Intra-urban spatial accessibility: An improved methodological approach

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Intra-Urban Spatial Accessibility: An Improved Methodological Approach

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Abstract

The study of accessibility is commonly utilized to further the social equity debate. However, the accessibility literature is ingrained with, and perpetuates, a form of spatial error; aggregation error. The presence of this spatial error severely hinders the applicability of accessibility research in the study of our environment. This thesis seeks to eliminate forms of spatial error from the study of accessibility through the use of comprehensive high resolution spatial information. A service accessibility study is undertaken utilizing origin data collected at the parcel level, while destinations are represented by a diverse and detailed database identifying businesses which cater to the personal needs of the resident. This high resolution data is used in the construction of a residential accessibility model for the City of Kitchener, Ontario, Canada. Accessibility is calculated for individual categories of service (37) and cumulatively throughout the study area. Additionally, accessibility is derived using two distinct distance measures; minimum distance and travel cost. Given the relative uniqueness of this approach, the resultant model is used to evaluate the form of urban accessibility with respect to that found throughout the literature. It is found that the form of accessibility, when calculated at a various levels of aggregation, will deviate from the classic distance decay model prevalent throughout the literature.

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1.0 Introduction

Accessibility is defined by Rodrigue (2006) as:

> "the measure of the capacity of a location to be reached by, or to reach different locations...The notion of accessibility consequently relies on two core concepts. The first is location where the relativity of space is estimated in relation to transport infrastructures, since they offer the means to support movements. The second is distance, which is derived from the connectivity between locations. Connectivity can only exist when there is a possibility to link two locations through transportation. It expresses the friction of distance and the location which has the least friction relative to others is likely to be the most accessible. Commonly, distance is expressed in units such as in kilometers or in time, but variables such as cost or energy spent can also be used. All locations are not equal because some are more accessible than others, which implies inequalities (Rodrigue 1998-2006)."

It is this knowledge that spatial inequalities exist which fuels the study of accessibility.

The study of urban spatial accessibility has been of interest to geographers for many years and has been shown to be a critical variable influencing the locational behavior of urban dwellers. Branching out of location analysis, urban accessibility examines the relationship between the population and existing services/amenities. As urbanites have become increasingly more dependent on services it follows that accessibility becomes a key indicator of the quality of a residential area. Given this dependency, services and their availability are often cited as entities, or variables, contributing to residential location and satisfaction. Accessibility is one measure which can be utilized to examine the spatial relationship between people and services. Moreover, accessibility is directly linked to the neighbourhood lifecycle with accessibility often decreasing in correspondence with neighbourhood decay. These potential accessibility findings of this study have considerable bearing on, and will likely contribute to, the substantive literature which examines urban decay.

Urban spatial structure can be described, in part, by the arrangements of residential neighbourhoods and services, and the infrastructure network that connects them (Alonso 1964; Muraco 1972; Koenig 1974; Knox 1978; Koenig 1980; Horner 2004). Thus residential neighbourhoods will vary in their accessibility to urban services and amenities. In this sense, accessibility is an indicator of neighbourhood quality of life (Talen 2003). Inequality in neighbourhood accessibility is one of several factors that will play a role in the decision making process of residential location and will vary considerably based on the needs of the household. At the much broader metropolitan scale, mapping the variation in neighbourhood accessibility provides the basis for another regionalization of urban space. The examination of urban form, in terms of neighbourhood accessibility, presents another dimension of the metropolitan environment that has yet to be explored spatially. In addition to contributing to the existing urban form literature this research avenue has the capacity foster an understanding of the intra-urban variations in quality of life and location behaviors.

Historically, accessibility research has focused on the journey to work and more recently services and amenities such as health care (Knox 1978), education (Pacione 1989), playgrounds (Smoyer-Tomic, Hewko et al. 2004), daycare (Truelove 1993), and parks (Talen 1997; Talen 2003). Unfortunately, due to technological, data, and computational limitations past accessibility research has been confined to the study of one or few types of services and thus lacks the scope to comprehensively evaluate urban accessibility on a metropolitan scale.

The fundamental goal of a service accessibility study is to discuss issues of spatial equity. However, before issues of spatial equity can be properly addressed there are methodological concerns inherent to the study of accessibility which must be addressed. This thesis accepts, and builds upon, the argument of Hewko et al., (2002) which suggests that the use of high resolution spatial information provides the capacity to overcome sources of aggregation error, the principle complication associated with accessibility research.

While the use of high resolution spatial data allows for a refinement in accessibility technique, it also provides for a comprehensive, multi-service accessibility analysis. This thesis suggest that such an approach can result in deviations from the established form of accessibility (Alonso 1964; Horner 2004). This research will compare the spatial accessibility of a diverse array of services, the outcomes produced by two commonly employed distance metrics, and issues of scale on the form of service accessibility.

This research provides a further understanding of the relationship between publicly available services and the community through two analyses: A ranking of urban neighbourhoods based on service accessibility to show deviations from the traditional form of accessibility; a ranking of services based on their accessibility to the community.

These analyses will establish benchmarks of the proximity to services which could later be utilized compare changes in urban form over time and among cities, and to explore issues of spatial inequity and sustainability (e.g. smart growth and the new urbanism).

Finally, this research will demonstrate how accessibility data can be integrated with socioeconomic information. By standardizing accessibility and census-based information in a geographic information system (GIS) this research will establish a conduit through which future investigation can be conducted into another dimension of geography's long standing interest in the urban social landscape. Eventually these products might be used to inform urban social policy in a substantive manner.

Overall this research helps to inform urban geography by describing and analyzing the urban spatial structure of residential services and amenities (i.e. the location and distribution of service and amenities relative to the spatial arrangement of residential neighbourhoods). As such, it is hoped that it can be extended and applied to a wide range of questions that are outlined in the conclusion.

The research method introduces two innovations to the study of accessibility. First, this study uses higher resolution spatial data than has been used in previous studies, thus resulting in more accurate accessibility analyses. Past accessibility studies have relied on Canada Census data. The highest spatial resolution of household data is at the level of the 'block face' although most analyses use data aggregated to the level of the dissemination unit. Use of these spatial units introduces spatial inaccuracy into the location of the households, their attributes, and the overall representation of accessibility. In this study, accessibility is calculated from each residential parcel to each of the services under consideration.

Second, in addition to utilizing high resolution geospatial data sources this research will also differ from the accessibility literature as it will adopt a macro/metro-wide approach, in an asocial context, attempting to examine the relationship between the entire population and the service industry fostering a more complete understanding of urban accessibility. Most often, authors choose to focus on a specific service or industry or adopt a case study approach when conducting accessibility research. This exploration of accessibility will employ a vast and diverse data set of local amenities[1].

The thesis begins with a review of literature relevant to accessibility. In this review an effort will be made to outline past and present accessibility research, gaps in the accessibility literature, and the accepted methodological practices associated with accessibility research. Chapter three will illustrate the methodology developed in this research which guides the development of a comprehensive/global, multi-service accessibility model employing high resolution spatial data. Chapter four is dedicated to the presentation and interpretation of the results produced in the accessibility analysis which will be followed by discussion in Chapter 5. Finally, Chapter six will conclude this thesis.

[1] The terms service and amenity are used interchangeably throughout this paper.

2.0 Literature Review

The intraurban accessibility literature is very broad in scope. This body ranges from service accessibility to issues of transportation and land use. The study of accessibility developed during the mid-twentieth century at the time of the quantitative revolution. As geographers shifted toward this analytical perspective comparative analyses and the identification of spatial equity/inequity became common. Distance and its variation between origins and destinations, which is the study of accessibility, is one avenue through which this discussion of spatial equity has progressed.

Talen (2003) defines accessibility as the ease with which a resident can reach a given destination; a definition supported by others (Hewko, Smoyer-Tomic et al. 2002; Smoyer-Tomic, Hewko et al. 2004). Unfortunately, she notes a "downplaying of the importance of access" which she attributes to "low-density suburban development......the outcome of post-Fordist urbanization". The growth of automobile ownership and dependency, identified by Filion et al. (1999) indicates a further diminishment of the importance of distance in North America and the relative nature of access.

While the planning literature would suggest that distance is becoming less important, Talen (2003) reminds the readership that importance is a relative concept. Distance, she notes, remains of paramount importance to those dependent on pedestrian access such as the elderly, disabled, poor, and working parents. Given the state of current petroleum prices distance will likely increase in importance during trip based decision making processes. Therefore, contrary to the opinion that distance is becoming irrelevant the cost of vehicular travel and the dependency of population segments on transportation forms other than the automobile (I extend

Talen's (2003) pedestrian dependency) lends further credibility to the continued examination of accessibility. This line of thought also has considerable bearing on the notion of urban sustainability.

Two fundamental and recurring themes in accessibility research are spatial accessibility and spatial equity. The study of spatial accessibility has evolved out of location analysis. Spatial accessibility examines the relationship between existing facilities and residents while location analysis concerns itself primarily with the potential allocation of facilities and the resulting consequences for residents (Hewko, Smoyer-Tomic et al. 2002). Most often authors choose to evaluate a particular service or demographic. Spatial accessibility to amenities generally refers to the ease with which amenities can be reached, as well as the quality, quantity and the type of activities offered by the amenities (Handy and Niemeier, 1997 as quoted in (Smoyer-Tomic, Hewko et al. 2004)).

Spatial equity has been a concern of, or noted by, many authors (Knox 1978; Pacione 1989; Truelove 1993; Talen 1997; Hewko, Smoyer-Tomic et al. 2002; Smoyer-Tomic, Hewko et al. 2004). The unifying line of inquiry questions whether access to a service satisfies the demand for it and whether disparities exist between particular population cohorts. Spatial equity involves the consideration of need, justice and fairness in the distribution of spatial inequalities (Talen and Anselin 1998). Lucy, 1981, suggests that equity is achieved when the provision of a service meets the needs of the population. Recently, post modern conditions have served to increasingly raise issues of spatial equity. It can further be argued that this post modern perspective and its influence on research approach has made this line of inquiry more relevant.

2.1. Past Accessibility Research

Thoughts on urban accessibility can be traced back to authors such as Alonso (1964), Muraco (1972), and Koenig (1974). Early accessibility research discussed issues of urban form (Alonso 1964), economic development (Alonso 1968; Koenig 1974), and the journey to work (Waldo 1974; Black and Conroy 1977). These preliminary accessibility studies precipitated research which investigates topics such as services (Lozano, Sena et al. 1974; Knox 1978), housing (Ball and Kirwan 1977), transportation and land use (Zakaria 1974; Black and Conroy 1977), and the development of more detailed analytical techniques (Lozano, Sena et al. 1974; Dalvi and Martin 1976). These examples of historical accessibility research, along with many others, provided a foundation upon which the study of accessibility was pursued into the 1980's and early 1990's (Koenig 1980; Ottensmann 1980; Mayhew and Leonardi 1982; Hanson and Schwab 1987; Martin and Williams 1992; Baum and Hassan 1993; Ihlanfeldt 1993; Zimmerman 1993). Beginning in the mid 1990's we begin to see the integration of geographic information systems (GIS) into the methodology of accessibility study (Arentze, Borgers et al. 1994; Geertman and Vaneck 1995). The development of the accessibility literature from the 1960's through to the mid 1990's has provided the theoretical and technical base for the current examination of accessibility. The following section will address the current state of the accessibility literature.

2.2. Current Accessibility Research

The body of accessibility research has become more diverse over time. Currently, this literature discusses topics of service accessibility, employment and commuting, housing, transit and travel behaviour, urban form, and transportation and land-use. In addition to these sub-literatures is another which focuses on issues of methodological development. Figure 1 illustrates the breadth of the accessibility literature while Table 1 demonstrates its depth. The following paragraphs will discuss these various sub-literatures in an effort to demonstrate the breadth of the accessibility literature.

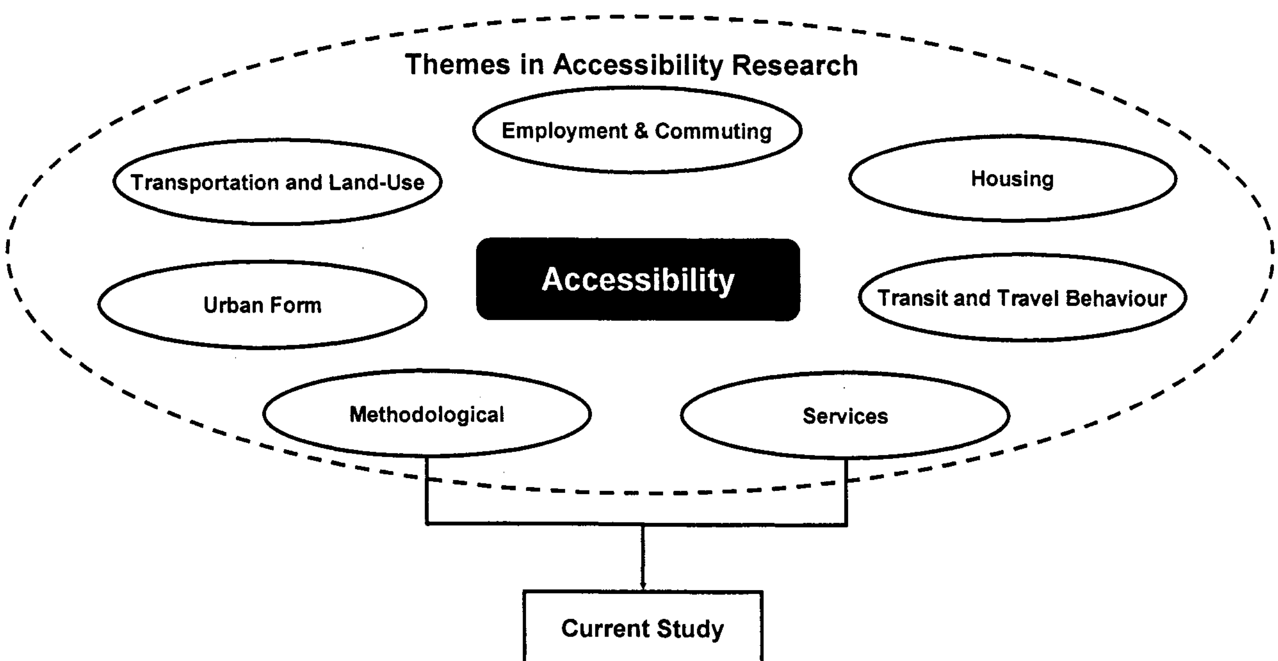


Figure 1: Themes in Accessibility Research

2.2.1. Service Accessibility

The literature on service accessibility can be broken down into two major categories; public and privately operated services. This research examines the relationship between residents and a variety of travel destinations within an urban region. Typically, this work will compare the access of residents to a particular service such as grocery stores (Dunkley, Helling et al. 2004), playgrounds (Talen and Anselin 1998), and hospitals (Tanser, Gijsbertsen et al. 2006). This line of inquiry aims to discover whether environmental inequity exists over space (i.e. are persons in location A receiving less benefit from their environment (lower service accessibility) than persons in locations B and C). Alternately, the literature will compare disparities of accessibility along socioeconomic lines in an effort to determine whether social inequities are present (Zimmerman 1993; Talen 1997; Thomas and Hwang 2003; Apparicio and Seguin 2006). To date attention has been directed toward issues of health (Mayhew and Leonardi 1982; Martin and Williams 1992; Reyes, Tome et al. 1998; Lovett, Haynes et al. 2002; Brindis, Klein et al. 2003; Luo and Wang 2003; Guagliardo, Ronzio et al. 2004; Tsoka and le Sueur 2004; Choi, Afzal et al. 2006), food retail and restaurants (Jones and Bentley 2002; Helling and Sawicki 2003; Dunkley, Helling et al. 2004; Stewart and Davis 2005; Smoyer-Tomic, Spence et al. 2006), education and child services (Webster and White 1997; Brindis, Klein et al. 2003; Diamond and Spillane 2004; Reyes and Rodriguez 2004), retail (Peron 2001; Dunkley, Helling et al. 2004; Krizek and Johnson 2006), public services (Campbell 1996; DeVerteuil 2000; Apparicio and Seguin 2006; Bar-El and Schwartz 2006; Gleeson 2006), and green space (Zimmerman 1993; Campbell 1996; Haughton 1999; Agyeman and Evans 2003) to list a few.

2.2.2. Employment and Commuting

Employment and commuting, best described as the 'Journey to Work' literature is one of the larger sub-topics found within the accessibility literature. This niche is replete with research which discusses the spatial relationship between residence and place of employment. Issues of residential location choice (Thakuriah and Metaxatos 2000; Pinto 2002), commuting (Cooke and Ross 1999; Wang 2000), employment equity (Thakuriah and Metaxatos 2000; Wang 2001), and the influence of urban form on commuting (Vandersmissen, Villeneuve et al. 2003; Kawabata and Shen 2006) have been presented.

2.2.3. Housing

The accessibility literature, with regard to housing issues, is not as large as other sub-literatures discussed in this thesis. Studies which integrate the topics of housing and accessibility can be grouped in one of several categories. The first body of research examines variations in home and land prices with respect to accessibility (Adair, McGreal et al. 2000; Fik, Ling et al. 2003; Cervero and Duncan 2004). Secondly, housing research has been linked to other literatures discussed in this section such as employment and commuting (Cervero, Rood et al. 1999) and service accessibility (Cho 2001). Finally, the housing/accessibility dynamic has been investigated using a social dimension exploring issues such as public housing and segregation (Rodman and Cooper 1995; Helling and Sawicki 2003; Lau and Chiu 2003; Apparicio and Seguin 2006).

2.2.4. Transit and Travel Behaviour

The literature surrounding transit and travel behaviour is arguably the most extensive within the overall literary body of accessibility. Issues such as public transit and the equity of its provision (Grengs 2001; Pendyala, Ubaka et al. 2002; Rastogi and Rao 2003; Rodriguez and Targa 2004) constitute the bulk of this literature. Other topics of note include pedestrian access (AultmanHall, Roorda et al. 1997; Talen 2003), cycling (Saelens, Sallis et al. 2003; Krizek and Johnson 2006), and accessibility for persons with disabilities (Church and Marston 2003; Beale, Field et al. 2006). The final component of this literature explores travel behaviour and the daily decisions of intraurban travelers (Ben-Akiva and Bowman 1998; Ghaeli and Hutchinson 1998; Pinto 2002; Srinivasan and Ferreira 2002; Haynes, Lovett et al. 2003).

2.2.5. Urban Form

The discussion of urban form and its relationship with accessibility is evident throughout the entire accessibility literature. Urban form is often discussed as a variable which influences accessibility (Vandersmissen, Villeneuve et al. 2003). Occasionally, work is published which directly explores the relationship between form and accessibility (Krizek 2003; Horner 2004). Finally studies such as Lima (2001) measure the influence of built form on accessibility and the resultant effects this dynamic exerts on social equity.

2.2.6. Transportation and Land Use

The transportation and land use dimension of intraurban accessibility research falls most directly within the planning literature and discusses the balance between maintaining access while maximizing land use potential (Badoe and Miller 2000; Johnston and de la Barra 2000; Krizek 2003; Lee 2003). Other work focuses on the evaluation of existing transportation infrastructure (Sathisan and Srinivasan 1998), while still others such as Chang (2003) have adapted an accessibility model to present the transportation issues associated with urban disaster planning. Finally, within the transportation and land use sub-literature are methodological papers which focus on operationalizing geospatial transport networks (Zakaria 1974); however, for the purposes of this literature review they will be discussed in the following paragraph.

2.2.7. Methodological Research

While the study of accessibility is inherently quantitative, some accessibility research presents a more detailed methodological focus than others. A large proportion of this literature furthers the development of technique in geographic information systems (GIS) with respect to accessibility (Lake, Lovett et al. 2000; O'Sullivan, Morrison et al. 2000; Wang 2000; Jones and Bentley 2002; Lee 2004; Liu and Zhu 2004; Reitsma and Engel 2004). Others choose to evaluate, discuss and improve upon the conceptual and methodological framework of accessibility (Talen 1998; Talen 2003; Horner 2004). Finally, there are authors which attempt to overcome barriers inherent to the study of accessibility with innovative data sources (Hewko, Smoyer-Tomic et al. 2002; Wang and

Trauth 2006). The methodological aspects of accessibility are central to this thesis and will be further discussed later in this chapter.

Table 1: Themes in Accessibility Literature

Theme	Sub-Theme	Author	Date
Employment and Commuting		Horner, M. W.	2004
Employment and Commuting		Ihlanfeldt, K. R.	1993
Employment and Commuting		Kawabata, M. and Q. Shen	2006
Employment and Commuting		Lau, J. C. Y. and C. C. H. Chiu	2003
Employment and Commuting		Lovett, A., R. Haynes, et al.	2002
Employment and Commuting		Ottensmann, J. R.	1980
Employment and Commuting		Wang, F. H.	2000
Employment and Commuting		Wang, F. H.	2001
Housing		Adair, A., S. McGreal, et al.	2000
Housing	Services	Apparicio, P. and A. M. Seguin	2006
Housing		Ball, M. J. and R. M. Kirwan	1977
Housing	Land Cost	Cervero, R. and M. Duncan	2004
Housing	Employment	Cervero, R., T. Rood, et al.	1999
Housing	Services	Cho, C. J.	2001
Housing	Land Cost	Fik, T. J., D. C. Ling, et al.	2003
Housing	Employment	Pinto, S. M	2002
Housing		Rodman, M. and M. Cooper	1995
Housing	Employment	Thakuriah, P. and P. Metaxatos	2000
Housing		Thomas, J. M. and H. Y. Hwang	2003
Methodological		Arentze, T. A., A. W. J. Borgers, et al.	1994
Methodological		AultmanHall, L., M. Roorda, et al.	1997
Methodological		Church, R. L. and K. L. Roberts	1983
Methodological		Cooke, T. J. and S. L. Ross	1999
Methodological		Current, J. R. and D. A. Schilling	1987
Methodological		Dalvi, M. Q. and K. M. Martin	1976
Methodological		Geertman, S. C. M. and J. R. R. Vaneck	1995
Methodological		Hewko, J., K. E. Smoyer-Tomic, et al	2002
Methodological		Hodgson, M. J., F. Shmulevitz, et al.	1997
Methodological		Lee, J.	2004
Methodological		Liu, S. X. and X. A. Zhu	2004
Methodological	Public Transit	Pendyala, R. M., I. Ubaka, et al.	2002
Methodological		Talen, E.	1998
Methodological		Talen, E.	2003
Methodological		Wang, H. and K. M. Trauth	2006
Services	Business Services	Alonso-Villar, O. and J. M. Chamorro-Rivas	2001
Services	Education	Brindis, C. D., J. Klein, et al.	2003
Services	Business Services	de Vaal, A. and M. van den Berg	1999
Services	Theory	DeVerteuil, G.	2000
Services	Grocery	Dunkley, B., A. Helling, et al.	2004
Services	Parks	Erkip, F.	1997
Services	Theory	Greenhut, M. L. and C. C. Mai	1980
Services	Health	Guagliardo, M. F., C. R. Ronzio, et al.	2004
Services	Health	Haynes, R., A. Lovett, et al.	2003
Services	Retail	Helling, A. and D. S. Sawicki	2003
Services	Health	Knox, P. L.	1978
Services	Theory	Lozano, E. E., M. Sena, et al.	1974
Services	Health	Luo, W. and F. H. Wang	2003
Services	Health	Martin, D. and H. Williams	1992
Services	Health	Mayhew, L. D. and G. Leonardi	1982
Services	Theory	Orloff, C. S.	1977

Table 1: Themes in Accessibility Literature (continued)

Theme	Sub-Theme	Author	Date
Services	Education	Pacione, M.	1989
Services	Health	Reyes, H., P. Tome, et al.	1998
Services	Parks	Smoyer-Tomic, K. E., J. N. Hewko, et al.	2004
Services	Grocery	Smoyer-Tomic, K. E., J. C. Spence, et al.	2006
Services	Fast Food	Stewart, H. and D. E. Davis	2005
Services	Parks	Talen, E.	1997
Services	Parks	Talen, E. and L. Anselin	1998
Services	Health	Tanser, F., B. Gijsbertsen, et al.	2006
Services		Truelove, M.	2000
Services	Health	Tsoka, J. M. and D. le Sueur	2004
Services	Methods	Tsou, K. W., Y. T. Hung, et al.	2005
Services	Education	Webster, C. J. and S. White	1997
Services		White, A. N.	1979
Transit and Travel Behavior	Disability	Beale, L., K. Field, et al.	2006
Transit and Travel Behavior	Methods	Ben-Akiva, M. and J. L. Bowman	1998
Transit and Travel Behavior	Disability	Church, R. L. and J. R. Marston	2003
Transit and Travel Behavior	Behavior	Ghaeli, R. and B. G. Hutchinson	1998
Transit and Travel Behavior	Public Transit	Grengs, J.	2001
Transit and Travel Behavior	Theory	Hanson, S. and M. Schwab	1987
Transit and Travel Behavior	Theory	Krizek, K. J.	2003
Transit and Travel Behavior	Housing	Krizek, K. J.	2003
Transit and Travel Behavior	Walking & Cycling	Krizek, K. J. and P. J. Johnson	2006
Transit and Travel Behavior	Public Transit	Rastogi, R. and K. V. K. Rao	2003
Transit and Travel Behavior	Public Transit	Rodriguez, D. A. and F. Targa	2004
Transit and Travel Behavior	Walking & Cycling	Saelens, B. E., J. F. Sallis, et al.	2003
Transit and Travel Behavior	Housing	Srinivasan, S. and J. Ferreira	2002
Transportation and Land Use	Planning	Ahas, R. and U. Mark	2005
Transportation and Land Use		Badoe, D. A. and E. J. Miller	2000
Transportation and Land Use	Planning	Chang, S. E.	2003
Transportation and Land Use	Methods	Melkote, S. and M. S. Daskin	2001
Transportation and Land Use	Public Transit	O'Sullivan, D., A. Morrison, et al.	2000
Transportation and Land Use		Sathisan, S. K. and N. Srinivasan	1998
Transportation and Land Use	Land Cost	Waldo, R. D.	1974
Transportation and Land Use	Methods	Zakaria, T.	1974
Theory		Black, J. and M. Conroy	1977
Theory		Koenig, J. G.	1980
Theory		Muraco, W. A.	1972
Urban Form		Horner, M. W.	2004
Urban Form		Kim, D. S., K. Mizuno, et al.	2003

2.3. Services

This research, as stated in Chapter One, aims to examine the spatial relationship of accessibility between neighbourhoods and publicly available consumer services. The term services, which will utilized frequently throughout the remainder of this thesis, is defined here, for the purposes of this research, as those destinations which provide goods, services (public and private), and programming to the general population and do not include those which service the business community. These services are engaged by the population throughout their daily lives and range from government social services to retail. There are many categories that would naturally fall within this range of services and amenities, however, due to data limitations it was not possible to incorporate these into this particular study. It is hoped that the information gathered throughout this study can later be used to contribute to research in location analysis, market research, and the rank ordering of services. By creating a bridge between accessibility and neighbourhood, in the manner and at the scale proposed, this study will is well positioned to inform the underdeveloped areas of consumer service within the geography of services literature.

The literature which examines the geographic nature of services is very diverse. Considerable effort has been made to examine producer, high-order, services and their linkages to the larger business community (Viladecans-Marsal, 2004; Stein, 2002; Gong, 2001; Alonso-Villar & Chamorro-Rivas, 2001; de Vaal & van den Berg, 1999). Attention has also been directed toward economic transition and the move from a manufacturing to a service economy (Beyers, 2002; Daniels & Bryson, 2002).

