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The role of urban form in shaping access to opportunities

An exploratory spatial data analysis

Darren M. Scott
McMaster University [a]

Mark W. Horner
Florida State University [b]

Abstract: This study employs a suite of accessibility indices to investigate whether American cities are designed in such a way that the locations of goods, services, and other opportunities favor certain socio-economic groups over others. In so doing, the study's findings contribute to pressing policy issues such as social exclusion. Seven counties of the Louisville, Kentucky-Indiana MSA serve as the study area for the investigation. Data are derived from three sources: a geocoded travel diary survey, a geocoded database of all opportunities in the area, and a database of shortest-path travel times. Accessibility indices (gravity, cumulative opportunity, and proximity) are defined for 34 types of opportunities: four aggregate types and 30 disaggregate types representing the 10 most popular destinations for trips for each of the first three aggregate types. These indices are computed for households that responded to the trip-diary survey. Non-parametric Wilcoxon rank sum tests are used to compare the levels of accessibility experienced by five socio-economic groups (i.e., individuals residing in rural communities, individuals residing in single-person and single-parent households, individuals residing in low-income households, women, and the elderly) to counterpart groups. Except for individuals residing in rural areas, the findings of this study indicate that groups conventionally considered to be at risk of social exclusion are not disadvantaged in terms of accessibility.

Keywords: Accessibility; Urban structure; Activities; Exclusion.

1 Introduction

There is growing concern over the ability of individuals living in urban environments to effectively access the goods, services, and other opportunities needed to sustain their well-being and participate fully in society (Kwan et al. 2003). Many factors potentially affect the ability of individuals to reach their desired destinations and thus fulfill basic life needs, including individuals' personal characteristics and time constraints (Miller

[a] scottdm@mcmaster.ca
[b] mhorner@fsu.edu

2007), the effectiveness of the local transportation system and the availability of transport choices (Handy 1996; Murray 2001), and the structure of the city itself (Levinson 1998; Sultana 2002). These factors interact with one another to determine a given individual's level of access to opporortunities, but at a basic level, it is the city's design or form—how its activities are organized spatially—that conditions personal accessibility and exclusion.

While a great deal of literature has explored aspects of urban form and accessibility, much of it has focused on people's access to job opportunities (e.g., Hess 2005; Horner 2004; Sultana 2002; Wang and Minor 2002). There has been far less emphasis on understanding people's access to other important opportunities such as grocery stores, hospitals, child care centers, etc. At issue is that if individuals or groups of individuals are disproportionately unable to access such destinations and activities, then they may be excluded from full participation in society. Within the emerging literature on social exclusion (Casas 2007; Church et al. 2000; Kenyon et al. 2002; McCray and Brais 2007; Schönfelder and Axhausen 2003; Social Exclusion Unit 2003), some have suggested that groups such as the elderly, the poor, and the disabled, among others, are more at risk of becoming isolated in this manner. Such arguments beg the question of whether urban form itself plays a direct role in restricting accessibility, or to put it another way, whether cities are designed in such a way that the locations of needed activities and opportunities favor certain groups over others.

To address this question, we perform exploratory spatial analysis to examine variation in people's accessibility to opportunities, focusing strictly on the structure of the city and its spatial organization. This work seeks to determine whether accessibility differences due to urban form manifest themselves across certain socio-economic groups. The definition of city structure or urban form adopted in this investigation is purposefully broad, and includes all locations other than private residences where individuals can engage in activities unrelated to employment or education. These locations, referred to as *opportunities*, include places such as grocery stores, hospitals, post offices, and churches, to name a few. The relationship between urban form and individuals is operationalized in our study through a variety of GIS-based accessibility indices derived with respect to the residences of individuals contained in a detailed travel diary survey for the year 2000.

To disentangle accessibility and urban form from mobility, all measures are estimated using uncongested street network travel times between residences and potential activity locations. In this manner, the spatial nature of urban form can be assessed for all individuals in a common fashion irrespective of the mobility tools and options available to them (i.e., personal cars, bus passes/tickets, etc.). Clearly, having better mobility tools (e.g., owning a car vs. relying on walking) alters personal accessibility, and these tools confer advantages on those who have them. However, the intention of this study is to explore how different groups of individuals vary in their geographical

proximity to opportunities—mobility is a separate consideration that is not taken up here.

The area studied in this research consists of seven counties of the Louisville, Kentucky-Indiana MSA (Metropolitan Statistical Area). Louisville is a mid-sized MSA with a well-defined urban core and several decentralized activity centers, and thus is representative of the typical American city. Empirically, our approach is to calculate and compare accessibility indices for several population groups. In each comparison, a group suggested by the literature as being at risk of social exclusion is compared to its counterpart (e.g., females vs. males). The goal of this analysis is to determine whether urban form presents itself differently to the population groups usually thought to be at risk of low accessibility and exclusion. Schönfelder and Axhausen (2003) have used a similar comparative framework in their analysis of activity spaces.

A key feature of this analysis is that it is tied directly to spatially disaggregate data assembled within a geographic information system (GIS). In essence, the data used in this study are frameless because the analysis is based on individually geocoded households and opportunities, in contrast to previous studies that have relied on data aggregated to zones (e.g., Church et al. 2000; Shen 1998, 1999, 2001). In other words, the accessibility indices in this research are derived for individuals, not zones, avoiding any complications that can result from the well-known modifiable areal unit problem (MAUP) (Horner and Murray 2002; Páez and Scott 2004). Furthermore, the opportunities may be classified by four-digit Standard Industrial Classification (SIC) codes, making it possible to derive both aggregate and disaggregate accessibility indices by type. In total, indices for four aggregate types of opportunities (i.e., retail, service, leisure, and religious) and 30 disaggregate types (i.e., the 10 most popular destinations for retail, service, and leisure) are computed. Lastly, three types of accessibility indices are computed: negative exponential, cumulative opportunity (i.e., travel time intervals of one, two, five, 10, 15, and 20 minutes), and proximity.

2 Background

A substantial body of recent research has dealt with issues of accessibility in a variety of contexts (Sadahiro 2005). One clear strand of research emanates from Hägerstrand's (1970) pioneering work and looks at how individuals' space-time constraints contributes to the level of accessibility they experience (Kwan et al. 2003; Miller 2007). Among their contentions, researchers dealing with this aspect of accessibility stress that demands on people's time (e.g., having to work) and their other personal characteristics (e.g., the nature of an individual's household responsibilities) hinders their ability to reach needed goods and services. Other, less human-centered lines of inquiry have investigated how the configuration and operation of transport systems affect the accessibility of locations (Horner 2004; Linneker and Spence 1992). Martin et al. (2004),

for example, devise a data envelopment analysis (DEA) application to measure the benefits of competing rail transport infrastructure configurations. Even more fundamentally, some researchers have probed whether there are sufficient transport alternatives available to people, arguing that accessibility via the system begins with having access to the system (e.g., Wu and Murray 2005).

