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Nonwork Accessibility as a Social Equity Indicator

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This study explains a method for deriving nonwork accessibility indicators and evaluates how nonwork accessibility varies among social groups in the Detroit metropolitan region. It finds that vulnerable social groups—including African Americans, Hispanics, low-income households, and households in poverty—experience an advantage in physical accessibility over more privileged groups for several trip purposes, including convenience stores, childcare facilities, religious organizations, and hospitals. However, vulnerable groups experience a distinct disadvantage in accessibility to shopping and supermarkets. These vulnerable social groups experience a substantially larger share of households with extremely low levels of accessibility, as a result of disproportionately low access to private vehicles.

Keywords: accessibility, equity, gravity model, nonwork travel, race

1. Introduction

The purpose of transportation is not movement but access. Accessibility—the potential for interactions (Hansen 1959)—is the ultimate goal of transportation policy, and the means to achieving that end include improvements in mobility (faster speeds) and proximity (higher density land-use arrangements) (Grengs et al. 2010). This view that achieving higher accessibility is the "core objective" of transportation planning (Cheng, Bertolini, and le Clercq 2007) is consistent with the consensus of the field that transportation is a "derived demand," meaning that travelers do not consume transportation for the sake of movement but in order to reach destinations (Meyer and Miller 2001; Wachs and Kumagai 1973). Lynch (1981) considered accessibility to be so important that he made it one among several elements in his normative theory of what makes a "good" city. Accessibility represents a measure of choice—as an indicator of a person's potential for seizing available opportunities. Where a person lives has a powerful effect on the choices available and the capacity to achieve a high quality of life (Dreier, Mollenkopf, and Swanstrom 2004). And having choice in one's life is a highly valued quality in and of itself (Sen 1985, 1988). Accessibility is inherently multidimensional, and to measure it is to gauge directly the outcome of transportation policy. As Wachs and Kumagai (1973) argued decades ago, accessibility indicators ought be used regularly by policy makers—along with more commonly used measures of income, health, and education—to assess conditions among social groups.

Nearly all studies of accessibility are based on travel to work. Policy makers and researchers have a long tradition of placing great emphasis on understanding journey-to-work commutes (Shen 2000; Roberto 2008; McLafferty and Preston 1997; Crane 2007; Hamilton and Röell 1982; Pisarski 2006; Rosenbloom 1992; Sanchez 2004). This focus on journey-to-work travel stems largely from peak-period traffic congestion, a problem widely understood by the public to be a top public policy concern. Studying travel to work is also important because the trip is essential: getting to a job is often the single most important travel activity for most people. And data are easier to collect for a work trip, in contrast to a nonwork trip, because it has a consistent origin and destination, the route is fixed, and several features of the trip are highly predictable, including the modal split, the time period each day, and the trip length in time and distance. Indeed, the U.S. Bureau of the Census collects travel data only on the journey-to-work.

Despite the emphasis on studying the journey-to-work, nonwork trips to engage in activities such as shopping, recreation, and personal business make up the majority of travel (Paget-Seekins 2011). In 2009, travelers in the United States made 78% of their trips and 73% of their vehicular travel distance for nonwork purposes (U.S. Department of Transportation 2011). While the share of overall trips devoted to nonwork purposes was 68% in 1969, it had grown to 78% by 2009. Several trends have contributed to the growth in nonwork travel, including growing household income, more vehicles available per household, more variety and choices available to consumers through shifts in retailing, and changes in "lifestyle" that result in more activities outside the home such as an increase in leisure interests, more

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restaurant visits, and elevated levels of recreation (Santos et al. 2011; Handy, DeGarmo, and Clifton 2002; Kitamura 2009). Nonwork travel has become an increasingly important topic of scholarly interest (Gordon, Kumar, and Richardson 1988; Polzin, Chu, and Rey 2001; Boarnet and Sarmiento 1998), and yet few studies have examined the nonwork implications of accessibility measurement.