Additionally, very large sub-literatures can be found which address issues of urban retailing (Potter 1980; Fotheringham and Knudsen 1986; Jones and Doucet 2001; Lombardo, Petri et al. 2004) and public facility location (Orloff 1977; White 1979; Greenhut and Mai 1980; Leonardi 1981; Leonardi 1981; Church and Roberts 1983; Ribeiro and Antunes 2000; Melkote and Daskin 2001; Ribeiro and Antunes 2002; Chen, Deng et al. 2003). In conjunction with these research topics, and by itself, globalization has been repeatedly addressed (Fujita & Thisse, 2006; Perkins & Neumayer, 2005; Taylor & Walker, 2001).

Another well developed area of study within the service literature is location theory and location analysis (Polese & Shearmur, 2006; Ahas & Mark, 2005; Yeates, 2001; DeVerteuil, 2000). Evolving from this theme are accessibility analyses which have already been discussed. It is fair to say, however, that the writing comprising the service literature is largely biased toward producer services. Collectively, consumer services, from a geographic standpoint, have received considerably less research attention (Maher, 2003). As mentioned throughout the course of this thesis these types of service are most commonly investigated individually or in small, very similar, groupings (Erkip, 1997; Smoyer-Tomic et al., 2004; Dunkley et al., 2004; Pacione, 1989).

Although this research, as described throughout the remaining chapters, does not borrow heavily from the service literature it is thought that future efforts building upon this work can benefit from a more secure linkage to this body. One of the principle aims of this research is to establish a technique through which a comprehensive representation of neighbourhood service accessibility can be created. Future accessibility research can adapt many of the taxonomic structures found in works such as Pinch (1985) and more fully integrate the literatures of service and accessibility.

2.4. Critique and Summary of Literature

2.4.1. The Accepted Form of Accessibility

The established body of accessibility literature suggests high levels of accessibility will be found within downtown and/or central urban areas (Knox 1978). Beginning with the work of Alonso (1964), Muraco (1972) and Knox (1978) a literature was established which identifies the city center as a node from which accessibility emanates. Authors such as Horner (2004) continue to find evidence that accessibility conforms to this defined pattern of centricity. This thesis proposes that while the spatial arrangement of accessibility will typically manifest in this pattern it does have the potential to deviate from this form. The following paragraphs will discuss the deficiencies in the accessibility literature which support this notion.

2.4.2. Limitations of Current and Past Accessibility research

The accessibility literature and the research comprising it are limited in three distinct dimensions; research design, technical, and data limitations. The following three paragraphs will discuss each.

2.4.2.1. Research Design Limitations

Accessibility research tends to have been carried out on a local scale, often examining a subset of neighbourhoods within an urban region. Current research narrowcasts in one of two ways. The first group of literature confines itself to the study of only select amenities (groceries, playgrounds, and day-care) attempting to inform policy with respect to individual service types (Truelove 1993; Dunkley, Helling et al. 2004; Smoyer-Tomic, Hewko et al. 2004). The second body examines accessibility in terms of selected individual social groups (Truelove 2000; Helling and Sawicki 2003). Often researchers use a combination of these two approaches. The research design limitations, described in this paragraph as narrowcasting, are an artifact of the data and technical limitations which will be described shortly.

2.4.2.2. Technical Limitations

Since the early accessibility research of Alonso (1964) and Knox (1978), urban geographers have been attempting to quantify the functions of the urban environment. Early techniques involving Euclidean and Manhattan distance have evolved into more advanced methods of calculating access throughout a metropolitan area (Liu and Zhu 2004). Even with these new computational techniques it is apparent that the literature has remained methodologically stagnant. While current techniques are capable of overcoming many of the limitations associated with accessibility analysis and creating a comprehensive understanding of intraurban accessibility they are themselves limited by the data which they employ. Without high resolution social and spatial information accessibility research will remain in its current state.

2.4.2.3. Data Limitations

The basic limiting factor associated with accessibility analysis is data. Spatial accessibility is a function of distance from and origin to a destination. The enormity of the potential origins and destinations to be found within an urban setting are staggering. Publicly available geospatial information sources of this nature are non-existent (Sawicki 1996) and while there are private sources for this information the cost associated with it is equally staggering. This leaves an accessibility researcher with several options: First, one could purchase a small subset of data and concentrate research efforts on a specific population group or service; second, one could utilize publicly available data sources (the limitations of which will be discussed later in this chapter); third, one could employ innovative methods of capturing the necessary data (Hewko, Smoyer-Tomic et al. 2002; Talen 2003; Wang and Trauth 2006). While the technical and theoretical background to carry out comprehensive accessibility research exists one finds that the development of accessibility research is ultimately impeded by data.

2.5. Argument for a global approach

As mentioned in the previous section, the accessibility literature suggests that accessibility radiates from the city center in a concentric pattern and is associated with compact urban forms (Alonso 1964; Burton 2000; Kim, Mizuno et al. 2003; Horner 2004). However, the literature to date has been constrained and compromised by issues of data, technical, and research design limitation. I argue that the form of accessibility has the ability to deviate from that which the literature has established in the following manners: that areas of relative inaccessibility can exist in the city center; and areas of relatively high accessibility can exist in the city periphery.

Furthermore, I argue that employing innovative data sources, similar to those suggested by Sawicki and Flynn (1997) and Wang and Trauth (2006) to capture high resolution origin and destination information, will allow for a global study of intraurban accessibility and overcome many of the limitations previously discussed in this chapter. It is in a parcel level, multi-service examination of accessibility that evidence can be found suggesting that the form of accessibility can deviate from the form established in the literature. Finally, I argue that the deviations in accessibility form, as discussed in this paragraph, can also be attributed to service type and the distance measure by which accessibility is calculated.

2.6. Methods in Accessibility Research

In order to undertake a global study of accessibility an understanding of accessibility methodology is needed. The following paragraphs will conduct a review of accessibility methodology. Specific attention will be paid to address techniques in distance measurement, distance metrics and the methodological impediments faced by accessibility research. Talen (2003) and Hewko et al. (2002) neatly summarize the five most common measures of accessibility and distance metrics which are discussed below.

Unfortunately, there are many factors affecting accessibility which cannot be adequately quantified and incorporated into a study of accessibility. Lindsey et al., (2001), and Mitchell, (1996), identify social, cultural, and gender based impediments affecting accessibility in addition to the traditional distance and traffic measures. Economic, health and behavioral constraints are other possible factors which may influence an individual's accessibility. Items such as these represent additional cost factors which determine inequity. As will be noted throughout this thesis this research will ignore these factors in an effort to examine, strictly, spatial accessibility.

2.6.1. Measures of Accessibility

While the study of accessibility varies in focus there is considerable consistency in the methods and techniques employed. Essentially, one calculates accessibility values, which are a function of distance from an origin (typically the centroid of a census polygon) to a destination (one or multiple service points). The techniques used to measure accessibility vary slightly. The following paragraphs outline the five most common measures of accessibility and the two most utilized distance metrics. Further discussion of the methodological aspects of the accessibility literature has been omitted from this chapter as it is dealt with in greater detail in the methodological chapter.

Container

This initial methodology in the development of accessibility analysis measures presence/absence of an amenity within a spatial unit and was developed prior to more advanced GIS networking techniques. The researcher defines a base spatial unit of study, such as a census or municipal boundary, and a frequency count of the amenity within its bounds. The value is then assigned as an attribute of the spatial unit[2].

Coverage

The coverage method is based on a variation of the presence/absence method. This technique returns a value corresponding to the frequency of services within a given catchment area. These two methodologies assume that residents living within the defined catchment area, or spatial unit, will only use the services within them and that services located outside the boundary do not factor into the residents overall accessibility. As will be evident in the methodological chapter, this technique is quite unrealistic when using high resolution data. There are several more assumptions and spatial errors present within each of the methodologies discussed in this section. These methodological idiosyncrasies, such as aggregation error, will be outlined and demonstrated in a later section.

Minimum Distance

The development of network analysis within GIS environments has allowed accessibility scholars to calculate accurate travel distances through urban street networks. The third accessibility methodology, and most common, is one which calculates shortest path distance, through a street network, from a catchment area's centroid to the closest facility of a service type. Advances in network analysis have allowed this method to

[2] For a more detailed description of this and other measures of accessibility please refer to:
Talen, E. "The Social Equity of Urban Service Distribution an Exploration of Park Access in Pueblo, Colorado, and Macon, Georgia." *Urban Geography* 18, no. 6 (1997): 521-41.

incorporate travel time, as a function of speed and traffic congestion thus developing a more complex and realistic representation of travel within the urban environment.

Travel Cost

This technique is a variation on the previous and also employs the use of GIS networking techniques. In this instance the researcher calculates the mean distance from an origin to all facilities of a type. GIS capabilities now extend the option of calculating travel cost or minimum distance to a specified number of facilities (i.e. the closest 5). As will be noted in chapter 3 the option to limit the networking analysis based upon such a parameter was not chosen. The use of the travel cost technique in this study is used to represent the availability of choice to the traveler and thus all possible destinations must be considered.

Gravity

The final measure of accessibility, the gravity measure incorporates an additional measure of friction along with distance. Size, quality or other quantifiable attribute which may influence residents to frequent a destination is employed. This gravity index is then divided by the friction of distance creating a more comprehensive measure of accessibility (Talen 2003). While gravity methods have become less prevalent since the onset of network analyses they remain a historical cornerstone of urban geographic analysis[3].

[3] While it is noted that gravity models have become less prevalent in spatial analyses many of the weighting functions and characteristics of spatial influence have been incorporated into the other techniques.

2.6.2. Distance Metrics

Essentially, three types of distance metrics exist in accessibility research. Distance metrics are the manner in which distance is calculated from the origin to the destination and include: shortest network path, Euclidean and Manhattan distance. Shortest network path is the most common metric and accurately reflects vehicular forms of travel. However, shortest network path measurement confines transportation solely to the street network and thus does not adequately depict forms of transportation such as the bicycle or walking, which are not dependent upon nor confined to a street network. When examining accessibility in a non-vehicular context Euclidean and Manhattan distances are more often utilized which provide a more direct route of access between origin and amenity (Hewko, Smoyer-Tomic et al. 2002; Talen 2003).[4]

2.6.3. Aggregation error

Aggregation error is a complication inherent to all accessibility analyses (Hodgson, Shmulevitz et al. 1997; Hewko, Smoyer-Tomic et al. 2002). While Hodgson et al. (1997) review the forms in which aggregation error can manifest, Hewko et al. (2002) discuss the effects of it with respect to accessibility analysis and varying sizes of base spatial units. Network analyses require two basic components, a starting point and an end point. A street network is often present as well representing a third component. Aggregation error is a result of the starting point. In an effort to further social research, the centroid of an aerial unit, often a census unit, is used as the point of origin for the analysis. In using a central feature a researcher assumes that all persons residing in a census polygon are located at the centroid. As citizens are distributed throughout the

[4] For a more detailed understanding of distance metrics please refer to Talen, 1997 or Hewko et al., 2002

aerial unit the sources of aggregation error must be acknowledged. The following paragraphs will outline the forms of aggregation error which arise when conducting networking analyses.

Source A aggregation error is the misestimation of distance from an aerial unit's centroid to a destination outside of the unit (Hewko, Smoyer-Tomic et al. 2002). Accessibility analyses, such as the p-median model, assume that the travel of all patrons within the aerial unit occur from the unit's centroid to the destination (Hodgson, Shmulevitz et al. 1997). This is the root of the error. Figure 2 represents Source A aggregation error using a measurement to the closest facility. In this example the accessibility value of the neighbourhood will be a function of the distance between the centroid and the facility. It is therefore assumed that all residences within the neighbourhood are the same distance from the facility. In reality some residences are closer to the facility than the centroid while others are more distant. According to Hodgson et al. (1997), the correct accessibillity measure would be the mean distance from all residences within the neighbourhood.

A second type of aggregation error, Source B, can be found when the closest facility and the neighbourhood's centroid spatially coincide with each other or are located in close proximity. Traditionally accessibility analyses would record the travel distance from origin to amenity as 0, which is in fact the distance between the centroid and the facility (Hodgson, Shmulevitz et al. 1997). As one can see from Figure 3 the distance from residents to the facility in question is not 0. Again, the correct accessibility measure would be the mean distance from all residences within the neighbourhood to the facility.

The third source of aggregation error, Source C, arises when accessibility is a function of distance from the neighbourhood centroid to it's closest facility when residences falling within the neighbourhood may in fact be located closer to other facilities. Thus demand is allocated to an incorrect facility (Hodgson, Shmulevitz et al. 1997; Hewko, Smoyer-Tomic et al. 2002). Figue 3 illustrates this complication. Hodgson et al. (1997) do not discuss a solution to this source of aggregation error. In order to avoid this source of aggregation error one must calculate the mean distance from each residence to its closest facility which is not tenable without high resolution spatial information.

The final manner in which aggregation error can manifest was identified by Hodgson et al. (1997) as Souce D error. Unlike the previous three forms of aggregation error, Source D error is not caused by the centroid of the neighbourhood. Instead, Source D error is found when the destination is an aerial unit. The centroid of the destination, the point to which distance is calculated, may in fact be further away from the point where the destination actually begins. Thus distance is exaggerated.

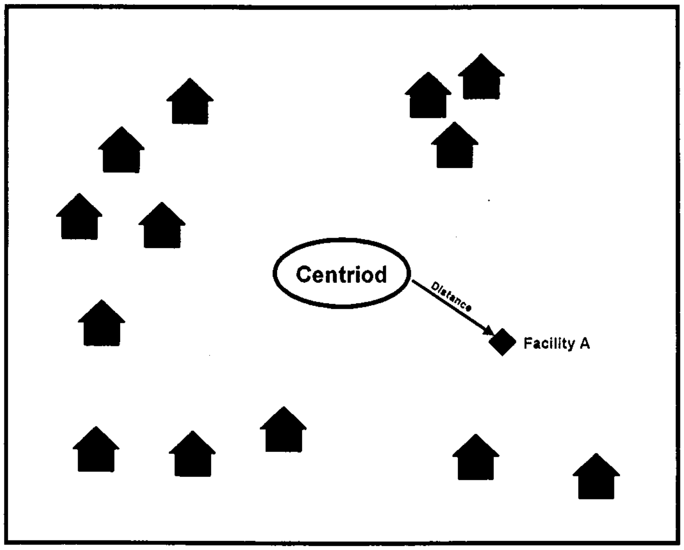


Figure 2: Source A

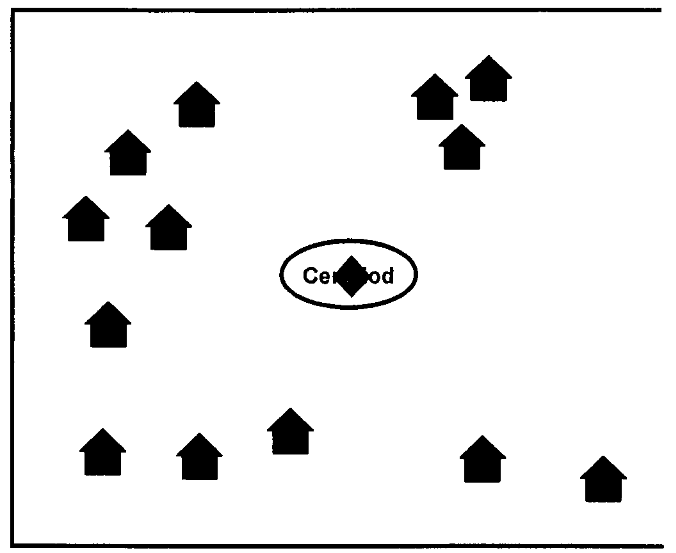


Figure 3: Source B

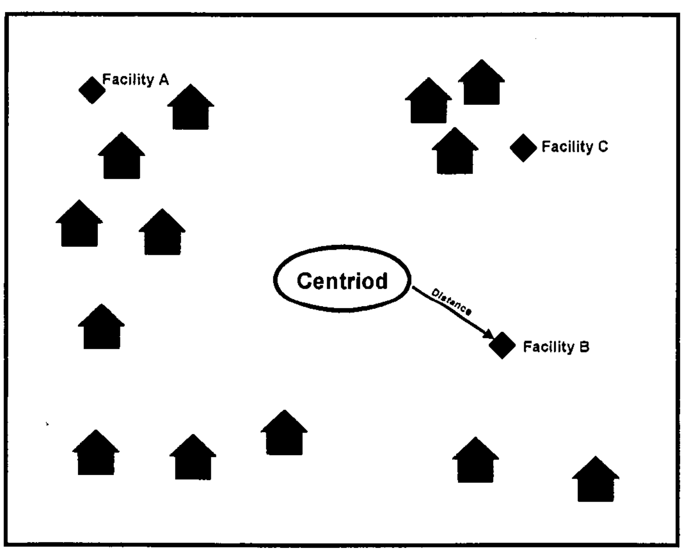


Figure 4: Source C

Virtually, every accessibility study is susceptible to one or more sources of aggregation error. Several methods have evolved in recent decades which aim to remove or minimize the effects of aggregation error within a dataset (Current and Schilling 1987; Hodgson, Shmulevitz et al. 1997) and focus on pre and post data processing using mathematical constructs such as the p-median model. Unfortunately, none of these methods address the underlying problem of aggregation error. These efforts concentrate on removing or controlling error by either preprocessing data or attempting to remove it mathematically following the accessibility analysis. It is the opinion of this author that these methods, while innovative and partially successful, do not address the problem of aggregation error; aggregated data.

Two existing methods of minimizing aggregation error involve the use of higher resolution spatial data (Hewko, Smoyer-Tomic et al. 2002; Smoyer-Tomic, Hewko et al. 2004). Most often the census block or postal code centroid are employed as they are the smallest census units available. First the finer resolution data can be utilized to calculate a population weighted centroid for the larger aerial unit being used such as the census tract. Second, accessibility can be derived from each finer resolution point and then aggregated to create a more accurate distance measurement (Current and Schilling 1987; Hodgson, Shmulevitz et al. 1997; Hewko, Smoyer-Tomic et al. 2002). At present the second of these two error reducing techniques offers the greatest success in attempting to minimize the effects of aggregation error.

The use of aerial unit varies throughout the literature. The size of the spatial unit selected will directly influence the degree of aggregation error present in the analysis (Hewko, Smoyer-Tomic et al. 2002). As such many authors have chosen to employ the census block or postal code centroid as their base spatial unit (Talen 1997; Hewko, Smoyer-Tomic et al. 2002; Dunkley, Helling et al. 2004; Smoyer-Tomic, Hewko et al. 2004). Still others continue to employ larger units such as the census tract (Talen and Anselin 1998; Truelove 2000; Helling and Sawicki 2003). Whichever base spatial unit is selected a degree of aggregation error will persist as the unit measurement assumes a centrally concentrated distribution of persons within it (Hewko, Smoyer-Tomic et al. 2002). Moreover, the degree of error will also be influenced by the size of the spatial unit. Thus larger areas such as the census tract will possess a greater amount of spatial error than smaller units such as the block face. While one would immediately assume that the block face would be the most logical unit of choice this decision must be balanced with the supression/availability of the sociodemographic data associated with such a level of measurement.

While finer resolution spatial information, individual land parcels, will provide the greatest precision when conducting neighbourhood accessibility analysis, Talen (2003) suggests that planners will want to address access in a socioeconomic context. Thus data availability will become an issue as socioeconomic information is most often impossible to obtain at the parcel level. She sees that the only way to realistically overcome this impediment of data availability is to use higher forms of spatial aggregated information available from the census. I contend that the accessibility of the neighbourhood should still be calculated at the parcel level. In a strictly spatial sense, the accessibility of a neighbourhood is a function of the cumulative measure of accessibility of all parcels within the neighbourhood. By calculating accessibility in this manner one can aggregate the parcel level accessibility data upward in order to match it any level of spatial aggregation found in the census.

The central reason why the problems presented by aggregation error have not been overcome lie in the fact that publicly available social information predominantly comes in aggregated form. Therefore it is not surprising that analyses, historically, have focused on the comparison of socioeconomic groups and equity while the more the intricate issues of spatial accessibility (residential level inequity), which ideally require disaggregate data, have not been explored. Researchers are reliant on data and thus their research interests are constrained by the capabilities and limitations of the data available to them. Privately available data sources present the additional difficulty of cost, which often increases with the level of disaggregation desired.

2.7. Model, Assumptions, and Hypotheses

As mentioned throughout this thesis, the spatial distribution of accessibility can be modeled from three generic elements; origins, destinations, and a street network. In the present study of service accessibility analyses will require the use of residences (origins), services (destinations), and a street network. The following paragraphs outline the assumptions upon which these analyses will be based and the hypothesized outcomes of this research under the conditions defined.

Accessibility methods make several assumptions about space and the mobility of individual persons similar to that of classic location theories. In an effort to focus on the physical aspects of accessibility and remove the confounding effects of aggregation error the following assumptions are made, many of which are typical of accessibility analysis, and include:

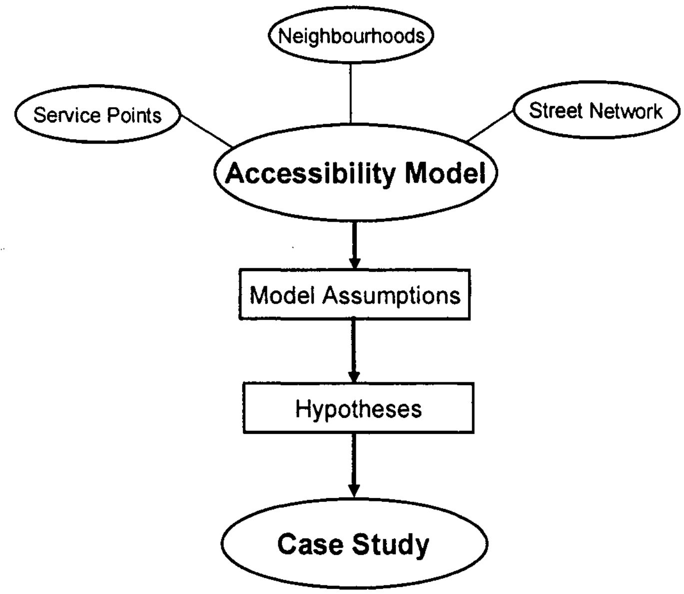


Figure 5: Accessibility Framework

1. Residents are equally distributed among residential buildings
2. Residential self-selection does not occur (the model assumes that persons will locate in the areas of highest accessibility possible)
3. Travel will be confined to the street network
4. Households will only travel as far as the nearest facility for a service (referring to the minimum distance technique)
5. Quality of service does not differ between facilities as it cannot be accounted for and properly weighted
6. Traffic patterns and speed remain static
7. Barriers other than spatial such as social and financial do not impede access to facilities
8. Edge effects arising from adjacent urban centers do not occur

Given the types of data to be employed and the assumptions upon which the model is based one can now begin to formulate a list of hypotheses. The following is a list of hypotheses and expected analytical outcomes:

1. While the literature suggests that the highest levels of accessibility will always be found in central city neighbourhoods (Knox 1978) this research will reveal that the form of accessibility can deviate from this established model.
2. The deviations from passed accessibility findings will likely be explained by:
    a. the nature of the individual service types in question
    b. the number of service types employed
    c. the type of distance measure utilized (Talen 1997)
    d. the presence of suburban service clusters
3. Aggregation error can be overcome using the data and techniques proposed by Hewko et al., 2002.

This review has outlined the vast scope of the accessibility literature and indicated the relative absence of a global accessibility research. Furthermore, it has identified the possibility that the form of accessibility can deviate from that which has been established throughout the literature. Finally, this review has illustrated the potential and complications associated with accessibility analysis, outlining the obstacles which must be overcome in order to provide a methodologically sound basis for a global study of accessibility. Chapter four will present the methodology developed for the purposes of this study which aims to contribute to accessibility analysis with refinements to technique and data.

3.0 Methodology

The methodology developed over the course of this study is the primary contribution of this effort to urban geographic literature. Upon a review of current literature two distinct observations are apparent; accessibility has not been satisfactorily explored at a global level and several methodological obstacles impeding the study of accessibility remain. This chapter will outline the methodological stages in the analysis and will then proceed to discuss each in more detail. Again, it should be noted that this methodology is reflective of the methods and techniques employed in the more recent accessibility literature. Its primary contribution lies in the attempt to bolster traditional research through the utilization of higher resolution geospatial data.

The objective of this research is to create a global, multi-service, representation of intraurban accessibility to determine if the form of accessibility can deviate from that found in the literature. A secondary objective is to develop an easily replicable methodology using readily available software and data to overcome aggregation error and link to the sociodemographic information available from the Canada Census. Finally, this thesis will present a ranking of neighbourhoods based on their accessibility to services while also ranking services based on their accessibility to the population. This information will offer a comprehensive understanding as to how accessibility varies spatially throughout the study area.

The first priority when preparing for the analytical process was to select a suitable study area. The City of Kitchener, Ontario, was chosen as it maintains a comprehensive municipal geographic information system that was available for use. The second stage involved supplementing the GIS with additional demographic and spatial information. To further this aim a dataset was procured from InfoCanada which identified the majority of public services and businesses located within the City. Data collection was completed by gathering information from the 2001 Canada Census at the dissemination area level. In the final prepatory stage the data acquired from InfoCanada was segmented into distinct service types and geocoded along the Kitchener street network for use in a network analysis. Using a GIS a network analysis was conducted in an effort to illustrate accessibility throughout the city. Finally, accessibility results were subjected to overlay and cluster analyses the products of which were employed in comparative analyses with the data acquired from the 2001 Canada Census. Figure 6 presents an overview of this methodology while the following paragraphs dissect each of the stages illustrated.