The concept of *opportunities* is common to virtually all studies of accessibility. Opportunities for conducting activities are distributed in space; persons wish to reach these opportunities in order to fulfill their needs and desires. The spatial arrangement of opportunities within the city is generally referred to as *urban form*. Urban form is an increasingly complex proposition (Dear and Flusty 1998), with low density residential sprawl dominating many metropolitan landscapes in the United States (Tsai 2005). At the same time, the business owners, entrepreneurs, governments, and other public and private entities who provide needed opportunities do so at locations chosen for practical or profit-maximizing objectives, and not necessarily based on social welfare or equity concerns. This results in a patchwork urban landscape in which individuals or groups may be disproportionately disadvantaged in terms of their proximity to needed activities when compared to other groups. The problem of such "mismatch" has been well-studied with respect to whether or not there are sufficient proximate job opportunities for minorities (Dawkins et al. 2005; Shen 1998, 1999, 2001). We contend that research is needed in order to understand whether or not mismatches exist with respect to the accessibility of goods and services.

Increasingly, accessibility and its measurement have been discussed in the context of larger concerns about social exclusion. Social exclusion is a broad concept intended to capture individuals' lack of participation within society (Murie and Musterd 2004). Certain groups, based on their characteristics and circumstances, are commonly thought to be at risk of exclusion. These groups include, among others, the elderly, low-income earners, single parents, disabled individuals and women (Schönfelder and Axhausen 2003; Wrigley et al. 2002).

Previous studies, largely conceptual in nature, have suggested that social exclusion is reinforced by the difficulty of reaching opportunities from a given location (Church et al. 2000; Kenyon et al. 2002; Social Exclusion Unit 2003). In other words, accessibility has been identified as a potential indicator of social exclusion. In fact, accessibility is incorporated (albeit in a limited way) into the Index of Multiple Deprivation (IMD), which is used to measure social exclusion for areal units in the United Kingdom.

Researchers have suggested many factors as contributors to low accessibility and social exclusion. Kenyon et al. (2002), for example, list a series of factors organized into nine "dimensions" or categories, including economic, social, political, personal, residential, temporal, and mobility-related factors. Of these, there is consensus in recent years that transportation systems can play a key role in mitigating social exclusion by affording individuals mobility, which allows them to access desired goods and services

(Church et al. 2000; Social Exclusion Unit 2003). At the same time, the changing, complex and dispersed nature of urban form that characterizes contemporary cities obfuscates the relationship between transportation and social exclusion. Not only does this situation increase the generalized cost of travel for persons at risk of exclusion (Schönfelder and Axhausen 2003), it also renders effective planning for transportation and mobility difficult. Thus, urban form may play a direct role in fostering social exclusion. Evidence gathered from recent studies of "food deserts" in the United Kingdom suggests that this may indeed be the case (Wrigley 2002; Wrigley et al. 2002).

Overall, however, it appears that mobility has dominated the research agenda in the area of transport and social exclusion (Wu and Hine 2003). Studies focusing on mobility suggest that differences in access to mobility tools can reinforce social exclusion (Social Exclusion Unit 2003). In the United Kingdom, for example, some individuals without a car identify transport as a barrier hindering their access to service, retail, and leisure opportunities (Social Exclusion Unit 2003). Improvements in public transit are suggested to counter this problem. A smaller percentage of individuals with cars are also known to have problems accessing the same opportunity types (Social Exclusion Unit 2003). These findings suggest that social exclusion is affected by the spatial distribution of opportunities relative to residential locations (i.e., urban form) in addition to differences in mobility tool ownership, and thus that accessibility and mobility must be examined separately as drivers of social exclusion.

In recent years, a few studies have emerged emphasizing poor accessibility as a contributor to, and therefore an indicator of, social exclusion (Church et al. 2000; Social Exclusion Unit 2003). In the majority of these studies, measures of accessibility are derived for spatial areas, rather than for individuals. This is indeed the case in the study by Church et al. (2000) examining transport and social exclusion in London. While it develops a rich conceptual framework from which to theorize social exclusion, the study is limited by its aggregate approach. Specifically, predefined areas are assumed to be at risk of social exclusion. This design seems to exemplify the ecological fallacy, because not all residents of an area are at risk of social exclusion, nor do all residents have equal access to opportunities. Further, the study does not precisely define the specific opportunities that are measured in the accessibility assessment.

The importance of deriving measures for individuals (rather than for geographic areas) in this type of research is articulated in research by Schönfelder and Axhausen (2003) focusing on the activity spaces of individuals. Among the questions the researchers consider is whether or not cases of social exclusion can be identified based on the activity space geometries of individuals. Among the notable findings of that research is that several of the groups that conventional wisdom would suggest are at risk of social exclusion (e.g., the elderly, low-income persons, and women) had activity spaces that did not differ markedly from the activity spaces of other groups. This result suggests several interesting possibilities. One is that the described geometric ap-

proaches may not be suitable proxies for social exclusion. If these measures are, in fact, performing well, then a second possibility is that conventional wisdom should be re-examined because the groups past experience would suggest are at risk were found not to be so (at least in this one case study). Placing a greater emphasis on the relative locations of the individuals under study and the characteristics of opportunities around them might have helped to sort out some of these difficulties. In other words, how were activity spaces influenced by the urban area in which they were situated, and how did this influence vary across the urban area?

To summarize, there has been a great deal of interest in the topic of accessibility, as evidence suggests its growing relevance for understanding pressing policy issues such as social exclusion. Although a substantial amount of research has been carried out on accessibility, detailed analyses of the activity locations comprising important opportunities have yet to be undertaken. The following sections describe such a study, consisting of exploratory GIS-based analysis of several rich spatial data sources.

3 Data

The data used in this study are derived from three sources: a travel diary survey conducted on behalf of the Kentuckiana Regional Planning and Development Agency (KIPDA) by ETC Institute (2001) for five counties (Bullitt, Clark, Floyd, Jefferson, and Oldham) in the Louisville KY-IN MSA in 2000 (Fig. 1); a geocoded database of all opportunities (i.e., potential destinations for trips, such as grocery stores, hospitals, post offices, and churches, to name a few) in an expanded study area[1] (Fig. 1); and a database containing shortest-path travel times between households and opportunities.

