when compared to the playgrounds. For community halls, the centroid deviated four times and the PWMC twice, with three neighbourhoods commonly identified under each method as clusters of high accessibility. I suspect that, for community halls, there are fewer differences for this type of spatial association because the likelihood of Source C error is reduced. Community halls are more dispersed and fewer in number than playgrounds, and therefore it is less

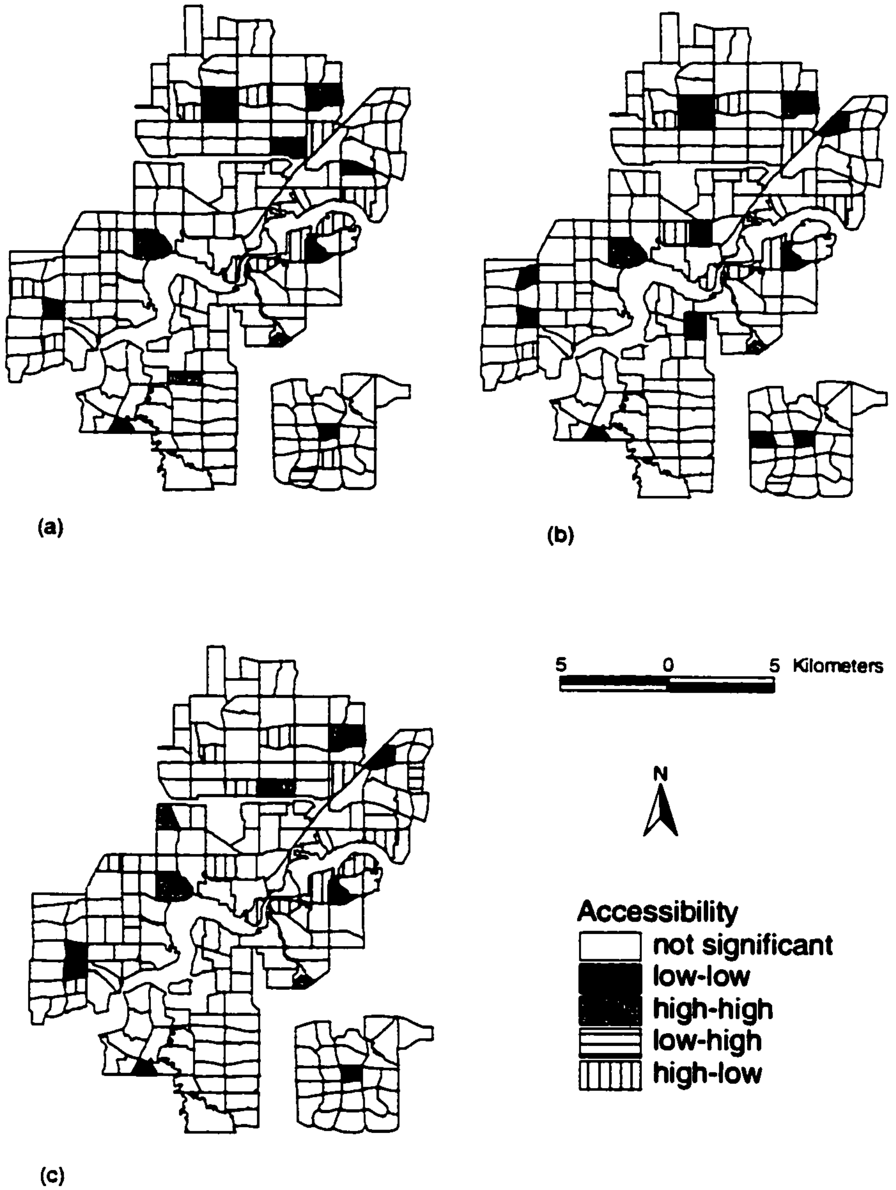


**Figure 2.7.** Community Hall Accessibility: LISA map for (a) WAPCD, (b) PWMC, and (c) Centroid method. Classification refers to accessibility, and not to the original variable, distance to the nearest facility (i.e., low accessibility corresponds to high distance to the nearest facility).

likely that postal codes within a given neighbourhood will be closer to halls other than the hall identified as being closest to the centroid or PWMC of the neighbourhood. There were some differences for the low accessibility cluster and low accessibility outlier patterns; however, five neighbourhoods were commonly identified as low accessibility clusters and eight neighbourhoods were commonly identified as low outliers. Overall, aggregation error appears to be less problematic for measuring NSA to community halls.

The local spatial patterning of NSA to leisure centres exhibits even fewer differences among the three measurement techniques (Figures 2.8a-c). The PWMC approach yielded identical patterns of local spatial association to the WAPCD approach, resulting in the same 18 significant observations. The centroid approach resulted in 23 significant observations, with a small number of differences arising in the high-high, low-low, and low-high categories. The few differences between the centroid and WAPCD approach, and the lack of difference between the PWMC and WAPCD approach, suggest that aggregation error has little effect on the measurement of NSA to leisure centres.

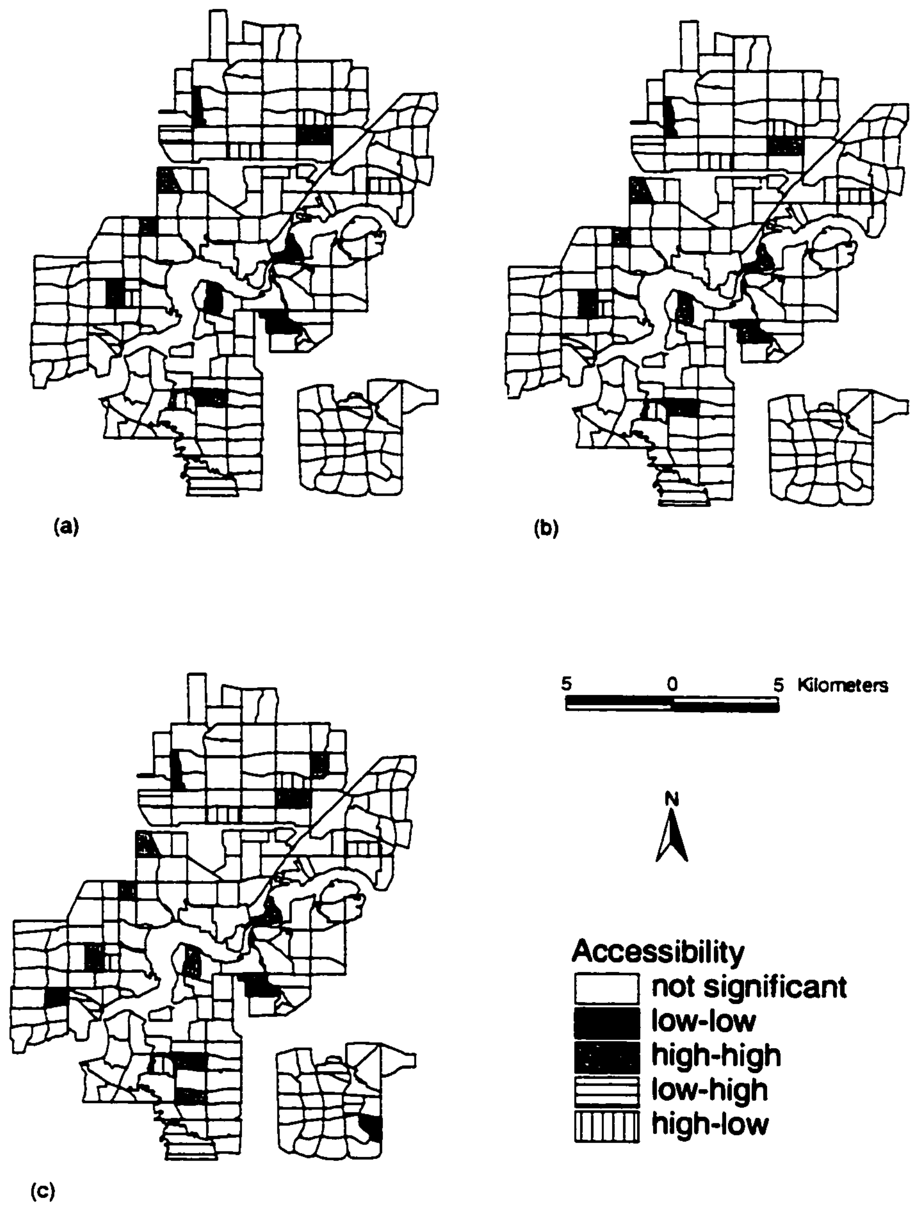


**Figure 2.8.** Leisure Centre Accessibility: LISA map for (a) WAPCD, (b) PWMC, and (c) Centroid method. Classification refers to accessibility, and not to the original variable, distance to the nearest facility (i.e., low accessibility corresponds to high distance to the nearest facility).

## 2.5 Conclusions

The preceding analysis indicates that aggregation error does affect NSA measurements; however, the magnitude of the effect is dependent on the type of facility under investigation. Both the correlation and spatial analyses indicate that aggregation error alters the ranking, as well as the local spatial patterning, of NSA to playgrounds. The effect of aggregation error on NSA to community halls is substantially less than for playgrounds, and is essentially non-existent for NSA to leisure centres. These differences are likely a product of the characteristics (in terms of number, spatial dispersion, and size of service area) of the facilities I have chosen for the analysis. Playgrounds are abundant (n = 301), located in close proximity to each other, and have highly localized service areas. This increases the probability of Source B (self-distance) and Source C (misallocation of postal codes) aggregation error occurring when the traditional centroid method is used to approximate the 'average' accessibility of a residential unit. The PWMC approach did not fare much better at approximating the ranks and spatial patterns obtained using the WAPCD method. This is not surprising, because the PWMC still involves using a single point, although weighted by population, to represent a neighbourhood. Leisure centres (n = 19), on the other hand, are spatially dispersed throughout the city and have large service areas. This drastically decreases the chance of Source B error, because for most neighbourhoods, residents will have to travel outside of their neighbourhood to reach a leisure centre. Also, Source C error is less likely to occur, as residents of the same neighbourhood are less likely to be allocated to different centres. If aggregation error were to occur, the bulk of it would have to be Source A error (misestimation of distance to a facility outside of a neighbourhood). In my case, though, Source A error has had little, if any, impact on NSA to leisure centres. This suggests that when facilities are few in number and dispersed throughout a city, the centroid approach is a good approximation of average NSA. Finally, community halls (n = 132) fall between playgrounds and leisure centres in terms of number, spatial dispersion, and size of service area. Accordingly, the effect of aggregation error was less than NSA to playgrounds, but greater than the effect for NSA to leisure centres.

My findings indicate that aggregation error should be considered in cases where neighbourhood (or any other highly aggregated unit) accessibility is being measured to facility types that are typically high in number, close to each other, and have highly localized service areas. Examples of such facility types include playgrounds, neighbourhood parks, or any other facility or amenity that typically serves the needs of proximate residents. It should be noted, however, that there is a substantial trade-off between the efficiency of the analysis (in terms of computing time, data preparation, etc.) and the improvement of the approximation of NSA. Of the three approaches, the WAPCD method was the most labour intensive, in terms of having to prepare the postal code data, and calculate distance to the nearest facility for 18 396 origin points. The PWMC approach still required preparation of the postal code data, however, after calculating the PWMC of each neighbourhood, only 200 (i.e., the number of neighbourhoods) distance calculations were required. The centroid method was the least labour intensive, as no postal code data were included, and only 200 distance calculations were necessary.

If the aim of the research is to measure NSA to more dispersed facilities (such as leisure centres), then aggregation error may not be as much of a concern. It is crucial to note, though, that problems related to Source B error could still arise in situations where the location of a facility of this type coincides with an areal unit's centroid (although in my study this was not the case). In such situations, it may be beneficial to incorporate finer resolution units (such as postal codes in Canada, or census blocks in the United States), as opposed to using alternative estimation procedures, such as those listed in section 2.3.3.

The widespread use of GIS has facilitated the ability of researchers in a variety of fields to use spatial accessibility indicators to inform urban policy issues. Such issues include assessing spatial equity and identifying areas in need of greater amenity provision. My analysis has demonstrated that for some types of facilities, aggregation error can alter the ranking and spatial patterning of NSA, thereby creating the potential for making policy recommendations based on erroneous results. In situations where the preferred or required unit of analysis is large, I recommend investigating potential aggregation error problems by incorporating finer resolution units. While doing so will result in a substantial increase in the amount of time required for the analysis, I feel that this trade-off is warranted in light of the potential implications that accessibility-based research has for urban policy issues.