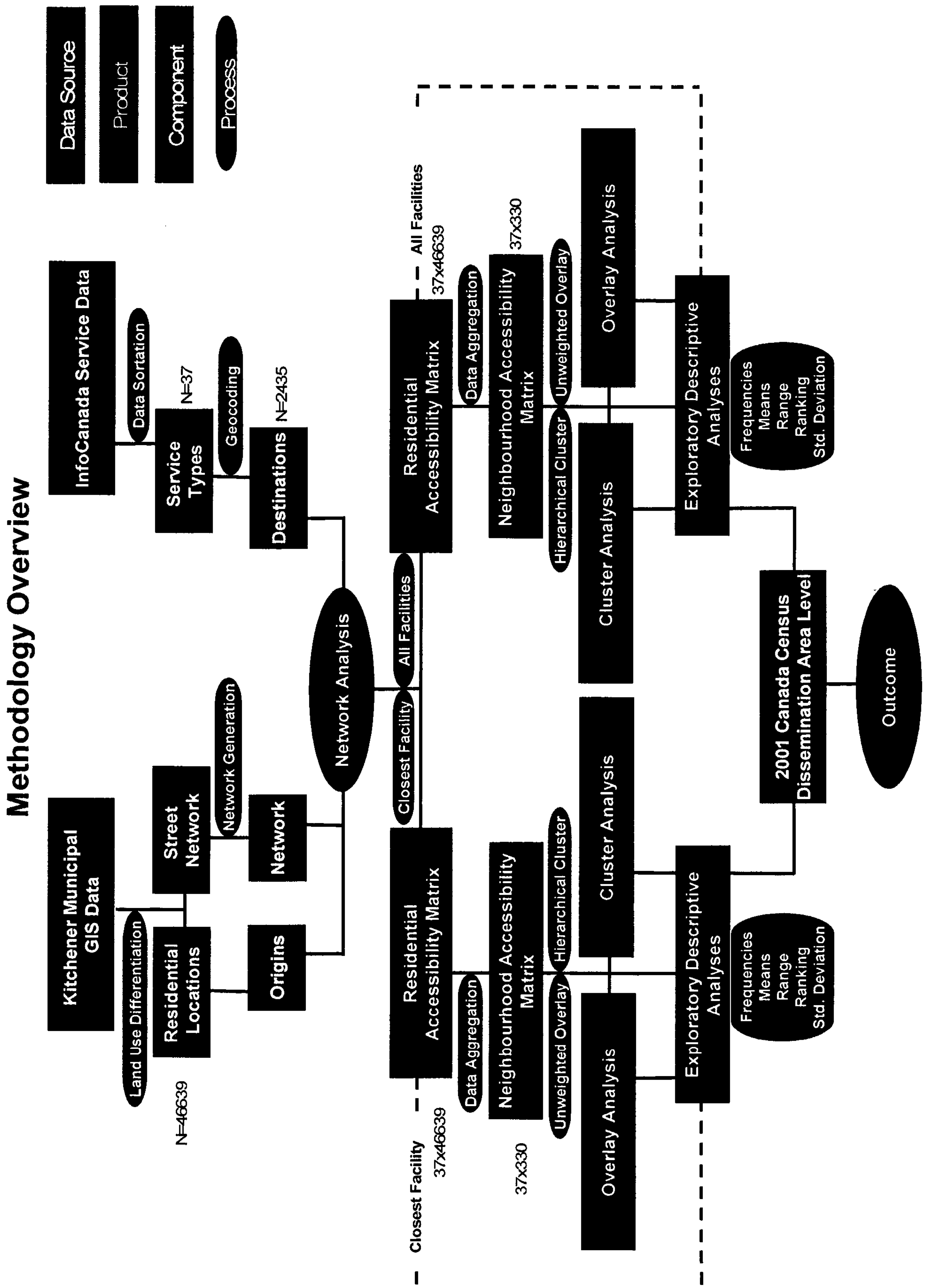


Figure 6: Methodology Overview

3.1 Study Area

As previously mentioned, the City of Kitchener, Ontario, Canada, was chosen as the study area for this analysis (Figure 7'). Kitchener is one city in a part of a larger polycentric urban system which includes the cities of Waterloo and Cambridge; a region which has been noted for its dispersed form (Filion, Bunting et al. 1999). The nature of the municipality's GIS naturally lent itself to this research. The most significant aspect of this GIS, aside from a comprehensive street network, was a detailed enumeration of all buildings within the municipality and their land use codes. The presence of this data mitigated the necessity to utilize remote sensing techniques (Wang and Trauth 2006) in order to identify residential buildings. While it would have been more desirable to include the cities of Waterloo and Cambridge in this study the incompatible nature of their respective municipal GIS's did not lend itself to this research. As a result, Kitchener, which possessed far superior municipal level data was the only city carried forward for analysis.

3.2 Data Acquisition and Synthesis

The data used in this analysis was compiled from three distinct sources; the City of Kitchener municipal GIS, InfoCanada (2005), and the 2001Canada Census (Statistics Canada, 2001). These data are all common forms of spatial and social information widely available for research purposes. Due to the dependency of this methodology on geospatial information sources the outcome of the research will be highly sensitive to the quality of the information obtained during this stage. Having reviewed the capabilities of wide array of data sources available, these threes data sources were selected as they provided the most current, accurate, and compatible forms of information pertinent to this research. These types of information were also used to encourage the replication of this method in future research.

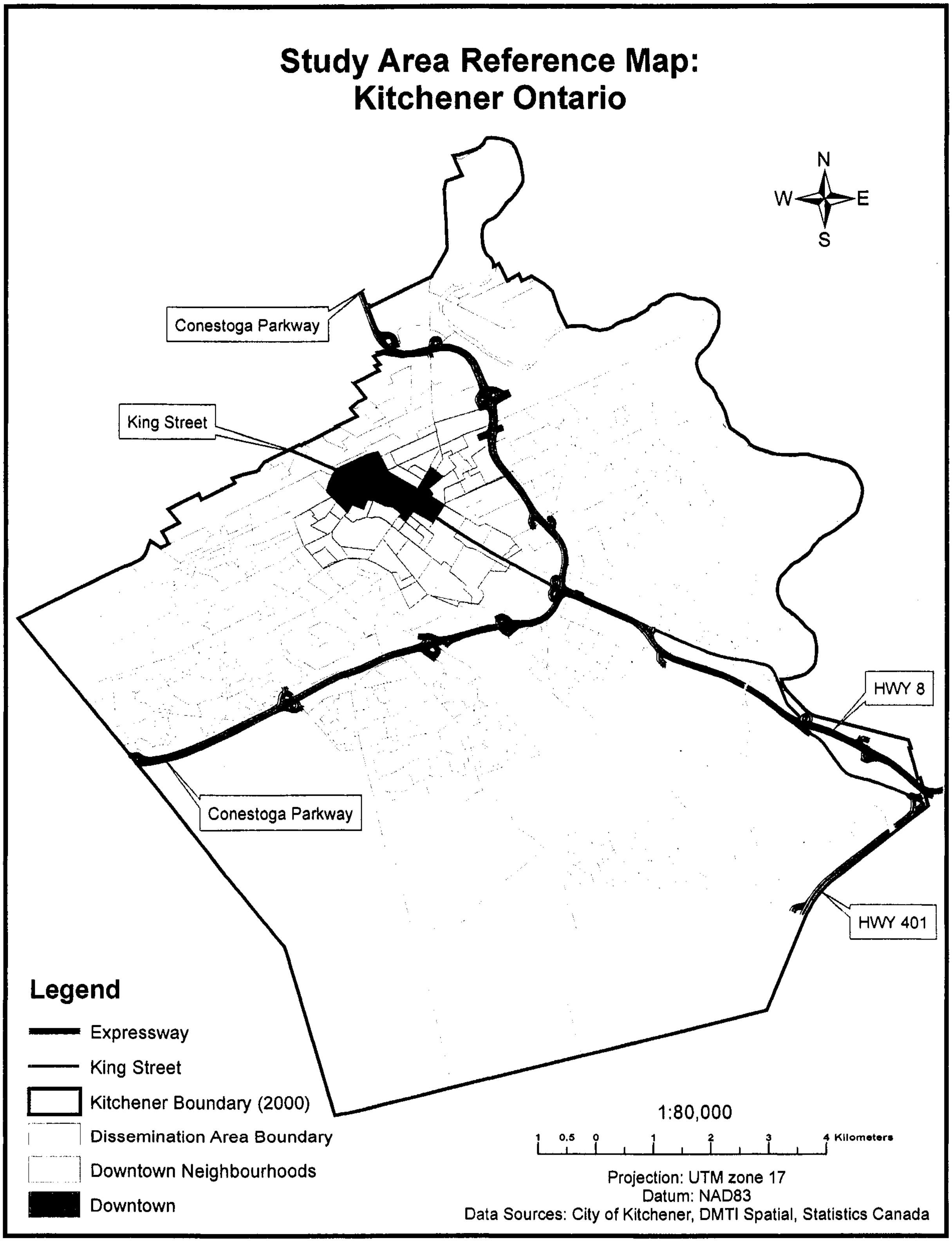


Figure 7: Study Area Reference Map

Each data component was employed in a specific role during the eventual analysis. Figure 6 illustrates when each was utilized. The municipal GIS information provided by the City of Kitchener was used to establish the spatial context in which the analyses would occur. This data component contained information pertaining to residential locations, land use, road networks and municipal boundaries. Service points, which refer to the individual amenities and services tested, were obtained in the InfoCanada dataset. This information was purchased as it contained a listing of the desired locations found within the city of Kitchener and possessed corresponding address fields which could be used to spatially reference each[5]. The InfoCanada data was aggregated based upon the author's subjective interpretation of service similarity. This subjective aggregation resulted in 37 distinct service types representing 7 overarching categories[6]. A listing of the service types created can be found in Table 2.

[5] The dataset purchased from InfoCanada provided significantly greater and more comprehensive data with respect to services and businesses within the study area. This is not to say that the listing encompasses every service of interest. After using this present study to establish a technique, future research must build upon the service data utilized here to create a more diverse service and business listing to create an even greater understanding of neighbourhood service accessibility.

[6] The categorization of services into various service types results in several very large service types (i.e. schools, personal services ect.). This analysis will be unable to differentiate between objects within the service types and as such each will be treated equally. This equal treatment will mean that variations in the service type, such as schools, cannot be accounted for (i.e. private, public, religious, linguistic, elementary, and secondary schools cannot be compared). Furthermore, this aggregation of services will inflate the choices available residents. It is recommended in future research that service types be further disaggregated in an effort to make these comparisons and improve upon the representation of accessibility.

Table 2: Service Type Categorization

	Subcategory	N	Represented Services	Corresponding SIC Codes
Entertainment	Amusement	11	Movie theatres; Amusement Places	799999; 799301; 783201
	Cultural	24	Live Theature; Museums, Libraries, Orchestras, Art Galleries	599969; 842207; 792202; 792901; 823106; 841201; 792207
	Night Life	32	Bars, Night Clubs, Pubs, Pool Halls, Live Music	581304; 581301; 799912; 581305; 792908; 792903
	Sports and Fitness	59	Fitness; Health Clubs; Bowling; Golf Courses; Martial Arts; Skating Rinks; Swimming; Tennis; Soccer	729906; 799101; 793301; 799201; 799945; 799901; 794102; 799969; 799971
	Travel	31	Travel Agencies and Bureaus	472404
	Video Rental	27	Video and Disc Rental	784102
Financial	Accountants	16	Accountants	872101
	Banks	47	Banks; Credit Unions	602101; 606101
	Insurance	75	Insurance; Life Insurance	641112; 641109
	Real Estate	46	Real Estate	653118
	Tax Services	26	Tax Return Preparation and Filing	729101
Food	Coffee Shops	65	Cafes; Coffee Shops; Doughnuts; Restraunts	581214; 581208; 581228; 546105
	Fast Food	117	Carry out; Ice Cream; Pizza; Restraunts	581206; 581203; 581222; 581208
	Grocers	86	Grocers-retail	541105
	Restraunts	147	Restraunts	581208
	Specialty Grocers	55	Bakers, Butchers, Cooperatives	546102; 205198; 546109; 209903;542103;201104; 542108; 514601; 581209; 653107
Health Care	Alternative	88	Health Spas; Health Foods; Nutritionists; Vitamins; Holistic Practioners; Hypnotherapy; Massage Therapists; Naturopathic Physicians; Weight Control Services; Acupuncture;	799105; 549901; 804909; 549904; 809909; 729917; 804901; 729934; 804913; 723118
	Chiropractors	34	Chiropractic Doctors	804101
	Clinics	11	Clinics	801104
	Dentists	87	Dentists	802101
	Eye Care	29	Opticians; Optometrists	599504; 804201
	Pharmacies	41	Pharmacies	591205
	Physicians	168	Physicians and Surgeons	801101
Instruction	Child Care	38	Child Care Services	835101
	Music Instruction	11	Music Instruction Instrumental/Vocal	829918
	Schools	98	Schools (Pre, Elementary, Secondary)	821103
Other	Home Services	79	Cleaning, Yard Maintenance; Repair	721704; 721201; 734922; 769962; 7206; 734910
	Malls and Department Stores	16	Department Stores; Malls and Shopping Centers	531102; 651201
	Personal Services	231	Beauty Salons; Barbers; Hair Replacement; Tattooing; Tanning Salons; Hair Removing; Manicuring; Spas-Beauty and Day; Estheticians	723106; 724101; 729913; 729944; 729931;729910;723102;723119;723113
Retail	Apparel	145	Childrens; Jeans; Leather; Men's; Shoes; Sportswear; Tailors; Women's; Apparel	564103; 565101; 561106; 594803; 561101; 569913; 599505; 569919; 562101; 729908
	Appliances	29	Major Household Appliance Dealers	572202
	Convenience	87	Convenience and Variety Stores	541103; 533101
	Electronics	73	Computer and Equipment dealers; Electronic Equipment; Television Dealers; Computer Service and Repair	573407; 573117; 573103; 573501; 737801
	Entertainment	11	Video Games; Hobby and Game Stores	594508; 573112
	Furniture	60	Furniture Dealers; Furniture Repair	571216; 764105; 764109
	Household	46	Small Household Items	531104; 571929; 526109; 571925; 571220; 523107; 594517
	Specialty Stores	189	Tobaconists; Florists; Gifts; Jewlers; Antiques; Bridal Shops; Alcohol; Sporting Goods; Books	599301; 599201; 594713; 594409; 573608; 593202; 562104; 592104; 592102; 599936; 599992; 594113; 594201

The final data component was acquired from the 2001 Canada Census. Information at the dissemination area level was collected as it possessed the highest spatial resolution to data suppression ratio. A listing of the acquired variables can be found in Table 3. This information was spatially referenced and employed for the purposes of comparative analyses following the completion of the asocial accessibility construct. Data was only collected from the 2001 Census due to the spatial changes between it and the previous census of 1996. The spatial differences between the enumeration area (1996) and the dissemination area (2001) are such that a temporal comparison would be inaccurate.

3.3 Establishing a Transportation Network

Generating a transportation network was a relatively simplistic, yet critical, stage of this analysis. The network analyses central to this study were dependent on the ability to construct an accurate representation of the Kitchener traffic environment. Using the Network Analyst functions of ArcGIS 9, a comprehensive street network of the study area was created based on the street files present in Kitchener's municipal GIS. While the resultant environment incorporated an elaborate network of road pathways it was decided, for reasons of simplicity, not to include measures of traffic speed, areas of congestion, or modes of transportation other than the automobile. Accessibility, based on these decisions, is therefore a function of absolute distance, not relative, through the street network. Undoubtedly, the resultant absolute accessibility surface will differ from a model of relative distance which incorporates additional traffic frictions. While, it is felt that discrepancies would exist between absolute and relative models of accessibility it was decided that a the demonstration of the accessibility model was more important to the research than establishing a higher level distance accuracy.

Table 3: Census Indicators

Category	Subcategory	Indicator
Housing	Tenure	Owned
		Rented
	Condition	Regular Maintenance Only
		Minor Repairs
		Major Repairs
	Period of Construction	Pre 1946
		1946 - 1960
		1961 - 1970
		1971 - 1980
		1981 - 1990
		1991 - 1995
		1996 - 2001
	Dwelling Type	Single Detached
		Semi Detached
		Row Housing
		Duplex
		Large Apartment Building
		Small Apartment Building
		Other Dwelling
	Size	Mean Bedrooms
Family		Persons per Family
	Marital Status	Single
		Married
		Separated
		Divorced
		Widdowed
		Common Law
Economic	Labour	Male Employment
		Female Employment
	Housing Cost	Average Rent
		Average Housing Payment
		Dwelling Value
	Income	Total Income
		Family Income
		Incidences of Low Income

3.4 Geocoding

Following the completion of the Kitchener street network the 37 service types were georeferenced based on their corresponding street addresses. This exercise was again conducted using ESRI's ArcGIS 9. Each service type was geocoded individually and stored as a unique Shapefile. The geocoding processes each achieved a spatial match of greater than 95%. In total 2435 distinct service points were identified. Figure 8 illustrates the distribution of the service points throughout the study area.

3.5 Network Analyses

The use of network analysis in a GIS forms the core of this study. All stages prior to the network analysis were conducted solely for the purpose of collecting and massaging the data necessary to satisfy the requirements of the software. The OD Cost Matrix function in ArcGIS's Network Analyst extension was used to conduct the accessibility analyses. There are three fundamental components inherent to every network analysis; a starting point (origins), a destination (in this case an amenity), and a method for measuring distance (a street network). It is at this point that the analysis deviates from traditional accessibility studies.

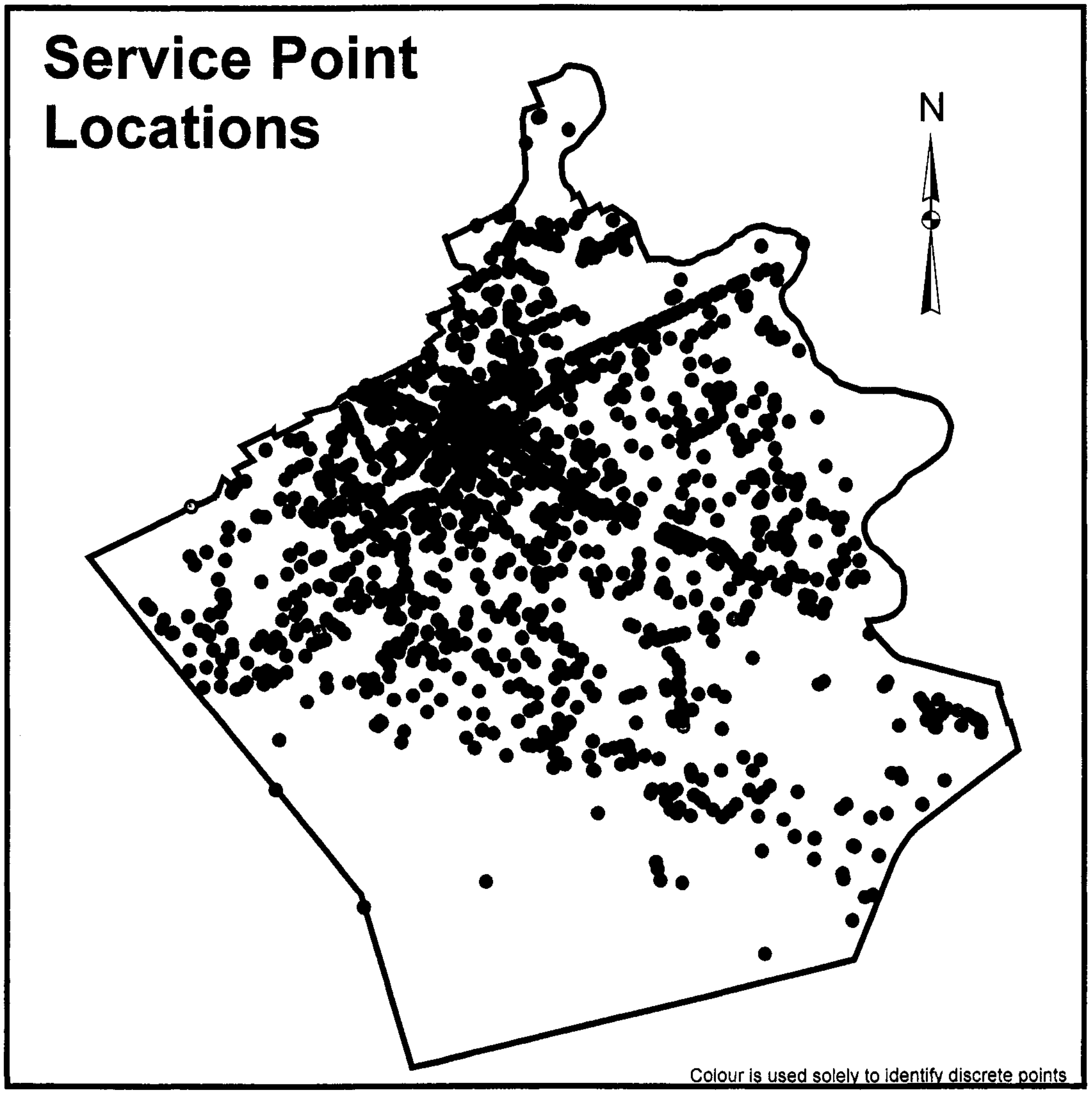


Figure 8: Service Points

The persistent problem of aggregation error is also an underlying concern for those examining accessibility from a multidimensional origin; in this case the neighbourhood (Hodgson, Shmulevitz et al. 1997; Hewko, Smoyer-Tomic et al. 2002; Smoyer-Tomic, Hewko et al. 2004). This study will employ a residential accessibility matrix to evaluate the overall accessibility of the neighbourhood thus eliminating the aggregation error impediment. More simply, accessibility indices will be calculated for each residence within the study area (N = 46,639). This will result in an initial residential accessibility matrix (37 x 46639) which will then be aggregated, using mean residential distance, to produce neighbourhood accessibility values. A breakdown of the Kitchener residences is presented below in Table 4. The overwhelming residential preference is the single family detached home. This is important to the methodology as multifamily dwellings cannot be distinguished and weighted appropriately. Therefore all origins are treated equally by the accessibility analysis. When viewed in a strictly spatial sense this consideration is not important as one is assessing the accessibility of a location regardless of the people living there. However, if one wishes to eventually progress into a population weighted model efforts must be made to identify these multifamily/multiunit residences.

There are several beneficial outcomes to using the aggregated residential accessibility procedure. These advantages overcoming the aggregation error previously outlined are depicted in Figure 9. The use of residential origins, as discussed in the following paragraphs, can overcome the obstacles to accessibility research presented by aggregation error and form a more comprehensive portrait of accessibility.

Source A aggregation error occurs as the use of an aerial unit's centroid assumes that all travel initiated within this unit will begin at the centroid. The centroid does not adequately represent the spatial distribution of persons within the unit and as such actual travel distances may be considerably greater, or lesser, than the results indicate. The residential accessibility construct moves beyond the assumption that the population is concentrated at the neighbourhood center and solves the difficulties presented by Source A aggregation error. Employing the exact locations of residences, this technique allows for an accurate representation of accessibility across space as accessibility is calculated for, and from, each residence. The individual dwelling accessibility values are then aggregated to the neighbourhood level using their mean as the new attribute value. The calculation of accessibility from each residence also mitigates any complications arising from the variation in neighbourhood size and shape While some may argue that the travel origins should be weighted by the populations residing at that location (Hewko, Smoyer-Tomic et al. 2002; Smoyer-Tomic, Hewko et al. 2004), this thesis takes the position that spatial accessibility is the study of access over space only. Accessibility, in this study, is a function of location only. The weighting of travel origins is only viable when conducting a socio-spatial analysis where it can be used to evaluate the demand for a service by identifying a target demographic and assigning a weighting accordingly. Thus this research employs the individual building as the analytical origin.

Source B error results from the close proximity of the centroid to the facility under investigation. The accessibility results precipitated by this situation will approach a distance of 0, significantly underestimating distance (Hodgson, Shmulevitz et al. 1997).

Again the residential accessibility construct can overcome this form of error. The mean neighbourhood accessibility is a function of the distance calculated for every residence within the neighbourhood, not just the centroid. The aggregation of multiple origins means that the amenity of study and the origin cannot spatially coincide.

Source C aggregation error is precipitated by the presence of multiple destinations. While accessibility analyses will reflect the distance from the neighbourhood centroid to its closest facility, often residences within that neighbourhood will be situated in more proximate locations to other facilities. In examining Figure 9 we see that the closest facility available to residences varies within the neighbourhood. The residences of this test neighbourhood are highlighted in colours corresponding to their shortest path to the closest facility. Thus, the orange residences are closest to the orange facility along the orange route.

Table 4: Kitchener Housing Composition

Land Use Description	N	%
Cooperative housing - equity	1	0.00
Cooperative housing - non-equity	12	0.03
Farm with a residence (with or without secondary structures) and farm outbuildings	20	0.04
Farm with a residence and having a commercial/ industrial operation	1	0.00
Freehold townhouse/rowhouse	23	0.05
Link home	28	0.06
More than one structure used for residential purposes with at least one of the structures occupied permanently	31	0.07
Multi-type complex - defined as a large modern complex having multi-residential (seven or more) and/or condominium together with commercial	1	0.00
Residence with a commercial/ industrial use building	42	0.09
Residence with commercial unit (e.g. doctor's office, agency)	126	0.27
Residence with more that one residential unit, typically a conversion	339	0.73
Residential condominium conversion still rented with seven or more units in the condominium plan [refer to Assessment Act, R.S.O. 1990, Chap	1551	3.33
Residential condominium, excluding those defined by codes 371 and 372	4267	9.15
Residential property with five self-contained units (1)	31	0.07
Residential property with four self-contained units (1)	48	0.10
Residential property with six self-contained units; does not include row housing (1)	135	0.29
Residential property with three self-contained units (1)	345	0.74
Residential property with two self-contained units (typically a duplex) (1)	1205	2.58
Rooming or boarding house	64	0.14
Row Housing, with seven or more units under one title	81	0.17
Row housing, with three to six units under one title.	14	0.03
Semi-detached residential use (includes true semi and single semi links)	4499	9.65
Semi-detached with both units under one ownership	128	0.27
Single family detached (not on water)	33647	72.14
Total	**46639**	**100**

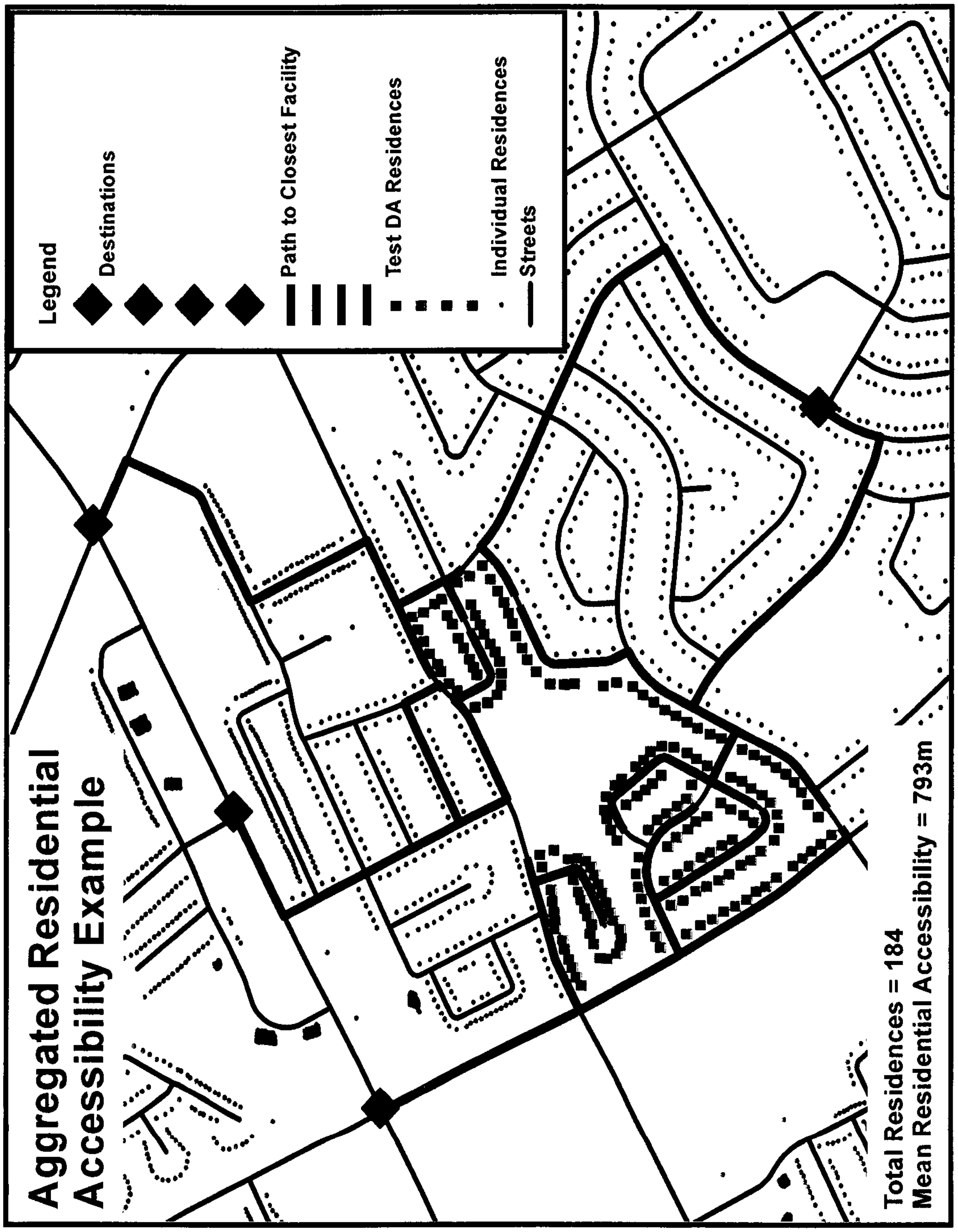

Aggregated Residential
Accessibility Example
Legend
Destinations
Path to Closest Facility
Test DA Residences
Individual Residences
Streets
Total Residences = 184
Mean Residential Accessibility = 793m

Figure 9

Upon the completion of a Cost Matrix in ArcGIS 9 a linear output file is generated which indicates the distance from each residence to the closest facility. When exported properly, this file can then be joined by a common identifier to the appropriate residential origins. An accessibility value for each distinct service type can therefore be embedded as an attribute for each residence.