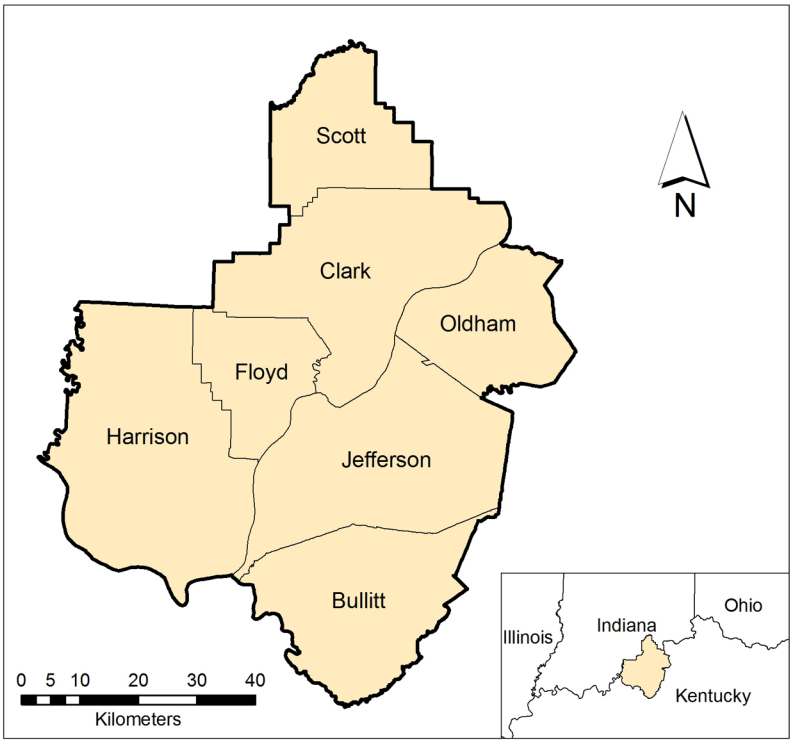
The survey of the the five-county area covered 4,383 households containing 9,787 persons, of which 8,393 were at least 16 years of age. Like other trip diary surveys, the one conducted in Louisville included data on the socio-economic characteristics of the households and all their members age five and up. A basic suite of trip purposes was used to classify trips: work, work-related, school, school-related, shopping, eating out, medical, pick-up/drop-off, religious, recreation, and other. Trip origins and trip destinations were geocoded, and respondents also reported the names of destinations.

The opportunity database was derived from data obtained from ReferenceUSA[2]

[1] The study area was expanded to include opportunities in two additional Indiana counties—Harrison and Scott. This was done to reduce potential boundary effects in the analysis after a preliminary investigation of trip start and end locations revealed some interaction with these counties.

[2] Increasingly, opportunity databases developed from ReferenceUSA and other commercial sources are being used to support a wide variety of research. For instance, Copperman and Bhat (2007) used a geocoded ReferenceUSA database for San Francisco to calculate the number of opportunities by type (e.g., restaurants, grocery stores, etc.) within one mile of an individual's residence. These data were then used as explanatory variables in their study of children's weekend physical activity participation. On the other hand, for her study concerning social exclusion and the disabled, Casas (2007) developed a geocoded

Figure 1: Study area consisting of seven counties of the Louisville (KY-IN) MSA.



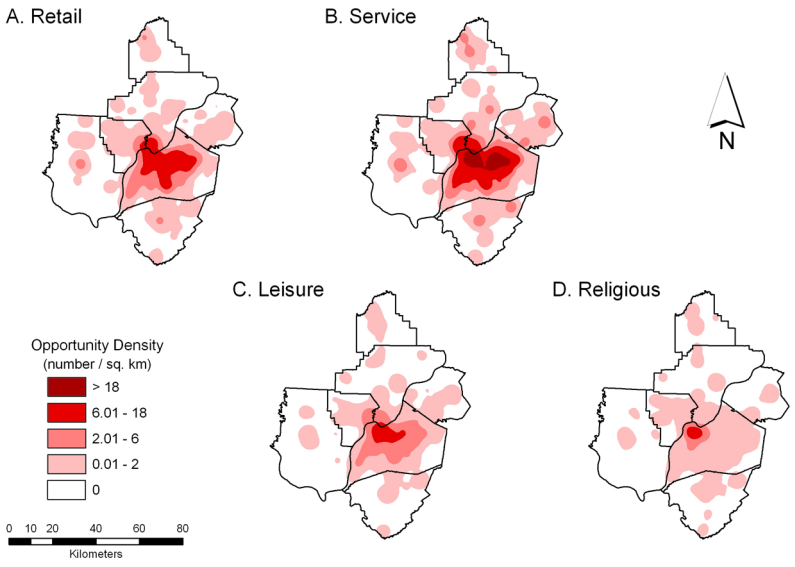
(infoUSA, 2000). This database contains not only the locations and names of opportunities in the seven-county study area, but also information on the places themselves such as a six-digit Standard Industrial Classification (SIC) code (which defines the type of economic activity taking place at the opportunity) and a numerical category for number of employees. A total of 34,440 unique opportunities were included in the database. The geocoded trips from the trip diary survey were matched to the SIC codes in the opportunities database, providing information necessary to compute the gravity measure of accessibility described in the next section.

Only 20,133 of the more than 34,000 opportunities included in the database were used in our analysis. The reason for this is that the accessibility measures are derived for non-work, non-school travel, so opportunities used must correspond to potential destinations for such travel (Handy and Niemeier 1997). A thorough review of SIC codes at the four-digit level resulted in the codes found in Table 1 being included in our

opportunity database for the Buffalo-Niagara region of New York using data obtained from the Internet Yellow Pages.

analysis. These opportunities were classified into four groups: retail, service, leisure, and religious (densities are shown in Fig. 2). As expected, the service classification contained the greatest number of opportunities—approximately 50 percent of the total number. This was followed by retail (27 percent), leisure (16 percent), and religious (7 percent). One item of note when viewing Table 1 is that educational services are included in the leisure category. The reason for this is that schools are not only destinations for school trips, but are also destinations for recreation, meetings, etc. An analysis of data from the trip diary survey confirmed that many trips coded as "recreation" were made to schools.

Figure 2: Density of urban opportunities by type.



The final source of data used in the analysis was a database of shortest-path free-flow travel times between the 4,383 household locations and the 20,133 opportunity locations (a total of 88,242,939 travel times). TransCAD 3.61 (Caliper Corporation, 2000), a GIS software package for transportation analysis, was used to compute these travel times using a Dynamap/Transportation 4.0 (Geographic Data Technology Inc., 2002) network obtained for the study area.

4 Accessibility Measures of Urban Form

Many types of accessibility measures could potentially be used in an analysis of urban form. In general, accessibility measures fall into two groups: integral measures, which

Table 1: Two-digit SIC codes used to select urban opportunities for analysis.