## 2.6 References

Anselin L, 1995, "Local indicators of spatial association – LISA" *Geographical Analysis* **27** 93-115

Anselin L, 1995a, *Spacestat Version 1.80 User's Guide* Regional Research

Institute, West Virginia University, Morgantown, WV

Anselin L, 1998, *Spacestat Version 1.90: A Program for the Analysis of Spatial Data*. Distributed by BioMedware, Inc.

Anselin L, 1999, *Spatial Data Analysis with Spacestat and ArcView Workbook 3rd Edition* Department of Agriculture and Consumer Economics, University of Illinois, Urbana, IL

Cervero R, Rood T, Appleyard B, 1999, "Tracking accessibility: employment and housing opportunities in the San Francisco Bay Area" *Environment and Planning A* **31** 1259-1278

City of Edmonton Community Services, 1998, *The Neighbourhood Park Development Program: Creating Special Places for Neighbourhood Play and Wellness 1997 – 2006* City of Edmonton, Edmonton, AB

Current J R, Schilling D A, 1987, "Elimination of Source A and B errors in *p*-median location problems" *Geographical Analysis* **19** 95-110

Dalvi M Q, Martin K M, 1976, "The measurement of accessibility: some preliminary results" *Transportation* **5** 17-42

Frost M E, Spence N A, 1995, "The rediscovery of accessibility and economic potential: the critical issue of self-potential" *Environment and Planning A* **27** 1833-1848

Geertman S C M, Ritsema Van Eck J R, 1995, "GIS and models of accessibility potential: an application in planning" *International Journal of Geographical Information Systems* **9** 67-80

Handy S L, Niemeier D A, 1997, "Measuring accessibility: an exploration of issues and alternatives" *Environment and Planning A* **29** 1175-1194

Hillsman E L, Rhoda R, 1978, "Errors in measuring distances from populations to service centres" *Annals of Regional Science* **12** 74-88

Hodgson M J, Shmulevitz F, Körkel M, 1997, "Aggregation error effects on the discrete-space *p*-median model: the case of Edmonton, Canada" *The Canadian Geographer* **41** 415-428

Knox P L, 1978, "The intraurban ecology of primary medical care: patterns of accessibility and their policy implications" *Environment and Planning A* **10** 415-435

Knox P L, 1980, "Measures of accessibility as social indicators: a note" *Social Indicators Research* **7** 367-377

Koenig J G, 1980, "Indicators of urban accessibility: theory and application" *Transportation* **9** 145-172

Ord J K, Getis A, 1995, "Local spatial autocorrelation statistics: distributional issues and applications" *Geographical Analysis* **27** 386-306

Ottensmann J R, 1994, "Evaluating equity in service delivery in library branches" *Journal of Urban Affairs* **16** 109-123

Pacione M, 1989, "Access to urban services – the case of secondary schools in Glasgow" *Scottish Geographical Magazine* **105** 12-18

Statistics Canada, 1997, *Postal Code Counts User's Guide: Population and Dwelling Counts* Catalogue No. 92F0086XCB

Statistics Canada, 1999, *Postal Code Conversion File October 1999 Postal Codes: Reference Guide* Catalogue No. 92F0027XDB

Talen E, 1997, "The social equity of urban service distribution: an exploration of park access in Pueblo, Colorado, and Macon, Georgia" *Urban Geography* **18** 521-541

Talen E, 1998, "Visualizing fairness: equity maps for planners" *Journal of the American Planning Association* **64** 22-39

Talen E Anselin, L, 1998, "Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds" *Environment and Planning A* **30** 595-613

Truelove M, 1993, "Measurement of spatial equity" *Environment and Planning C* **11** 19-34

Truelove M, 2000, "Services for immigrant women: an evaluation of locations" *The Canadian Geographer* **44** 135-151

# CHAPTER 3

# Spatial Equity: Playground Location and Quality in Edmonton

## 3.1 Introduction

The spatial distribution of public amenities within cities has been a central focus in much geographical research. While past studies have varied in context, methodological approach, and the amenity of interest, a common task has been to address spatial equity within the urban environment (Knox 1978; Pacione 1989; Truelove 1993; Talen 1997). Research of this nature typically asks, does the spatial distribution of a particular amenity correspond to the geographical variation of 'need' for that amenity, or more generally do *socially* disadvantaged populations live in *spatially* disadvantaged areas? Asking these types of questions not only contributes to geographers' understanding of equity issues within cities, but also allows policymakers (e.g., agencies responsible for amenity provision) to assess the effectiveness of existing amenity provision policies and identify areas of under-provision, thereby potentially resulting in improved amenity and service delivery.

This paper draws upon some of the ideas and methods commonly used in spatial equity research and applies them to the case of public playgrounds in Edmonton, Canada. Specifically, the aim is to assess patterns of neighbourhood spatial accessibility (NSA) to playgrounds in relation to underlying neighbourhood population characteristics. In doing so, the analysis provides a general, preliminary evaluation of the Neighbourhood Park Development Program (NPDP), the program under which neighbourhood parks and playgrounds are developed in Edmonton. The program will be evaluated according to how well it promotes equity and addresses community-based need, two of the principles outlined in the city's Integrated Service Strategy, a long-term plan set out by the city's newly developed Community Services Department (City of Edmonton, 2000). The programs will be assessed through a spatial analytical framework, similar to recent U.S.-based work by Talen (1997) and Talen and Anselin (1998). This approach includes the use of Geographic Information Systems (GIS) in combination with some basic exploratory spatial data analysis (ESDA) methods. The results will not only be of direct use to the city of Edmonton for planning purposes, but will also allow for a comparison of spatial equity and recreational amenity location within a Canadian urban context, versus that within U.S. cities.

The next two sections provide a more explicit discussion of the concepts of spatial equity and NSA, while reviewing previous spatial equity research that is most relevant to this study. This will be followed by a general overview of public playground provision in Edmonton, including the NPDP, and how it fits in with the overall mandate of the city's Community Services Integrated Service Strategy. NSA to playgrounds will then be examined in relation to the underlying population and socioeconomic structure of neighbourhoods. Spatial equity will also be considered in terms of differences in *quality* of playgrounds throughout the city, an aspect of playgrounds that has not been explicitly addressed in previous research. Finally, I will discuss the implications of the results for playground provision and equity in Edmonton, while making suggestions for policy and future equity research.

## 3.2 Defining and Measuring Neighbourhood Spatial Accessibility

Spatial accessibility to amenities generally refers to the ease with which amenities can be reached, as well as the quality, quantity, and type of activities offered by the amenities (Handy and Niemeier, 1997). NSA to playgrounds, then, refers to the ease with which residents can reach playgrounds, in addition to some aspect of the quality of the reachable playgrounds. Measuring accessibility to amenities at the neighbourhood (or other similarly aggregated units) level allows for a *general* portrait of accessibility patterns within cities. Such measures have been used to measure accessibility to primary health care facilities (Knox, 1978), secondary schools (Pacione, 1989), public parks (Talen, 1997), and immigrant services (Truelove 2000), in each case allowing for an assessment of spatial equity, the identification of 'under-serviced' areas, and recommendations for planning policy.

Accessibility measures have been used extensively in past research, however, the *type* of accessibility measure used has varied among studies. I will briefly outline some of the more commonly used measures, as noted in Talen and Anselin (1998). The *container* approach is a summation of the number of amenities within a neighbourhood – it is positively related to accessibility. The remaining indices treat the distance that neighbourhood residents have to travel to reach amenities as a key component of accessibility. The *minimum distance* method is simply the distance that neighbourhood residents have to travel to reach the closest amenity of interest – it is inversely related to accessibility. The *travel cost* method measures the distance that neighbourhood residents have to travel to reach all facilities in the study area. This measure can be expressed as a summation or an average, and is also inversely related to accessibility.

The *gravity potential* approach is usually the sum of, for all facilities, some function of facility attractiveness mitigated by distance – it is positively related to accessibility. Finally, the *coverage* model has also been used extensively in accessibility and equity research. This method sums up the total number (or amount) of amenities within a specified radius around neighbourhood residents. The more opportunities available within the distance threshold, the greater is the accessibility.

Talen and Anselin (1998) demonstrate that using different accessibility measures can produce markedly different spatial patterns of accessibility: the choice of the type of indicator to be used is critical and should be made based on the purpose of the study. I have chosen to measure accessibility using two approaches, the minimum distance and coverage methods. Playgrounds are typically highly localized facilities with small service areas. Assuming that individuals are likely to visit the closest playground, then the minimum distance method is an appropriate measure of accessibility (Talen and Anselin, 1998). This method, however, assigns individuals to the single closest facility, when in some areas residents may have a multitude of playgrounds within a reasonable distance. The coverage model accounts for this issue, and is therefore also included in the analysis. I use a distance threshold of half of a mile (roughly 805 metres), which corresponds to Edmonton's specification of the maximum distance residents should have to travel to reach a neighbourhood park (City of Edmonton Community Services, 1998).

Another methodological issue in spatial accessibility research is the choice of the *type* (e.g., Euclidean, Manhattan, or shortest network paths) of distance measurement. The most commonly used types of distance measures in accessibility research are shortest network paths (Ottensmann, 1994; Talen, 1997; Talen and Anselin, 1998; Cervero et al., 1999) and to a lesser extent Euclidean (straight-line) distance (Truelove, 1993; Truelove, 2000). The type of measurement used can alter assessments of spatial accessibility (Nicholls, 1999). Travel to playgrounds is likely on foot, over shorter distance using a combination of network-based travel (sidewalks) and 'short-cuts' or walking trails, which are not always available on digital representations of street networks. I feel, therefore, that travel to playgrounds may be reasonably typified by Euclidean distance.

### 3.3 Defining and Measuring Spatial Equity

Equity is a complex concept, and when applied in a spatial context, can be variously defined and measured (for a review see Hay, 1995). Facilities are necessarily located as discrete entities, whereas the populations who they serve are spatially continuous, thereby inevitably resulting in some inequality in accessibility (Dear, 1974). In other words, regardless of where amenities are located, there will always be some persons who are closer to them than others. As noted by Knox, "The crucial question to ask of planned or established facility location patterns is, therefore, *how much* inequality is produced, and *which groups* are most disadvantaged?" (1978:414).

The idea of spatial equity arises when spatial inequalities are considered in terms of need, justice, and fairness (Talen and Anselin, 1998). Of course, the determination of what is just, fair, or equitable varies, and is often based on underlying value systems (Truelove, 1993). The purpose of this article is not to explore or debate the concept of equity; rather I adopt a definition (and hence criteria for the evaluation) of equity that has been frequently used in relation to the distribution of public amenities and services.

Lucy (1981) originally noted the idea of service or amenity provision equal to need. In this respect, resources are distributed equitably if the distribution is based on population characteristics, such as poverty. 'Needs-based' criteria have been used in a number of instances to evaluate the equity of amenity location (Truelove, 1993; Talen, 1997; Talen, 1998; Talen and Anselin, 1998).

With respect to playgrounds in Edmonton, spatial equity (from the needs-based perspective) implies that neighbourhoods with higher levels of need should have better accessibility to playgrounds. A variety of neighbourhood demographic and socioeconomic indicators, obtained from the 1999 Edmonton civic census, were used to estimate the level of need for playgrounds in Edmonton. The selection of indicators is based on variables that have been used as surrogates for need in previous spatial equity research, as well as neighbourhood characteristics that I hypothesize to be relevant in determining the level of need for playgrounds in Edmonton. Playgrounds are designed specifically as play spaces for children; the percentage of children living in each neighbourhood is an important determinant of need. Playgrounds are intended to serve children under twelve years old (City of Edmonton Community Services, 2000). I chose to use the percentage of children under fourteen years of age to approximate the intended age group, as this is the closest age bracket reported by the Edmonton census.