Two networking analyses were undertaken in an effort to foster a broader understanding of accessibility throughout the study area and to discover whether the distance measure employed would influence the form of accessibility. The first run, similar to Hewko et al. (2002), employed a minimum distance technique which examined the accessibility relationship as far as the closest facility. This technique was selected as it most accurately represents immediate accessibility to a type of amenity and is expressed as:

$$Z_i^E = \min|d_{ij}|$$

where it is equal to the minimum distance path between a dwelling of origin (*i*) and the closest destination (*j*) of a particular service type.

A second networking analysis was conducted following the minimum distance run. The parameters of the second analysis were altered so that the resulting accessibility values would represent the cumulative distance from a residential point to all facilities of a specific service type; the travel cost technique (Talen 2003). This measure is expressed as:

$$Z_i^T = \sum_j \frac{d_{ij}}{N}$$

where accessibility is equal to the sum of the distances between a residential point (i) and each destination (j) of a service type standardized by the number of service points within that type (N).

Having completed these two analyses the accessibility of the neighbourhood or the residence could now be evaluated as a function of its immediate (absolute) and overall (relative) proximity to a particular type of service. These two measurements most accurately account for need and choice[7]. Need represents an individual's immediate need for the services being sought. Choice is defined here as an individual's decision to seek a service from a location other than the closest facility due to perceptions of product quality or customer loyalty (Dunkley, Helling et al. 2004).

Accessibility, as mentioned, is conducted at the dwelling level; however it is later aggregated to the neighbourhood level for two reasons. First, given the vast number of origins and services the matrices (GIS attribute tables) produced are of such size as to place technological limitations on this research. Second, the aggregation of residential/dwelling level accessibility to the neighbourhood/dissemination area level makes the values of accessibility compatible with forms of socio-demographic/economic information thus expanding the applicability of this research. Neighbourhood accessibility represents the mean distance from all residential points in the neighbourhood to the service type under investigation.

[7] Although the minimum distance and travel cost do most accurately reflect reality they remain predicated on the assumptions discussed in chapter 2.

The use of the neighbourhood concept in conjunction the residential accessibility analysis lends tremendous freedom to this research. As neighbourhood is such a flexible entity, both socially and spatially, residences within the study area can be aggregated to match any number of neighbourhood criteria. Therefore, as the physical understanding of neighbourhood progresses aggregation criteria may also evolve without compromising the methodological foundation of the analysis. For the purposes of this research the dissemination area (Statistics Canada, 2001) will serve as a spatial proxy for neighbourhood.

The dissemination area (DA) is a small, relatively stable geographic unit composed of one or more blocks. It is the smallest standard geographic area for which all census data are disseminated (Statistics Canada, 2001). According to Statistic Canada (2001) the dissemination area is delineated based on the following considerations:

1. DA boundaries respect the boundaries of census subdivisions and census tracts. DAs therefore remain stable over time, to the extent that census subdivisions and census tracts do.
2. DAs are uniform in terms of population size, which is targeted from 400 to 700 persons to avoid data suppression. DAs with lower population counts (including zero population) may result in order to respect the boundaries of census subdivisions and census tracts. DAs with higher population counts may also result.
3. DA boundaries follow roads. DA boundaries may follow other features (such as railways, water features, power transmission lines), where these features form part of the boundaries of census subdivisions or census tracts.
4. A DA within a DA is formed when the population of apartment or townhouse complexes meets or exceeds 300 persons.

5. DAs are compact in shape, to the extent possible while respecting the above criteria. Operational requirements limit to 99 the number of blocks that can be included in a DA.

Whereas neighbourhood is both a social and physical entity, dissemination areas are irregular spatial objects which are delineated based on the distribution of the population. The decision to use the dissemination area was reached for two reasons: First, so little is known about the physical properties of neighbourhood that a standardized approximation of it would lend consistency and validity to this initial neighbourhood accessibility research. Second, the use of the dissemination area offers a simplistic, standardized and reproducible approximation which can be replicated across Canada in urban research.

3.6 Mapping and Overlay Analyses

As those studies comprising the literature tend to focus on a very narrow portion of the accessibility spectrum (i.e. one or few services) there has been little need to compile the accessibility results for each service in any form other than a simple table. The overlay procedures to be outlined in this section allow for the compilation of the disparate service accessibility results into a cumulative representation of urban service accessibility. It is with these individual service accessibility results in conjunction with the overlay that we can begin to compare the influences of service type, distance measure, and scale on the form of accessibility.

Talen (1998, 2003) emphasizes the importance of accessibility mapping as fundamental tools for urban policy decisions. Following the two networking runs a series of accessibility maps for each service type and an exploratory overlay were conducted. The dissemination areas in each accessibility map were classified into 9 categories of accessibility (most accessible to least accessible) using a natural breaks technique. Neighbourhoods of high accessibility correspond with low mean travel distances while larger distances indicate less accessibility to a service.

The overlay procedure involved a simplistic additive spatial overlay without weighting individual service types. The idea of weighting the accessibility values based on service type was rejected as the importance of each service type is dependent on the socio-demographic/economic constitution of an individual. Given the diversity inherent within Canadian cities weighting, and thus placing preference on, services would be inappropriate unless one chooses to examine a specific cohort within the larger population. As this research is concerned solely with the spatial accessibility of neighbourhoods weighting does not apply. The overlay is a summation of the neighbourhood accessibility values for each service type and thus represents accessibility to all services. As with the accessibility maps, the overlay product was classified into 9 classes again using a natural breaks classification scheme. While the accessibility maps illustrate the variations in immediate and overall accessibility to the individual service types throughout the study area, the overlay presents a cumulative representation of accessibility that is the aim of this research. Each perspective is equally important. While individual service accessibility results may reveal that residents in the south of

Kitchener enjoy high spatially accessibility to retail due to the presence of a large regional shopping mall, the overlay may reveal that with respect to general accessibility (all service types) this same area is minimally accessible.

The overlay analysis represents a cumulative measure of neighbourhood accessibility throughout the study area. It is a compilation of the accessibility surfaces derived for each individual service type. This measure offers an alternate, macro level, regionalization of urban form; a form based on accessibility. While this research has focused on a cumulative measure of global accessibility it would undoubtedly prove beneficial to explore more discrete aspects of accessibility using an overlay technique. Alternate overlays may focus on specific demographics, isolating the services most important to them and incorporate a scheme to weight each accordingly. Such a study could be used to further an understanding of neighbourhood spatial compatibility for various segments of the population. A weighting technique, or parallel overlay procedure, could also be utilized to explore the accessibility differences between essential/non-essential services, public/private, or the various orders of services. These are just several possible avenues through which an overlay procedure can benefit the study of accessibility.

3.7 Cluster Analyses

Hierarchical cluster analyses were employed following the overlay in an effort to group like neighbourhoods based on their relationships to the different service types. Ward's method utilizing a squared euclidean distance measure was employed to carry out this analysis. In this instance the individual service type becomes the variable with neighbourhoods becoming cases. Nine clusters were again chosen to provide continuity with the overlay analysis. Given the impossibly cumbersome size of the resultant cluster matrix the neighbourhoods comprising each cluster were aggregated together. Thus the initial cluster matrix was reduced to a 9x37 matrix with the cluster means for each service now becoming the table values. Having completed this data reduction the values were recoded based on whether a case fell above, at, or below the mean accessibility demonstrated for each particular service type. This step was conducted for the ease of interpreting the cluster data at a later stage.

3.8 Exploratory Descriptive, Comparative and Bivariate Analyses

In the final stage of this research the matrices resulting from the two networking runs were subjected to a wide array of descriptive, comparative, and bivariate analyses. While the objective of this research was to demonstrate a more thorough means of evaluating accessibility it was felt that linking the neighbourhood accessibility results to the census would further demonstrate the validity of this methodology. As such this testing does not seek to test any particular theorized hypotheses but instead aims to highlight the possibility of future research. A series of descriptive tests were employed in an effort to characterize the various service types under examination. Having completed the descriptive testing a comparative analysis was undertaken which was followed by exploratory bivariate analyses.

The purpose of the descriptive analyses were to provide a characterization of each accessibility type. A series of common indicators were utilized to further this aim. Having established this series of indicators comparative analyses sought to identify discrepancies amongst service types. Finally, the bivariate tests sought to connect the measures of service accessibility with census variables relating to economics, housing, and family. To further this objective a series of correlation analyses were conducted to examine this relationship in an exploratory context. The census indicators employed in these tests have been previously outlined in Table 3. The individual service type accessibility values were utilized in the bivariate analyses as distinct variables.

3.9 Multi-Criteria Neighborhood Accessibility Mapping

Accessibility, in this thesis, can be described as a function of two principle components; immediate access and choice. In order to create the most comprehensive representation of accessibility possible it was necessary to integrate the results of the two overlay analyses, minimum distance and travel cost. The former serving as a measure of immediate accessibility while the latter serves as a proxy for choice.

Utilizing a natural breaks method of classification, each individual neighbourhood accessibility overlay was reclassified into one of three accessibility classes; low, moderate, and high. This reclassification was conducted for the purposes of data reduction. A crosstabulation technique was then employed in an effort to integrate the two reclassified accessibility surfaces. The results of this crosstabulation were finally incorporated into a single comprehensive accessibility surface.

4.0 Results and Interpretation

The following chapter comprises the results section of this thesis and is organized according to the methodological stages of this research. This chapter will be prefaced by a discussion of the interpretation of descriptive indicators used in this analysis. These paragraphs will be followed by sections which outline the findings of the minimum distance and travel cost analyses. Finally, this chapter will address integration of distance measures and census information.

The network analysis figures (minimum distance and travel cost), when aggregated, produced two matrices (immediate and overall service accessibility) of services (37) by neighbourhoods (307) utilizing the mean of the residential accessibility results as the value in the aggregated matrix. Descriptive and comparative analyses were conducted on the various service types found within each matrix. The following chapter will discuss the outcome of each network analysis run. This discussion will include a breakdown of the overlay and cluster analyses associated with the use of each technique. In the hope of avoiding confusion, each matrix and its associated measures will be discussed separately as minimum distance (immediate access) and travel cost (overall choice) service accessibility are entirely disparate measures. This discussion will begin by reviewing the findings of the minimum distance analysis.

When examining the accessibility information several factors must be considered. The size of the mean neighbourhood accessibility value will demonstrate the relative access of a service type throughout the study area. A smaller mean value will indicate greater accessibility as the distances from residences to the service are less. Conversely, a larger mean accessibility value will reflect lesser accessibility of a service. The mean value also has the capacity to serve as an accessibility threshold for each service type, determining which neighbourhoods are more accessible than others by their distribution around the mean. The range descriptor can also be employed to examine the disparities between dissemination areas within a service type. Larger range values will most often suggest greater spatial disparity within the community with respect to a single service type.

It should be noted that although every effort was made to obtain and prepare the most accurate service dataset possible the resultant construct is not free of error. As outlined in the methodology chapter, the 2435 individual service points found within the borders of the study area were categorized into 37 service types. Each service type represents a variety of similar businesses. Unfortunately, this classification of individual services produced several very large service types which precipitate several issues that the reader must remain aware of. For example in this study a restaurant is a restaurant; each individual restaurant is treated equally. This methodology was developed to evaluate spatial accessibility. As such, it cannot account for variables such as an individual restaurant's reputation, the affordability of its menu, or the clientele that it caters to. Another issue of which the reader must remain cognizant is the nature of each service type. While some services types provide a uniform service others do not. A convenience store is an example of a uniform service. Each service point will offer roughly the same service; general merchandise. Conversely, restaurants represent a non-uniform service as the service each establishment provides will vary depending on the factors mentioned in the previous paragraph. Thus, non-uniform service types will be confounded by preferences of the citizen.

Throughout the remainder of this chapter data will be presented from both network analysis runs; immediate accessibility, representing the minimum distance analysis and overall accessibility, illustrating spatial accessibility with respect to travel cost.

4.1 Immediate Accessibility

Immediate accessibility values are an aggregated measure of the distance between individual places of residence and the closest facility of a particular service type; the minimum distance of travel. Therefore, the number of service points and their spatial distribution will significantly influence the accessibility outcomes for the City's neighbourhoods. Those service types with numerous and evenly dispersed facilities will possess greater spatial accessibility, while service types having few and concentrated facilities will have less spatial accessibility. Schools and amusement services provide excellent examples of these differences.

Schools are an example of a highly accessible service. A very low mean accessibility value (687m) reveals that residences are located in close proximity to their closest facility of this type (in this example all schools, elementary, secondary, and private, are included). The large clustering of neighbourhoods below the mean confirms that in most areas of the City immediate accessibility is even greater than indicated by the mean accessibility value. Education is a service whose provision is designed to accommodate the needs of the entire school aged population on a daily basis while minimizing transportation time. As such schools are a highly decentralized and abundant service. Each facility is part of a greater network and is designed to be accessible only to the immediate population. Figure 10 depicts the spatial distribution of accessibility values and the schools located throughout the study area. As one can see, areas of high accessibility do not cluster together and are dispersed throughout the City. Therefore, one can conclude that schools within the study area are immediately accessible to the entire population.

Amusement facilities, such as cinemas and amusement parks, represent the center of the accessibility spectrum. This service type is designed to accommodate the entire population on a relatively infrequent basis. As the demand for this type of facility is considerably lower than that of schools the community cannot support numerous facilities of the type. If only a limited number of facilities can exist a more central location would be prudent as it would maximize the individual facility's accessibility to the entire population. In the case of amusement services the mean accessibility value of 2,645m indicates a considerable travel distance to the closest facility.

When examining the distribution of the individual neighbourhoods around the mean one can clearly observe a relatively normal distribution. The spatial distribution of amusement facilities and the corresponding accessibility values can be found in Figure 11 and Table 6. This distribution does in fact reveal a highly centralized spatial arrangement with the majority of the service points, and high accessibility values, falling within the City's downtown area. Moving away from the City's core we see a gradational decrease in accessibility nearing the periphery. There is, however, a break in this overall form as an outlier dissemination area possess two such facilities within it thus minimizing travel distances and increasing accessibility for those residents when using the minimum distance technique. This outlier can be attributed to a suburban service cluster associated with a regional shopping center. These two examples provide a context in which one can review the remaining 35 service types. Table 6 and Figure 12 provide information pertaining to the remaining service types.

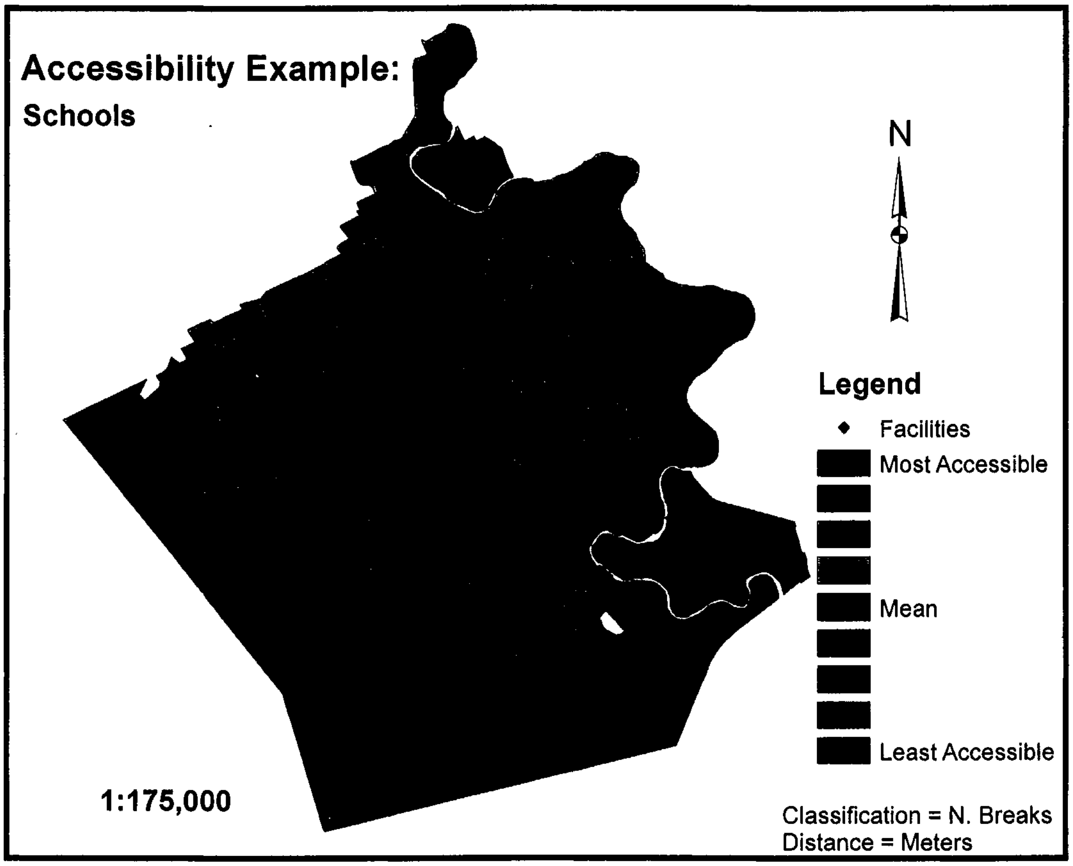
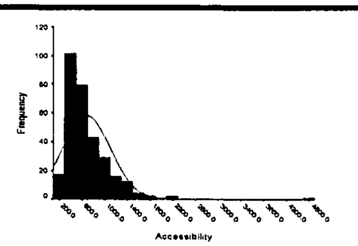
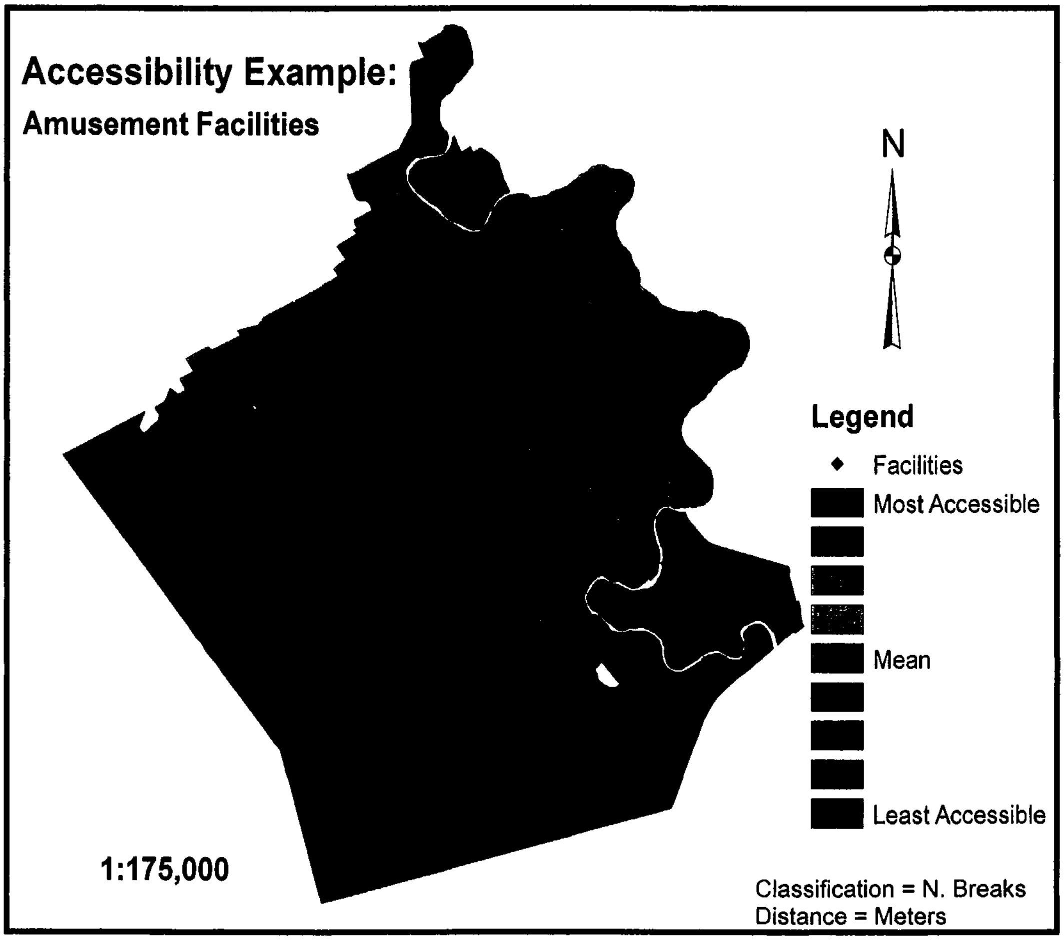


Figure 10

Accessibility Rank	**2**
Facilities	98
Mean	687
Range	4480
Minimum	182
Maximum	4662
Std. Deviation	422





Accessibility Rank	**36**
Facilities	11
Mean	2645
Range	5859
Minimum	245
Maximum	6104
Std. Deviation	1412

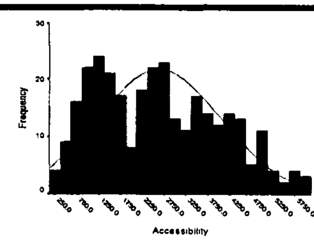


Figure 11

The minimum distance analysis is ideal for examining the spatial distribution of the individual service types. Accessibility will mimic the distribution of the amenity being studied. Dispersed and highly accessible service types such as schools, grocery stores and restaurants/fast food will be characterized by a skewed frequency distribution below the mean. This skewness indicates that neighbourhoods are located in close proximity to the facilities comprising the service type. Since we know that neighbourhoods are dispersed throughout the study area and the descriptive findings indicate that the majority of neighbourhoods are highly accessible it is reasonable to conclude that the facilities must be dispersed evenly throughout the study area as well. Table 5 provides a deconstruction of the possible descriptive combinations that contribute to accessibility using the minimum distance technique. Highly accessible services, such as schools, will be characterized by a very small mean and a negatively skewed distribution. Conversely, a service exhibiting low spatial accessibility will possess a very large mean and will be normally distributed. The degree of service type accessibility will be further influenced by the number of facilities comprising the service in question. When examining the information presented in Table 6, Figure 12 and Figure 13 the reader should remain aware of these factors influencing the nature of service accessibility.

Table 6 provides a summary of the descriptive statistics for each service type while Figure 12 illustrates the best examples of services which represent very high and very low accessibility and their relationship with neighbourhood variability. These representative services were selected based on the service rankings provided in the descriptive testing. There is considerable disparity in service availability between the highly accessible downtown area and the relatively inaccessible periphery of Kitchener. This figure also illustrates this spatial disadvantage. Finally, Figure 13 will serve to illustrate the distribution of neighbourhood service accessibility with respect to all services.