The purpose of this study is to evaluate how nonwork accessibility varies among social groups, by race, ethnicity, income, and poverty status. Because measuring accessibility for nonwork travel is far more conceptually complex than for work travel, this study also aims to explain several methodological innovations that are required for calculating measures of accessibility based on the common gravity model. Nonwork travel involves a wide range of trip purposes—shopping, recreation, religious activities, and so forth—and travelers behave differently depending on the purpose of their trip. People are willing to travel long distances for some kinds of purposes (buying furniture or a car) but not for other purposes (buying a carton of milk). Few studies have used measures that adequately model the difference in people's willingness to travel among trip purposes. Also, to evaluate the outcome of accessibility comparatively among social groups requires accounting for the vast difference in accessibility among travel modes. Accessibility by automobile tends to be far superior to accessibility by public transit nearly anywhere in the United States. This study explains an approach to controlling for the critical difference in automobile availability among social groups to allow for an equity analysis across a full metropolitan population, unlike many studies that focus strictly on a population using a single mode of travel.

2. The Challenges of Measuring Accessibility for Nonwork Travel

Some studies have focused on a single kind of nonwork destination. Grengs (2001) focused on the essential destination of supermarkets in a study of accessibility in Syracuse, New York. The study found that over 12% of households in the city did not have reasonable means for reaching a supermarket, and that low levels of accessibility were associated with neighborhoods of high poverty and with high shares of African Americans. Talen (2001) examined schools in West Virginia and found little support for her hypothesis that households with lower socioeconomic status experience lower levels of accessibility to elementary schools. Handy (1993), in a case study of shopping in the San Francisco Bay Area, found that people living in places with higher levels of accessibility tend to travel shorter average shopping distances but do not make fewer shopping trips. These studies, even though using different measures for accessibility, illustrate approaches that do not require differentiating among trip purposes. However, when Handy (1993) introduced the distinction between what she calls "local" accessibility and "regional" accessibility in shopping, she was acknowledging that travelers are willing to cover longer distances for some kinds of shopping than for others, suggesting the importance of treating categories of nonwork trips differently when measuring accessibility.

Studies that have examined multiple nonwork trip purposes have treated the issue of willingness to travel in various ways, ranging from disregarding the issue to modeling it explicitly. Helling and Sawicki (2003), in a study that compares accessibility to a set of shopping destinations by race in Atlanta, found that for several trip purposes, African Americans experience lower accessibility than whites, even when controlling for income. Their study acknowledged that accessibility measures are highly sensitive to small differences in travel time, and yet their measures did not distinguish between the substantial differences in the willingness to travel that people feel among various shopping destinations. Their study also focused exclusively on travel by car rather than transit—a reasonable approach given that the main hypothesis dealt with affluent African Americans—and therefore was not capable of distinguishing between disadvantages in accessibility that are based on location from those that are based on transit-dependency.

Apparicio and Seguin (2005), in a highly detailed study of Montreal, focused their analysis on residents of public housing and access to a range of services. They found that about half of residents of public housing experienced what they refer to as "very good" accessibility to services and facilities but concluded that "access to urban resources is not equitable for all residents of Montreal public housing" (p. 209). Although the study resourcefully used a database with a wide range of different services and facilities, it relied on a simple measure of accessibility defined as the shortest network distance from a building to a destination. This approach assumed that a person's willingness to travel is the same for all kinds of services, when instead we know that people are far more willing to travel long distances for some kinds of services (supermarkets, clothes shopping) than for others (convenience stores, child care facilities). The approach also assumed that all travel was by walking and therefore could not address the important differences in accessibility that stem from a person's lack of access to a private vehicle.

Two studies of nonwork accessibility have modeled the difference in willingness to travel among trip purposes explicitly. Zhang (2005) calculated separate impedance functions to model willingness to travel for various kinds of nonwork destinations (school, shopping, and other) and found that nonwork trip-making behavior—in terms of travel time and trip frequencies—varied by degree of accessibility, but that the type of trip purpose was central to the results. The study, however, did not calculate impedance functions separately for travel by auto and transit even though they are substantially different, an outcome that would have severe implications if the goal was to assess social equity because access to a private car is highly correlated with socioeconomic status. In a comprehensive study of accessibility in the Louisville metropolitan area, Scott and Horner (2008) also calculated impedance functions separately for categories of destinations (retail, service, leisure, and religious) and found that traditionally vulnerable social groups are not disadvantaged in their transportation accessibility to these nonwork activities. Like Zhang (2005), however, this study did not distinguish between the substantial difference in willingness to travel between auto and transit modes.