The percentage of children is undoubtedly a key factor in determining neighbourhood need for playgrounds. However, several socioeconomic factors are also likely to contribute to need in a neighbourhood, and therefore play an important role in the assessment of spatial equity. To identify neighbourhoods with a high level of social need (i.e., *socially* disadvantaged neighbourhoods), I included the following neighbourhood-level variables: low income, households without an automobile, attached households (apartments, row houses, etc.), and people who have lived less than five years at their current address, all expressed in percentages. Low income was used to identify populations that may be less able to afford private recreational activities (e.g., club sports, private fitness programs, etc.), and therefore have a greater need for no-cost recreational facilities, like playgrounds. Low-income levels were based on Statistics Canada's (2001) before tax low-income cutoffs for urban areas with 500 000 people and over for 1999. The 1999 Edmonton Civic Census reports cross tabulations of household size by household income. The cross tabulations were used in tandem with the low-income cutoffs to construct the percentage of low-income households per neighbourhood. Because Edmonton income data were reported in $10 000 brackets, I chose to round Statistics Canada low-income cutoffs to the nearest bracket boundary (Table 3.1).

**Table 3.1** 1999 Before Tax Low Income Cutoffs Used for Percentage Low Income Households Calculation

| Household Size | Statistics Canada Low-income Cutoffs[1] | Rounded to Nearest $10 000 |
|---|---|---|
| 1 | 17 886 | 20 000 |
| 2 | 22 357 | 20 000 |
| 3 | 27 805 | 30 000 |
| 4 | 33 658 | 30 000 |
| 5 | 37 624 | 40 000 |
| 6 | 41 590 | 40 000 |
| 7 or more | 45 556 | 50 000 |

[1] Source: Statistics Canada, 2001, *Low Income Cutoffs from 1990 to 1999 and Low Income Measures from 1989 to 1998* Catalogue No. 75F0002MIE – 00017

Households that do not have access to a vehicle represent populations that have poorer mobility, and may be less able to overcome distance barriers with respect to traveling to recreational opportunities. Having playgrounds closely located to these populations is crucial. The percentage of attached households was considered to contribute to playground need, as these types of residences typically have less available private space (i.e., backyards) for recreational activities. Areas with a high percentage of attached dwellings, therefore, require a higher provision of public play spaces. Finally, the percentage of people who have lived at their current residence for less than five years was included as a crude estimate of neighbourhood stability. Public recreational spaces, such as playgrounds, provide settings for social interaction among neighbourhood residents, thereby creating the potential for the building of community cohesion, and hence neighbourhood stability. It can be argued that neighbourhoods with higher percentages of transient population have a greater need for social interaction-increasing facilities, such as playgrounds.

Spatial equity will be assessed in terms of the relationship between neighbourhood need and neighbourhood accessibility to playgrounds. Evidence of equity would be provided if, for example, neighbourhoods with high need (socially disadvantaged) had better access (spatially advantaged) to playgrounds. Several univariate and bivariate exploratory measures will be used to examine the relationship between need and accessibility, which can be used to inform policy for playground provision in Edmonton.

### 3.4 Public Playground Provision in Edmonton

The NPDP is the mechanism through which the City of Edmonton, in coordination with community and neighbourhood-based groups, allocates neighbourhood based parks and playgrounds. The purpose of this section is to provide a general overview of some of the key features of the NPDP, as outlined by the City of

Edmonton's Community Services Department (1998). The current program (1997 – 2006) is an extension of the original NPDP, which originated in 1983 and was approved for extension by City Council in 1996. Essentially, the program advocates a cost-sharing partnership between the Community Services department and neighbourhood/community groups for the development of neighbourhood parks and playgrounds in Edmonton. If neighbourhood residents decide that they would like to create or redevelop a neighbourhood park or playground space, they can apply for Community Services' assistance via Phase 1 NPDP funding. Through Phase 1 NPDP, the city will match funds raised by the neighbourhood, with the city providing a maximum of $70 000 per neighbourhood. The city's funding, therefore, never exceeds 50% of the total park or playground (re)development costs. The average NPDP playground costs roughly $ 125 000 to build (City of Edmonton Community Services, 2000a), in which case neighbourhood residents would have to provide $62 500, and the city would then provide the remainder. Activities that are eligible for Phase 1 NPDP include the development of playgrounds, park pathways and entrances, landscaping, and various other park amenities (e.g., gazebos). Once Phase 1 funding has been utilized, the neighbourhood can apply for Phase 2 NPDP, in which the city provides up to 50% of project costs to a maximum of $30 000 per neighbourhood. Phase 2 NPDP funding is primarily intended for upgrading or replacing existing play structures while maintaining the basic elements of the playground. Both Phase 1 and 2 NPDP funding are available only once per neighbourhood throughout the duration of the NPDP program (1997-2006).

The NPDP includes another funding program, the Conservation and Rehabilitation Program, which does not involve cost sharing with neighbourhoods. The purpose of this program is to provide funds for repairing and/or upgrading playground equipment that is in need of immediate repair and presents a safety hazard to playground users. The funding is administered on a per play site basis, and consists of a maximum of $15 000. One component of the NPDP program is the maintenance of a playground inventory, in which a variety of playground characteristics, including condition of the equipment, are collected and routinely reviewed. Playground equipment condition is assessed by qualified safety inspectors, and is classified as good, fair, or poor; playgrounds with fair or poor equipment are targeted for the Conservation and Rehabilitation Program (City of Edmonton Community Services, 1998).

The cost-sharing aspects of the NPDP program provide the opportunity for community involvement in the park and playground planning process. Such involvement is vital for many reasons, including allowing communities to dictate planning initiatives in their neighbourhoods, as well as providing a mechanism for residents to interact, and hence build community cohesion. One potential concern with cost-sharing programs, however, is that some communities/neighbourhoods may have a greater capacity than others for generating the resources required for playground development. Because the city only matches (not exceeds) the funds raised through the neighbourhood/community, it is possible that neighbourhoods raising lower amounts of money may end up with inferior playgrounds. This can potentially result in inequity in terms of playground number and quality throughout the city. In addition, if certain types of neighbourhoods have problems generating enough revenue to apply for either Phase 1 or 2 of the NDPD, then it is likely that the playgrounds in those neighbourhoods will be maintained through the Conservation and Rehabilitation Program. While the program is critical to ensure that playgrounds meet basic safety standards, it may result in inferior playgrounds, as the cap on funding for any one playground is substantially less than the amounts available through Phase 1 and 2 NPDP.

It is the aim of this paper to examine whether the NPDP results in an equitable distribution, in terms of quantity and quality, of playgrounds. The first assessment involves measuring NSA to playgrounds, without consideration of differences in playground quality. Then the analysis is limited to include only playgrounds that the city has classified as being in good condition. This allows for an examination of whether the patterns of accessibility to *good* playgrounds differ from accessibility patterns to all playgrounds, and if the differences in pattern are greater in some parts of the city than others. By comparing NSA patterns with underlying population characteristics, I provide a preliminary assessment of whether the NPDP promotes spatial equity, with respect to playgrounds, in Edmonton.

**3.5 Data**

Edmonton's municipal boundaries contain just over 647 000 people and roughly 663 $km^2$ of land, divided into 299 neighbourhoods (City of Edmonton, 1999). Of these neighbourhoods, 198[1] were identified as primarily urban-residential and were therefore included in the analysis (Figure 3.1). Industrial/commercial neighbourhoods were not

[1] This number differs slightly from Chapter 2. Three of the neighbourhoods (Canadian Forces Base Griesbach, Clareview Campus, and the University of Alberta) that were used in Chapter 2 were excluded in this analysis due to insufficient census data. Also, because of the integration of more recent postal code population data, two neighbourhoods (Wedgewood Heights and Wild Rose) that were not present in Chapter 2 are included in this chapter.

included because they lack residential land use; mobile-home parks and rural-residential areas were excluded because of inconsistencies in the locational accuracy of postal code data in such areas (the use of postal codes will be discussed in the Methods section). The neighbourhood boundaries were digitized based on the City of Edmonton 2000 Wards and Standard Neighbourhoods map.

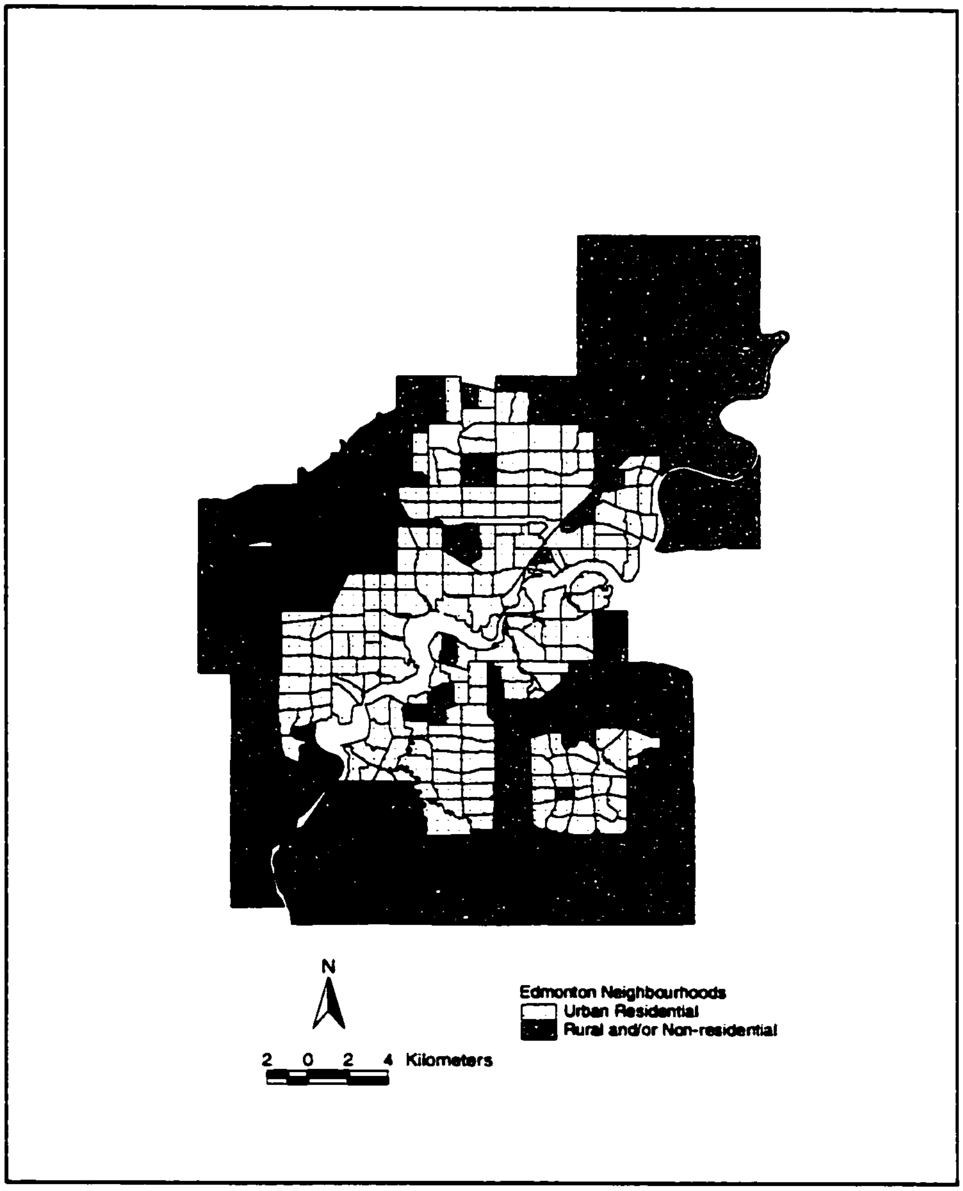


**Figure 3.1** Edmonton neighbourhoods classified by type.

Information on the demographic and socioeconomic character of each neighbourhood was obtained from the 1999 Edmonton civic census. All variables collected through the civic census are based on a 100% sample of the population. This is advantageous compared to the Census of Canada, in which several socioeconomic variables (e.g., income) are based on a 20% sample of the population (Statistics Canada, 1999). Further, the civic census data are disseminated at the neighbourhood level. The neighbourhood is the ideal unit of analysis for this study, as public playgrounds, via the NPDP, are allocated on a neighbourhood basis.

Edmonton's Community Services department provided the approximate street addresses of all publicly funded playgrounds in the city. I identified 312 playgrounds, of which 11 were eliminated from the analysis because they are located in the city's river valley. Playgrounds in the river valley, an essentially non-residential area that spans the city from east to west, are subject to different funding programs than those within Edmonton neighbourhoods, and hence are located based on a different set of criteria (City of Edmonton Community Services, 1998). Included in the playground data file were data on the year that the play site was constructed, the program under which each playground was funded, and the condition (good, fair, or poor) of the equipment at each site.