Table 5: Accessibility vs. Service Type Attribute Combinations

			Facilities (N)	Skewness	Mean
Accessibility	High	Dispersed	High (>150)	Negative	Smallest
		Mod. Dispersed	Low (<50)	Negative	
		Centralized	High(>150)	Normal	
	Low	Mod. Clusered	Low (<50)	Normal	Largest

Table 6: Minimum Distance Service Descriptives

		Rank	Facilities (#)	Mean (meters)	Range	Minimum	Maximum	Std. Deviation
Entertainment	Amusement	36	11	2645	5859	245	6104	1412
	Cultural	32	24	2127	5812	119	5931	1445
	Night Life	29	32	1729	5542	156	5698	1124
	Sports and Fitness	17	59	1206	4252	175	4428	733
	Travel	24	31	1489	4337	201	4538	813
	Video Rental	13	27	1061	3198	0	3198	648
Financial	Accountants	33	16	2292	7962	168	8129	1383
	Banks	18	47	1208	5157	259	5417	712
	Insurance	14	75	1072	3784	40	3824	615
	Real Estate	21	46	1363	6423	111	6535	1248
	Tax Services	27	26	1596	6336	293	6628	1041
Other	Child Care	15	38	1184	3604	221	3824	572
	Music Instruction	34	11	2396	6285	273	6558	1315
	Schools	2	98	687	4480	182	4662	422
	Home Services	6	79	860	2606	98	2704	427
	Malls and Department Stores	31	16	2124	6970	177	7147	1283
	Personal Services	1	231	633	3705	79	3784	414
Food	Coffee Shops	16	65	1192	4753	176	4928	866
	Fast Food	4	117	830	2851	156	3007	458
	Grocers	5	86	834	2971	59	3030	472
	Restraunts	10	147	981	2860	179	3039	537
	Specialty Grocers	12	55	1041	3529	189	3718	581
Retail	Apparel	26	145	1562	5367	164	5532	1043
	Appliances	30	29	1791	4150	264	4414	1017
	Convenience	8	87	950	3522	140	3662	543
	Electronics	11	73	990	2476	170	2647	523
	Entertainment	37	11	2902	6701	328	7029	1455
	Furniture	22	60	1388	4138	176	4314	817
	Household	23	46	1431	4965	259	5224	876
	Specialty	3	189	798	2593	119	2712	450
Health Care	Alternative	7	88	861	2777	136	2913	499
	Chiropractors	19	34	1221	4270	79	4348	732
	Clinics	35	11	2517	6234	317	6551	1325
	Dentists	9	87	955	3040	179	3219	524
	Eye Care	25	29	1494	5669	209	5878	999
	Pharmacies	20	41	1236	3744	127	3871	690
	Physicians	28	168	1727	7619	79	7698	1544

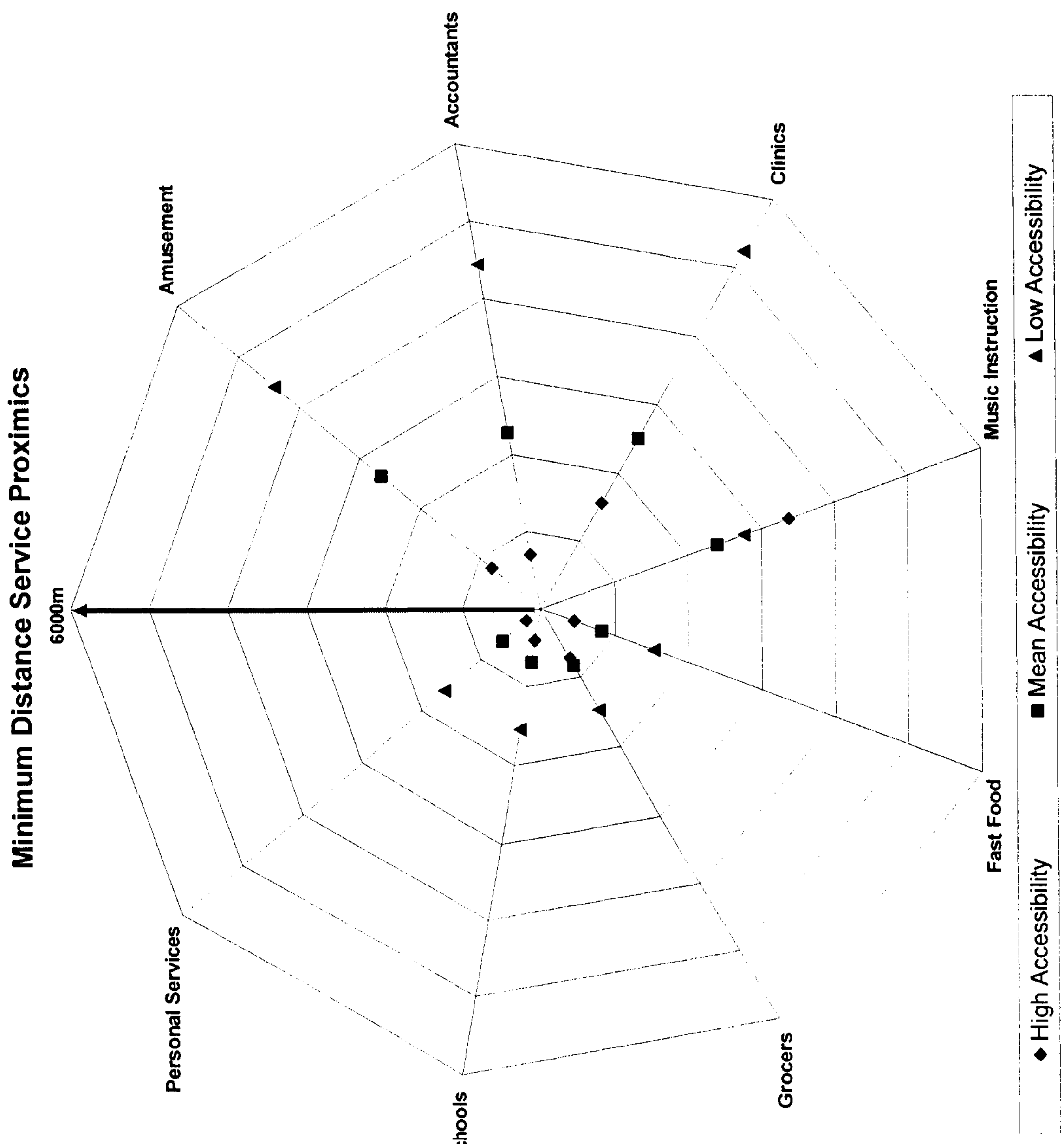

Minimum Distance Service Proximics
6000m
Accountants
Clinics
Music Instruction
Fast Food
Grocers
Schools
Personal Services
Amusement
High Accessibility
Mean Accessibility
Low Accessibility

Figure 12

As is apparent from Table 6 tremendous diversity exists between the 37 service types. We do see, however, that the majority of services are skewed below the mean and that this skewness is offset by a handful of outlier neighbourhoods present within the study area. These outlier neighbourhoods, when individually identified in the GIS, are found to be located in the extreme peripheral areas of the study area. Provided the more accessible neighbourhoods are found at the City's center, this finding would suggest an exponential decrease in accessibility as one moves outward from the core areas of the City. However, as the following paragraph explains, the minimum distance technique only assigns values based on the distance to the nearest facility and therefore accessibility will correspond to the distribution of the amenity.

The diversity identified through the descriptive measures presented in Table 6 is also reflected spatially in Figure 13. This figure illustrates the geographic distribution of neighbourhood accessibility, for each individual service type, throughout the study area. Neighbourhoods in this diagram are classified into one of 9 categories of accessibility. The individual service maps identify the downtown core of the City (the north central region) as largely receiving the greatest benefits of spatial accessibility. Conversely, peripheral neighbourhoods consistently reflect a spatial disadvantage with respect to accessibility. While this statement confirms the accepted form of accessibility as maintained by Horner (2004) for most service types, it also confirms the hypothesis that the form of accessibility can and does deviate from the norm based on the type of service under consideration.

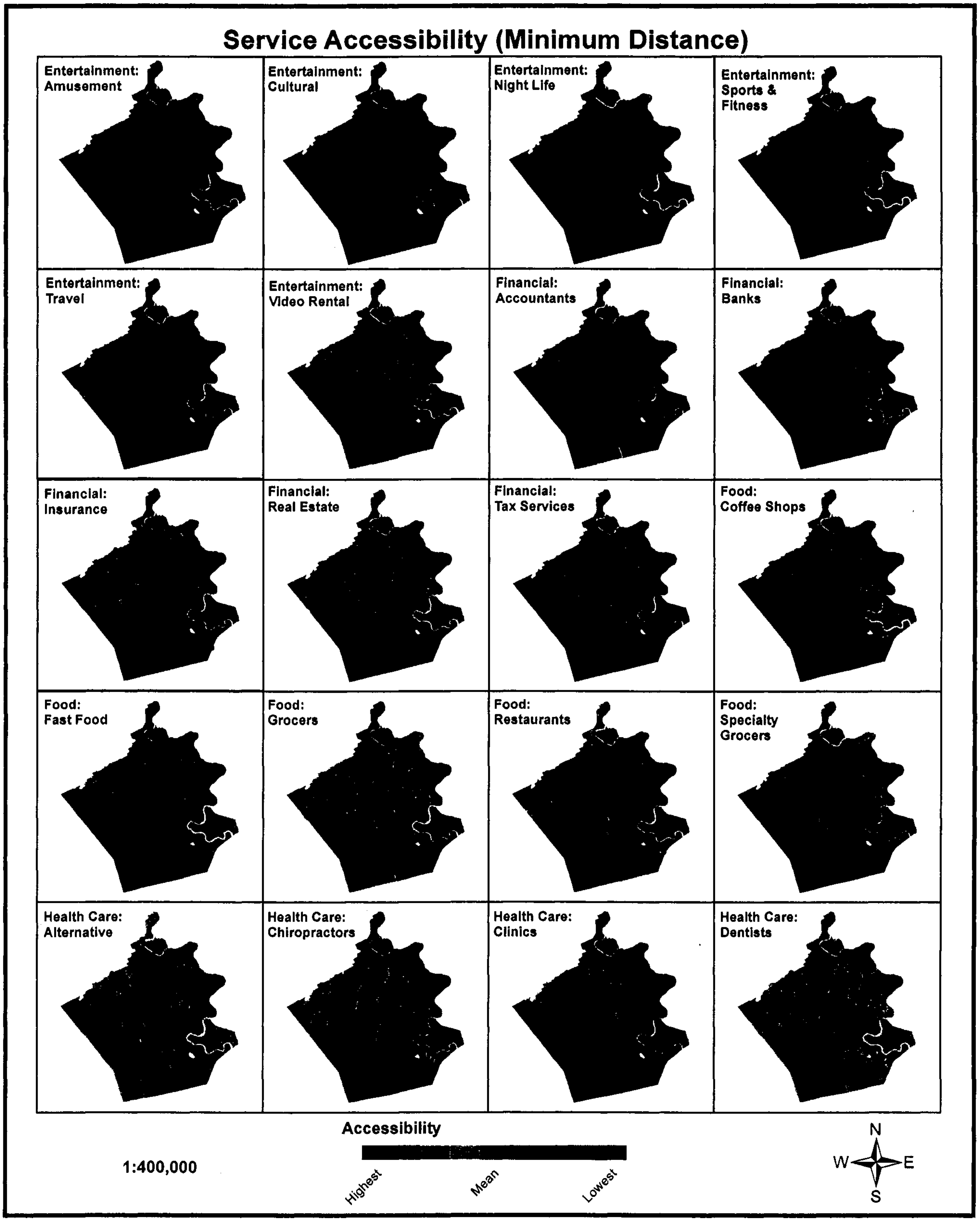

Service Accessibility (Minimum Distance)
Entertainment: Amusement
Entertainment: Cultural
Entertainment: Night Life
Entertainment: Sports & Fitness
Entertainment: Travel
Entertainment: Video Rental
Financial: Accountants
Financial: Banks
Financial: Insurance
Financial: Real Estate
Financial: Tax Services
Food: Coffee Shops
Food: Fast Food
Food: Grocers
Food: Restaurants
Food: Specialty Grocers
Health Care: Alternative
Health Care: Chiropractors
Health Care: Clinics
Health Care: Dentists
Accessibility
Highest
Mean
Lowest
1:400,000
N
W
E
S

Figure 13A

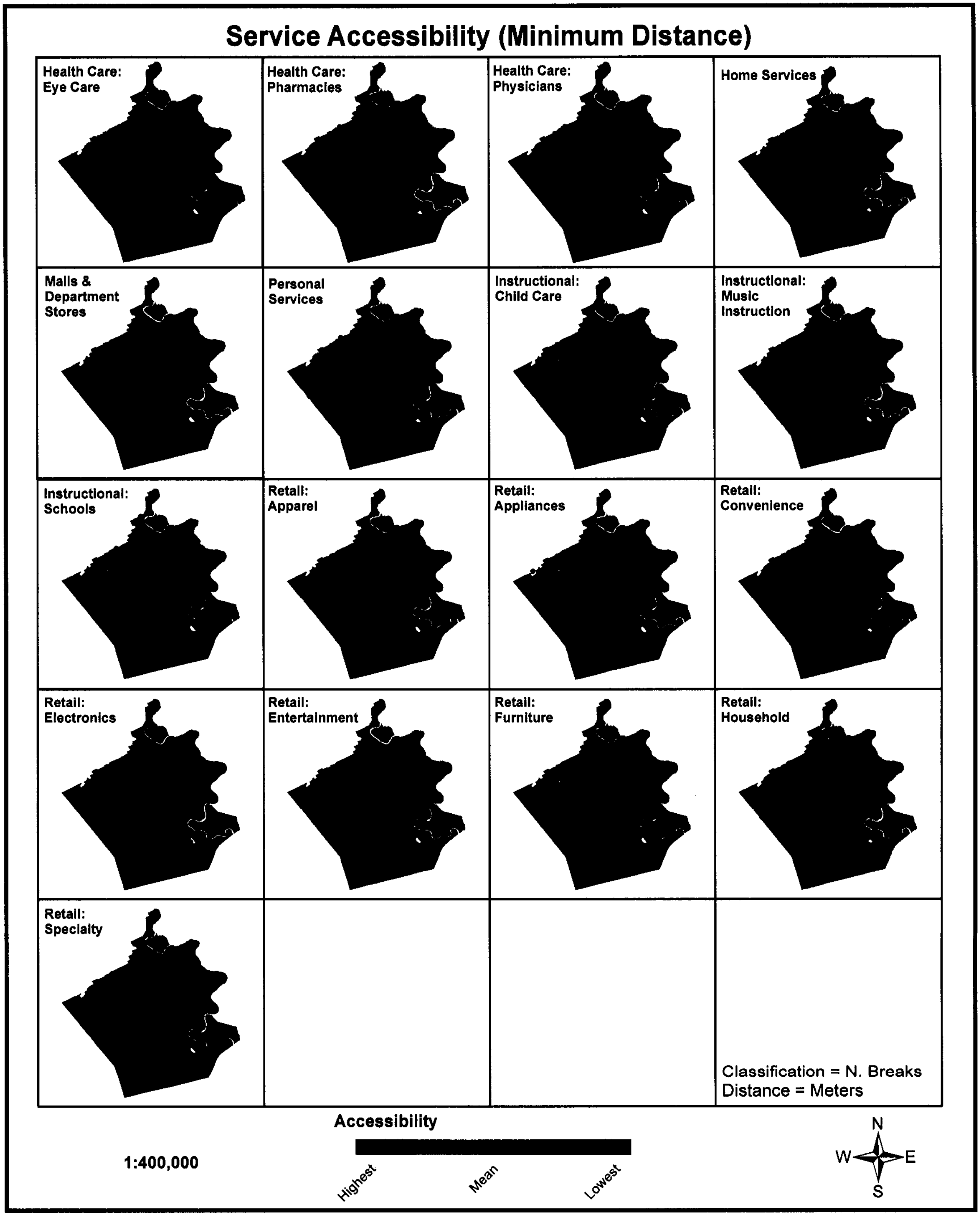

Service Accessibility (Minimum Distance)
Health Care: Eye Care
Health Care: Pharmacies
Health Care: Physicians
Home Services
Malls & Department Stores
Personal Services
Instructional: Child Care
Instructional: Music Instruction
Instructional: Schools
Retail: Apparel
Retail: Appliances
Retail: Convenience
Retail: Electronics
Retail: Entertainment
Retail: Furniture
Retail: Household
Retail: Specialty
Classification = N. Breaks
Distance = Meters
Accessibility
1:400,000
Highest
Mean
Lowest
N
W
E
S

Figure 13B

4.1.1 Overlay

The use of an unweighted addition overlay analysis was employed to measure neighbourhood service accessibility using all of the 37 service types. It was hoped that a spatial pattern could be identified based on a cumulative measure of neighbourhood accessibility. The overlay of the mean accessibility values, as illustrated in Figure 14, indicates a concentration of highly accessible neighbourhoods in the downtown core of the City. This cumulative measure of immediate accessibility, which remains based on the minimum distance technique, would seem to confirm that the scale at which accessibility is examined has considerable bearing on the resultant form. As seen earlier, individual service accessibility assessments proved that accessibility varies based on the service. This figure proves that without the use of comprehensive multiple service data we would be unable to detect these variations.

Of note are several outlier neighbourhoods clustered in the southern portion of the study area. These neighbourhoods exhibit uncharacteristically high spatial accessibility, with respect to services, than is typical of residential areas located in peripheral areas. Upon further investigation it is revealed that said neighbourhoods are situated in close proximity to a major regional shopping center and are also adjacent to a major transportation artery with direct access to the urban core. This situational advantage coupled with a disproportionate number of service points has created this pocket of atypical accessibility.

An additional number of neighbourhoods exhibiting atypical levels of service accessibility are situated immediately adjacent to the downtown core of the City. In areas which are characterized by high levels of accessibility these neighbourhoods possess considerably lower accessibility values. The explanation for these accessibility values, which cannot be substantiated empirically, would appear to be nature of the surrounding transportation network. Each of these neighbourhoods is situated at the end of, or is comprised of, a sinuous labyrinth of streets and cul du sacs thus maximizing the vehicular travel distances necessary to access the surrounding amenities. It would interesting, in future study, to examine the relationship between accessibility and urban form, associated with twentieth and twenty first century urban planning paradigms.

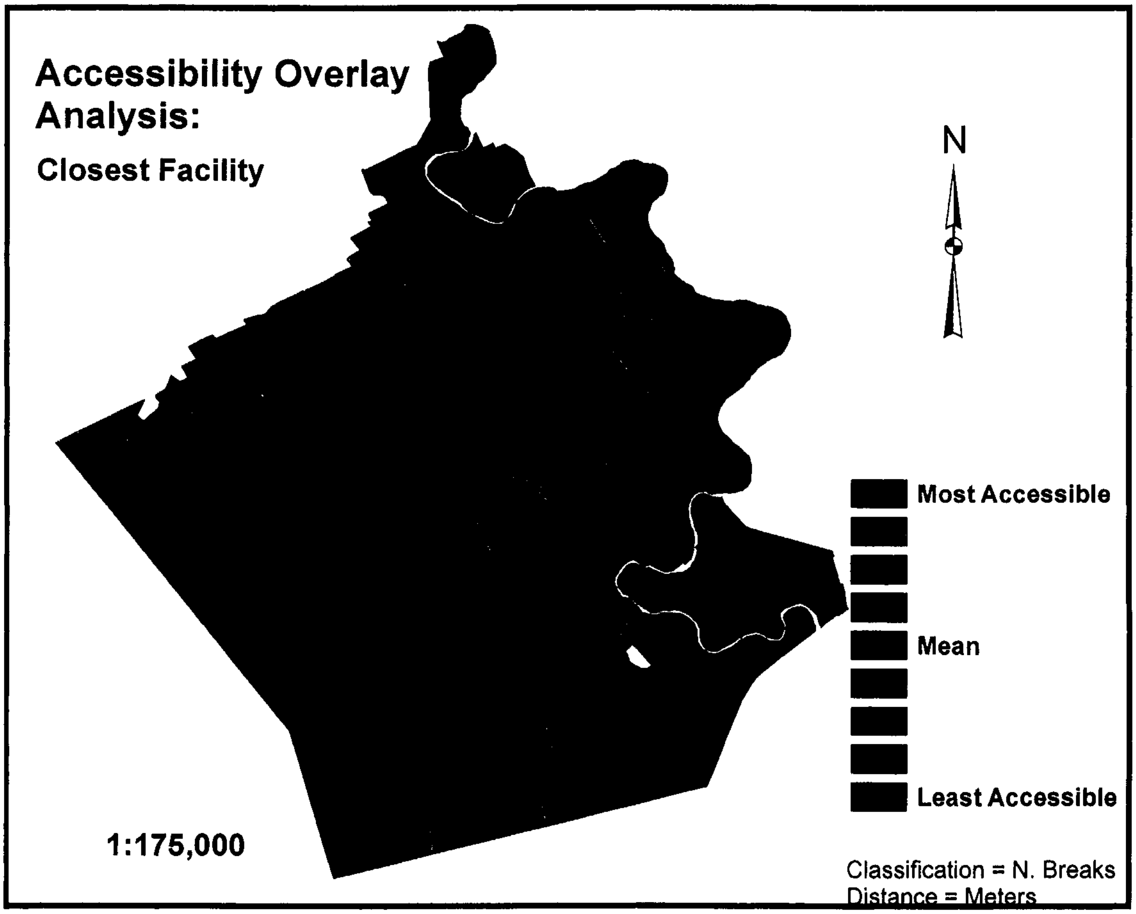
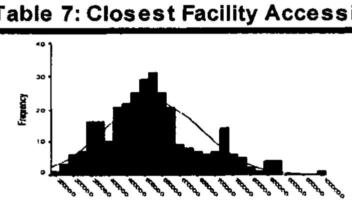


Figure 14

Table 7: Closest Facility Accessibility Overlay



N	307
Mean (m)	52374
Range	74392
Minimum	26213
Maximum	100606
Std. Deviation	13332

In conjunction with the individual service accessibility assessments the overlay supports the hypothesis that accessibility will vary based on service type. However, the overlay lacks the ability to identify similar neighbourhoods based on their accessibility to groups of services. This being said the initial success of the overlay procedure lends validity to the use of a weighted overlay process as a method in developing a residential compatibility surface which could then be tested using different population cohorts.

4.1.2 Cluster Analysis

A hierarchical cluster analysis, conducted using the service type accessibility variables, offered another cumulative measure of accessibility and yielded results which essentially mirrored the overlay findings. When viewed spatially, as in Figure 15, it was surprising to see the degree to which geographic clustering was present in the data. Similar to the overlay procedure, we see that the most accessible neighbourhoods can be found in the downtown core areas of the City. The cluster membership results produced by this analysis can be found in Table 8. This table highlights which clusters are associated with which service types throughout the study area.

The most accessible cluster is confined to a single region in the downtown while the neighbourhoods comprising the second most accessible cluster are located immediately adjacent to the first. Table 8 reveals that the neighbourhoods of these most accessible clusters are, overall, highly accessible with consistently high accessibility to the entertainment and financial industries. Where these two groups of neighbourhoods appear to differ is in their accessibility to retail as cluster 2 is considerably less accessible than cluster 1 in this regard.

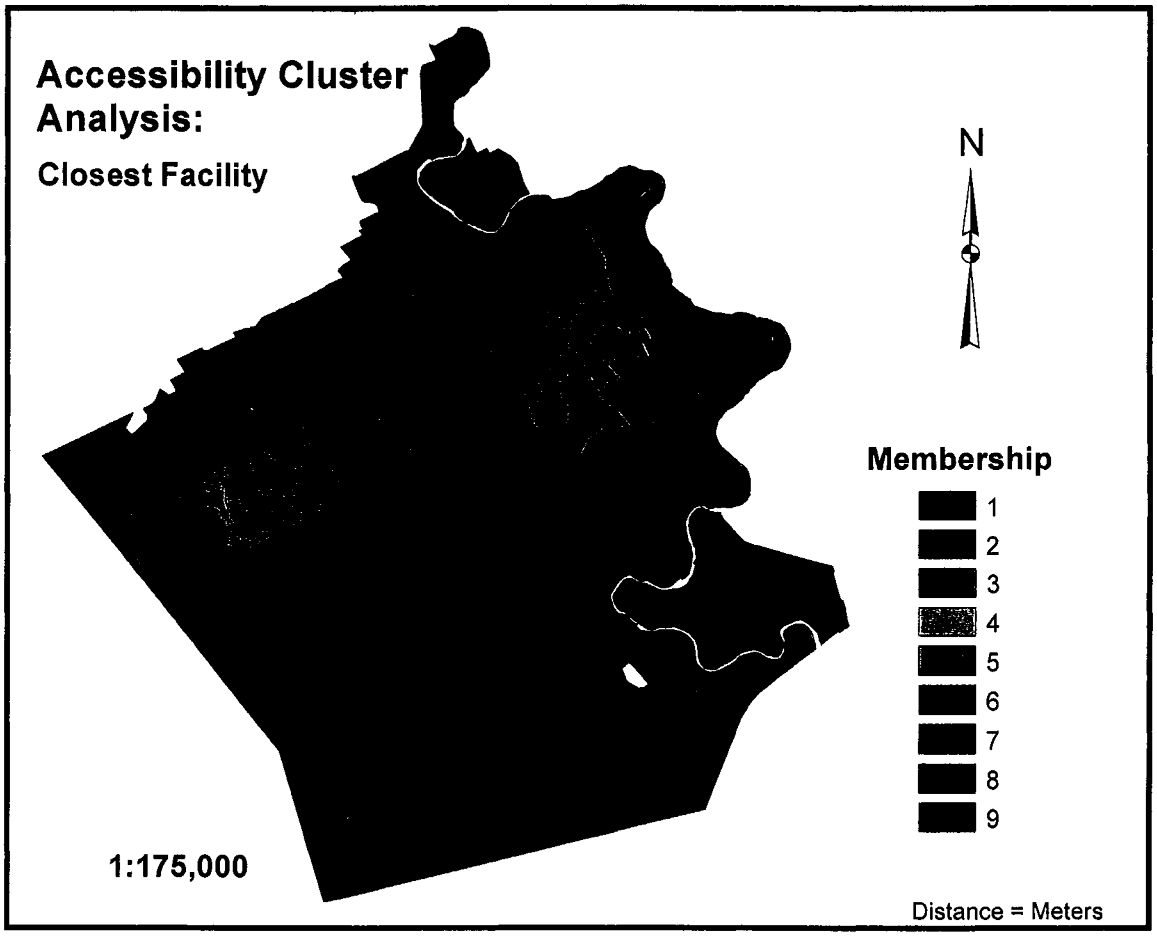

Accessibility Cluster
Analysis:
Closest Facility
N
Membership
1
2
3
4
5
6
7
8
9
1:175,000
Distance = Meters

Figure 15

When one examines the arrangement of the remaining accessibility clusters it is apparent that accessibility diminishes as one nears the more peripheral areas of the City. Accessibility cluster 3 is segmented and dispersed in a concentric pattern around the downtown. Moving outward we find clusters 4 and 5. Until this point the pattern remains consistent with that of an older North American manufacturing city with a centralized downtown nucleus and a spatially inaccessible periphery. The third cluster, as seen in Table 8, exhibits average accessibility to the majority of service types. As one moves outward to examine clusters 4 and 5 we see that the levels of accessibility become more widely varied and that little consistency can be found within the larger service categories. Table 8 outlines the diminishment of accessibility through the remaining clusters.

Clusters 6 and 9 do not conform as neatly to the mono-nucleic model as the other seven clusters. Cluster 9, the most inaccessible, is situated in a more proximate location to the downtown area than cluster 6. Upon closer examination it is revealed that several of the neighbourhoods comprising cluster 9 are relatively undeveloped. At the time the City collected its residential land use data there were little to no residential land parcels in several of these neighbourhoods (N<30). Such neighbourhoods were also characterized by the presence of an underdeveloped street network transecting the neighbourhoods. Further investigation of additional neighbourhoods in this cluster found evidence that while the cluster is in a more spatially advantageous location than cluster 6, the reality of its accessibility is considerably different as populated neighbourhoods within the cluster are situated at the extremities of sinuous local road networks, as mentioned in the previous section.

Table 8: Aggregated Cluster Matrix-Minimum Distance

		Cluster Membership (Relative)								
		1	2	3	4	5	6	7	8	9
Entertainment	Amusement	High	High	High	Avg.	Avg.	Low	Low	Low	Low
	Cultureal	High	High	High	High	Low	High	Low	Low	Low
	Night Life	High	High	High	Avg.	Avg.	Low	Avg.	Low	Avg.
	Sports & Fitness	High	High	Avg.	Avg.	High	Avg.	Low	Low	Low
	Travel	High	Avg.	Avg.	Avg.	Avg.	Low	Avg.	Low	Avg.
	Video Rental	High	High	Avg.	High	Avg.	Avg.	Avg.	Avg.	Low
Financial	Accountants	High	High	High	High	Low	Low	Low	Low	Low
	Banks	High	Avg.	Avg.	High	Avg.	Avg.	Avg.	Low	Avg.
	Insurance	High	Avg.	High	Avg.	Avg.	Low	High	Low	Avg.
	Real Estate	High	High	High	High	Avg.	Low	High	Avg.	High
	Tax Services	High	High	Avg.	High	Avg.	Avg.	Avg.	Low	Avg.
Food	Coffee Shops	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Low	High
	Fast Food	Avg.	High	Avg.	Avg.	Low	Avg.	Avg.	Low	Avg.
	Grocers	Avg.	High	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Low
	Restaurants	Avg.	Avg.	Avg.	Avg.	High	High	Low	Avg.	Low
	Specialty Grocers	Avg.	Avg.	Avg.	High	Avg.	Avg.	Avg.	Low	Low
Health Care	Alternative	Avg.	Avg.	Avg.	Avg.	High	High	Avg.	Avg.	Low
	Chiropractors	High	High	Avg.	High	Avg.	Avg.	Avg.	Low	Low
	Clinics	High	High	High	High	Avg.	Low	Low	Low	Low
	Dentists	Avg.	Low	Avg.	Avg.	High	High	Avg.	Avg.	Low
	Eye Care	High	High	Avg.	High	Avg.	Low	High	Low	High
	Pharmacies	Avg.	Avg.	High	Low	High	High	High	High	Low
	Physicians	High	High	High	High	Low	Low	High	Low	High
Other	Home Services	Avg.	Avg.	Avg.	Low	Avg.	High	Avg.	Avg.	Low
	Child Care	High	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Low	Avg.
	Music Instruction	Low	High	Avg.	High	High	High	Low	High	Low
	Schools	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Low	Avg.
	Malls & Department Stores	High	Low	High	Avg.	High	High	High	High	Low
	Personal Services	High	Avg.	Avg.	Avg.	Avg.	Low	Avg.	Low	Avg.
Retatil	Apparel	Avg.	Low	High	High	High	High	High	High	Low
	Appliances	High	High	High	High	Avg.	Avg.	Low	Low	Low
	Convenience	Avg.	Avg.	Avg.	Avg.	Avg.	High	Avg.	Avg.	Low
	Electronics	High	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Low	Avg.
	Entertainment	High	Low	High	Low	High	High	High	Avg.	Low
	Furniture	High	High	Avg.	Low	High	Low	Avg.	Low	Avg.
	Household	Avg.	Avg.	High	Avg.	High	High	Avg.	High	Low
	Specialty	High	Avg.	Avg.	Avg.	Avg.	Low	Avg.	Low	Avg.