This small collection of research suggests that vulnerable social groups tend not to be as disadvantaged as generally understood. Yet, for certain kinds of trip purposes—most notably in travel to supermarkets—vulnerable social groups appear to be systematically disadvantaged. These results demonstrate the importance of studying nonwork accessibility separately for distinct types of trip purpose. This research also demonstrates a wide range of approaches to dealing with the methodological challenges of measuring nonwork accessibility, and yet none of them sufficiently address the issue of distinguishing between cars and transit among social groups. From a social equity standpoint, it is essential that measures can account for the vast difference in accessibility by travel mode because much of the disadvantage that some urban residents experience stems more from their dependence on the accessibility-inferior mode of transit than from their location in regional space (Shen 1998; Grengs 2010; Páez et al. 2010).

3. Method: Developing Accessibility Measures for Nonwork Travel

This study uses a common form of the gravity model such that the amount of interaction between an origin zone i and a destination j is positively related to the attractive power of the destination zone (e.g., the number of opportunities at the destination) but is inversely related to the cost of the spatial separation between the zones (e.g., distance or travel time) as follows (Hansen 1959):

$$A_i = \sum_j O_j f(c_{ij}) \tag{1}$$

where:

A_i is the accessibility indicator for people living in zone i;

O_j is the attractiveness factor based on the number of opportunities in destination zone j;

$f(c_{ij})$ is the impedance function associated with the cost of travel c for travel between zones i and j;

For a metropolitan region with N zones, $i, j = 1, 2, \ldots, N$.

3.1 Attractiveness Factor

The attractiveness factor (O_j in Equation 1) is a measure of the propensity to make a trip to a particular destination, and it is a reflection of the geographic distribution of opportunities determined by land-use development. When many destinations are nearby, accessibility will be high, all else being equal. The attractiveness of a destination can be defined in many ways, including store size, pricing, service quality, or a function of several such indicators. For measuring employment accessibility, most transportation researchers define attractiveness as the number of jobs in a destination zone (Cervero, Sandoval, and Landis 2002; Helling 1998; Hess 2005; Kawabata 2003; Sanchez, Shen, and Peng 2004; Shen 1998, 2000; Wachs and Kumagai 1973; Wang 2003). Securing data on floor space, sales volume, and parking availability is extremely difficult and expensive. As a result, a common approach in calculating nonwork accessibility indicators is to use the number of employees by industry as the attractiveness factor. Krizek (2003), for example, derives an accessibility indicator by using total retail employment in a zone. Handy (1993) similarly uses employment from retail and service sectors. Helling and Sawicki (2003) isolate shopping locations like grocery stores, drug stores, and liquor stores by Standard Industrial Classification (SIC) categories and use the total employment in a zone among those establishments. This study follows this convention and uses the number of employees by industry category at a location as the indicator of attractiveness. In the case of social visits, the indicator of attractiveness is population rather than number of employees. Data come from the private vendor InfoUSA, Inc., a provider of proprietary business data, and a source of data commonly used for small-scale employment analysis. InfoUSA collects data on businesses from a variety of sources, including the U.S. Department of Labor, telephone books, county agencies, the U.S. Postal Service, and private utility companies. The database used consists of 65,400 business establishments in the Detroit three-county region in 2005, located as a point with coordinates of latitude and longitude. Each establishment has a code based on the Standard Industrial Classification (SIC) system which is used to identify the establishments within a trip purpose.