## 3.6. Methods

### *3.6.1 Measuring Neighbourhood Spatial Accessibility*

The primary task was to calculate spatial accessibility to playgrounds for each neighbourhood in the study area. All mapping and distance calculations were performed using ESRI's ArcView 3.2 GIS. As previously noted, two criteria (minimum distance and coverage) were used to measure accessibility. The minimum distance approach asks, on average how far do residents (or more specifically, children) of a particular neighbourhood have to travel to reach the closest playground? On the other hand, the coverage approach asks, on average, how many playgrounds do neighbourhood residents have within a 0.5-mile radius of their residence? The usual method of measuring distance from a neighbourhood to a facility involves locating the neighbourhood's centroid (i.e., unweighted geometric centre), and using the distance between the centroid and the facility to typify the average distance that residents of that neighbourhood must travel to reach the facility (e.g., Pacione, 1989; Talen, 1998; Truelove, 2000). It is likely that there is considerable spatial variation in the location of individuals within highly aggregated units, such as neighbourhoods; as a result the centroid approach can produce considerable aggregation error. Aggregation error is the error associated with representing an areal unit, which in turn represents spatially distributed individuals, by a single point (Hodgson et al., 1997). As indicated in Chapter 2, the potential for error in distance measurements is particularly high when measuring NSA to highly-localized, small service area amenities, such as playgrounds.

To get a better approximation of the spatial distribution of children within each neighbourhood (and therefore reduce aggregation error problems) I obtained counts of the number of children 0 – 14 years old per residential postal code in 1999 from Alberta Health. Within most major Canadian cities, postal codes roughly correspond to the size of a city block (Statistics Canada, 1999a). In Edmonton, for example, there is an average of 7 children per residential postal code. Small amounts of aggregation error exist within postal code areas, but because they are the least aggregate data available, they offer the best approximation of the spatial distribution of children within neighbourhoods. The postal code demographic data were linked to a postal code conversion file (available through Statistics Canada), which contains the latitude and longitude co-ordinates of all Canadian postal code centroids. In total, I identified 18 761 residential postal codes with total population counts of at least one person within Edmonton.

In cases where Statistics Canada was unable to precisely locate the co-ordinates of particular postal codes, the postal codes were assigned to the centroid of their enumeration area (EA), a census unit that falls between the postal code and census tract in size. Of the 18 761 postal codes, 962 (5.1 %) were assigned the EA co-ordinates instead of the more precise postal code co-ordinates. To rectify this problem, I used the 1999 Select Phone CD-ROM Canadian Edition address and telephone directory, which contains the corresponding address ranges of all Canadian postal codes. In most cases, any given postal code corresponds to a sequential series of addresses along a city block. After extracting the improperly located postal codes from Statistics Canada, the CD-ROM was queried to obtain the address ranges of these postal codes. After retrieving the address ranges, the erroneous postal codes were relocated to the midpoint of their corresponding address range. I was able to correct 702 of the 962 of the improperly located postal codes, leaving only 260 (roughly 1%) of the original 18 761 postal codes assigned to their EA centroids. I trust that the effects on the analysis of some less accurately located postal codes are minimal.

Instead of using neighbourhood centroids to make distance calculations from neighbourhoods to facilities, I use the weighted average postal code distance (WAPCD) for each neighbourhood. For the minimum distance criterion, this involves calculating the distance from each postal code to the nearest playground, and then taking the child population-weighted average of the postal code distances for each neighbourhood. The coverage method consists of the following process: (a) creating a 0.5-mile buffer around each postal code, (b) summing the number of playgrounds within each postal code's buffer zone, c) and then taking the child population weighted average of (b) for each neighbourhood. While integrating postal codes is considerably more time intensive, in terms of extra data preparation and analysis, than using traditional centroid methods, the postal code approach results in a more accurate assessment of 'average' accessibility to playgrounds for each neighbourhood (see Chapter 2).

Spatial accessibility was first measured without reference to playground quality, and therefore all 301 playgrounds were included in the analysis. As a means of addressing one aspect of differences in playground quality, the accessibility measures were then calculated while considering only good condition playgrounds (n = 201). In total, four accessibility measures per neighbourhood were calculated: minimum distance (all playgrounds), minimum distance (good playgrounds), coverage (all playgrounds), and finally coverage (good playgrounds).

*3.6.2 Assessing Spatial Equity*

I seek to assess whether there is an association between neighbourhood need and accessibility. Two exploratory methods are used to assess this relationship. Spearman Rank correlation coefficients are calculated between the need indicators and accessibility measurements. Dalvi and Martin (1976) noted that when examining accessibility for residential zones, interest typically lies in a given zone's accessibility *relative* to other zones in the study area, rather than its *absolute* accessibility level. Spearman Rank coefficients allow for an assessment of the association between relative need and relative accessibility.

The second technique used to explore the association between need and accessibility is local spatial autocorrelation. *Spacestat Version 1.90* (Anselin 1998), a software package designed for the analysis of spatial data, was used to assess local spatial autocorrelation. Local indicators of spatial association (LISA) are defined as any statistic that can be used to identify significant spatial patterning around individual locations, and to decompose measures of global spatial association based on the contribution of each individual observation to the strength of the global measure (Anselin, 1995a). When used in equity analyses, interest lies in examining whether there is overlap between significant local patterns of accessibility, and significant local patterns of need (Talen 1997; Talen and Anselin 1998). As a means of identifying significant local spatial patterns, I used local Moran's *I*, defined as:

$$I_i = z_i \sum_j w_{ij} z_j \ ,$$

where $z_i$ and $z_j$ represent the variables in standardized form (mean = 0, standard deviation = 1), and the summation over $j$ pertains to all contiguous values of $i$ according to the spatial weights $w_{ij}$. Spatial weights matrices can be based on a variety of criteria, such as adjacency or distance thresholds. Edmonton's spatial structure makes some urban-residential neighbourhoods into 'islands' – residential areas bordered oniy by non-residential neighbours. I was thus obliged to use distance-based contiguity to define each neighbourhood's set of spatial neighbours. A distance cut-off of 1.6 kilometres was selected, which was the minimum distance allowable to ensure that each observation had at least one spatial neighbour. This corresponds to the furthest first-nearest neighbour criterion for establishing contiguity (Getis and Ord, 1992). Neighbourhoods that are within 1.6 km of a particular observation are considered as contiguous with that observation, and are therefore included in the LISA statistic for that observation.

Local Moran statistics were calculated separately for need and accessibility. To assess the significance of the local Moran statistics, a conditional permutation approach was used [for a detailed review of this approach see Anselin (1995a)]. Basically, this consists of assessing the 'extremeness' of the observed local Moran statistic by generating a number of random permutations (in this case 9 999) of the values of each observation's neighbouring values, and recalculating the local Moran statistic under each permutation. The local patterning around an observation would be considered significant at the 0.05 level, for example, if of the roughly 10 000 permutations, only 5% of the calculated statistics were more extreme than the observed local statistic. There is debate within the literature as to whether LISA significance levels should be adjusted to compensate for potential problems associated with multiple comparisons and correlated tests [for detailed discussions see Anselin (1995a); Ord and Getis (1995)]. I adopt a traditional unadjusted 0.05 significance level, which has been commonly used to assess LISA significance in a variety of spatial analyses (Barkley et al. 1995; Mencken and Barnett 1999; Messner et al. 1999; Talen and Anselin 1998).

The local Moran statistics can be used in conjunction with a Moran Scatterplot to identify the *type* of spatial clustering around each observation [for technical discussions see Appendix A, Anselin (1995a), or Anselin (1995b)]. For each observation with a significant local Moran value, it is possible to identify the nature of the spatial patterning around each observation. The Moran Scatterplot allows for the identification of four types of local spatial association. The first two types, which are indicative of positive spatial association (i.e., local clustering of like values), are (a) high values (above the mean) surrounded by high neighbouring values, and (b) low values (below the mean) surrounded by low neighbouring values. The remaining two types indicate spatial outliers, and are either a high value surrounded by low neighbouring values, or a low value surrounded by high neighbouring values. The *Spacestat* interface with ArcView allows for the creation of LISA significance maps, which are maps indicating significant LISA as well as the type of spatial patterning around the significant observations (Anselin, 1999).

The two methods used, Spearman Rank correlation and LISA, provide the basis for a preliminary exploration of the association between playground need and accessibility. In the case of the correlation analysis, an equitable situation would be one in which there is a positive association between neighbourhood rank of need and accessibility. For LISA, I seek to compare local spatial patterns of need with patterns of accessibility. Upon visual inspection of the local patterns, an association between high need areas and high accessibility areas would provide indication of equitably distributed playgrounds.

## 3.7 Results

### *3.7.1 Descriptive Statistics and Correlation Analysis*

Basic descriptive statistics for accessibility and need indicators are reported in Table 3.2 (see following page). Average NSA to playgrounds according to the minimum distance criterion is roughly 399 metres. In other words, children typically travel 399 metres to reach the closest playground. With respect to the coverage criterion, children typically have approximately 2.5 playgrounds within 0.5 miles of their residence (as approximated by postal code locations). If only good condition playgrounds are considered, then children, on average, have to travel about 524 metres to reach a good playground, or have 1.6 playgrounds within the specified distance threshold.

**Table 3.2** Descriptive Statistics for Accessibility and Need Indicators

| | Mean | Stand. Dev. | Median | Minimum | Maximum |
|---|---|---|---|---|---|
| Accessibility | | | | | |
| Minimum Distance[1] (all) | 398.70 | 145.43 | 379.05 | 171.35 | 1323.84 |
| Minimum Distance (good) | 523.64 | 255.72 | 434.21 | 171.35 | 1630.23 |
| Coverage[2] (all) | 2.46 | 1.16 | 2.28 | 0.00 | 6.25 |
| Coverage (good) | 1.62 | 0.97 | 1.50 | 0.00 | 5.26 |
| Need | | | | | |
| % Low Income | 23.20 | 15.08 | 21.65 | 0.00 | 81.43 |
| % Attached Dwellings | 40.23 | 27.10 | 39.35 | 0.00 | 100.00 |
| % Transient | 51.71 | 13.39 | 50.86 | 23.68 | 100.00 |
| % Population 0-14 years | 19.20 | 5.91 | 19.14 | 1.96 | 31.88 |
| % No Vehicle | 12.87 | 11.26 | 10.44 | 0.00 | 62.89 |

[1] values reported are in metres
[2] values reported are number of playgrounds

The descriptive statistics also provide a general picture of the range of need for playgrounds in the city. Neighbourhood incidence of low income varies from 0 to just over 80%, attached dwellings from 0 to 100%, transient population from 23.68 to 100%, children aged 0 to 14 years from 1.96 to 31.88%, and finally the percentage of households without a vehicle ranges from 0 to roughly 63%. The wide range of social conditions among neighbourhoods suggests that there are diverse levels of need for public recreational amenities, such as playgrounds, in Edmonton.

If playgrounds were equitably distributed, I would expect the diversity in need to be reflected by corresponding variation in accessibility to playgrounds. The correlations between need indicators and the various accessibility measures indicate that this expectation is somewhat fulfilled (Table 3.3).

**Table 3.3** Spearman Rank Correlations[1] between Need and Accessibility

| | Need Indicators | | | | |
|---|---|---|---|---|---|
| Accessibility | %Population 0-14 years | %Attached Dwellings | %Low Income | %Transient | %No Vehicle |
| Minimum Distance (all) | 0.17* | -0.14 | -0.38** | -0.09 | -0.40** |
| Minimum Distance (good) | 0.09 | 0.02 | -0.14 | 0.06 | -0.13 |
| Coverage (all) | -0.31** | 0.11 | 0.48** | 0.10 | 0.53** |
| Coverage (good) | -0.12 | -0.02 | 0.19** | -0.09 | 0.21** |

[1] The correlations between need and minimum distance are opposite to those between need and coverage because higher values of minimum distance reflect *poorer* accessibility; whereas, higher values of coverage reflect *greater* accessibility.

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Upon interpreting the correlation coefficients it is crucial to reiterate that higher values of the minimum distance variable correspond to poorer accessibility, whereas higher values of the coverage variable represent higher accessibility. According to the minimum distance criterion, accessibility tends to be slightly higher in areas with high percentages of low-income households, as well as in areas with high proportions of households that do not own a vehicle. Minimum distance is positively, yet weakly associated with percentage of children. This suggests that neighbourhoods with higher proportions of children have somewhat poorer accessibility to playgrounds. The coverage criterion displays similar results, although in all cases the aforementioned associations are slightly greater in magnitude than in the case of minimum distance.