	52	Building materials, hardware, garden supply, and mobile home dealers	431
	53	General merchandise stores	146
Retail	54	Food stores	766
	55	Automotive dealers and gasoline service stations	881
	56	Apparel and accessory stores	426
	57	Home furniture, furnishings and equipment stores	781
	59	Miscellaneous retail	1,919
	07[a]	Agricultural services	228
	43	United States Postal Service	60
	60[b]	Depository institutions	520
	61c	Non-depository credit institutions	313
	62	Security and commodity brokers, dealers, exchanges and services	225
Service	64	Insurance agents, brokers and service	800
	65[d]	Real estate	713
	72	Personal services	1,883
	75[e]	Automotive repair, services and parking	1,125
	76	Miscellaneous repair services	422
	80f	Health services	2,058
	81	Legal services	674
	83	Social services	1,110
	58	Eating and drinking places	1,719
	78g	Motion pictures	69
	79	Amusement and recreation services	592
Leisure	82	Educational services	618
	84	Museums, art galleries, and botanical and zoological gardens	23
	86[h]	Membership organizations	268
Religious	86[i]	Membership organizations	1,363
Total			20,133

[a] Includes 0742 (veterinary services for animal specialties) and 0752 (animal specialty services, except veterinary) only.
[b] Excludes 601 (Central Reserve depository institutions).
c Excludes 615 (business credit institutions).
[d] Includes 653 (real estate agents and managers) only.
[e] Excludes 752 (automobile parking).
f Excludes 807 (medical and dental laboratories) and 808 (home health care services).
g Includes 783 (motion picture theaters) and 784 (video tape rental) only.
[h] Includes 864 (civic, social and fraternal associations), 865 (political organizations) and 869 (membership organizations, not elsewhere) only.
[i] Includes 866 (religious organizations) only.

are computed relative to a single location in space (Kwan 1998; Handy and Niemeier 1997; Hansen 1959; O'Kelly and Horner 2003; Wachs and Kumagai 1973; Wickstrom 1971); and space-time measures, which are based on the spatio-temporal constraints of individuals (Burns 1979; Kwan 1998; Miller 1991; Scott 2006; Weber and Kwan 2002). Because the research presented in this paper focuses on the relationship between urban form and people's personal characteristics—and, ultimately, implications for social exclusion—rather than the effects of spatio-temporal constraints on social exclusion, we chose to employ integral measures of accessibility derived for the residential locations of households. Three such indices are used in this study: gravity, cumulative opportunity, and proximity.

For all measures of accessibility described, i refers to a household and j refers to an opportunity. The gravity-type measure of accessibility, first introduced by Hansen (1959), is computed as:

$$A_i = \sum_j W_j f(d_{ij}) \tag{1}$$

where A_i is the accessibility of household i, W_j is the number of employees at opportunity j (specifically, the mean of the employee size class), d_{ij} is the shortest path travel time on the road network linking household i to opportunity j and $f(d_{ij})$ is an impedance function. In our case, $f(d_{ij})$ is given as $\exp(-\beta d_{ij})$. This gravity measure of accessibility is often referred to as the negative exponential due to the nature of the impedance function whose decay is governed by the parameter β. Rather than assigning an arbitrary value to β, we compute separate measures for each opportunity type in Table 1 (i.e., retail, service, leisure, and religious) using the following distance-decay model:

$$I_k = \alpha \exp(-\beta t_k) \tag{2}$$

where k is the travel-time category, t_k is the travel time in one-minute increments (beginning at one minute) for category k and I_k is the number of trips for category k. Matching trips in the travel diary survey to urban opportunities made these calculations possible. Thus, only trips with the appropriate SIC codes were used in the computation of each β parameter. The final number of trips for each opportunity type was obtained after a thorough screening process to ensure that only non-work, non-school trips were included for persons age 16 and up. Also, pick up/drop off trips were not considered for schools in the calculation of the β parameter for leisure. In this case, leisure travel to schools was captured in the trip diary survey through the stated purpose of recreation. It should also be mentioned that network-based, free-flow travel times from home to opportunity were used in the calculations. Remarkably, similar values for β were derived for three of the opportunity types: -0.1113 for retail, -0.1118 for service, and -0.1151 for religious. In comparison, a value of -0.0929 was found for leisure. These findings suggest that individuals are willing to travel similar distances for the first three

types of opportunity. Furthermore, these distances tend to be shorter than those for leisure activities—suggesting, as expected, that people are willing to travel farther in the pursuit of leisure.

The simplest type of accessibility measure is cumulative opportunity (Handy and Niemeier 1997). Early examples of its use include the work of Wachs and Kumagai (1973) and Wickstrom (1971). Simply stated, such measures enumerate the number of opportunities that can be reached within a given distance or travel time from a location. In total, we computed six such measures for this study using time thresholds, or bandwidths, of one, two, five, 10, 15, and 20 minutes. Furthermore, we adjusted our values of travel time upward by 25 percent to account for network delays due to stopping at intersections, turning, and traffic congestion. In this way, the opportunities reached within the thresholds given are more realistic than assuming free-flow travel times. The lower time thresholds (i.e., one and two minutes) are included to capture the number of opportunities within possible walking distance of a household. These measures were computed not only for the four aggregate opportunity types already mentioned, but also for the 30 specific types shown in Table 2. The types shown for retail, service, and leisure represent for each category the 10 most popular destinations for trips as found in the travel diary survey. In arriving at these destinations, the trips were screened in the manner described above for the gravity measure of accessibility. The reasoning behind the inclusion of such disaggregate destinations is that from a behavioral perspective, individuals think in terms of visiting specific locations such as post offices or banks. Also, measures of accessibility for aggregate opportunities may mask important differences with respect to specific types of opportunities. For example, a household may have high accessibility to services overall, but may lack a post office or bank within a 10-minute drive from home.

The final accessibility measures are simply the travel times to the nearest opportunity for each of the aggregate and disaggregate types shown in Table 2. These measures capture proximity to opportunities.

5 Results

5.1 Overview of Accessibility Measures and Patterns

Table 3 presents average values of household accessibility computed for specific opportunity types. For the cumulative opportunity measures, moving left to right from the smallest threshold (one minute) to the largest threshold (20 minutes), all accessibility values in each considered opportunity class increase substantially. For example, for department stores, the results show that for one minute, there are on average 0.1 stores within a given household's reach. However, when the bandwidth is expanded to 20 minutes, then approximately 40 department stores are within that reach. This is

Table 2: Six-digit SIC codes representing popular destinations for out-of-home, non-work, non-school activities in the Louisville region.

Opportunity Type	SIC Code	Description	No. of Opportunities
Retail	5211-38	Home centers	6
	5251-04	Hardware	49
	5311-02	Department stores	108
	5331-01	Variety stores	26
	5411-03	Convenience stores	247
	5411-05	Grocers	214
	5541-01	Service stations (gasoline and oil)	223
	5912-05	Pharmacies	146
	5942-01	Book dealers	43
	6512-01	Shopping centers and malls	19
Service	4311-01	Post offices	60
	6021-01	Banks	358
	7212-01	Cleaners	171
	7231-06	Beauty salons	699
	8011-01	Physicians and surgeons	885
	8021-01	Dentists	443
	8062-02	Hospitals	48
	8322-18	Social service and welfare organizations	224
	8351-01	Child care service	294
	7241-01	Barbers	186
Leisure	5812-08	Restaurants	1191
	7832-01	Movie theaters	21
	7841-02	Video tapes and disks (renting)	46
	7933-01	Bowling centers	18
	7991-01	Health clubs, studios and gymnasiums	36
	7999-11	Bingo games	18
	8211-03	Schools	392
	8231-06	Public libraries	41
	8641-02	Veteran and military organizations	28
	8641-08	Clubs	107

exactly what is to be expected when applying the cumulative opportunities measure.