3.1.1 *Defining Trip Purposes*

Data on trip purposes come from a household travel survey conducted for the state of Michigan in 2005 (Michigan Department of Transportation 2005). The database contains 30,300 self-reported trips that originated in the three-county region, with origin and destination locations, and with codes describing the travel activities (e.g., go to work; attend childcare; eat out) and destination types (e.g., office building; childcare center; restaurant). Table 1 lists the 13 trip purposes used in this study, along with corresponding SIC codes. Selecting the set of trip purposes was guided by three criteria. First, the trip purpose must have a clearly defined set of industries associated with it. Second, the trip purpose must appear in a regional household travel survey. Each trip purpose in this study was assigned a travel impedance function based on a calculation using data from a household travel survey. Third, a sufficiently large set of trips in the household travel survey must be associated with any trip purpose for the geographic extent of the study. For example, the trip purpose "Supermarkets" has 994 trips in the survey originating in the three-county region, a set of trips large enough to reliably estimate an impedance function. By contrast, a more specific trip purpose of "Movie theaters" has only 27 trips in the survey and is not sufficiently large to warrant a trip purpose category.

Table 1. Trip purpose and business establishment industries

	Trip purpose	SIC code[a]
1	Supermarkets	541105[b]
2	Convenience stores	541103, 541105[c]
3	Banks	602101, 602102, 602103, 606101, 606102
4	Childcare facilities	8351
5	Schools	8211
6	Services	7231, 7241, 7532, 7533, 7534, 7536, 7537, 7538, 7539
7	Libraries	8231
8	Religious organizations	8661
9	Medical clinics	8011, 8021,
10	Shopping	5311, 5331, 5399, 5251, 5261, 5611, 5621, 5632, 5641, 5651, 5661
11	Social visits	NA[d]
12	Hospitals	8062
13	Restaurants	5812

[a]Six-digit Standard Industrial Classification (SIC) codes were established by private marketing-data vendors, and are a further refinement of official four-digit SIC codes.
[b]Only establishments larger than 45,000 square feet are included.
[c]Only establishments smaller than 2,500 square feet are included.
[d]NA: Not applicable; "Social visits" is based not on business establishments but population.

3.1.2 *Assigning Business Establishments to Trip Purposes*
Several refinements were required for assigning establishments to trip purposes. First, the SIC codes alone do not adequately distinguish between grocery stores and convenience stores. The SIC code for grocery stores, for example, includes some small convenience stores. And the SIC code for convenience stores includes some large markets. This study aims to capture the two ends of the food supply spectrum. Supermarkets are intended to be full service markets where fresh fruit, vegetables, and meat are available and a wide range of products are offered at competitive prices. Convenience stores are intended to be small stores serving residential areas that are normally open long hours and sell a limited variety of food and pharmaceutical items. A recent study in Detroit suggests that supermarkets of around 45,000 square feet achieve economies of scale that enable them to offer low prices for a wide range of goods, and that mid-range stores offer substantially less to customers (Molnar 2003). I therefore eliminated mid-sized grocery stores from the analysis, focusing instead on large, full service stores, by restricting the set of establishments to those of at least 45,000 square feet. This cutoff eliminates several specialty stores such as meat markets and ethnic food stores—places that are undoubtedly valuable to nearby customers, but which do not meet my definition of offering a wide range of products at competitive prices. Similarly, I restricted convenience stores to those that do not exceed 2,500 square feet. A second refinement is in defining the attractive capacity of the trip purpose "Social visits." Instead of using jobs as the indicator of attractiveness, I used instead residential population derived from block groups and 2000 Census data.

Finally, assigning business establishments to trip purposes required judgment on which businesses fit best each trip purpose. For example, "Shopping" includes clothing, department stores, and hardware stores; it does not include gas stations, supermarkets, and convenience stores. "Services" includes beauty shops, barber shops, auto repair shops, and post offices; it does not include banks, medical/dental clinics, and other professional services such as legal services, physical fitness centers, and social services. "Schools" are restricted to elementary and secondary schools, not universities and technical institutes.

3.2 Cost of Travel

The second factor in a gravity model is the cost of overcoming the spatial separation between the origin and destination of a trip (c in Equation 1). Cost can be represented by physical distance, travel time, monetary cost, or some combination of these. Although some analysts use physical distance as the cost variable (for example, Ong and Blumenberg 1998), travel time is the most common measure of cost and the one used in this study (Cervero et al. 2002; Grengs 2004; Handy 1993; Helling 1998; Hess 2005; Kawabata 2003; Krizek 2003; Sanchez et al. 2004; Shen 1998; Wachs and Kumagai 1973). Zone-to-zone travel times, based on home-based nonwork trips during the nonpeak period for both auto and transit, were provided by the Southeast Michigan Council of Governments (SEMCOG) and are estimates derived from standard travel demand modeling techniques. Because travel time is vastly different by travel mode, I calculated separate accessibility indicators for travel by automobile and by public transit.