When only good playgrounds are considered, the apparent advantage of low income and low vehicle ownership areas diminishes under both the minimum distance and coverage criteria. In the case of minimum distance, there is no longer an association between the noted variables and accessibility, whereas, for the coverage criterion, the association remains, although it is of lower magnitude than when playground quality was ignored. In both cases, the slight disadvantage of areas with high percentages of children disappears. In other words, there is no association between percentage of children and accessibility to good playgrounds.

*3.7.2 Local Spatial Autocorrelation Patterns*

LISA significance maps for accessibility are displayed in Figures 3.2 (a)-(d). The map legend categories for minimum distance refer to accessibility, and not to the original distance values. Again, low distance values correspond to high accessibility on the maps, and high distance values correspond to low accessibility. Without considering playground condition, the minimum distance approach reveals a concentration of low accessibility clusters (i.e., low accessibility neighbourhoods surrounded by low accessibility neighbourhoods) in the northern-most part of Edmonton (Figure 3.2a). High accessibility clusters (i.e., high accessibility neighbourhoods surrounded by high accessibility neighbourhoods) exist in north central Edmonton, with smaller pockets of high accessibility clusters in the west. Low accessibility outliers (i.e., low accessibility neighbourhoods surrounded by high accessibility neighbourhoods) are found primarily

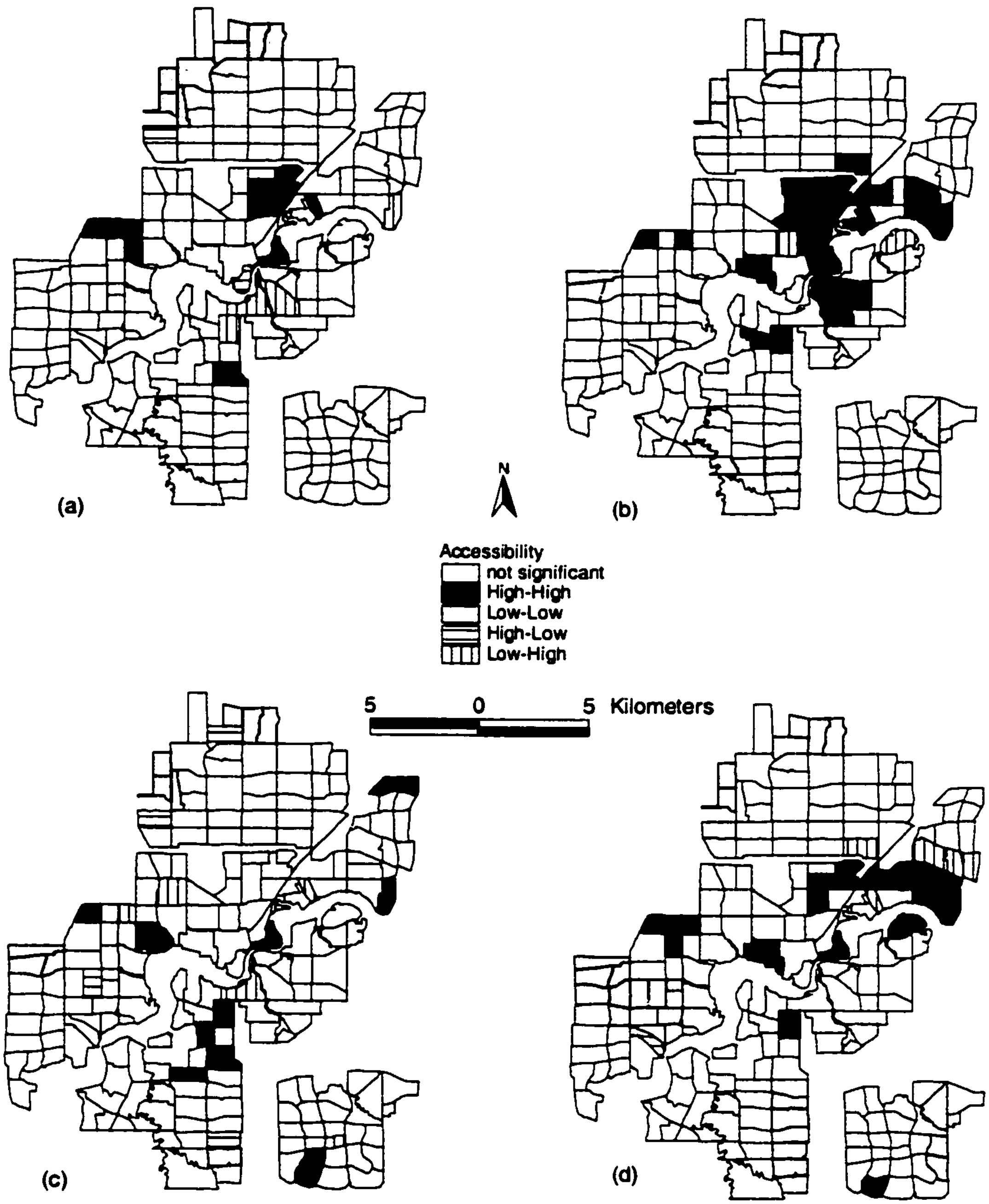


**Figure 3.2** LISA maps for a) minimum distance (all playgrounds) b) coverage (all playgrounds) c) minimum distance (good playgrounds), and d) coverage (good playgrounds). Classification refers to accessibility, so that low values of minimum distance have been categorized as high accessibility, and high distance values as low accessibility.

in the south central, and eastern parts of the city. There is one high accessibility outlier (i.e., high accessibility neighbourhood surrounded by low accessibility neighbourhoods), and it is located in the northwest.

The coverage approach (Figure 3.2b), with all playgrounds considered, reveals somewhat different patterns than the minimum distance criterion. This is consistent with Talen and Anselin's (1998) findings, which show that different accessibility measures can result in different accessibility patterns. Like the minimum distance approach, the coverage approach identifies a concentration of low accessibility clusters in north Edmonton. The coverage approach, however, also identifies low accessibility clusters in the west, southwest, and southeast. Although both approaches point to clusters of high accessibility in central Edmonton, the coverage approach identifies a greater number of significant neighbourhoods in the area. In addition, the coverage approach identifies clusters of high accessibility in the northeast, and to a lesser extent in south central Edmonton. There are only three low accessibility outliers, all of which are located within the primary cluster of high accessibility neighbourhoods. In no case was there a significant high accessibility neighbourhood surrounded by low accessibility neighbourhoods.

When only playgrounds with good condition equipment are considered, there are some changes in the accessibility patterns. Both approaches indicate a decrease in the clustering of high accessibility in central Edmonton. Using the minimum distance criterion (Figure 3.2c), there is a slight decrease in the clustering of low accessibility neighbourhoods in the north, with one neighbourhood becoming a high accessibility outlier. In the west, there is also a decrease in the number of high accessibility clusters, with new clusters of low accessibility appearing on the western most edge of the city. Other notable changes include a slight increase in the number of high accessibility clusters in south central Edmonton, as well as pockets of high accessibility clusters in the northeast and southeast. Under the coverage method (Figure 3.2d), there remains a concentration of high accessibility in the northeast; however, there is also an increase in the number of low accessibility outliers in the area. In addition, a new concentration of low accessibility clustering becomes evident in the west.

As opposed to mapping each individual need indicator, I chose to examine the local spatial patterns of only the variables that had significant associations with accessibility, namely percentage children aged 0-14 years, percentage low income, and percentage of households without a vehicle (Figures 3.3a-c). The local spatial patterning of need indicators shows the divergent distribution of social, versus demographic need in the city. Local clusters of high percentage of children aged 0-14 are located primarily in southeast and northeast Edmonton (Figure 3.3a). As might be expected based on typical urban ecological patterns in North American cities, local clusters of low percentage of children are located primarily in the central part of the city. In addition there are a few outliers (both high and low) scattered throughout Edmonton. Both percentage of low income and non-vehicle ownership households show similar local spatial patterning, with high values of each indicator primarily concentrated in north central Edmonton, and low value clusters found in various outlying areas, particularly southwest.

Generally, accessibility to playgrounds (without regard to playground condition) appears to correspond to social need, as opposed to demographics. In no cases do high

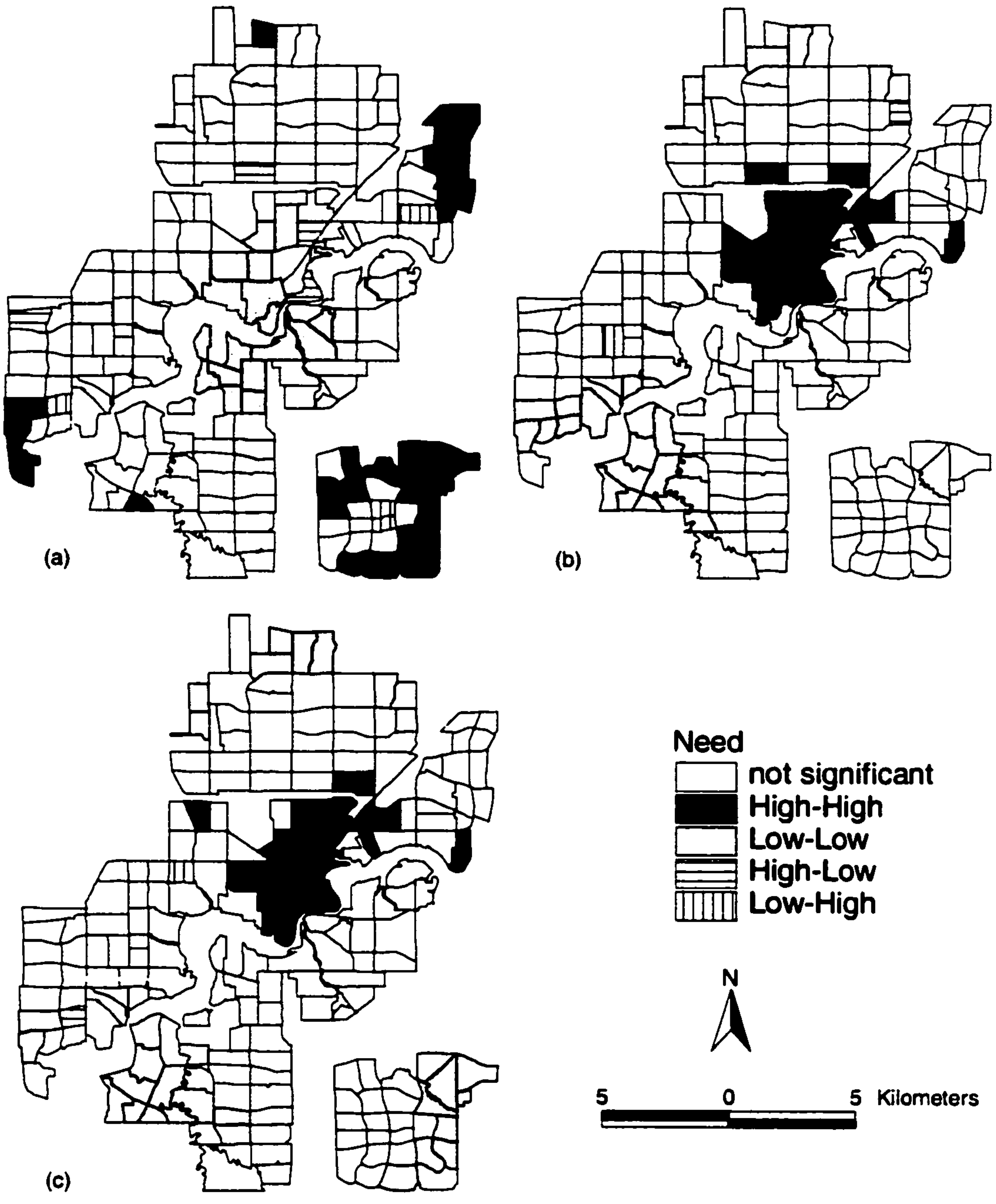


**Figure 3.3** LISA maps for a) percentage children aged 0-14 years b) percentage low income households, and c) percentage non-vehicle ownership households.

percentage children clusters correspond to high accessibility clusters; however, of the four high percentage children outliers, two coincide with high accessibility patterns. In central Edmonton, there is a close association between high percentage low income and non-vehicle ownership with high accessibility clusters (especially under the coverage approach). There are only two high outliers of non-vehicle ownership and low income, neither of which displays any type of significant accessibility patterns. When only good playgrounds are considered, there is less overlap between high accessibility and high social need clusters in central Edmonton. While the coverage method still indicates a few high accessibility clusters in this area, the minimum distance technique only yields one high accessibility cluster in the high social need, central part of the city. This coincides with the correlation results, in which there was a decrease in the association between the two indicators of social need and accessibility when only good playgrounds were considered.