Cluster 6 is a collection of neighbourhoods found in one of the most peripheral areas of Kitchener. Given the City's conformity to the mono-nucleic model a peripheral location would seem to be disadvantageous. Again the reader must be aware that this cluster analysis is the representation of the immediate accessibility analysis. A cursory visual analysis reveals that there are enough service points present in close proximity to these neighbourhoods to warrant several above average accessibility values. Moreover, an adequate transportation conduit is ideally situated to connect the residences directly with the central node of the city. The direct linear nature of this corridor facilitates an unexpected number of average accessibility relationships across the varying service types. Due to Kitchener's geographic adjacency to other urban areas it is quite possible that the outlying neighbourhoods comprising the sixth cluster are influenced by this proximity.

4.2 Overall Accessibility

The second networking run, using the travel cost technique, produced a series of overall residential accessibility values. These values are general in nature and represent the accessibility relationship between each residence and all service points of a type. When aggregated, the residential accessibility figures produced a second neighbourhood accessibility matrix embodying this broader relationship. In this second analysis the initial values could no longer be utilized as accurate descriptors for understanding and ranking service accessibility. The descriptive measures calculated using a travel cost technique are a function of the cumulative distance to all service points and thus their distance value will increase, and their accessibility decrease, in direct proportion to the number of service points within a type; ultimately precipitating a misleading result. Therefore, each descriptor was standardized by the number of facilities within a service type to more accurately reflect accessibility. The findings discussed in the paragraphs to follow reflect only these standardized values. The examples of study area schools and amusement facilities are carried forward in an effort to discuss and comparatively examine the differences between the two measures of accessibility.

The travel cost analysis, due to its holistic nature, lacks the capacity to recognize the geographic arrangement of neighbourhood accessibility around individual service points within a broader service type. As stated, it is a general indicator which represents the relationship between a neighbourhood and the overall service. The travel cost technique, as discussed in the methodology, was selected for its breadth which most accurately reflects the potential for choice when selecting an amenity. Therefore, highly accessible neighbourhoods, as defined by the travel cost technique, will be characterized by a greater array of choice when selecting a destination from which to procure an item or service. As geographic centrality is beneficial to choice, and thus spatial accessibility, this measure will accurately reflect the degree to which accessibility will decay from the City's downtown (Figure 16).

As seen in Figure 16 the neighbourhood accessibility values for schools, utilizing the travel cost technique, are quite different from those of the immediate accessibility analysis, which employs the minimum distance technique (Figure 10). Whereas the minimum distance analysis indicated a spatially dispersed arrangement of the service it is apparent that spatial disparities exist at higher levels of spatial scale. The decentralized nature of this service type, as discussed previously, is inherent to the nature of public education. Consequently, those neighbourhoods situated in the most central locations of the City will be more accessible to all of the City's schools and could also be explained as a response to population density[8]. What we begin to see is that decentralized services benefit all neighbourhoods immediately and central neighbourhoods overall. Centralized services benefit central neighbourhoods in both instances as will be discussed in the following paragraph.

Centralized services, as in minimum distance analysis, continue to benefit central neighbourhoods as reflected in Figure 17. This finding is not surprising as a spatially central location will minimize the travel distances from neighbourhood residences to all service points of a type. We see that centralized services, often a tenet of good business

[8] The reader should note that schools are used in this discussion solely as an example of a decentralized service. It is not the aim of school boards to make each individual school accessible to every household, nor does this paper claim they do or ought to.

practice, perpetuate an overall spatial disadvantage between neighbourhoods with respect to choice and service diversity. The decay of accessibility becomes more pronounced as distance from the city center increases. The concentric pattern demonstrated by these centralized services again conforms to the mono-nucleic urban model. Having performed a cursory examination and discussed the capabilities and benefits of the travel cost technique and its applicability to neighbourhood accessibility research, the remainder of this section will devote attention to the findings of the descriptive testing, identical to that employed in the minimum distance analysis.

A visual comparison of the results from the minimum distance and travel cost analyses reveal that the form of accessibility will vary depending upon the distance measure employed. When reviewing Table 9 we see that the holistic nature of the travel cost technique creates a more uniform distribution of accessibility values amongst neighbourhoods. A comparison of the mean service type accessibility values reveals that there is little discrepancy present between services at this larger scale of measurement. Therefore, the ranking of service accessibility using the travel cost technique may not be entirely appropriate as the ranking of one service over another, while numerically valid, may in fact be caused by the internal constitution of the individual service types; the number of neighbourhood origins or merely coincidence. It is recommended that future study explore this possibility which would most effectively be undertaken by the study of disaggregate services across several urban areas.

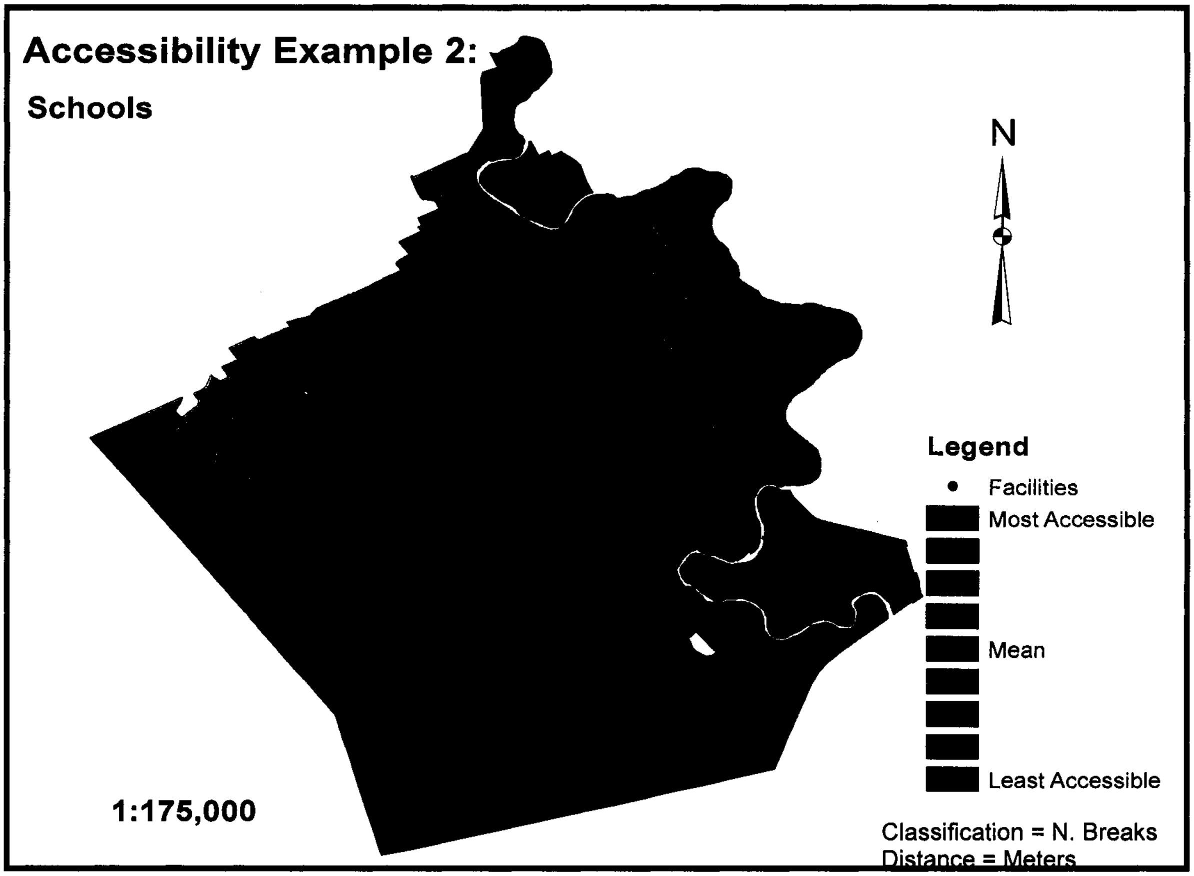
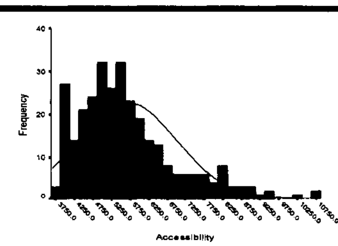


Figure 16

Accessibility Rank	23
Facilities	98
Mean	5682
Range	6897
Minimum	3831
Maximum	10727
Std. Deviation	1346



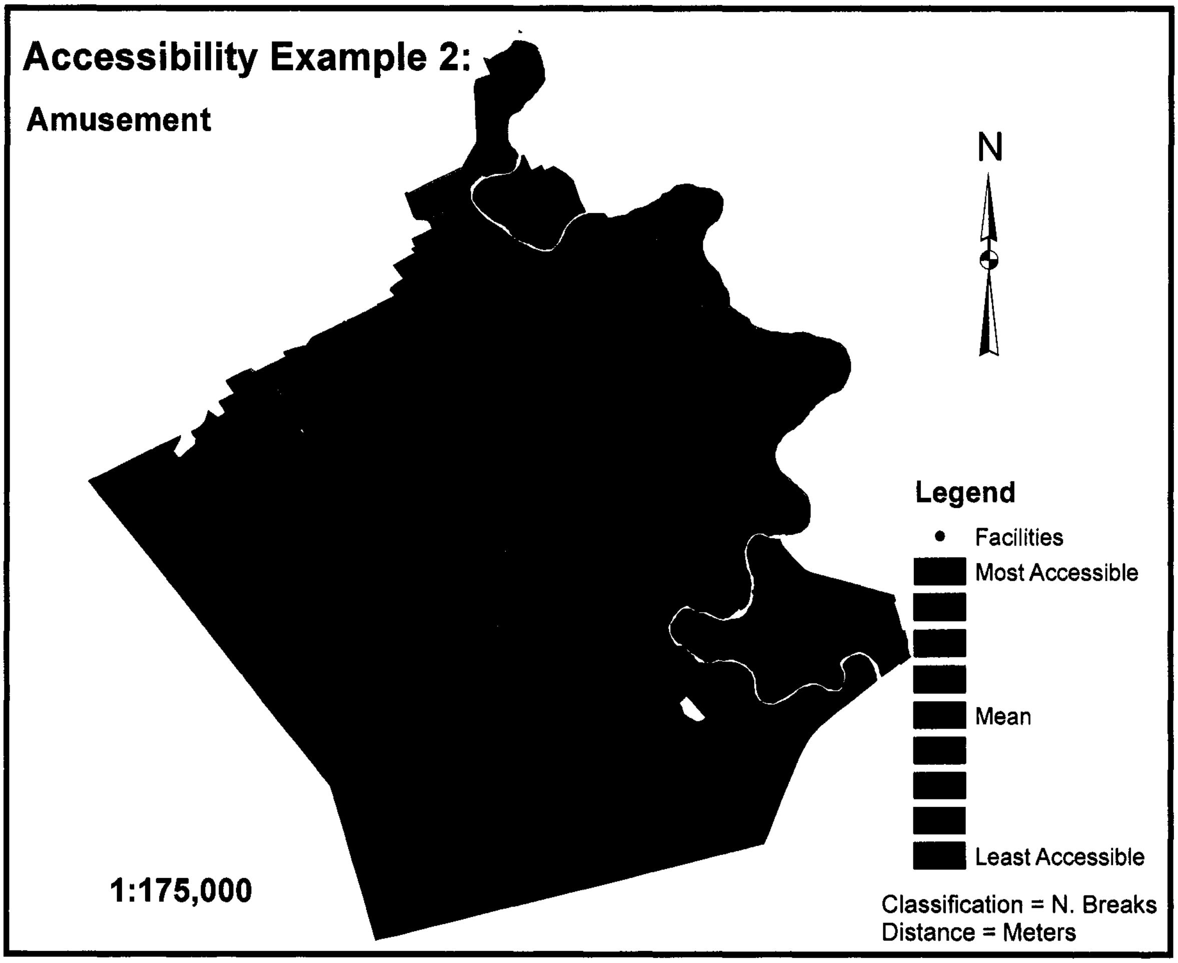


Figure 17

Accessibility Rank	35
Facilities	11
Mean	6222
Range	6790
Minimum	3801
Maximum	10592
Std. Deviation	1625

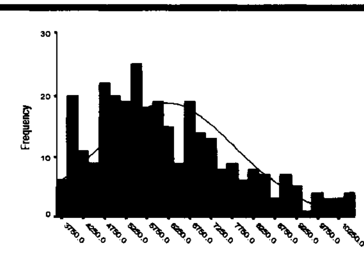


Table 9: Travel Cost Service Descriptives

Category	Service	Rank	Facilities (#)	Mean (meters)	Range	Minimum	Maximum	Std. Deviation
Entertainment	Amusement	35	11	6222	6790	3801	10592	1625
	Cultural	6	24	5277	7944	2639	10583	1635
	Night Life	1	32	5009	7952	2574	10527	1630
	Sports and Fitness	5	59	5269	6251	3259	9510	1311
	Travel	7	31	5279	7166	3096	10262	1431
	Video Rental	24	27	5695	6396	3820	10216	1284
Financial	Accountants	12	16	5392	9329	2605	11934	1885
	Banks	9	47	5300	6789	3298	10088	1366
	Insurance	10	75	5375	8644	2802	11446	1754
	Real Estate	21	46	5620	8378	3227	11605	1658
	Tax Services	15	26	5505	7812	3277	11089	1541
Other	Child Care	37	38	7750	7717	5532	13248	1519
	Music Instruction	2	11	5152	6331	3273	9604	1386
	Schools	23	98	5682	6897	3831	10727	1346
	Home Services	31	79	5912	6328	3925	10253	1318
	Malls and Department Stores	16	16	5522	6950	3293	10243	1454
	Personal Services	4	231	5266	8067	2913	10980	1599
Food	Coffee Shops	18	65	5557	7328	3185	10513	1512
	Fast Food	29	117	5873	5820	4142	9962	1219
	Grocers	20	86	5617	7432	3513	10945	1467
	Restraunts	25	147	5698	7459	3023	10482	1614
	Specialty Grocers	13	55	5424	7341	3258	10600	1449
Retail	Apparel	22	145	5667	6252	3213	9464	1498
	Appliances	8	29	5295	10845	32	10877	1634
	Convenience	27	87	5819	7561	3354	10915	1596
	Electronics	34	73	6147	11436	1207	12643	2019
	Entertainment	36	11	6664	7517	4062	11579	1801
	Furniture	32	60	5929	6868	3778	10645	1554
	Household	33	46	5976	6289	3979	10268	1362
	Specialty	14	189	5439	7292	3295	10588	1461
Health Care	Alternative	26	88	5790	7877	3317	11194	1671
	Chiropractors	17	34	5543	7675	3456	11131	1535
	Clinics	19	11	5593	7890	3361	11251	1583
	Dentists	30	87	5897	7722	3519	11241	1659
	Eye Care	11	29	5375	8164	3222	11387	1616
	Pharmacies	28	41	5832	7700	3502	11203	1621
	Physicians	3	168	5266	11073	1608	12681	2378

The bias toward high accessibility for centrally located neighbourhoods, as described in the literature, is prevalent in slightly greater than 50% of the service types subjected to the travel cost analysis. While clustered, spatially central, services continue to benefit the inner urban core, the degree to which the discrepancy between core and periphery exists has become more pronounced. Moreover, several service types which produced more evenly distributed neighbourhood accessibility rankings as a result of the minimum distance technique demonstrate the tendency to favor centrally situated neighbourhoods in this analysis. The neighbourhood accessibility distributions with respect to the individual service types, as produced by the travel cost analysis, can be seen in Figure 18. A surprising finding was that a significant number of service types did not conform to the hypothesis that central neighbourhoods would primarily receive the benefits of accessibility as depicted by the travel cost analysis. This outcome, while unexpected, leads one to believe that there are transportation barriers impeding access between certain neighbourhoods and facilities.

The bivariate correlation test of the service type accessibility values produced an interesting matrix which identifies multiple associations. Appendix 2, which presents these associations, effectively highlights the differences between centrally clustered and dispersed services. As one can see from the table, the broader categories of entertainment and financial services, save video rental outlets, demonstrate strong positive correlations to one another. Therefore, as the accessibility of one service type increases or decreases the other service type will conform to this change. Additional amenity types are found to correlate highly with financial and entertainment services.

Given the tendency for centrally situated services to demonstrate such high positive correlations with each other it may be prudent in future research, for reasons of expediency, to minimize the number of service types utilized. Proxy services, representing each category type, could then be employed to calculate neighbourhood accessibility, inferring accessibility for smaller accessibility subtypes and minimizing computational effort. Alternately, as these service types share near identical distributions and rates of accessibility, each of the service subtypes could be aggregated into one larger category and tested in an accessibility analysis again minimizing the time and effort required to conduct the analysis. These methodological recommendations are only applicable to the travel cost technique.

Those sectors of the service economy not positively correlating with the established central city services are those which are dispersed throughout the study area in arrangements other than a centrally situated cluster. Many of these dispersed service types (ex. alternative health care, dentists, and pharmacies), which can also be identified in Figure 18, again correlate highly with each other. However, a significant proportion of these services are negatively associated with one another suggesting that while they may share a non-central distribution the spatial arrangement of each is quite different. Therefore, it would be inappropriate to employ the above mentioned labour saving techniques in this instance. Instead, it may be beneficial to further dissaggregate these service types in an attempt to identify other patterns of spatial distribution.

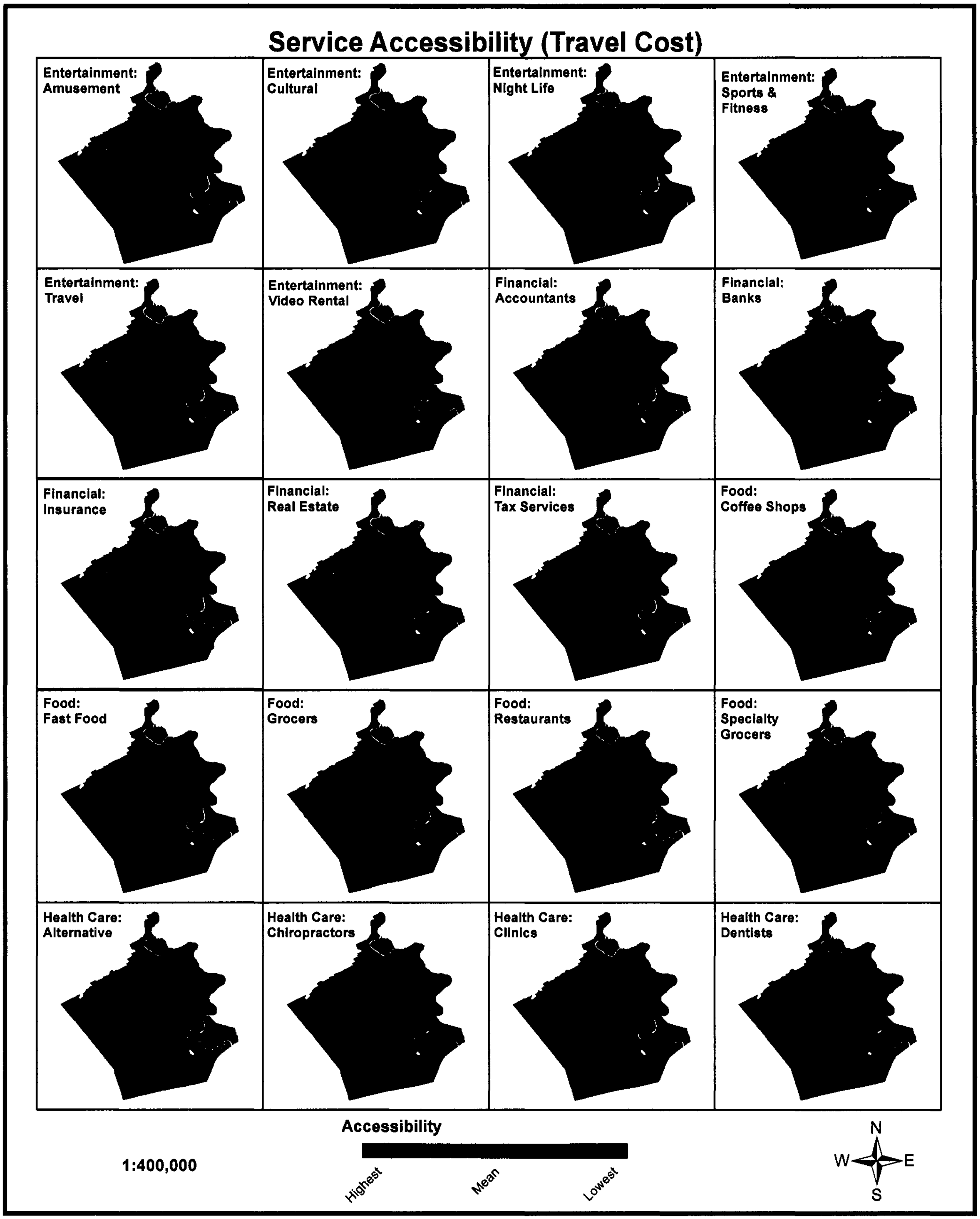

Service Accessibility (Travel Cost)
Entertainment: Amusement
Entertainment: Cultural
Entertainment: Night Life
Entertainment: Sports & Fitness
Entertainment: Travel
Entertainment: Video Rental
Financial: Accountants
Financial: Banks
Financial: Insurance
Financial: Real Estate
Financial: Tax Services
Food: Coffee Shops
Food: Fast Food
Food: Grocers
Food: Restaurants
Food: Specialty Grocers
Health Care: Alternative
Health Care: Chiropractors
Health Care: Clinics
Health Care: Dentists
Accessibility
Highest
Mean
Lowest
1:400,000
N
W
E
S

Figure 18A

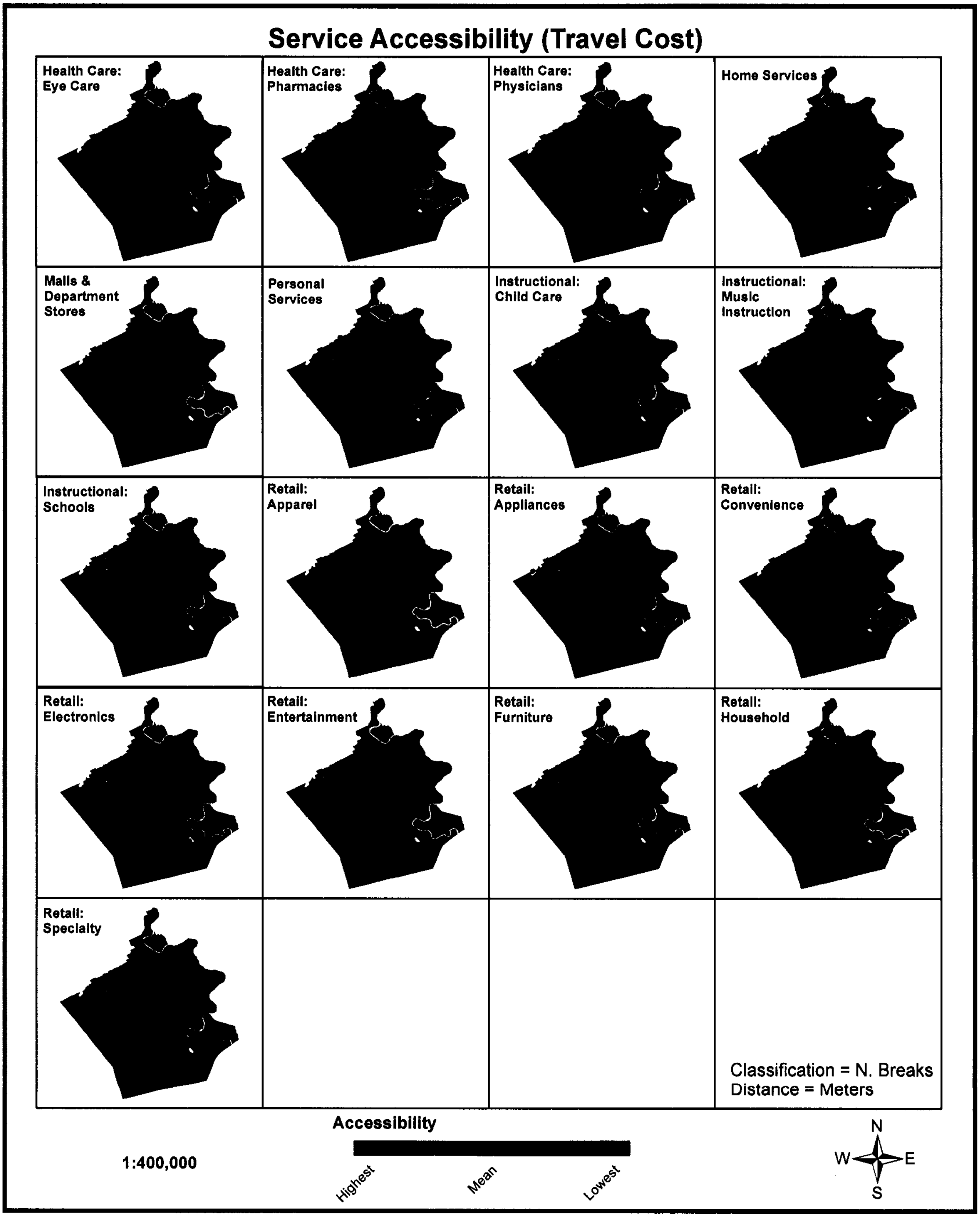

Service Accessibility (Travel Cost)
Health Care: Eye Care
Health Care: Pharmacies
Health Care: Physicians
Home Services
Malls & Department Stores
Personal Services
Instructional: Child Care
Instructional: Music Instruction
Instructional: Schools
Retail: Apparel
Retail: Appliances
Retail: Convenience
Retail: Electronics
Retail: Entertainment
Retail: Furniture
Retail: Household
Retail: Specialty
Classification = N. Breaks
Distance = Meters
Accessibility
1:400,000
Highest
Mean
Lowest
N
W
E
S

Figure 18B

4.2.1 Overlay

The addition overlay of the individual accessibility types, for the travel cost analysis, again revealed a mono-centric portrait of urban service accessibility in the study area (Figure 19). This overlay map, as opposed to that prepared using the minimum distance technique, illustrates a more concentric pattern of neighbourhood accessibility around the downtown core neighbourhoods. Indeed, from a cumulative vantage and but for a few outlier neighbourhoods, accessibility is a function of distance to the city center; as one approaches the periphery of Kitchener their accessibility will decrease. Figure 20 serves to illustrate this point. Similar to the minimum distance proximics diagram this figure represents those services which best represent high and low accessibility as identified in the descriptive testing. Whereas the minimum distance service proximics were relatively irregularly distributed it can be seen from the travel cost results that neighbourhood disparities in service access remain consistent regardless of service accessibility rankings. Distances do not appear to vary to the same extent and remains largely static throughout the specific level of accessibility (i.e. neighbourhoods characterized by a high level of accessibility can expect service distances to all services to be within 3 to 6 kilometers and as accessibility decreases to an average level service travel distances can be expected to be 6 kilometers).