The results paint a clear picture of how access to various types of urban opportunities differs. Table 3 shows that, among retail establishments, levels of access to convenience stores, grocers, and service stations are much higher than levels of access to book dealers and shopping malls. This finding is consistent with what is known about the retail mix in cities and the hierarchy and frequency of goods offered. There are also contrasts among the service activities; households in Louisville are characterized by high average levels of access to banks and salons, but much lower levels of access to hospitals (e.g., PROX 4.5 minutes for salons vs. 8.3 minutes for hospitals).

However, differences in precisely what is modeled by these indices may cause them to produce conflicting results. For example, based on the overall measures computed for retail and service, there is some ambiguity about which is the most accessible. Focusing on PROX, the average is 3.4 minutes for retail versus 3.2 minutes for service—quite close. However, if the gravity indices are compared, the difference is much more pronounced: 14,457 for retail versus 34,759 for service. This difference can be attributed to the way these measures are calculated; PROX is based on the average of a series of nearest opportunities, while the gravity measures are driven by the continuous distribution of activities over the entire urban landscape.

In the leisure category, schools—an activity type at the center of many community functions—are found to be among the most accessible opportunities, irrespective of index considered. Restaurants are also quite accessible, as these establishments are a mainstay on the urban landscape. Given the magnitude of values in the leisure category, average household accessibility to movie theaters appears to be much lower, as does household accessibility to gymnasiums. Finally, households' average levels of access to religious activities are fairly high, and are comparable to the levels of access to many of the opportunity types found in other categories.

Table 3: Average values of household accessibility computed for opportunity types.

Opportunity Type	GRAV	CUM01	CUM02	CUM05	CUM10	CUM15	CUM20	PROX
Retail	*14,457.2*	*4.6*	*20.5*	*132.6*	*575.6*	*1300.9*	*1926.9*	*3.4*
Home centers		0.0	0.0	0.1	0.5	1.1	1.7	12.1
Hardware		0.1	0.2	1.0	4.1	9.5	14.1	6.7
Department stores		0.1	0.4	2.6	11.6	26.1	39.5	6.2
Variety stores		0.0	0.1	0.5	2.4	5.7	8.7	9.1
Convenience stores		0.2	0.9	6.0	24.8	55.6	82.7	4.8
Grocers		0.2	0.9	5.4	23.1	51.7	76.3	5.2
Service stations (gasoline and oil)		0.2	0.9	5.5	24.2	54.5	81.0	5.2
Pharmacies		0.2	0.7	3.8	16.1	36.3	54.0	5.7
Book dealers		0.1	0.3	1.6	6.2	13.0	18.6	9.0
Shopping centers and malls		0.0	0.1	0.5	2.1	4.8	7.3	12.1
Service	*34,759.7*	*11.7*	*49.1*	*291.8*	*1211.6*	*2684.4*	*3890.9*	*3.2*
Post offices		0.0	0.1	0.7	3.1	7.1	10.9	6.5
Banks		0.4	1.7	9.7	39.8	89.4	131.7	4.9
Cleaners		0.2	0.8	4.5	19.4	44.1	65.7	5.4
Beauty salons		0.8	3.2	19.6	80.1	176.4	257.6	4.5
Physicians and surgeons		1.7	2.0	33.2	131.5	282.1	393.3	5.2
Dentists		0.5	2.0	12.1	52.1	116.9	172.6	5.0
Hospitals		0.1	0.3	1.6	6.3	13.7	19.3	8.3
Social service and welfare organizations		0.4	1.6	9.1	33.8	69.7	96.3	6.2
Child care service		0.3	1.2	7.3	30.0	68.9	103.0	4.8
Barbers		0.2	1.0	5.9	23.8	52.3	75.7	5.5

Continued on next page

Opportunity Type	GRAV	CUM01	CUM02	CUM05	CUM10	CUM15	CUM20	PROX
Leisure	*21,653.4*	*3.4*	*14.6*	*89.9*	*381.8*	*846.5*	*1236.6*	*3.6*
Restaurants		1.2	5.3	33.4	140.6	311.7	455.5	4.5
Movie theaters		0.0	0.1	0.7	2.6	5.4	7.6	9.9
Video tapes and disks (renting)		0.0	0.2	1.0	4.2	9.6	14.6	7.2
Bowling centers		0.0	0.1	0.4	2.0	4.4	6.5	9.6
Health clubs, studios and gymnasiums		0.0	0.1	0.7	3.2	7.7	11.7	9.0
Bingo games		0.0	0.1	0.4	1.9	4.3	6.7	10.7
Schools		0.4	1.4	8.4	36.7	84.4	126.2	4.5
Public libraries		0.1	0.2	1.0	4.0	8.6	12.3	6.8
Veteran and military organizations		0.0	0.1	0.8	3.3	7.0	10.2	9.3
Clubs		0.1	0.5	3.0	13.1	29.0	42.2	6.3
Religious	*1,465.8*	*1.4*	*5.6*	*34.6*	*142.6*	*313.5*	*509.6*	*3.6*

GRAV = gravity-based measure; CUM01 to CUM20 = 1-minute to 20-minute cumulative opportunity measures; PROX = proximity measure.

5.2 Accessibility Comparisons by Socio-Economic Characteristics

Mapping accessibility values at the household level makes it easier to understand patterns of accessibility. Figure 3 shows the interpolated household exponential-based gravity measures for the four major opportunity types. Here the values have been standardized to z-scores to show patterns across each opportunity type. The patterns are visually very similar, indicating that in the aggregate, areas are not necessarily deprived of one opportunity type over another, though there are differences. Overall, centralized locations in the metropolitan area experience the highest levels of access to the aggregate opportunity types considered in this study.

Figure 3: Standardized accessibility surfaces by opportunity type.

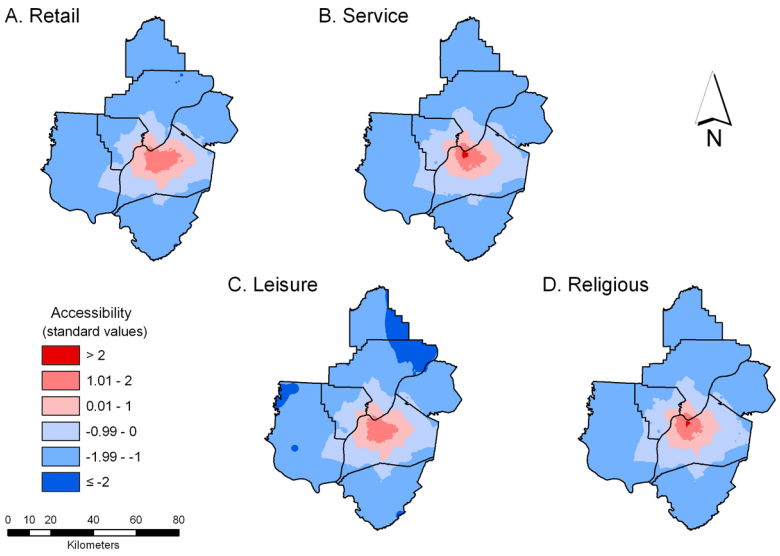


Figure 3 shows that, spatially, access to opportunities is fairly regular and centralized. These results suggest that individuals residing at the periphery of the city are most disadvantaged in terms of their access to goods, services, and other opportunities needed to sustain their well-being. If segments of the population known to be at risk of social exclusion concentrate at the periphery, then it is possible to conclude that urban form may reinforce exclusion. One way to further explore this issue is to compare differences in accessibility across groups defined according to their socio-economic characteristics.