### 3.8 Discussion

Both the correlation coefficients and the LISA suggest that accessibility to public playgrounds corresponds more strongly to neighbourhood social characteristics, than to demographics. From a needs-based perspective this is spatially equitable, as playground provision favours socially disadvantaged areas. While the most socially disadvantaged areas tend not to correspond to the areas with the highest percentage of children, the children that do live within these disadvantaged areas are probably less likely to be able to overcome barriers (e.g., greater travel distances and enrollment in private sports activities) related to poor accessibility to public recreational amenities.

While keeping in mind that the methods used in this analysis are highly exploratory in nature, the results indicate that the city's NPDP generally results in an equitable distribution of playgrounds. The findings do, however, point to a couple of issues that may warrant further research and attention from Edmonton's Community Services department. Despite the general divergence in patterns of clusters of children and clusters of low income/non-vehicle ownership, there is one neighbourhood in north Edmonton, Lauderdale, which indicates both high levels of children and low-income households. I would expect that such a neighbourhood would have high accessibility, however, neither the coverage nor minimum distance approach indicate a significant high accessibility pattern in this area. In addition, there are two neighbourhoods (Riverdale and Parkdale) in central Edmonton that have high levels of social and demographic need. Riverdale has high accessibility, even when only good playgrounds are considered. Parkdale has high accessibility; however, when only good playgrounds are considered, it no longer remains as a high accessibility cluster. Playground provision in the Lauderdale and Parkdale areas deserves special attention from Community Services.

Another important issue that arose in the analysis was that of playground condition. When considering only good playgrounds, the distribution of playgrounds still favoured low-income/non-vehicle ownership areas; however, there was considerably less overlap than was witnessed when playground condition was ignored. I used playground condition as a crude indicator of playground quality. From a service delivery perspective, two playgrounds may start out similar in quality (e.g., in terms of expenditures, type of equipment, etc.); however, several extraneous factors may lead to one playground being in poorer condition than the other. This relates to what Lucy (1981) refers to as differences in resources (e.g., expenditures, equipment, etc.) versus results (e.g., intended and unintended) as service indicators. In terms of the NPDP, the provision of playgrounds may be equitable, but intra-urban variations in factors that influence playground condition may lead to some areas having poorer access to good playgrounds. In this respect, I feel that investigation into factors that may influence playground condition is vital. Examples include: the number of children who use each playground, ambient crime and deviance (e.g., vandalism) levels, environmental factors (e.g., landscape features such as lighting, tree coverage, etc.), as well as proximity to 'undesirable' land uses (e.g., liquor stores, derelict housing, etc.). These types of land uses may have spillover effects into nearby playgrounds and parks, such as drug or alcohol use in such spaces. Ideally, investigating this issue would require the integration of quantitative and qualitative methods, as well as secondary and primary (e.g., interviews with playground users and nearby residents) data sources.

Finally, the findings should be considered in terms of the methods used in this analysis. The methods used are largely exploratory in nature, and are aimed at looking for patterns and associations in the data. These results, however, can be used to generate further hypotheses regarding spatial equity and playground location in Edmonton. For instance, it is likely that when more comprehensive aspects of playground quality are considered, such as those listed above, there would be an even greater discrepancy between areas of high social need and areas with high access to high quality playgrounds.

Also, as was shown by Talen and Anselin (1998), different methods of measuring spatial accessibility can alter assessments of equity. In my analysis, the coverage approach resulted in greater intra-urban variation in accessibility than did minimum distance. Whether the minimum distance or coverage approach was adopted, the same general relationship to playground need resulted. There were, however, slight differences in the magnitude of the correlation coefficients, as well as the local spatial patterning suggested by each approach. The question arises, then, which approach is the most accurate assessment of NSA to playgrounds? The minimum distance approach makes the assumption that children are likely to travel to the nearest playground, and all other things equal, shorter distances are desirable. The minimum distance approach, however, fails to recognize that there may be a multitude of playgrounds within a reasonable distance from residents' homes. While the coverage approach compensates for this problem, it does not differentiate between distances traveled within the specified distance radius (in my case half of a mile), and further it assumes that children will not use playgrounds outside of the half a mile range. Ideally, residents should be surveyed to determine what they believe to be most important in defining their access to playgrounds. Residents' responses can then be used to rationalize the use of one accessibility indicator over another. Without the benefit of such consultation, it is better to consider more than one measure of accessibility, as opposed to assuming that one is more 'correct' than the other. By including two accessibility indicators, I have captured more than one dimension of playground accessibility, and have therefore provided a reasonably accurate assessment of NSA to playgrounds in Edmonton.

## 3.9 Conclusions

The purpose of this analysis was to provide a preliminary assessment of public playground provision and spatial equity in Edmonton, and in doing so evaluate the city's NPDP. Using exploratory techniques, I compared NSA patterns (using both coverage and minimum distance approaches) with underlying neighbourhood need. When no consideration was given to differences in playground quality, there was a moderate positive correlation between social need (indicated by the percentage of households with low income, and non-vehicle ownership households) and accessibility to playgrounds. There was a low to moderate negative association between percentage of children aged 0-14 years and accessibility. Local spatial autocorrelation patterns confirmed these results, with high social need clusters generally corresponding to high accessibility clusters. The findings indicate that playground provision seems to correspond more closely with social need than the distribution of children. From a needs-based perspective, playgrounds appear to be equitably located. When only playgrounds in good condition were included, low income and non-vehicle ownership remained positively correlated with accessibility; however, the correlations were considerably lower, with the minimum distance indicator no longer being significantly correlated with either of the variables.

Overall, this preliminary evaluation of the NPDP indicates that the program promotes spatial equity in terms of playground location in Edmonton, although differences in playground quality affect the observed relationships between need and accessibility. As a result, future research on playgrounds and spatial equity in Edmonton should not only examine locations of playgrounds in relation to population characteristics, but also focus on factors that may influence the condition of playground equipment. Further, because the results in Edmonton suggest that *quality* of amenities may influence spatial equity, I urge researchers examining similar issues in other cities to give greater consideration to differences in amenity quality.

**3.10 References**


Anselin L, 1995a, "Local indicators of spatial association – LISA" *Geographical Analysis* **27** 93-115

Anselin L, 1995b, *Spacestat Version 1.80 User's Guide* Regional Research Institute, West Virginia University, Morgantown, WV

Anselin L, 1999, *Spatial Data Analysis with Spacestat and ArcView Workbook* 3rd Edition University of Illinois, Urbana, IL

Barkley D L, Henry M S, Bao S, Brooks K R, 1995, "How functional are economic areas? Tests for intra-regional spatial association using spatial data analysis" *Papers in Regional Science* **74** 297-316

Cervero R, Rood T, Appleyard B, 1999, "Tracking accessibility: employment and housing opportunities in the San Francisco Bay Area" *Environment and Planning A* **31** 1259-1278

City of Edmonton Community Services, 1998, *The Neighbourhood Park Development Program: Creating Special Places for Neighbourhood Play and Wellness 1997 – 2006* City of Edmonton, Edmonton, AB

City of Edmonton, 1999, *Edmonton Civic Census 1999* City of Edmonton, Edmonton, AB

City Of Edmonton Community Services, 2000, *Towards 2010: A New*

*Perspective: An Integrated Service Strategy* City of Edmonton, Edmonton, AB

City of Edmonton Community Services, 2000a, *Internal playground standards document*

Dalvi M Q, Martin K M, 1976, "The measurement of accessibility: some preliminary results" *Transportation* **5** 17-42

Dear M, 1974, "A paradigm for public facility location theory" *Antipode* **6** 46-50

Getis A, Ord J K, 1992, "The analysis of spatial association by use of distance statistics" *Geographical Analysis* **24** 189-206

Handy S L, Niemeier D A, 1997, "Measuring accessibility: an exploration of issues and alternatives" *Environment and Planning A* **29** 1175-1194

Hay A M, 1995, "Concepts of equity, fairness and justice in geographical studies" *Transactions of the Institute of British Geographers* **20** 500-508

Hodgson M J, Shmulevitz F, Körkel M, 1997, "Aggregation error effects on the discrete-space *p*-median model: the case of Edmonton, Canada" *The Canadian Geographer* **41** 415-428

Knox P L, 1978, "The intraurban ecology of primary medical care: patterns of accessibility and their policy implications" *Environment and Planning A* **10** 415-435

Lucy W, 1981, "Equity and planning for local services" *Journal of the American Planning Institute* **47** 447-457

Mencken F, Barnett C, 1999, "Murder, nonnegligent manslaughter, and spatial autocorrelation in mid-south counties" *Journal of Quantitative Criminology* **15** 407-422

Messner S F, Anselin L, Baller R D, Hawkins D F, Deane G, Tolnay S E, 1999, "The spatial patterning of county homicide rates: an application of exploratory data analysis" *Journal of Quantitative Criminology* **15** 423-450

Nicholls S, 1999, "Measuring accessibility and equity of public parks: a case study using GIS" paper presented at the *Geographic Information and Society* conference, 20-22 June, University of Minnesota, Minneapolis

Ord J K, Getis A, 1995, "Local spatial autocorrelation statistics: distributional issues and applications" *Geographical Analysis* **27** 386-306

Ottensmann J R, 1994, "Evaluating equity in service delivery in library branches" *Journal of Urban Affairs* **16** 109-123

Pacione M, 1989, "Access to urban services – the case of secondary schools in Glasgow" *Scottish Geographical Magazine* **105** 12-18

Statistics Canada, 1999, *1996 Census Dictionary – Final Edition* Catalogue No. 92-351-UIE

Statistics Canada, 1999a, Postal Code Conversion File October 1999 Postal *Codes: Reference Guide* Catalogue No. 92F0027XDB

# CHAPTER 4

# Summary and Recommendations for Future Research

## 4.1 Research Summary

### *4.1.1 Review of Research Goals*

This research had two primary goals: (1) to examine aggregation error effects on NSA measures, and (2) to assess the spatial equity of playground location and quality in Edmonton. The first goal, which was achieved through my analysis in Chapter 2, consisted of drawing on ideas and methodologies in LA research and applying them to NSA measurement, determining whether aggregation error affects NSA indicators, and suggesting strategies for reducing aggregation error problems when measuring NSA. The second goal, which was achieved via the analysis in Chapter 3, dealt with measuring NSA to playgrounds, while accounting for differences in playground quality, and assessing whether playground accessibility corresponded to population need in Edmonton. The following sections review some of the key findings of each of the preceding chapters.

### *4.1.2 Aggregation Error Effects on NSA Measurement*

The aim of Chapter 2 was to determine if accessibility measures are susceptible to aggregation error, and hence whether accessibility researchers should give greater consideration to aggregation error. NSA was measured to three different recreational amenities: playgrounds, community halls, and leisure centres. I hypothesized that if aggregation error were to have an effect on NSA, then the magnitude of the effect would likely depend on the type of amenity under investigation. Playgrounds were selected as an example of amenities that have highly localized service areas, and are abundantly located throughout the city. Leisure centres, on the other hand, were included to represent facilities that typically have large service areas, with relatively few located within the city. Community halls were selected as an amenity that fell between playgrounds and leisure centres in terms of service area size and number of facilities.

NSA to each facility type was measured in three ways. In all cases, the aim was to typify how far neighbourhood residents have to travel to reach the closest of each amenity type. The first method consisted of measuring distance from each neighbourhood's unweighted centroid to each closest facility type – an approach that essentially ignores the spatial distribution of individuals within neighbourhoods. The other two approaches required the integration of postal code population counts to indicate better the spatial distribution of individuals within neighbourhoods. The second method involved calculating the PWMC of each neighbourhood's postal codes, and then measuring distance from that point to the various amenities. The final approach consisted of measuring the distance from each postal code to the different facilities, and then calculating the WAPCD for each neighbourhood.

Because the WAPCD approach was assumed to be the most accurate approximation of average NSA, it was treated as the 'gold-standard' approach. My aim was to determine whether the other approaches produced different accessibility levels and patterns for each neighbourhood, and hence whether the centroid and PWMC methods are susceptible to aggregation error. My findings suggested that aggregation error did have an impact on NSA; however, the effect depended on amenity type.