3.3 Mathematical Form of the Impedance Function

The third factor required for a gravity model is the mathematical function representing the impedance of travel between zones. While the first two parameters are derived from characteristics of the built environment—the geographic distribution of destinations, and the cost of traversing the separation of those destinations—the third parameter incorporates human behavior and is thus a complicated measure to estimate. It is meant to approximate the resistance or unwillingness people feel in their conception of space. Indeed, Wilson (1971) refers to calibrating gravity models as measuring *perceived cost*.

The impedance function captures the tendency for people to decrease exponentially the number of trips they make as distance increases. This ''distance-decay'' effect says that one unit of distance added to a long trip is of less importance than one unit of distance added to a short trip (Carrothers 1956). Although many mathematical functions have been applied to capture the distance-decay effect, the most common form used in standard transportation planning models is the negative exponential function (Meyer and Miller 2001; Transportation Research Board 1998). This study used a negative exponential function for the impedance factor, as follows:

$$f(c_{ij}) = \exp(-\beta T_{ij}) \tag{2}$$

where:

exp denotes the base of the natural logarithm;

T_{ij} is the travel time in minutes between zones i and j; and

β is a parameter empirically derived to maximize the fit between predictions of the gravity model and the observed distributions of travel times.

The impedance factor includes an empirically derived exponent β, which is often thought of as a measure of the friction of distance (Sheppard 1995). It can be interpreted as a measure of a traveler's willingness to travel long distances (Transportation Research Board 1998). It is most accurate to think of β as an index of a traveler's *unwillingness* to travel long distances: we can interpret a high β as meaning a high unwillingness to travel long distances (or long time durations). In other words, the larger the β, the more rapidly trips decrease as distance (or travel time) increases.

The impedance function plays a particularly important role in the study of nonwork accessibility, because nonwork travel involves a wide range of trip purposes and travelers behave differently depending on the purpose of their trip. Theories of urban form such as Christaller's (1933/1966) central place theory have long recognized that a person's willingness to travel long distances varies by the purpose of a trip. Central place theory explains urban form as a hierarchy of places determined in part by a desire of consumers to minimize travel to purchase goods and services (Lösch 1954; O'Sullivan 2000). Different business types have different trade areas. People tend to buy certain goods and services for the convenience of not traveling far—typically near home or work—such as groceries, gasoline, or hair salons. Conversely, people tend to travel farther for other kinds of goods and services for which convenience is less important than the ability to make comparisons before a purchase, such as furniture, household appliances, or a car. To illustrate, people could easily spend 45 minutes of travel time to purchase a new couch but rarely spend more than about 10 minutes to pick up a carton of milk. Travelers who set out to buy milk feel a greater ''friction'' compared to going to a furniture store because most people have many milk-selling destinations closer to home than furniture stores, and because the value they derive from buying milk is far lower than for making a major purchase like a couch. So the impedance function must be calculated separately for each trip purpose. I calculated impedance functions by using automobile trips from the 2005 household travel survey referenced above (Michigan Department of Transportation, 2005). I used a single, automobile-based impedance function for both modes, in part because the set of transit trips are too small for a reliable estimate, but also because automobile travel more accurately reflects the ''norm'' of expectations from travelers throughout the region. This assumption is likely to marginally understate the disadvantage experienced by racial and ethnic minorities because they disproportionately constitute transit riders.