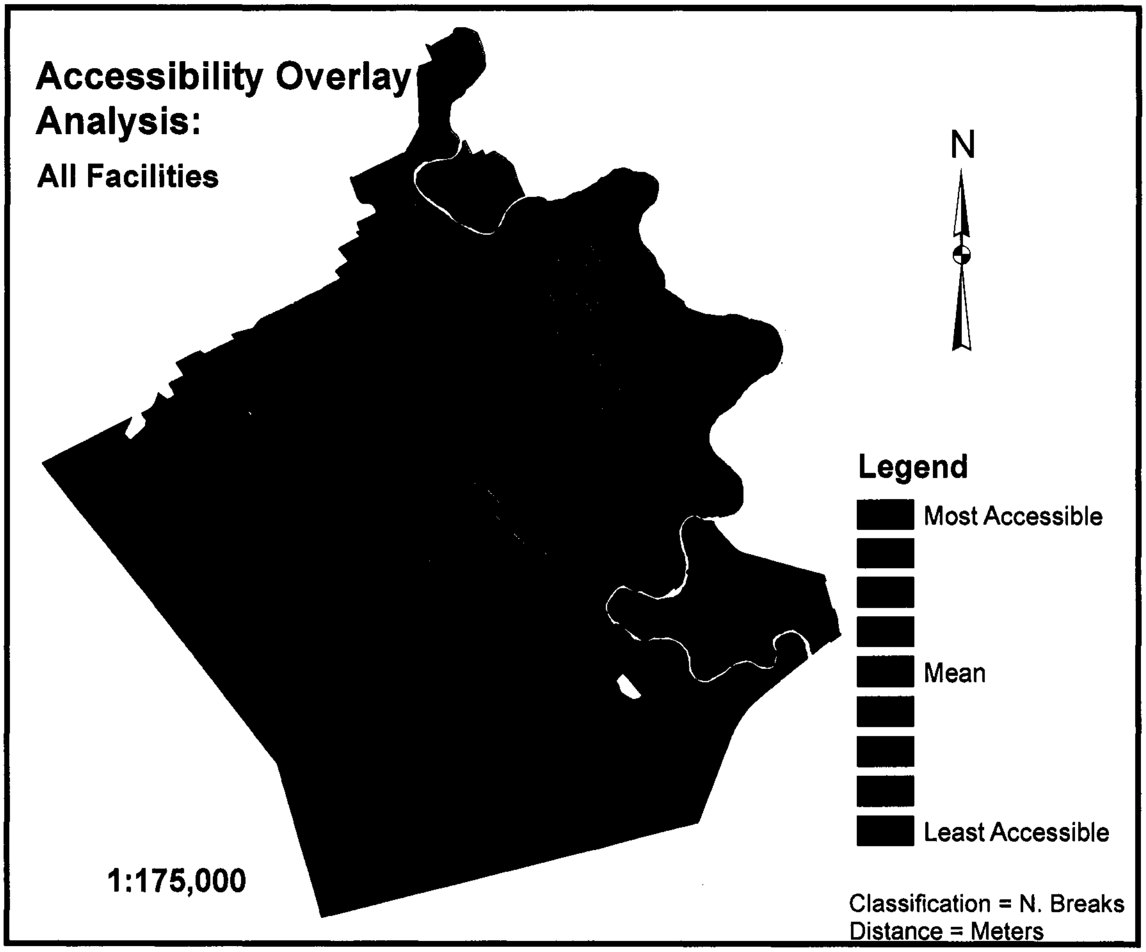
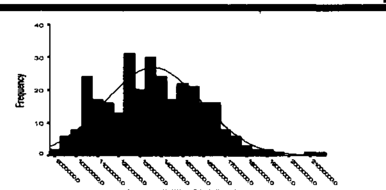


Figure 19

Table 10: All Facilities Accessibility Overlay



N	307
Mean (m)	13607908
Range	12343337
Minimum	9153983
Maximum	21497321
Std. Deviation	2277010

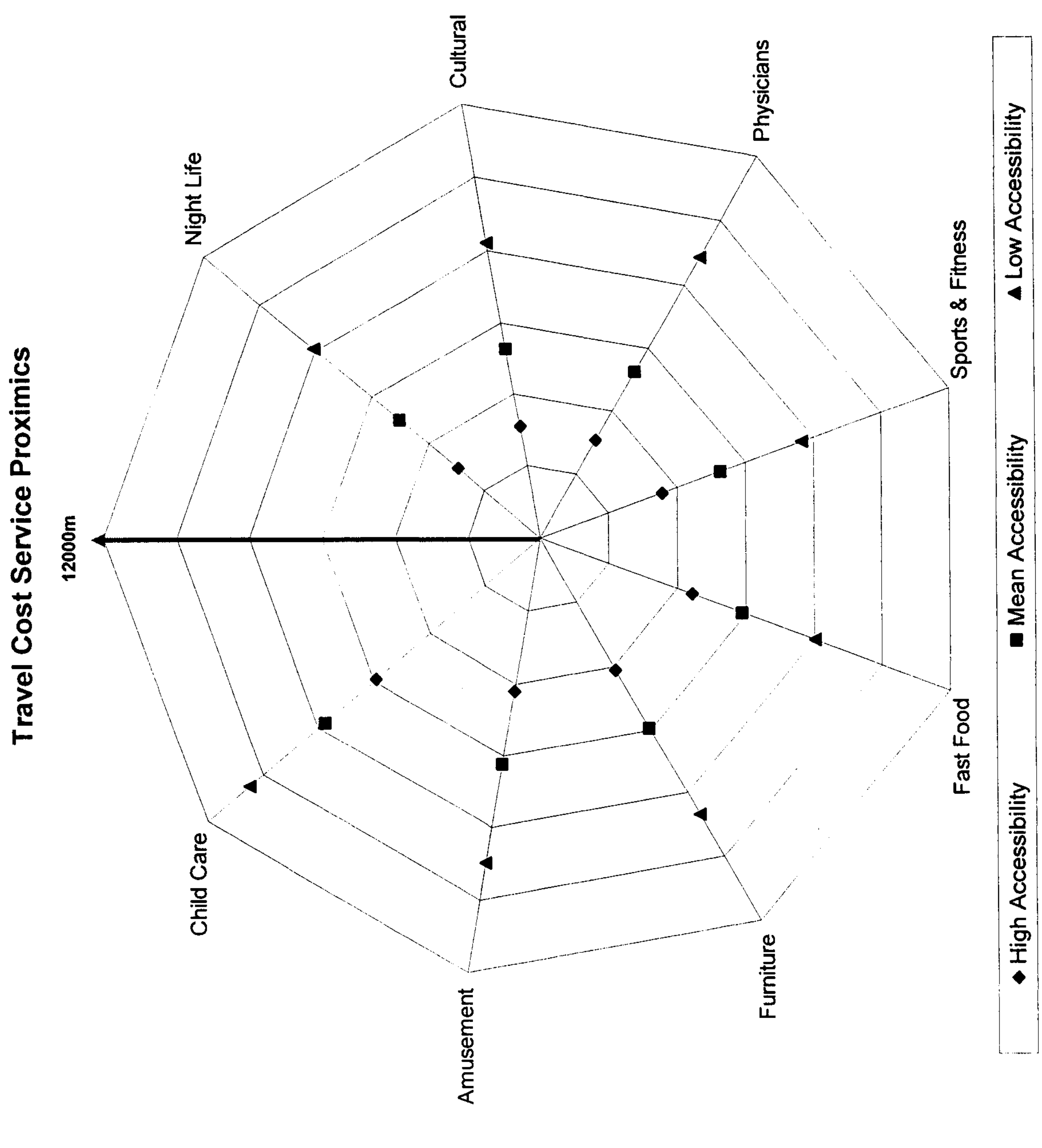

Travel Cost Service Proximics
12000m
Cultural
Physicians
Sports & Fitness
Fast Food
Furniture
Amusement
Child Care
Night Life
◆ High Accessibility
■ Mean Accessibility
▲ Low Accessibility

Figure 20

4.2.2 Cluster Analysis

The hierarchical cluster analysis of the travel cost service accessibility results again echoed the findings established in the minimum distance analysis. Similar to the overlay procedure we see that the spatial pattern of neighbourhood accessibility, in the travel cost analysis, is more concentricly distributed around the downtown core neighbourhoods (Figure 21). Table 10 provides a summary of how each cluster scored in terms of accessibility to each service type. It would appear from this data that the categories of entertainment, financial, and food services form the basis upon which the nine clusters have been delinated based on their consistency within the individual clusters.

The four cumulative measures of spatial accessibility with respect to services, two overlay and two cluster, indicate that the City of Kitchener conforms neatly into the mono-centric model of urban form, with respect to accessibility. Given the high levels of spatial accessibility for neighbourhoods situated in and around the downtown area it would follow that the central business district is still of considerable importance, in terms of service accessibility. This observation is supported by the high degree of accessibility present there and in the immediate area.

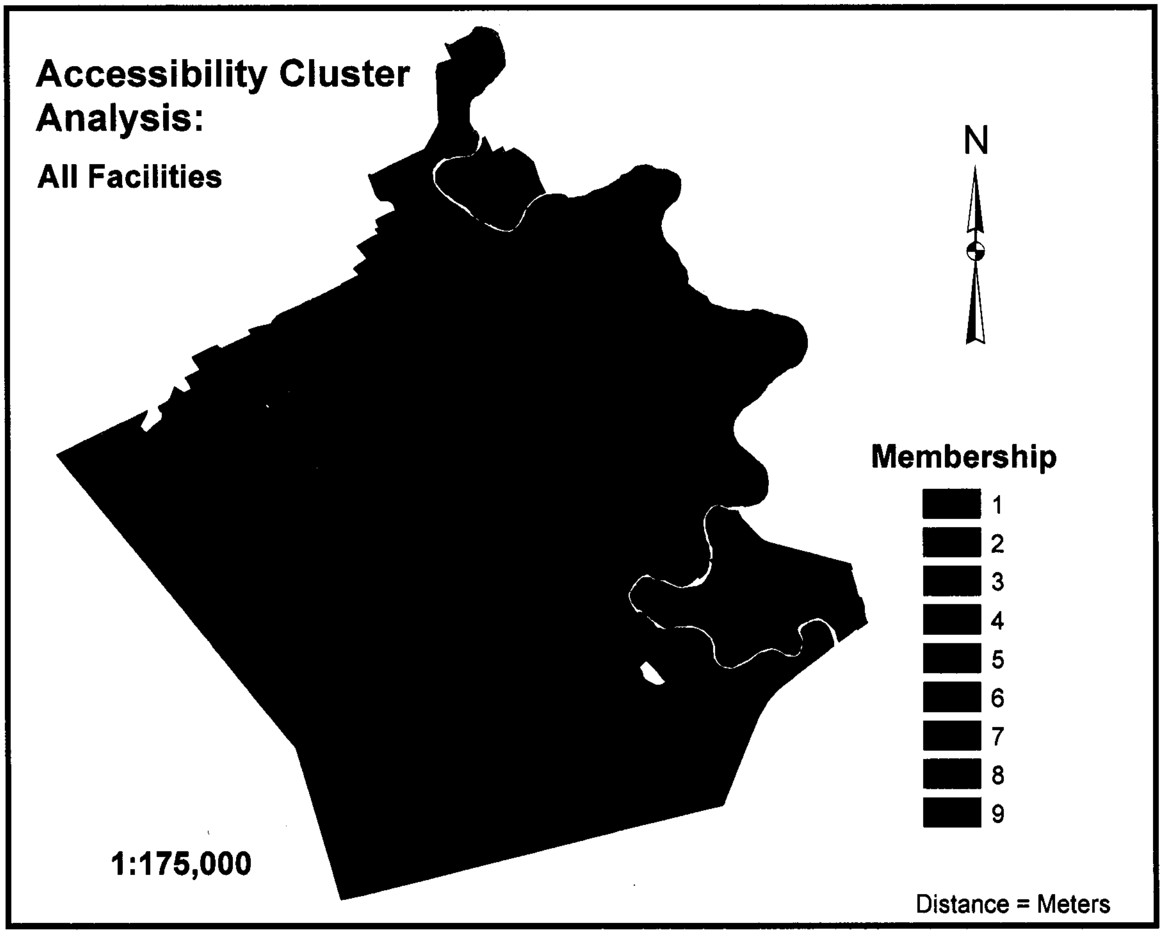

Accessibility Cluster Analysis:
All Facilities
N
Membership
1
2
3
4
5
6
7
8
9
1:175,000
Distance = Meters

Figure 21

Table 11:Aggregated Cluster Matrix-Travel Cost

		Cluster Memebership (Relative)								
		1	2	3	4	5	6	7	8	9
Entertainment	Amusement	Avg.	High	High	High	Avg.	Avg.	Low	Low	Low
	Cultureal	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Night Life	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Sports & Fitness	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Travel	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Video Rental	Avg.	High	Low	Low	Avg.	Avg.	Low	High	High
Financial	Accountants	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
	Banks	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Insurance	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Real Estate	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Tax Services	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
Food	Coffee Shops	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Fast Food	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Grocers	High	Avg.	High	Avg.	Low	High	Avg.	Low	Low
	Restaurants	Avg.	High	Low	Low	High	Low	High	Avg.	Avg.
	Specialty Grocers	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
Health Care	Alternative	Low	High	Low	Low	High	Avg.	Avg.	High	Avg.
	Chiropractors	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
	Clinics	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
	Dentists	Low	High	Low	Low	High	Avg.	Avg.	High	Avg.
	Eye Care	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
	Pharmacies	Low	High	Low	Low	High	Avg.	Avg.	High	Avg.
	Physicians	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
Other	Home Services	Low	High	Low	Low	High	Avg.	High	Avg.	Avg.
	Child Care	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Music Instruction	Low	High	Low	Low	High	Avg.	Avg.	High	Avg.
	Schools	High	Avg.	High	High	Low	Avg.	Avg.	Low	Low
	Malls & Department Stores	Avg.	High	Avg.	Low	High	Low	High	Avg.	Low
	Personal Services	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
Retatil	Apparel	Avg.	High	Low	Low	High	Low	High	Avg.	Avg.
	Appliances	Avg.	High	High	High	Avg.	Avg.	Low	Low	Low
	Convenience	Low	High	Low	Low	High	Avg.	Avg.	High	Avg.
	Electronics	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low
	Entertainment	Avg.	High	Avg.	Low	High	Low	High	Low	Avg.
	Furniture	Avg.	High	High	High	Avg.	Avg.	Low	Low	Low
	Household	Avg.	High	Low	Low	High	Low	High	Avg.	Avg.
	Specialty	High	Avg.	High	High	Avg.	Avg.	Low	Low	Low

4.3 Accessibility Integration

As has been mentioned throughout the body of this thesis, the two distance measures that have been employed (minimum distance and travel cost) were selected as each best represents the two key aspects of locational behaviour with respect to accessibility. These aspects being immediate access and choice. This chapter has made it evident that while accessibility will typically conform to the established form it can and will vary depending on the service, distance measure, and scale in question. In an effort to reduce one of these variations the two overlay products previously created (minimum distance and travel cost) were combined using a crosstabular technique. While the cumulative scale chosen cannot account for service variations, this procedure integrates the two distance measures into a surface depicting another form of neighbourhood service accessibility (Figure 22). The neighbourhood values in this figure, which can be obtained from the map legend, are given in terms of immediate access (minimum distance) first and choice (travel cost) second.

In order to substantiate these combined accessibility findings the results of the minimum distance testing were correlated with those produced utilizing the travel cost technique. The resultant matrix is presented in Appendix 1 and reveals very low to low-moderate correlations indicating that both techniques, minimum distance and travel cost, are indeed indicators of different aspects of accessibility. These finding further suggest that while a neighbourhood may receive the immediate benefits of an amenity its overall choice of amenities, for that particular service type, may be limited. A reciprocal arrangement is also possible.

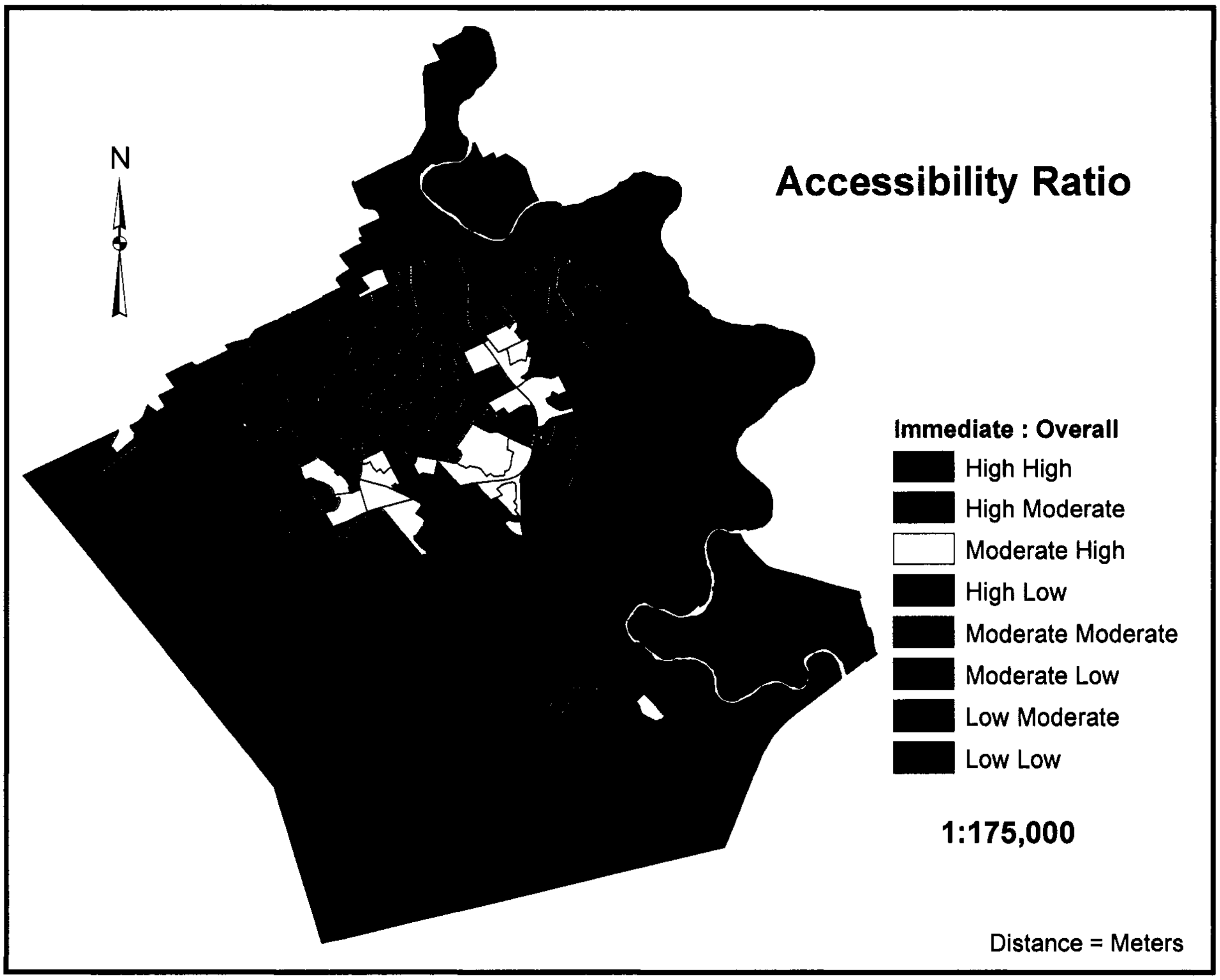

N
Accessibility Ratio
Immediate : Overall
High High
High Moderate
Moderate High
High Low
Moderate Moderate
Moderate Low
Low Moderate
Low Low
1:175,000
Distance = Meters

Figure 22

4.4 Social Analyses

This thesis has stated that the census level data, and the focus on spatial disparity, have limited the methodological development of accessibility research. Moreover, it has demonstrated that free of the limitations of census based information accessibility research can be conducted in a methodologically valid manner. Although the calculation of accessibility must remain asocial, the outcome of an accessibility analysis may easily be used in conjunction with sociodemographic information. When these two components are employed correctly, as outlined in this research, one can effectively examine the relationships between spatial accessibility and the population of a study area.

The following paragraphs present the findings of the exploratory bivariate analyses which link each measure of accessibility with indicators of family, housing, and economics obtained from the 2001 Canada Census (Table 3). The results of the bivariate correlation analyses can be found in appendicies 3 and 4. Accessibility analyses, as well as the correlation analyses presented in each of these tables, are based on measures of distance. Accessibility, however, shares an inverse relationship with distance (i.e. as distance increases accessibility decreases). Thus, with respect to the relationship between accessibility and the census indicators, the correlation values found in each matrix must be treated in a recipricol fashion.

The findings presented in these two tables reveal that forms of older housing, constructed in the mid twentyfirst century, correlate moderately with spatial accessibility in this study area. Given the nature of urban development throughout the twentieth century in Canada, with growth radiating from a city center, it is not surprising that accessibility would mirror this progression

It is no surprise that accessibility shares a relationship with the built environment and in this study spatially coincide[9]. Unfortunately, the built environment has been examined extensively in a literature which suggests that geography move beyond this idea and explore the social aspects of the urban landscape. This section, while not the direct focus of this research, has been included as it demonstrates the interoperability of the resultant accessibility constructs and information available from the Canada Census.

Although the correlation analyses conducted in this section substantiate the relationship between accessibility and built form they are unable to support a further conclusion that accessibility is related to any of the other socioeconomic indicators tested. No systematic variance could be found between socioeconomic measures of a dissemination area and accessibility. This does not mean that the study area is without depravity or that depravity does not spatially coincide with accessibility. Instead these results suggest that accessibility, in its various manifestations, will occur throughout the City regardless of socioeconomic conditions.

This chapter has presented the results of the spatial and socio-spatial analyses conducted in this study. It has demonstrated the validity, adaptability, and simplicity of the methodology in addition to its ability to overcome the existing methodological errors to produce a tangible result; a true representation of urban spatial accessibility. The

[9] The finding of this spatial coincidence should not be taken as absolute. This research has analyzed the accessibility of Kitchener, a single city within a larger polycentric urban region and is incapable of accounting for the influence that the cities of Waterloo and Cambridge exert on it.

following chapter will provide a discussion which will attempt to contextualize these results and place this research within the overall literary body.

5.0 Discussion

This thesis set out to uncover variations from the established form of accessibility, which is described throughout the literature (Alonso 1964; Koenig 1974; Knox 1978; Horner 2004). Given the data, technical, and research limitations inherent to the study of accessibility, as discussed in chapter two, this research sought to prove that deviations from the established form could exist. It was thought that the form of accessibility could vary based on service type, distance measure employed, and scale (the level of service type aggregation). Furthermore, this research employed high resolution spatial information to establish a means by which this accessibility study could be conducted while doing so in a manner free of aggregation error (Hewko, Smoyer-Tomic et al. 2002). The remainder of this chapter will discuss the findings of this research: First, consideration will be given to the general implications of the results; second, the findings will be discussed in the context of the study area; and finally, the contributions of this research to the literature will be presented.

5.1 Implications

While the literature suggests that the highest levels of accessibility will be found in central city neighbourhoods (Knox 1978; Horner 2004), this research reveals that the form of accessibility can deviate from the established model. As seen in the previous chapter the form of accessibility will vary based on the type of service under consideration. Furthermore, it has been found that the form of accessibility is largely dependent on the distance measure employed. Table 12 indicates the individual services which possess variations in form and under which distance measure that this deviation occurs. It was apparent in chapter four, when visualizing the individual service accessibility results for each distance measure (minimum distance and travel cost), that the measure employed significantly influences the resultant form of accessibility. The third column in Table 12 highlights those service types which share a similar spatial arrangement under both distance measures. From this table one can identify those services which absolutely will deviate from the concentrated form proposed by authors such as Alonso (1964), Knox (1978) and Horner (2004) and those which will conform to it. Finally, as evidenced by a comparison between individual service assessments and cumulative assessments (overlay and cluster analyses), the form of accessibility will be dependent on the number of services aggregated into the analysis. We see that while variations exist within the individual assessments they become lost in the larger picture of service accessibility.

These findings have considerable bearing on the accessibility literature. Accessibility analysis have been commonly utilized to inform public policy and issues of social equity (Mayhew and Leonardi 1982; Ihlanfeldt 1993; Helling and Sawicki 2003; Tsou, Hung et al. 2005; Apparicio and Seguin 2006; Smoyer-Tomic, Spence et al. 2006). However, evidence proving that the form of accessibility is dependent upon the service(s) in question, the manner in which accessibility is calculated, and the scale at which it is investigated has been produced. This thesis does not state that the form of accessibility will deviate from the norm, only that it has the potential to based on these variables. This evidence questions whether policy can, and should, be informed based on such a variable outcome.

Table 12: Deviation from Established Form		Distance Measure		
		Minimum Distance	Travel Cost	Both
Entertainment	Amusement	No	No	No
	Cultural	Moderate	No	
	Night Life	Moderate	No	
	Sports & Fitness	Yes	No	
	Travel	Moderate	No	
	Video Rental	Yes	Yes	Yes
Financial	Accountants	No	No	No
	Banks	Yes	No	
	Insurance	Moderate	No	
	Real Estate	Moderate	No	
	Tax Services	No	No	No
Food	Coffee Shops	Moderate	No	
	Fast Food	Yes	No	
	Grocers	Yes	Moderate	
	Restaurants	Yes	Yes	Yes
	Specialty Grocers	Moderate	No	
Health Care	Alternative	Yes	Yes	Yes
	Chiropractors	Moderate	No	
	Clinics	No	No	No
	Dentists	Yes	Yes	Yes
	Eye Care	Yes	Moderate	
	Pharmacies	Yes	Yes	Yes
	Physicians	No	No	No
Other	Home Services	Yes	Yes	Yes
	Child Care	Yes	No	
	Music Instruction	Yes	Yes	Yes
	Schools	Yes	No	
	Malls & Department Stores	Yes	Yes	Yes
	Personal Services	Moderate	No	
Retatil	Apparel	Yes	Yes	Yes
	Appliances	No	No	No
	Convenience	Yes	Yes	Yes
	Electronics	Moderate	Moderate	Moderate
	Entertainment	Yes	Yes	Yes
	Furniture	Moderate	No	
	Household	Yes	Yes	Yes
	Specialty	Moderate	No	

5.2 Kitchener

Although the Kitchener accessibility study was designed primarily to test the theoretical and methodological ideas proposed in this thesis it presented the opportunity to conduct a thorough analysis of spatial accessibility in this city. We can see from the cumulative service accessibility results that the City, in general, conforms to the mononucleic form proposed by Alonso (1964). Additionally, the highest levels of neighbourhood service accessibility can be found in the core neighbourhoods of Kitchener while levels of low accessibility are typical of the peripheral areas.