Correlation and LISA analysis indicated that for playgrounds, the centroid and PWMC approaches produced markedly different ranking and local spatial patterning of NSA than the WAPCD method. This suggested that when NSA is measured for playgrounds, aggregation error does matter. When the three approaches were compared for community halls, the PWMC and centroid methods resulted in slight deviations from the WAPCD approach, though the deviations were not as great as for playgrounds. Finally, for leisure centres, the PWMC and centroid approaches produced essentially identical NSA ranks and spatial patterns to the WAPCD method, suggesting that aggregation error is not problematic for NSA measurement to leisure centres.

Based on the results, I concluded that the effect of aggregation error on NSA measurement varied as a result of differences in the character (e.g., number of facilities and service area size) of the amenity that was under investigation. Playgrounds were particularly problematic because, due to the number of playgrounds in the study area, there was a greater likelihood of Source C aggregation error (allocation of individuals to 'incorrect' facilities). As a result, studies measuring accessibility from highly aggregated units, such as neighbourhoods, to amenities that have highly localized service areas, and are abundantly located in cities (e.g., playgrounds or neighbourhood parks), should give greater consideration to aggregation error. Specifically, finer resolution units, such as postal codes, or census blocks, should be integrated into NSA measures to ensure that aggregation error problems are reduced.

*4.1.3 Spatial Equity and the Location and Quality of Playgrounds in Edmonton*

The main goal of Chapter 3 was to assess whether the distribution of playgrounds, in terms of location and quality, in Edmonton is spatially equitable. This was achieved by examining the association between NSA to, and neighbourhood need for, playgrounds in Edmonton. While integrating methods for reducing aggregation error that were suggested in Chapter 2 (e.g., measuring distance from each postal code to the nearest amenity), I measured NSA to playgrounds using the minimum distance and coverage approaches. NSA to playgrounds was then compared to neighbourhood need, which was measured in terms of various socioeconomic and demographic neighbourhood characteristics. Correlation analysis revealed that there was a positive, low to moderate association between NSA and two indicators of social need – percentage of low-income households and percentage of households that do not own a vehicle. There was a negative, low to moderate relationship between NSA and the percentage of children per neighbourhood. LISA confirmed these associations, with clusters of high accessibility generally corresponding to clusters of high social need, rather than clusters of high percentages of children per neighbourhood. The correlation and LISA analyses suggested that playground provision corresponds to social need, as opposed to demographic need. From a needs-based perspective, this indicated that playgrounds are equitably distributed in Edmonton.

The above analysis was then repeated, but in this case I included only playgrounds that the City of Edmonton had classified as being in good condition. My aim was to assess whether differences in playground quality affected spatial equity. When only good playgrounds were considered, there was still a positive association between NSA and social need; however, the magnitude of the relationship decreased, and in the case of the minimum distance measure, became non-significant. The LISA echoed these results, with a decrease in the number of high accessibility clusters in the areas with the highest levels of social need.

I concluded that quality of playgrounds has implications for spatial equity in Edmonton. In general, there is an association between social need for, and NSA to playgrounds, which from a needs-based equity perspective is desirable. But because this association is reduced when playground quality is considered, greater attention must be given to differences in playground quality throughout the city. Specifically, research that examines factors that may adversely affect playground condition in Edmonton is needed.

### 4.2 Relevance of the Research

I have addressed two aspects of spatial accessibility and equity that have been largely neglected in existing research, namely aggregation error and amenity quality. The results of my research reveal that each of these matters should be given greater consideration by researchers working on accessibility and equity issues within the urban environment. With respect to aggregation error, my results showed that using traditional measurement methods, such as the centroid approach, produces misleading information about intra-urban accessibility. These findings should be highly relevant to spatial equity researchers; methods that produce erroneous accessibility patterns and values will undoubtedly affect assessments of spatial equity.

As noted in Chapter 2, considerable literature exists regarding various methodological issues in relation to accessibility measurement; however, little work has been done to assess whether different sources of aggregation error affect accessibility measurement, and whether the extent to which aggregation error is problematic depends on the type of amenity under investigation. I anticipate that the analysis presented in Chapter 2 will begin to fill this void, and hopefully spur further interest and methodological investigations into aggregation error and accessibility measurement by other researchers.

Amenity quality is another issue that is lacking in existing spatial equity research, specifically in the case of recreational amenities such as playgrounds and neighbourhood parks. This is unfortunate, because as was discovered in Chapter 3, amenity quality can have adverse implications for spatial equity. My research sheds light on the idea that, with respect to access to recreational amenities, quantity may not necessarily be equated with quality. In other words, there may be deviations between areas that have high accessibility to amenities, and areas that have high accessibility to *high-quality* amenities. I anticipate that the findings of Chapter 3 will generate increased interest among spatial equity researchers regarding amenity quality.

Accessibility to public amenities has implications for various issues in the urban environment, ranging from the health and well-being of urban dwellers, to urban desertification and its associated problems. Spatial equity research, in addition to assessing whether principles of justice, fairness, and equity are being considered in the provision of public amenities, contributes to our understanding of these issues. The findings of this research are, therefore, not only relevant to spatial accessibility and equity researchers, but they also have implications for a host of other geographic and sociological fields of study. Growing interest in neighbourhood characteristics and how they relate to individual well-being, crime and deviance, urban desertification, and other urban problems and processes, coupled with the widespread availability of the technologies (e.g., GIS) needed to handle and analyze spatial data, has enabled researchers in various fields to examine accessibility to amenities. Regardless of the application, it is necessary that detail is given to measurement issues, such as aggregation error, and that multi-dimensional aspects of accessibility, such as the quality of amenities, be explored. If these issues are neglected, an inaccurate representation of accessibility may result, thereby discounting its usefulness to the problem to which it is being applied.

### 4.3 Future Research Directions

The findings of my study, as well as some of the issues that I have encountered throughout the course of this project, have prompted a plethora of further research questions in relation to spatial equity and accessibility. In terms of aggregation error, there are numerous issues that remain to be addressed. I selected minimum distance to investigate aggregation error effects on NSA measurement, primarily because of its simplicity and the ease with which it can be interpreted. It would be interesting, however, to determine whether other accessibility measures (e.g., coverage, gravity potential, etc.) are affected by aggregation error in the same manner as minimum distance. Talen and Anselin (1998) noted that different accessibility measures produce different patterns of intra-urban accessibility. I suspect, therefore, that accessibility measures would vary in how, and to what extent, they are affected by aggregation error.

Another aspect of aggregation error that should be addressed in further research has to do with the geographical unit of analysis. I presumed that the extent to which aggregation error was problematic was a function of the size of the unit of analysis, with smaller units being less susceptible to aggregation error than larger units. It would be interesting to validate this presumption by repeating the analysis in Chapter 2 for different units of analysis. Specifically, repeating the analysis with enumeration areas, which are larger than postal codes, but smaller than neighbourhoods, and then comparing the results with those in Chapter 2 would allow for an assessment of the relationship between aggregation error and census unit size.

There are also several areas that require further research with respect to spatial equity and playgrounds in Edmonton. One relates, again, to the geographical unit of analysis. As noted by Openshaw (1984), analyses performed at different units of analysis can result in different findings – an issue that is commonly referred to as the modifiable areal unit problem (MAUP). Although the neighbourhood was the most appropriate unit for my analysis, largely because playground funding in Edmonton is based on neighbourhoods, it would be beneficial to validate the findings at an additional unit of analysis. Specifically, spatial equity should also be assessed for enumeration areas. This would allow me not only to assess the MAUP, but to examine variations in accessibility and population need *within* neighbourhoods.

Another issue that deserves further attention relates to playground quality. I used playground equipment condition, as classified by Edmonton's Community Services department, as an indicator of playground quality. It is likely that a multitude of other factors influence playground quality, such as the amount and type of garbage (e.g., used condoms, syringes, or discarded alcohol bottles) in playgrounds, and that these factors vary according to where in the city the playground is located. Such analysis would have to go beyond the methods used in the current research project, and incorporate qualitative strategies.

In addition, while playgrounds were the substantive interest of my analysis, the methods that I have used can be applied to various other issues in Edmonton related to accessibility and spatial equity. For instance, recent school closures in central Edmonton (Edmonton Journal, 2001; Unland, 2001) have various accessibility and spatial equity implications. Socially disadvantaged families generally populate the areas in which schools are being closed; closing schools in such areas leaves these families at a spatial disadvantage. An analysis of spatial equity in relation to school closures in Edmonton, similar to work done by Pacione (1989) in Scotland, would likely yield interesting results.

The findings of my research indicate that accessibility and spatial equity researchers should give greater attention to issues related to accessibility measurement, specifically aggregation error. Improved measurement methods, however, *must* be accompanied by further investigation into the effect that amenity quality has on accessibility and spatial equity. In order to capture multiple dimensions of amenity quality, researchers will have to move beyond the purely spatial analytical approach, and incorporate qualitative methods. In general, greater consideration of methodological issues affecting the accuracy of accessibility measures, as well as the integration of qualitative methods is likely to result in a more accurate, and comprehensive understanding of spatial equity in the urban environment.

**4.4 References**

*Edmonton Journal* 2001, "School closing will test parents", 5 May, page A14

Openshaw, S., 1984, *The Modifiable Areal Unit Problem* Concepts and Techniques in Modern Geography, number 38 (Geo-Abstracts, Norwich)

Pacione M, 1989, "Access to urban services – the case of secondary schools in Glasgow" *Scottish Geographical Magazine* **105** 12-18

Talen E, Anselin, L, 1998, "Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds" *Environment and Planning A* **30** 595-613

Unland K, 2001, "Tears, fury as schools closed: two schools, two junior high programs closed by board looking to save $2M" *Edmonton Journal* 25 April, page B1

# APPENDIX A

# Exploratory Spatial Data Analysis

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Exploratory spatial data analysis (ESDA) refers to a set of tools and methods that enable the description of spatial distributions, and the identification of spatial patterns in data (Anselin and Bao, 1999). Both papers presented in this thesis involve the use of ESDA methods. The purpose of this appendix is to provide detail on some of the main ESDA tools used in the thesis, including global spatial autocorrelation, Moran Scatterplots, and local indicators of spatial association. *Spacestat Version 1.90* (Anselin, 1998), a program developed specifically for the analysis of spatial data, was used to perform all of the noted procedures. This discussion is based primarily on information that can be found in Chapter 8 of *Spacestat Version 1.80 User's Guide* (Anselin, 1995); however, other references will be noted when necessary.

## Spatial Autocorrelation

Central to many forms of spatial analysis is the concept of spatial autocorrelation. Spatial autocorrelation is concerned with the spatial arrangement of values of a variable of interest within a study area, and refers to the relationship between adjacent, or nearby values in two-dimensional space (Ebdon, 1985). Spatial autocorrelation assesses "whether values at close-by locations are more correlated than values at locations that are far apart" (Anselin, 1993: 457). If nearby values are positively correlated, then positive spatial autocorrelation exists, reflecting spatial clustering in the data. Negative spatial autocorrelation, on the other hand, refers to a negative association between nearby values, and is indicative of dispersed spatial patterns. Generally, spatial autocorrelation can be used to judge whether the spatial patterning of phenomena (e.g., crime, disease, poverty, accessibility, etc.) is non-random, and whether phenomena are clustered or dispersed over space.

**Spatial Weights Matrices**

As mentioned, spatial autocorrelation is concerned with the association of values between adjacent, or nearby locations. It is, therefore, necessary, that the spatial structure of the study area (i.e., which locations are nearby each other) be identified. This is achieved through the use of a spatial weights, or connectivity matrix, of dimension (N), the number of observations in the study area, by (N), with each element of the matrix, $w_{ij}$, referring to an observation pair. Typically, $w_{ij}$ will be assigned a value of one, when observations are contiguous to each other, and a zero when they are not. For a given observation, every non-zero value represents that observation's spatial neighbours (i.e., those observations that are contiguous to the observation in question). For ease of interpretation (see below), the matrix can be row-standardized, such that each non-zero value is divided by the sum of the values in its corresponding row. In other words, if a particular observation has four spatial neighbours, each neighbour will be assigned a weight of 0.25. Two criteria that are commonly used to establish whether observations are contiguous (i.e., whether they are spatial neighbours) are adjacency, and distance. For the former, observations are treated as contiguous if they share a border. In the latter case, observations are contiguous if they are within a specified distance from each other. For instance, a 2.0 kilometre distance criterion means that for a given observation, all other observations within 2.0 kilometres of the observation are considered to be contiguous, and hence form that observation's set of spatial neighbours.