Socio-economic characteristics are used in this study to define five groups within the general population that conventional wisdom suggests are at risk of social exclusion: residents of rural communities; individuals residing in single-person and single-parent

households, individuals residing in low-income households, women, and the elderly. These groups are compared to counterpart groups (e.g., low-income households to medium-income households) in order to ascertain whether the groups differ in their abilities to access spatially distributed oppportunities. If the groups at risk of social exclusion are found to experience lower levels of access than their counterparts, then urban form may play a role in the exclusion of the at-risk groups. The non-parametric Wilcoxon rank sum test is used for this analysis, as the data are not normally distributed. The results from this analysis are summarized in Tables 4 through 7. The results from the two-, five-, 15-, and 20-minute cumulative opportunity measures are also considered in the analysis, but the tables are not shown.

Household Location

Classifying households according to their locations relative to the 2000 Census-defined urbanized area results in a simple rural/urban dichotomy. With few exceptions, rural households experience lower levels of access than urban households on all measures. This is to be expected given the concentration of opportunities in the central, urbanized part of the study area (Fig. 2). It is only at lower measures of cumulative opportunity that urban and rural households do not differ. For example, as can be seen in Table 5, there is no difference between the two groups in terms of access to home centers or post offices. These findings suggest that urban form may play a role in the exclusion of individuals residing in rural areas.

Table 4: Comparisons of gravity-based measures of accessibility by socio-demographic characteristics.[a]

Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Retail	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Service	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Leisure	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Religious	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y

F = female, H = high-income household (≥ $80,000), L = low-income household (< $20,000), M = medium-income household (≥ $20,000 and < $80,000), MA = male, O = other household, OLD = age 65+, R = rural, SPA = single-person household, SPE = single-parent household, U = urban, Y = < age 65.

[a] Wilcoxon rank sum text results are significant at 0.05.

Table 5: Comparisons of 1-minute cumulative opportunity measures of accessibility by socio-demographic characteristics.[a]

Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Retail	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Home centers							
Hardware	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Department stores	R < U	SPE > O		L > M	H < M		
Variety stores	R < U						
Convenience stores	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Grocers	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Service stations (gasoline and oil)	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Pharmacies	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Book dealers	R < U	SPE > O		L > M			OLD > Y
Shopping centers and malls	R < U						
Service	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Post offices		SPE > O		L > M	H < M		OLD > Y
Banks	R < U	SPE > O		L > M	H < M		OLD > Y
Cleaners	R < U	SPE > O		L > M	H < M		OLD > Y
Beauty salons	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Physicians and surgeons	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Dentists	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Hospitals	R < U	SPE > O		L > M			OLD > Y
Social service and welfare organizations	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y

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Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Child care service	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Barbers	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Leisure	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Restaurants	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Movie theaters	R < U	SPE > O		L > M			OLD > Y
Video tapes and disks (renting)	R < U	SPE > O		L > M			
Bowling centers	R < U						OLD > Y
Health clubs, studios and gymnasiums	R < U	SPE > O					OLD > Y
Bingo games	R < U				H < M		
Schools	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Public libraries	R < U	SPE > O	SPA > O	L > M	H < M		OLD > Y
Veteran and military organizations	R < U	SPE > O	SPA > O	L > M	H < M		
Clubs	R < U	SPE > O	SPA > O	L > M			OLD > Y
Religious	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y

F = female, H = high-income household (≥ $80,000), L = low-income household (< $20,000), M = medium-income household (≥ $20,000 and < $80,000), MA = male, O = other household, OLD = age 65+, R = rural, SPA = single-person household, SPE = single-parent household, U = urban, Y = < age 65.

[a] Wilcoxon rank sum text results are significant at 0.05.

Table 6: Comparisons of Gravity-based Measures of Accessibility by Socio-demographic Characteristics.[a]

Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Retail	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Home centers	R < U	SPE > O			H < M		OLD > Y
Hardware	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Department stores	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Variety stores	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Convenience stores	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Grocers	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Service stations (gasoline and oil)	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Pharmacies	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Book dealers	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Shopping centers and malls	R < U	SPE > O	SPA > O		H < M	F > MA	OLD > Y
Service	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Post offices	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Banks	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Cleaners	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Beauty salons	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Physicians and surgeons	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Dentists	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Hospitals	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Social service and welfare organizations	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y

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Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Child care service	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Barbers	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Leisure	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Restaurants	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Movie theaters	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Video tapes and disks (renting)	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Bowling centers	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Health clubs, studios and gymnasiums	R < U	SPE > O				F > MA	OLD > Y
Bingo games	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Schools	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Public libraries	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Veteran and military organizations	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Clubs	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y
Religious	R < U	SPE > O	SPA > O	L > M	H < M	F > MA	OLD > Y

F = female, H = high-income household (≥ $80,000), L = low-income household (< $20,000), M = medium-income household (≥ $20,000 and < $80,000), MA = male, O = other household, OLD = age 65+, R = rural, SPA = single-person household, SPE = single-parent household, U = urban, Y = < age 65.

[a] Wilcoxon rank sum text results are significant at 0.05.

Table 7: Comparisons of Gravity-based Measures of Accessibility by Socio-demographic Characteristics.[a]

Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Retail	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Home centers	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Hardware	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Department stores	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Variety stores	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Convenience stores	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Grocers	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Service stations (gasoline and oil)	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Pharmacies	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Book dealers	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Shopping centers and malls	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Service	R > U	SPE < O	SPA < O	L < M	H > M		OLD < Y
Post offices	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Banks	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Cleaners	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Beauty salons	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Physicians and surgeons	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Dentists	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Hospitals	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Social service and welfare organizations	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y

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Opportunity Type	Rural vs. Urban	Household Type		Household Income		Female vs. Male	Old vs. Young
		Single Person vs. Other	Single Parent vs. Other	Low vs. Medium	High vs. Medium		
Child care service	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Barbers	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Leisure	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Restaurants	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Movie theaters	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Video tapes and disks (renting)	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Bowling centers	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Health clubs, studios and gymnasiums	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Bingo games	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Schools	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Public libraries	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Veteran and military organizations	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Clubs	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y
Religious	R > U	SPE < O	SPA < O	L < M	H > M	F < MA	OLD < Y

F = female, H = high-income household (≥ $80,000), L = low-income household (< $20,000), M = medium-income household (≥ $20,000 and < $80,000), MA = male, O = other household, OLD = age 65+, R = rural, SPA = single-person household, SPE = single-parent household, U = urban, Y = < age 65.