3.4 Estimating the Impedance Function by Trip Purpose

Three steps are required to calculate the impedance function by trip purpose. First, SIC codes are used to aggregate the number of employees associated with a trip purpose to zones (for the trip purpose ''Social visits,'' population is used instead of employees). Zones are transportation analysis zones (TAZs), delineated by local transportation officials for tabulating traffic-related census data. A TAZ in the Detroit region consists of one or more census-designated block groups. Second, the trips associated with a trip purpose are converted into an origin–destination matrix of TAZs and linked to travel times between TAZs. Third, the impedance function is calculated with TransCAD software following a gravity-model calibration technique commonly used in travel demand modeling, using an iterative process of entering various impedance functions until the theoretical ''trip length distribution'' (i.e., a frequency distribution of all trips in the region) converges on the empirical trip length distribution (Papacostas and Prevedouros 1993). Table 2 lists

Table 2. Trip purpose and empirically derived impedance function parameter, by automobile travel, 2005

	Trip purpose	β (Impedance function parameter)
1	Supermarkets	0.3899
2	Convenience stores	0.3967
3	Banks	0.1865
4	Childcare facilities	0.3763
5	Schools	0.3204
6	Services	0.2784
7	Libraries	0.3521
8	Religious organizations	0.2934
9	Medical clinics	0.1981
10	Shopping	0.2811
11	Social visits	0.2297
12	Hospitals	0.2067
13	Restaurants	0.3228

Note. Refer to Equation 2 for the β term.

the empirically derived impedance function values for the 13 trip purposes, based on travel by automobile.

The following equation modifies Equation 1 to account for differences in mode of travel and trip purpose:

$$(A_i)^{p,m} = \sum_j E_j^p f(c_{ij})^{p,m} \tag{3}$$

where:

$(A_i)^{p,m}$ is the accessibility indicator for people living in zone *i*, for trip purpose *p*, and for travel mode *m* (auto or transit);

E_j^p is the nonwork attractiveness factor for zone *j*, based on the number of employees in zone *j* who work at destinations associated with trip purpose *p*;

$f(c_{ij})^{p,m}$ is the impedance function associated with the cost of travel *c* for travel between zones *i* and *j*, for trip purpose *p*, and for travel by mode *m* (auto or transit); equal to $\exp(-\beta^p T_{ij}^m)$, where *exp* is the base of the natural logarithm, β^p is a parameter calculated separately for each trip purpose *p* and is empirically derived to maximize the fit between predictions of the gravity model and observed distributions of travel times, T_{ij}^m is the travel time (minutes) between zones *i* and *j* for travel mode *m*.

For a metropolitan region with N zones, $i, j = 1, 2, \ldots, N$.

The result of Equation 3 is an indicator of accessibility from each zone to all other zones in the region. It is a dimensionless index and its magnitude has meaning only when compared to the index of another zone. When comparing two zones for any trip purpose, the zone with a higher absolute value of accessibility implies that people living in it are likely to find more nonwork opportunities nearby, or that traveling to nonwork opportunities is faster, or some combination of the two.

4. Method: Comparing Accessibility Among Social Groups

An effective analysis of social equity requires that accessibility indicators be comparable on a common scalar across social groups. But the gravity model presents a problem in making comparisons across social groups, and the problem stems from the differing use of travel modes among social groups. It is well known that in most regions of the United States accessibility by auto is far superior to accessibility by transit (Grengs 2010; Kawabata and Shen 2007; Sanchez et al. 2004; Shen 1998). My objective is not to compare auto drivers to transit riders because the disadvantage of transit riders is well understood. Instead, my objective is to compare social groups while controlling for the fact that some groups are disproportionately dependent on the inferior mode of public transit. Racial and ethnic minorities depend on public transit far more than whites: African Americans are about eight times as likely as whites to make a trip by bus (Pucher and Renne 2003).

4.1 Method of Assigning Accessibility to Households

I assigned social groups to one of two zone-level accessibility scores: they either experience auto accessibility or transit accessibility. Any household without a vehicle is considered to be dependent on public transportation, and such a household experiences only transit accessibility. Conversely, I assumed any household that owns a vehicle will experience auto accessibility. I expect the assumption is a conservative one: it likely overestimates the number of people who experience auto accessibility—the better of the two accessibility outcomes—because the condition where *people living in a household with a vehicle but who nevertheless must rely on other means of travel* is a more frequent occurrence than the condition where *people living in a carless household are able to share rides by automobile*.