All spatial autocorrelations statistics in this thesis use row standardized distance-based spatial weights matrices.

**Global Moran's *I***

Various statistics have been established to formally assess spatial autocorrelation. Global indicators of spatial autocorrelation report a single value for an entire study area, in other words they indicate the *general* spatial patterning of phenomena in a study area. A common measure of global spatial autocorrelation is Moran's *I*, mathematically defined as:

$$I = (N / S_o)\sum_i \sum_j w_{ij}(x_i - \mu)(x_j - \mu) / \sum_i (x_i - \mu)^2, \qquad (1)$$

where $\mu$ is the mean of variable $x$, $w_{ij}$ are the elements of the spatial weights matrix, and $S_o$ is the sum of the elements of the spatial weights matrix (Anselin, 1993: 459). The resultant *I* value can then be converted to a *z* value (observed *I* – expected *I* / the standard deviation of the statistic), and its significance can then be assessed under the assumption of normality or randomization [The formulae for the expected value of *I* and the associated standard deviations are provided in Ebdon (1985)]. *Z* scores greater than 1.96 indicate significant ($p < 0.05$) positive spatial autocorrelation, whereas *z* scores less than -1.96 note significant negative spatial autocorrelation. In Chapter 2, I use the global Moran's *I* to assess the general spatial patterning of accessibility under the null hypothesis of randomization. Ebdon (1985) notes that the randomization assumption is a 'safer' choice, as it avoids assuming that the observed values represent a random sample of values selected from a normally distributed population.

**Moran Scatterplot**

As noted by Anselin (1995, 1995a), for a row-standardized spatial weights matrix with observations in standardized form (mean = 0 and standard deviation = 1), Moran's *I* represents the slope coefficient of a linear regression of spatial lag (i.e., the weighted average of observations' spatial neighbours) on observed values (Figure A.1).

**Figure A.1** Moran Scatterplot for Distance to Nearest Playground

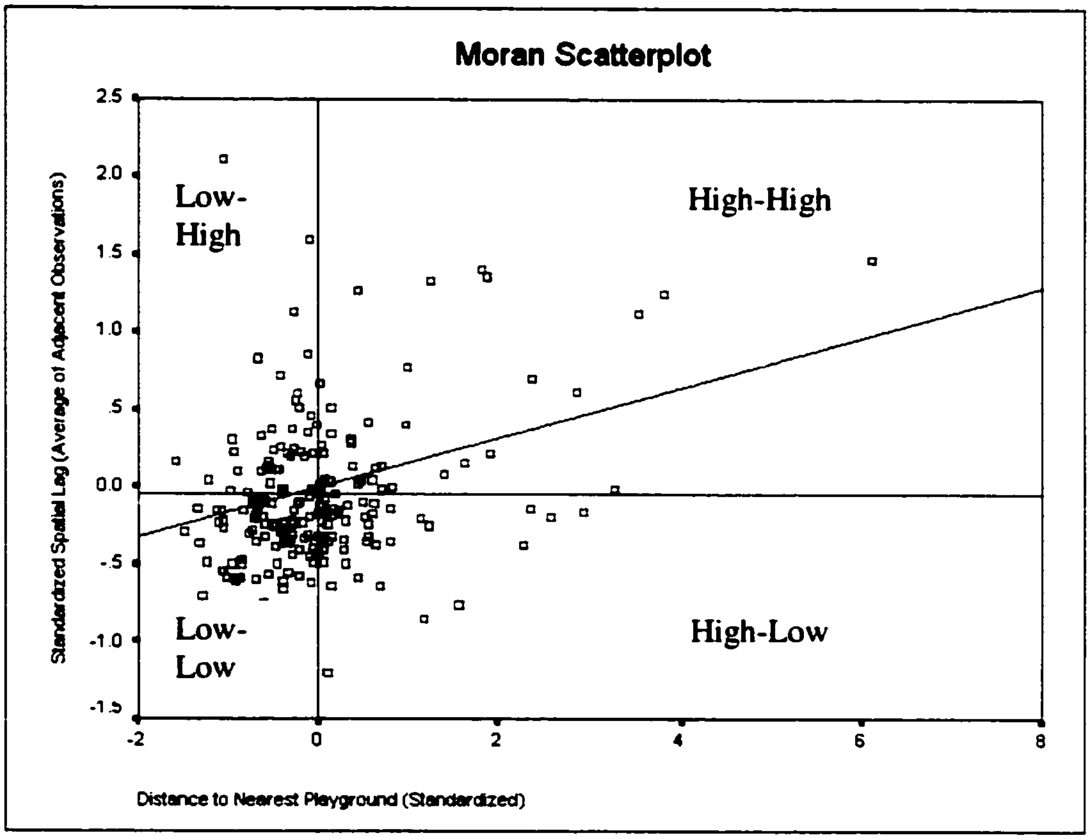

Figure A.1 shows the Moran Scatterplot for the variable distance to the nearest playground. Distance to the nearest playground (in standardized form) for each observation is plotted on the x-axis, with each observation's standardized spatial lag (i.e., the weighted average of its spatial neighbours) plotted on the y-axis. The slope of the line is equivalent to Moran's *I*, which in this case is positive, indicating positive spatial autocorrelation. In addition to being a useful visualization and diagnostic tool for global spatial autocorrelation, the Moran Scatterplot is instrumental in the interpretation of local spatial autocorrelation statistics, which will be discussed in the following section.

**Local Spatial Autocorrelation**

Global spatial autocorrelation measures assess the *general* spatial patterning of phenomena over a study area. These measures can mask important *local* spatial patterns in the data (Talen and Anselin, 1998). Anselin (1995) defines a local indicator of spatial association (LISA) as any statistic that can be used to identify significant spatial patterns around an individual location, and to decompose measures of global spatial association based on the contribution of each individual observation to the strength of the global measure. Global measures of spatial autocorrelation, such as Moran's *I*, report a single value to indicate the degree of spatial clustering for an entire study area, whereas LISA provide a measure of the strength and type of spatial patterning around *each individual* location within the study area. In both chapters, I assess local spatial patterning using the local counterpart of Moran's *I*, mathematically defined as

$$I_i = z_i \sum_j w_{ij} z_j \,, \qquad (2)$$

where $z_i$ and $z_j$ represent the variables in standardized form (mean = 0, standard deviation = 1), and the summation over $j$ pertains to all contiguous values of $i$ according to the spatial weights $w_{ij}$. Essentially, the local Moran's $I$ for a particular location is the product the location's standardized value multiplied by its standardized spatial lag.

To assess the significance of local Moran statistics, a conditional permutation approach can be used (Anselin, 1995). Basically, this consists of assessing the 'extremeness' of the observed local Moran statistic by generating a number of random permutations (in this case 9 999) of the values of each observation's neighbouring values, and recalculating the local Moran statistic under each permutation. The local patterning around an observation would be considered significant at the 0.05 level, for example, if of the roughly 10 000 permutations, only 5% of the calculated statistics were more extreme than the observed local statistic. Because of potential problems associated with multiple comparisons and correlated tests, there is debate over what the appropriate significance level for LISA should be (for detailed discussions see Anselin, 1995; Ord and Getis, 1995). Through the thesis, I use a probability level of 0.05 to assess significance of local spatial association, which is appropriate considering the exploratory nature of the analyses (Talen and Anselin, 1998).

The observed local Moran statistics can be used in conjunction with a Moran Scatterplot (refer back to Figure A.1) to identify the type of spatial clustering around each observation (Anselin, 1995; Anselin 1995a). For each observation with a significant local Moran value, it is possible to identify the nature of the spatial patterning around each observation. The Moran Scatterplot allows for the identification of four types of local spatial association, corresponding to the four quadrants of the scatterplot. The type of local spatial patterning for a given observation can be obtained by noting which quadrant the observation's value, and spatial lag fall within. The first two types, which are indicative of positive spatial association (i.e., local clustering of like values), are (a) high values (above the mean) surrounded by high neighbouring values, and (b) low values (below the mean) surrounded by low neighbouring values. These correspond to the upper right, and lower left quadrants respectively. The remaining two types indicate spatial outliers, and are either a high value surrounded by low neighbouring values (the lower right quadrant), or a low value surrounded by high neighbouring values (the upper left quadrant). The *Spacestat* extension for ArcView allows for the creation of LISA significance maps, which are maps indicating significant LISA as well as the type of spatial patterning around the significant observations (for examples see Chapters 2 and 3). LISA significant maps are used throughout this thesis to indicate the local spatial patterning of spatial accessibility and various neighbourhood population characteristics.

**References**

Anselin L, 1993, "Discrete space autoregressive models", in *Environmental Modeling with GIS* Eds M F Goodchild, B O Parks, L T Steyaert (Oxford University Press, New York) pp 454-469

Anselin L, 1995, *Spacestat Version 1.80 User's Guide* Regional Research Institute, West Virginia University, Morgantown, WV

Anselin L, 1995a, "Local indicators of spatial association – LISA" *Geographical Analysis* **27** 93-115

Anselin L, 1998, *Spacestat Version 1.90: A Program for the Analysis of Spatial*

*Data*. Distributed by BioMedware, Inc.

Anselin L, Bao S, 1997, "Exploratory spatial data analysis linking Spacestat and ArcView", in *Recent Developments in Spatial Analysis – Spatial Statistics, Behavioural Modeling and Neurocomputing* Eds M Fischer, A Getis (Springer, Berlin) pp 35-59

Ebdon D, 1985, *Statistics in Geography* 2nd Edition (Basil Blackwell, Oxford)

Talen E, Anselin L, 1998, "Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds" *Environment and Planning A* **30** 595-613

# APPENDIX B

# Executive Summary for Policymakers

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## Spatial Equity and Neighbourhood Accessibility to Playgrounds in Edmonton: Executive Summary

Public amenity provision involves the difficult task of ensuring that amenity distribution corresponds to the needs of the underlying population. In other words, amenity provision consists of ensuring that amenities are distributed equitably among the population. Typically, the goal of amenity providers is to make sure that the individuals of greatest need have good access to amenities. Geographic Information Systems (GIS) can aid in assessing whether equity is being achieved in the delivery of urban services and amenities. The following is a summary of a study that involved using GIS to assess the location and quality of public playgrounds in Edmonton, in terms of how well playground distribution corresponds to the needs of the population. As such, it evaluates whether the Neighbourhood Park Development Program (NPDP) program results in an equitable distribution of playgrounds.

***Highlights of the Study***

*Methods*

- Playground locations and condition were obtained from the Community Services' Playground Inventory file.
- For each residential neighbourhood, GIS was used to measure (1) how far children have to travel to reach the playground nearest to their home, and (2)

how many playgrounds, on average, are located within half a mile of children's homes.

- To assess equity, the accessibility measures were then compared to various indicators of neighbourhood need for playgrounds, which were based on 1999 Edmonton civic census data.
- To address differences in quality of playgrounds, the analysis was then repeated, including only playgrounds that Community Services classified as being in 'good' condition.

*Key Findings*

- Without considering playground condition, neighbourhoods with higher *social* need (as measured by the percentage of low income households and households that do not own vehicles) had better accessibility to playgrounds.
- Without considering playground condition, neighbourhoods with higher *demographic* need (as measured by the percentages of children aged 0 – 14) had slightly poorer accessibility to playgrounds.
- When only good condition playgrounds were considered, the advantages in accessibility of high social need neighbourhoods decreased somewhat, with high social need areas having only slightly better access to playgrounds.
- When only good playgrounds were considered, there was no association between accessibility to playgrounds and neighbourhood demographic need.

*Conclusions and Recommendations*

- Generally, the findings indicate that public playground provision corresponds to social need, rather than demographic need. In terms of equity, this is desirable as children living in poorer areas are less likely to be able to overcome barriers related to poor accessibility to playgrounds.

- The analysis highlights two issues that may warrant greater attention from Community Services. First, the Lauderdale neighbourhood has both high social *and* demographic need, yet relatively low accessibility to playgrounds. Second, the findings suggest that when differences in playground condition are considered, playground distribution is less equitable.
- Further research into factors that may influence playground condition, such as the number of children who use each playground, neighbourhood crime and deviance levels, as well as proximity to 'undesirable' land uses (e.g., liquor stores, derelict housing), is necessary.