[a] Wilcoxon rank sum text results are significant at 0.05.

Furthermore, inspection of Table 5 reveals that single-person households experience greater accessibility within walking distance to specific opportunities (such as banks, post offices, and cleaners) than single-parent households. Further inspection also suggests that single-person households are more likely to live near commercial centers than single-parent households. This may be due in part to the fact that households in the former category are made up of younger individuals who have fewer responsibilities. Households in the latter category, on the other hand, are likely to locate farther away from such centers given the presence of children in the household; for these households, schools and a pleasant environment in which to raise children may be more important than accessibility.

Household Income

The results presented in Tables 4 through 7 are also consistent with respect to groups defined according to household income. In total, three income groups are defined: low ($0–$20,000), medium ($20,001–$79,999) and high ($80,000+). As in the preceding analysis, one group is defined as the reference group for testing purposes—in this case, medium-income households. The results indicate that low-income households experience the greatest accessibility, while high-income households experience the lowest. Obviously, this finding suggests that urban form does not play a role in the exclusion of low-income households. Louisville, like many American cities, is experiencing high rates of urban sprawl with higher-income households living farthest from the urban core. Low-income households, by comparison, are found largely in inner-city neighborhoods, which experience higher levels of accessibility.

Sex

When female versus male accessibility is compared for the one-minute bandwidth, it is seen in Table 5 that they differ on very few of the opportunity types. The exceptions are schools, the general leisure category (of which schools are a part), and religious opportunities. In these cases, females experience significantly higher levels of access. If the bandwidth is expanded to two minutes, several opportunity types in the retail and service classes show a significant difference between males and females. For example, females have significantly greater access to grocers, convenience stores, service stations, and book dealers, as well as such opportunities as banks, cleaners, and beauty stores. For bandwidths of five minutes and greater, females have significantly greater access to almost all activities compared to their male counterparts. This finding is the same for the gravity-based measures of accessibility shown in Table 4 and the proximity-based measures shown in Table 7 (in the latter case, females have shorter travel times to nearest opportunities than males). Overall, the results for sex suggest that females are not disadvantaged when it comes to accessibility.

Age

Differentiating the ages of individuals in the study area also reveals interesting contrasts in access to opportunities. Here, individuals are separated into those under 65 years of age and those age 65 and older. From Tables 5, 6 and 7, it is clear that older people are significantly more able to access opportunities than younger people. For the one-minute bandwidth, it is perhaps more instructive to look at the cases for which a significant difference was not found. In the retail sector, the two age classes had similar levels of access to home centers, department and variety stores, and shopping centers/malls. In the leisure sector, a few opportunity types (e.g., video rental, bingo games, and veterans' organizations) also turned out to be insignificant. A partial explanation for the greater accessibility experienced by the elderly could be that this group tends to be more centrally located in older suburbs, which (as shown in Fig. 3) have higher levels of accessibility. Again, the elderly do not appear to be at a disadvantage with respect to urban opportunities.

6 Conclusions

As noted at the beginning of this paper, there has been a great deal of interest in the topic of accessibility—especially in its relevance for understanding pressing policy issues such as social exclusion. Simply put, are cities designed in such a way that the locations of needed activities and opportunities favor certain groups over others? Our study sought to address this question. In so doing, we defined urban form with respect to sites of opportunities, which are simply the potential destinations for trips. A suite of accessibility measures (i.e., gravity, cumulative opportunity, and proximity) were computed for households found in a travel diary survey conducted in five counties of the Louisville, Kentucky-Indiana MSA in 2000. These measures were defined for 34 types of opportunities: four aggregate types (i.e., retail, service, leisure, and religious) and 30 disaggregate types representing the 10 most popular destinations for trips for each of the first three aggregate types. This combination of measures and opportunity types represents a significant departure from previous studies in the social exclusion literature, which have suggested that poor accessibility is a contributor to social exclusion without validating the assumption empirically (Church et al., 2000; Social Exclusion Unit, 2003). In testing this assumption, our study suggests that in an American setting, the relationship between urban form, accessibility, and social exclusion is not as expected.

This study found that most groups that conventional wisdom would suggest are at risk of social exclusion are not disadvantaged in terms of spatial accessibility. Rather than suffering from poor accessibility, they experience higher accessibility, in general, than their counterparts on all measures tested. At most, for the one-minute band-

width of the cumulative opportunity measure, some groups did not differ from their counterparts with respect to accessibility. All tests conducted were consistent in the direction of their results. In fact, the only group tested that followed conventional wisdom was rural households. Individuals residing in low-income, single-parent, and single-person households, along with women and the elderly, all experienced higher accessibility than their counterparts.

Returning to the issue at hand, our results suggest that, for most groups, urban form does not reinforce geographies of exclusion—at least, for now. This could change, however, if the relationship between residential location and opportunity location is altered for such groups. For instance, should baby boomers choose to remain in the suburbs after retiring, the locational advantage enjoyed by today's elderly may not carry over to the next generation. Members of the aging population may be forced—by declining health and physical abilities, or by economic necessity—to reduce or eliminate their driving; in such a scenario, the locational disadvantage of aging in place, coupled with declining mobility, could have significant personal impacts including restricted social contacts and reduced quality of life (Marrattoli et al., 2000). Other implications may include an increased demand for public transit services for older individuals who are no longer able to drive.

The findings of this study are in line with those reported in earlier work by Shen (1998, 2001), who examined the ability of low-wage workers to access employment opportunities and job openings in the Boston Metropolitan Area using a rigorous analytical framework that incorporated the notion of "demand" in the computation of accessibility. Shen found that such workers residing in inner-city neighborhoods enjoyed higher accessibility to such opportunities and job openings than low-wage workers residing elsewhere in the metropolitan area. Although this was true for auto drivers and transit riders, their respective levels of accessibility differed considerably, obviously favoring the automobile. This finding suggests a point of departure for our own work—that is, if urban form does not presently reinforce social exclusion, then other factors, such as access to mobility tools, must be investigated. Investigating mobility would require computation and comparison of accessibility indices using transit time as the measure of impedance. Other factors that warrant investigation (i.e., economic, social, political, personal, residential, and temporal) are suggested by Kenyon et al. (2002).

More generally, future research dealing with accessibility and related issues of social exclusion is wide open in terms of the directions that could be taken. The work presented in this paper has dealt with a limited subset of the land-use and transportation issues underpinning social exclusion. Thus, future work could use more complex models to explain people's trip-making behavior in terms of the accessibility measures presented in this paper, assuming that such behavior is a measure of social exclusion. In such a situation, individual and land-use characteristics could be accounted for in

a trip generation model that seeks to discern the interplay of land use and transport, and what it means for social exclusion.

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References

Burns, L.D. 1979. Transportation, Temporal, and Spatial Components of Accessibility. Lexington, MA: Lexington Books.

Caliper Corporation 2000. TransCAD® 3.61. [CD-ROM]. Newton, MA: Caliper Corporation.