Aggregation error has discussed throughout the literature and is inherent to every accessibility study to some degree (Hewko, Smoyer-Tomic et al. 2002). Previous attempts have been made to create a means through which aggregation error can be overcome or suppressed (Current and Schilling 1987; Hodgson, Shmulevitz et al. 1997; Hewko, Smoyer-Tomic et al. 2002). The comprehensive nature of the City of Kitchener's geographic information system has allowed this study to depart from the accessibility literature to create a means of examining spatial accessibility which is free of aggregation error. This study improves upon and surpasses previous efforts to overcome the influences of aggregation error by stepping back and examining this obstacle from a simplistic view point. While authors such as Hodgson (1997) and Current and Schilling (1987) sought to reduce the influence of this error through means of advanced mathematical technique, this research focused on the cause of aggregation error; the origins. Due to the dependency of geographic research on traditional geospatial data sources, namely the Canada Census, analyses to date have been forced to employ polygon centroids, such as dissemination areas and census tracts, as the origins from which travel is initiated.

The use of parcel level data suggested by Talen (2003) and captured through remote sensing by Wang and Trauth (2006) demonstrated a manner in which high resolution origin data could be obtained. Using this data to supplement a traditional accessibility model this study has contributed to the literature by demonstrating the use of a residential accessibility technique (Figure 9). Not only does this technique provide a means with which to overcome aggregation error but it also allows for the user to conduct meaningful social analyses as well. The use of high resolution parcel data allows for the resultant accessibility information to later be matched to any level of spatial construct one chooses to study (i.e. a census level of measurement or planned community boundaries) for integration with socioeconomic information.

5.3 Contributions

This research has proven the validity of the aggregated residential accessibility model and its ability to minimize/overcome the effects of aggregation error inhibiting current accessibility research. While others have devised means to minimize the effects of aggregation error (Hodgson, Shmulevitz et al. 1997; Hewko, Smoyer-Tomic et al. 2002) this study has been able to successfully mitigate the influence of the impediment. The successful completion of Kitchener accessibility study has demonstrated the effectiveness of this technique. While most authors conducting accessibility research depend heavily on the census (Helling and Sawicki 2003; Dunkley, Helling et al. 2004; Smoyer-Tomic, Hewko et al. 2004) this research has demonstrated that a valid and comprehensive representation of urban spatial accessibility can be achieved by discarding census based information in favor of higher resolution residential data. The use of disaggregate data has been suggested previously (Sawicki 1996; Hodgson, Shmulevitz et al. 1997). However, Talen (2003) suggested that the pursuit of such a methodology was impractical as the asocial nature of non-census based information, which excludes socioeconomic investigation, would not be attractive to planners.

While this avenue of research may be deemed of little interest to the planning discipline it remains of interest to those conducting geographical analysis. Not only has this research been able to develop the technique alluded to by Hewko et al. (2002) and Talen (2003) it has addressed concerns that such an exercise would be restricted to asocial study, a study without the ability for socioeconomic comparison. The present capability of geographic information systems to spatially aggregate high resolution data upward (Sawicki & Flynn, 1996) enables the researcher to undertake this asocial study of accessibility and, upon completion, match the results to the arrangement of any level of census based information for the purposes of social analysis. Therefore, the study of socio-spatial accessibility is possible without the use of census based information in the initial calculation of accessibility.

Throughout this thesis mention has been given to those presently contributing to the study of urban accessibility. While most authors use the study of accessibility to inform and perpetuate debate in areas of social justice, equity, and policy there are very few who seek to identify a more thorough means of quantifying urban spatial accessibility (Hewko, Smoyer-Tomic et al. 2002; Talen 2003). This research has also sought to make a methodological contribution. The development of the aggregated residential accessibility technique and its successful demonstration are important to the field of accessibility research for several reasons.

The most basic importance of this research is that it lends a methodological validity to the study of accessibility by increasing the accuracy, breadth, and precision of the data and technique. By eliminating aggregation error one can be assured that the measure of spatial accessibility will conform to the parameters of distance measurement and metrics established by the author. One can therefore inform and participate in policy debate without having to qualify the degree of error present in their findings. Of greater significance is the flexibility of this accessibility methodology. As the techniques employed are dependent on widely available forms of information the study of accessibility can be conducted in a uniform manner throughout multiple metropolitan areas. The ability to effectively conduct a comparative accessibility study, and incorporate additional destinations, is thus the next step to be taken in the study of urban accessibility. Another critical contribution of this research is the establishment of the methodology and the compilation of a global depiction of accessibility. While this research limited itself to the construction of a methodology, several exploratory tests, and a discussion of the global form of accessibility it is apparent that there is considerable variability amongst the individual service types from the overall form that has been established throughout the literature (Alonso 1964; Knox 1978; Horner 2004). This global measure, and the means to establish a similar measure in other metropolitan areas, can serve as a baseline of accessibility through which an evaluation of individual service, neighbourhood, and demographic specific geographies can be conducted.

While this thesis has highlighted the benefits of a residential level approach to urban accessibility research care should be taken when applying its findings and making recommendations based upon them. Although methodologically sound, this model is unrealistic in two critical aspects; first, this model measures absolute distance and, second, it confines itself solely to the City of Kitchener. Given these limitations the model is incapable of accounting for the cost associated urban travel, such as traffic congestion, road condition, and speed limits, as well as the edge effects undoubtedly present due to the close proximity of the Cities of Waterloo and Cambridge.

The concern of this thesis centered on the establishment of a methodology and model capable of addressing forms of spatial error present within accessibility research. Outlined in the following section is a listing of possible approaches to future research which can be based upon this thesis. By pursuing a more realistic representation of urban travel and accounting for the edge effects of the larger urban region one will incorporate the realism necessary to address policy issues using this residential accessibility model.

Considerable time and effort have been invested in the study of urban spatial accessibility. The literature is replete with authors using accessibility analysis to examine neighbourhood-service relationships with respect to health care, education, playgrounds, daycare, and parks (Knox 1978; Pacione 1989; Truelove 1993; Talen 1997; Smoyer-Tomic, Hewko et al. 2004). Although this discussion has raised new questions of service type, distance measure, and scale variations which pertain to the effectiveness of accessibility analysis, it is nonetheless a valid endeavor. By recognizing and accounting for these potential limitations the use of accessibility analysis can be justified. A further limitation exists in the aggregation of services into service types. While the use of overarching service types lends a greater analytical simplicity to this research the use of a service type can be criticized as arbitrary or too cumbersome for more discrete analyses. As this research expended considerable effort in establishing a method for a global accessibility analysis the aggregation of services was considered acceptable. Having established a viable method, another logical step would be to disaggregate the service types in hopes of finding variations which may be suppressed by their current level of aggregation. The following points listed below indicate the multiple avenues along which further accessibility research can be pursued:

5.4 Applications and Future Research

1. Apply this methodology to a larger study group in an attempt to compare urban accessibility across a variety of cities.
2. Compare various urban planning designs in terms of accessibility.
3. Assess neighbourhood accessibility with regard to its compatibility with a single demographic thus determining which neighbourhoods are best able to support that demographic. This could be achieved with a weighted overlay model. An example of this potential research would be to identify neighbourhoods which provide the necessary lifestyle and essential services for independent living for elderly persons within a defined acceptable distance.
4. Incorporate additional forms of transportation, other than the automobile, in an effort to evaluate the degree to which a city accommodates those forms of transportation. This can be accomplished through the use of parallel analyses (automobile, transit, cycling, walking). Each would incorporate unique travel

frictions and the resulting accessibility surfaces could then be integrated using weighted overlay or cross-tabulation methods.

5. Create a more comprehensive measure of accessibility by incorporating additional travel frictions, in addition to path distance, such as time of day and traffic congestion
6. Assess the spatial provision of a particular service. Such a study could be conducted across multiple urban regions and could possibly incorporate accessibility barriers other than the spatial through the use of a survey. For example, one could assess the provision of public education across multiple urban centers.
7. Create an overlay using multiple accessibility measurement techniques. Accessibility to a service type would be conducted using the most appropriate measurement (container, coverage, minimum distance, travel cost, and gravity). The outcomes would then be standardized and overlayed to compile a more comprehensive representation of accessibility.
8. Conduct non-demographic accessibility research at the parcel level in order to obtain a true representation of accessibility. The results of a parcel accessibility analysis could then be grouped using a clustering technique to identify neighbourhoods. Additionally, one could utilize the trend surface analysis to explore the accessibility in a three dimensional environment to examine the decay from city center to periphery.

If, as Talen (2003) suggests, planners want to make use of accessibility tools it is imperative that the technical impediments associated with the study of accessibility study be addressed. This preliminary and exploratory research has shown that the difficulties associated with the study of accessibility can be overcome. It is hoped that future research can further refine the techniques demonstrated in this study. The implications of making planning decisions based on spatial research known to contain spatial error have serious ramifications. Not only does this misinform the decision making process but it has the potential to negatively influence the everyday lives of the citizenry. It is hoped that this methodological contribution can be used to create a more secure foundation upon which to base future spatial accessibility research and preempt these issues.

5.5 Concluding Remarks

The goal of accessibility study is to invariably discuss issues of spatial equity. However, this thesis contends that before issues of spatial equity can be investigated methodological concerns inherent to the study of accessibility must be overcome. This thesis has built upon the argument of Hewko et al., (2002) which suggests that the use of high resolution spatial information provides the capacity to overcome sources of aggregation error.

The use of high resolution spatial data, in this study, has allowed for a refinement in accessibility technique and provided a platform for a comprehensive, multi-service accessibility analysis. This thesis proves that such an approach can uncover deviations from the established form of accessibility (Alonso 1964; Horner 2004) whereby low levels of accessibility can exist at the city center and high levels of accessibility can be found in peripheral areas. This research has compared the spatial accessibility of a diverse array of services, the outcomes produced by two commonly employed distance measures, and issues of scale on the form of service accessibility. It has been found that the form of accessibility can vary based on the service, distance measure, and scale of the service type.

Throughout the course of this research the following products were also produced which further an understanding of the relationship between publicly available services and the community: A ranking of urban neighbourhoods based on service accessibility and a ranking of services based on their accessibility to the community. These analyses have establish benchmarks of the proximity to services which can be utilized to draw temporal and interurban accessibility comparisons in future research and to investigate issues of spatial inequity and sustainability (e.g. smart growth and the new urbanism). Finally, this thesis has demonstrated that accessibility analyses, even under these methodological changes, can still be integrated with socioeconomic forms of spatial information.

Overall, this research has made a strong methodological contribution to the accessibility literature. It has created a stable footing, using high resolution data sources, upon which to base further analyses. Furthermore, it has proved the existence of services which do not conform the traditional model. These findings raise questions of accuracy and methodological consistency which must be addressed if accessibility research is to continue to fuel debates of spatial equity.

Appendices:

Initial Accessibility Correlation Matrix

		Entertainment						Financial					Food					Health Care							Instructional						Retail							
		Amusement	Cultural	Night Life	Sports & Fitness	Travel	Video Rental	Accountants	Banks	Insurance	Real Estate	Tax Services	Coffee Shops	Fast Food	Grocers	Restaurants	Specialty Grocers	Alternative	Chiropractors	Clinics	Dentists	Eye Care	Pharmacies	Physicians	Home Services	Child Care	Music Instruction	Schools	Malls & Department Stores	Personal Services	Apparel	Appliances	Convenience	Electronics	Entertainment	Furniture	Household	Specialty
Entertainment	Amusement	1.00																																				
	Cultural		1.00																																			
	Night Life			1.00																																		
	Sports & Fitness				1.00																																	
	Travel					1.00																																
	Video Rental						1.00																															
Financial	Accountants							1.00																														
	Banks								1.00																													
	Insurance									1.00																												
	Real Estate										1.00																											
	Tax Services											1.00																										
Food	Coffee Shops												1.00																									
	Fast Food													1.00																								
	Grocers														1.00																							
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	Specialty Grocers																1.00																					
Health Care	Alternative																	1.00																				
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	Eye Care																					1.00																
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	Physicians																							1.00														
Instructional	Home Services																								1.00													
	Child Care																									1.00												
	Music Instruction																										1.00											
	Schools																											1.00										
	Malls & Department Stores																												1.00									
	Personal Services																													1.00								
Retail	Apparel																														1.00							
	Appliances																															1.00						
	Convenience																																1.00					
	Electronics																																	1.00				
	Entertainment																																		1.00			
	Furniture																																			1.00		
	Household																																				1.00	
	Specialty																																					1.00

As the accessibility of service 1 increases or decreases so does the accessibility of service 2

As the accessibility of service 1 increases or decreases service 2 will moderately do so

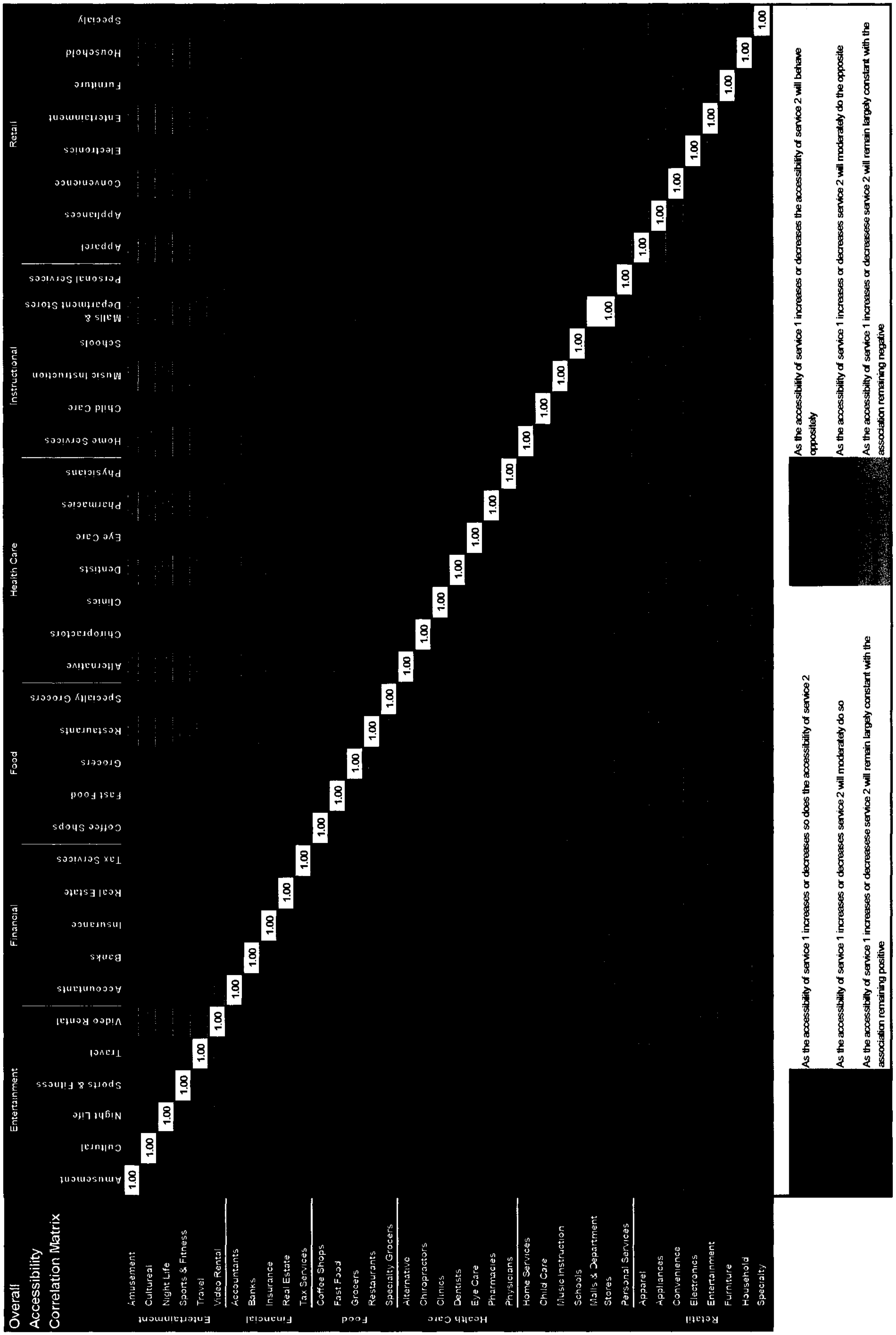
As the accessibilty of service 1 increases or decreasese service 2 will remain largely constant with the association remaining positive

As the accessibility of service 1 increases or decreases the accessibility of service 2 will behave oppositely

As the accessibility of service 1 increases or decreases service 2 will moderately do the opposite

As the accessibilty of service 1 increases or decreasese service 2 will remain largely constant with the association remaining negative

Appendices:


Overall Accessibility Correlation Matrix
Entertainment
Amusement
Cultural
Night Life
Sports & Fitness
Travel
Video Rental
Financial
Accountants
Banks
Insurance
Real Estate
Tax Services
Food
Coffee Shops
Fast Food
Grocers
Restaurants
Specialty Grocers
Health Care
Alternative
Chiropractors
Clinics
Dentists
Eye Care
Pharmacies
Physicians
Instructional
Home Services
Child Care
Music Instruction
Schools
Malls & Department Stores
Personal Services
Retail
Apparel
Appliances
Convenience
Electronics
Entertainment
Furniture
Household
Specialty
1.00
As the accessibility of service 1 increases or decreases so does the accessibility of service 2
As the accessibility of service 1 increases or decreases service 2 will moderately do so
As the accessibility of service 1 increases or decreasese service 2 will remain largely constant with the association remaining positive
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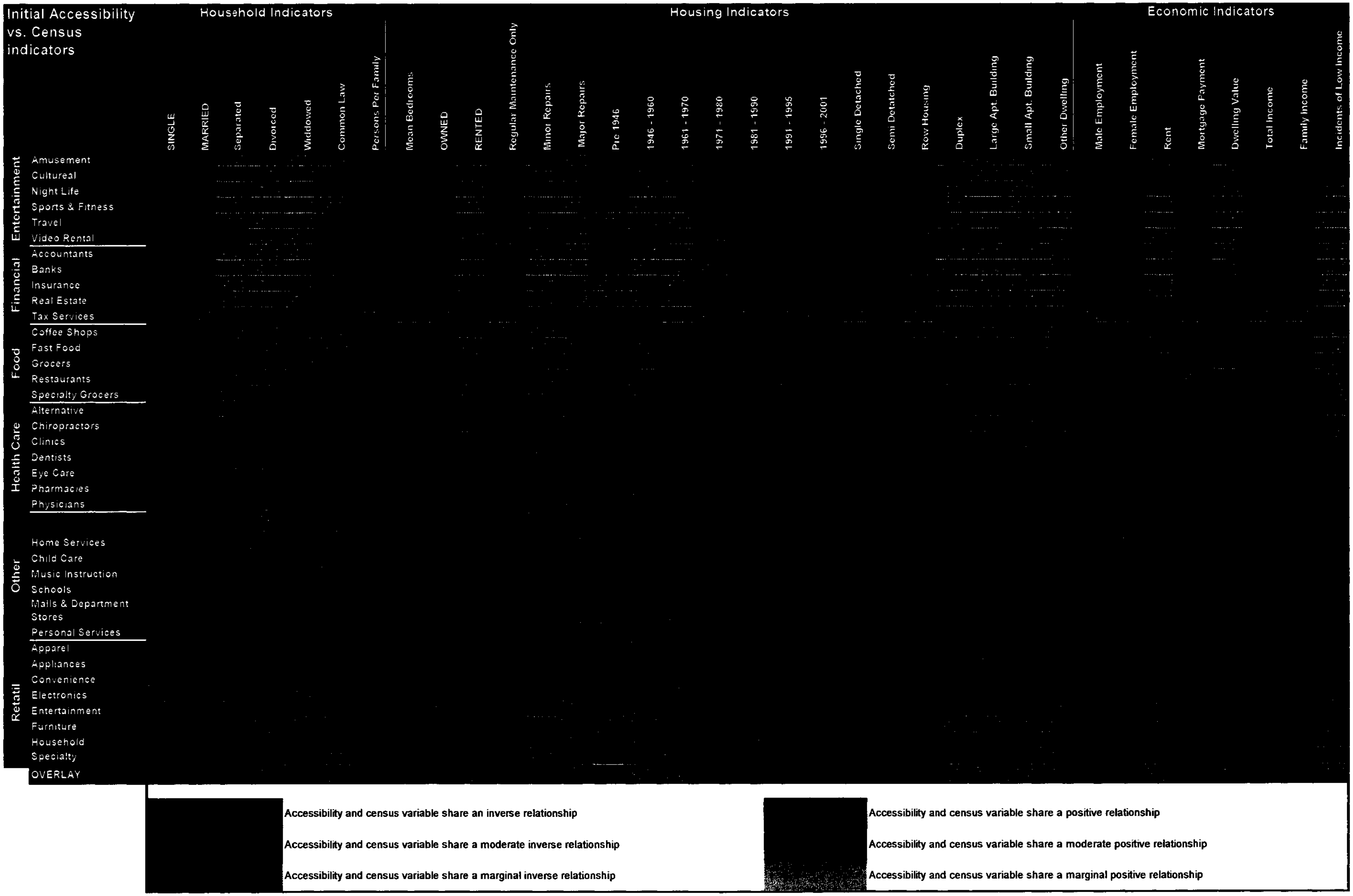
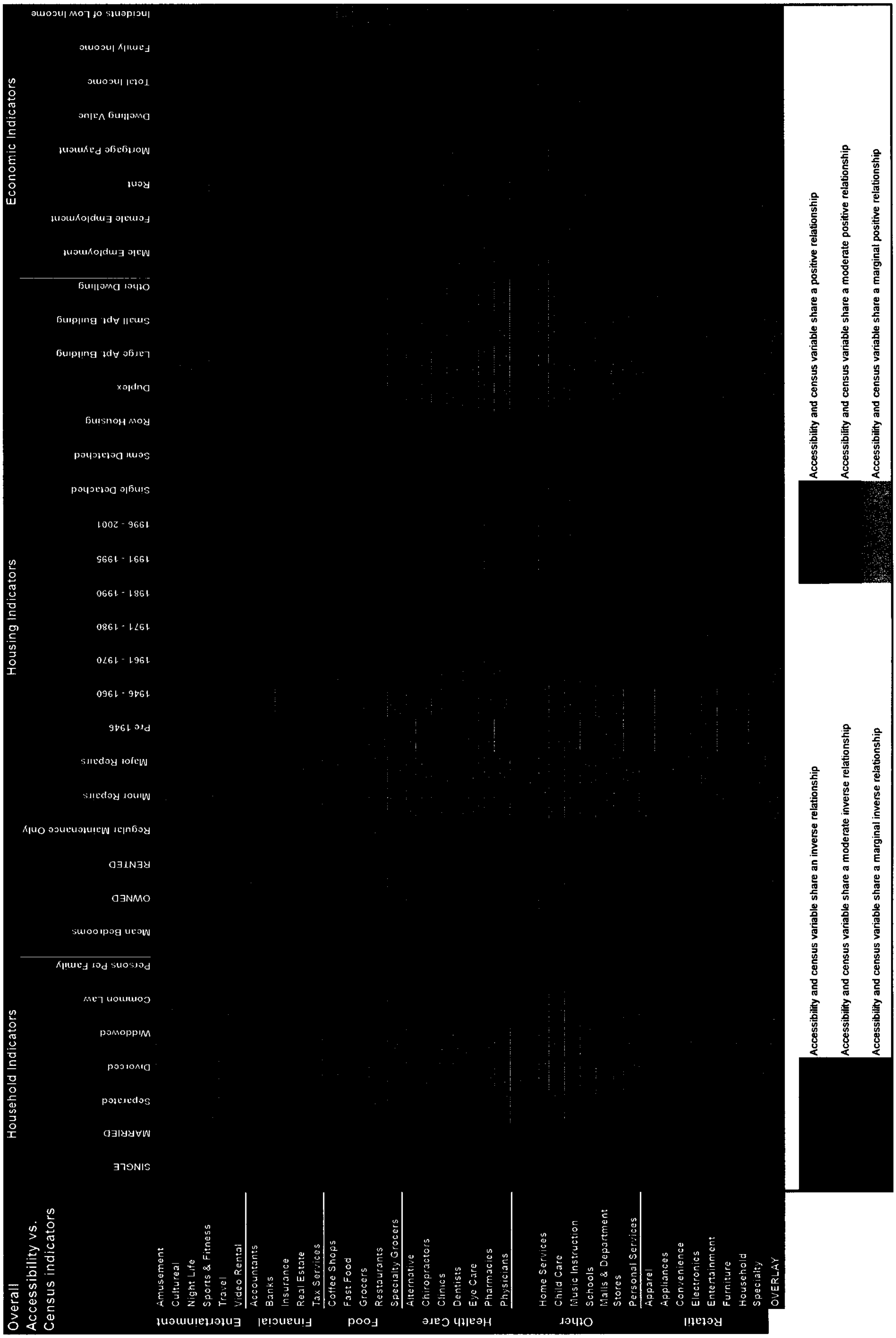
Appendices:


Initial Accessibility vs. Census indicators
Household Indicators
Housing Indicators
Economic Indicators
SINGLE
MARRIED
Separated
Divorced
Widdowed
Common Law
Persons Per Family
Mean Bedrooms
OWNED
RENTED
Regular Maintenance Only
Minor Repairs
Major Repairs
Pre 1946
1946 - 1960
1961 - 1970
1971 - 1980
1981 - 1990
1991 - 1995
1996 - 2001
Single Detached
Semi Detached
Row Housing
Duplex
Large Apt. Building
Small Apt. Building
Other Dwelling
Male Employment
Female Employment
Rent
Mortgage Payment
Dwelling Value
Total Income
Family Income
Incidents of Low Income
Entertainment
Amusement
Cultureal
Night Life
Sports & Fitness
Travel
Video Rental
Financial
Accountants
Banks
Insurance
Real Estate
Tax Services
Food
Coffee Shops
Fast Food
Grocers
Restaurants
Specialty Grocers
Health Care
Alternative
Chiropractors
Clinics
Dentists
Eye Care
Pharmacies
Physicians
Other
Home Services
Child Care
Music Instruction
Schools
Malls & Department Stores
Personal Services
Retatil
Apparel
Appliances
Convenience
Electronics
Entertainment
Furniture
Household
Specialty
OVERLAY
Accessibility and census variable share an inverse relationship
Accessibility and census variable share a moderate inverse relationship
Accessibility and census variable share a marginal inverse relationship
Accessibility and census variable share a positive relationship
Accessibility and census variable share a moderate positive relationship
Accessibility and census variable share a marginal positive relationship

Appendices:



Overall Accessibility vs. Census indicators
Household Indicators
Housing Indicators
Economic Indicators
SINGLE
MARRIED
Separated
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Mean Bedrooms
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Minor Repairs
Major Repairs
Pre 1946
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Single Detached
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Large Apt. Building
Small Apt. Building
Other Dwelling
Male Employment
Female Employment
Rent
Mortgage Payment
Dwelling Value
Total Income
Family Income
Incidents of Low Income
Entertainment
Amusement
Cultureal
Night Life
Sports & Fitness
Travel
Video Rental
Financial
Accountants
Banks
Insurance
Real Estate
Tax Services
Food
Coffee Shops
Fast Food
Grocers
Restaurants
Specialty Grocers
Health Care
Alternative
Chiropractors
Clinics
Dentists
Eye Care
Pharmacies
Physicians
Other
Home Services
Child Care
Music Instruction
Schools
Malls & Department Stores
Personal Services
Retail
Apparel
Appliances
Convenience
Electronics
Entertainment
Furniture
Household
Specialty
OVERLAY
Accessibility and census variable share an inverse relationship
Accessibility and census variable share a moderate inverse relationship
Accessibility and census variable share a marginal inverse relationship
Accessibility and census variable share a positive relationship
Accessibility and census variable share a moderate positive relationship
Accessibility and census variable share a marginal positive relationship

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