Casas, I. 2007. Social exclusion and the disabled: An accessibility approach. *The Professional Geographer* 59: 463–477.

Church, A., M. Frost, and K. Sullivan 2000. Transport and social exclusion in London. *Transport Policy* 7: 195–205.

Dawkins, C.J., Q. Shen, and T.W. Sanchez 2005. Race, space and unemployment duration. *Journal of Urban Economics* 58: 91–113.

Dear, M. and S. Flusty 1998. Postmodern urbanism. *Annals of the Association of American Geographers* 88: 50–72.

ETC Institute 2001. KIPDA Regional Household Survey Final Report. Available at: http://www.kipda.org/files/PDF/Transportation_Division/Information/Full_Report--Laser.pdf [Accessed 29 February 2008].

Geographic Data Technology Inc. 2002. Dynamap®/Transportation 4.0. [CD-ROM]. Lebanon, NH: Geographic Data Technology Inc.

Hägerstrand, T. 1970. What about people in regional science? *Papers of the Regional Science Association* 24: 7–21.

Handy, S. 1996. Methodologies for exploring the link between urban form and travel behavior. *Transportation Research Part D* 2: 151–165.

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

Hansen, W.G. 1959. How accessibility shapes land use. *Journal of the American Institute of Planners* 25: 73–76.

Hess, D.B. 2005. Access to employment for adults in poverty in the Buffalo-Niagara Region. *Urban Studies* 42: 1177–1200.

Horner, M.W., and A.T. Murray 2002. Excess commuting and the modifiable areal unit problem. *Urban Studies* 39: 131–139.

Horner, M.W. 2004. Spatial dimensions of urban commuting: a review of major issues and their implications for future geographic research. *The Professional Geographer* 56: 160–173.

infoUSA 2000. ReferenceUSA™. Omaha, NE: infoUSA.

Kenyon, S., G. Lyons, and J. Rafferty 2002. Transport and social exclusion: Investigating the possibility of promoting inclusion through virtual mobility. *Journal of Transport Geography* 10: 207–219.

Kwan, M.-P. 1998. Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis* 30: 191–216.

Kwan, M.-P., A.T. Murray, M. O'Kelly, and M. Tiefelsdorf 2003. Recent advances in accessibility research: Representation, methodology and applications. *Journal of Geographical Systems* 5: 129–138.

Linneker, B.J., and N.A. Spence 1992. Accessibility measures compared in an analysis of the impact of the M25 London orbital motorway on Britain. *Environment and Planning A* 24: 1137–1154.

Levinson, D., 1998. Accessibility and the journey to work. *Journal of Transport Geography* 6: 11–21.

Marrattoli, R.A., C.F. Mendes de Leon, T.A. Glass, C.S. Williams, L.M. Cooney, and L.F. Berkman 2000. Consequences of driving cessation: Decreased out-of-home activity levels. *Journal of Gerontology: Social Sciences* 55B: S334–S340.

Martin, J.C., J. Gutierrez, and C. Roman 2004. Data envelopment analysis (DEA) index to measure the accessibility impacts of new infrastructure investments: The case of the high-speed train corridor Madrid-Barcelona-French border. *Regional Studies* 38: 697–712.

McCray, T., and N. Brais 2007. Exploring the role of transportation in fostering social exclusion: The use of GIS to support qualitative data. *Networks and Spatial Economics* 7: 397–412.

Miller, H.J. 1991. Modelling accessibility using space-time prism concepts within geographical information systems. *International Journal of Geographical Information Systems* 5: 287–301.

Miller, H.J. 2007. Social exclusion in space and time. In K.W. Axhausen, ed. *Moving Through Nets: The Social and Physical Aspects of Travel*. Oxford: Elsevier. pp. 353–380.

Murie, A., and S. Musterd 2004. Social exclusion and opportunity structures in European cities and neighborhoods. *Urban Studies* 2: 1441–1459.

Murray, A.T. 2001. Strategic analysis of public transport coverage. *Socio-Economic Planning Sciences* 35: 175–188.

O'Kelly, M.E., and M.W. Horner 2003. Aggregate accessibility to population at the county level: U.S. 1940–2000. *Journal of Geographical Systems* 5: 5–23.

Páez, A., and D.M. Scott 2004. Spatial statistics for urban analysis: A review of techniques with examples. *GeoJournal* 61: 53–67.

Sadahiro, Y. 2005. Spatiotemporal analysis of the distribution of urban facilities in terms of accessibility. *Papers in Regional Science* 84: 61–84.

Schönfelder, S., and K.W. Axhausen 2003. Activity spaces: Measures of social exclusion? *Transport Policy* 10: 273–286.

Scott, D.M. 2006. Constrained destination choice set generation: A comparison of GIS-based approaches. In: Transportation Research Board 85th Annual Meeting Compendium of Papers, [CD-ROM], Washington, D.C., January 22-26.

Shen, Q. 1998. Location characteristics of inner-city neighborhoods and employment accessibility of low-wage workers. *Environment and Planning B* 25: 345–365.

Shen, Q. 1999. Transportation, telecommunications, and the changing geography of opportunity. *Urban Geography* 20: 334–355.

Shen, Q. 2001. A spatial analysis of job openings and access in a U.S. metropolitan area. *Journal of the American Planning Association* 67: 53–68.

Social Exclusion Unit 2003. Making the Connections: Final Report on Transport and Social Exclusion. London, UK: Office of the Deputy Prime Minister.

Sultana, S. 2002. Jobs-housing imbalance and commuting time in the Atlanta metropolitan area: Exploration of causes of longer commuting time. *Urban Geography* 23: 728–749.

Tsai, Y.H. 2005. Quantifying urban form: Compactness versus 'sprawl.' *Urban Studies* 42: 141–161.

Wachs, M., and T.G. Kumagai 1973. Physical accessibility as a social indicator. *Socioeconomic Planning Science* 7: 327–456.

Wang, F., and W.W. Minor 2002. Where the jobs are: Employment access and crime patterns in Cleveland. *Annals of the Association of American Geographers* 92: 435–450.

Weber, J., and M.-P. Kwan 2002. Bringing time back in: A study on the influence of travel time variations and facility opening hours on individual accessibility. *The Professional Geographer* 54: 226–240.

Wickstrom, G.B. 1971. Defining balanced transportation: A question of opportunity. *Traffic Quarterly* 25: 337–350.

Wrigley, N. 2002. 'Food deserts' in British cities: Policy context and research priorities. *Urban Studies* 39: 2029–2040.

Wrigley, N., C. Guy, and M. Lowe 2002. Urban regeneration, social inclusion and large store development: The Seacroft development in context. *Urban Studies*

39: 2101–2114.

Wu, C., and A.T. Murray 2005. Optimizing public transit quality and system access: The multiple route maximal covering/shortest path problem. *Environment and Planning B* 32: 163–178.

Wu, B.M., and J.P. Hine 2003. A PTAL approach to measuring changes in bus service accessibility. *Transport Policy* 10: 307–320.