4.2 Comparing Social Groups

I evaluated whether nonwork accessibility is evenly distributed among social groups, and I made comparisons among the following groups: by race (restricted here to blacks and whites), Hispanic origin, household income, and poverty status. Household income and poverty status are household-level variables and are available directly from the 2000 Census Transportation Planning Package (CTPP) at the TAZ level, cross-tabulated with vehicle availability (U.S. Bureau of the Census 2004). Race and Hispanic origin are not household-level variables; members of a household may be of multiple races or ethnicities. So for these two variables, I assumed that all members of a household share the race or ethnicity of the householder. Also, race and Hispanic origin are not available cross-tabulated with vehicle availability from the CTPP, but they are as census-tract level variables from the 2000 Census of Population and Housing, Summary File 3, Tables HCT33 (U.S. Bureau of the Census 2002b). I therefore assigned TAZ-level accessibility values to census tracts with a spatial join procedure.

For the case of race, I restricted the analysis to comparisons between whites and African Americans, the two most prominent groups in the Detroit region. The case of Hispanic origin compares accessibility between households headed by a person who identifies as Hispanic in the census questionnaire against households for whom the householder does not (the Census Bureau uses the term "Hispanic" to represent people who identify themselves as "Spanish, Hispanic, or Latino," and may be of any race). Household income is presented in three categories of "Low" (0 to \$35,000 annual household income, in 1999 dollars), "Medium" (\$35,000 to \$70,000), and "High" (over \$70,000), with each category containing about one-third of the households in the study region. Poverty status is based on Census Bureau data which uses the federal government's official definition of poverty. This study represents poverty in two conditions, as either in poverty (where the household annual income in 1999 falls below the poverty standard) or not in poverty (income falls above the poverty standard) (U.S. Bureau of the Census 2002a).

5. Results and Discussion

To give context to the results that follow, the Detroit region is marked by distinct geographic patterns where African

Americans, households in poverty, and people who depend on public transit are disproportionately located within the central city. The Detroit region shows extreme levels of racial segregation between blacks and whites (Iceland, Weinberg, and Steinmetz 2002), as illustrated in the map of Figure 1, with only 23% of African Americans in the three-county region residing outside of the central city. In 2000, 20% of households headed by African Americans in the three-county Detroit region did not have an automobile available, compared to just 6% of households headed by whites. And 29% of households in poverty in the region (with incomes below the federally defined threshold) had no automobile available, compared to 7% of households above the poverty line (U.S. Bureau of the Census 2003).

The approach to comparing how various social groups experience nonwork accessibility is to plot accessibility indices against the regional share of households across the three-county region. The chart in Figure 2 illustrates the approach, showing the accessibility index on the y-axis against the percentile of households on the x-axis, for the case of travel to convenience stores, and comparing whites to blacks. A total of 52 charts were created, representing accessibility for 13 trip purposes across the four dimensions of social groups (race, Hispanic origin, household income, and poverty status). I show selected examples in the following discussion, focusing primarily on comparisons of race.

Figure 2 shows that black households experience higher accessibility to convenience stores than white households across nearly the entire regional population: almost 80% of black households experience higher accessibility, and the advantage is substantial (indicated by the vertical distance between the lines). To further illustrate, we can look at the 50th percentile and find that half of black households experience accessibility at a value of 11 or higher, but half of white households experience accessibility of only 2.5 or higher. Alternatively, comparing the accessibility value of 15 across the race categories, we find that 37% of black households experience at least this level of accessibility, compared to only 3% of white households. The map of Figure 3 shows the geographic distribution of accessibility to convenience stores, with the highest accessibility territory occurring primarily in the center of the region.

Focusing on comparisons of race, and looking at all 13 trip purposes, I find three distinct patterns in the charts. The first pattern, represented by Figure 2 below, can be seen by contrasting the shapes of the two lines. For black households, the line proceeds in a straight rise, at a relatively constant slope. The diagonal does not start at the chart's origin, however, but rather at about the value of 20 on the x-axis. This means that about 20% of black households experience extremely low accessibility (seen between 0 and about 20 on the x-axis). For the other 80% of black households, accessibility is fairly evenly spread among them: about 40% of black households experience high accessibility, and about 40% of black households experience low accessibility. By contrast, for white households, the line is curvilinear, with a constantly

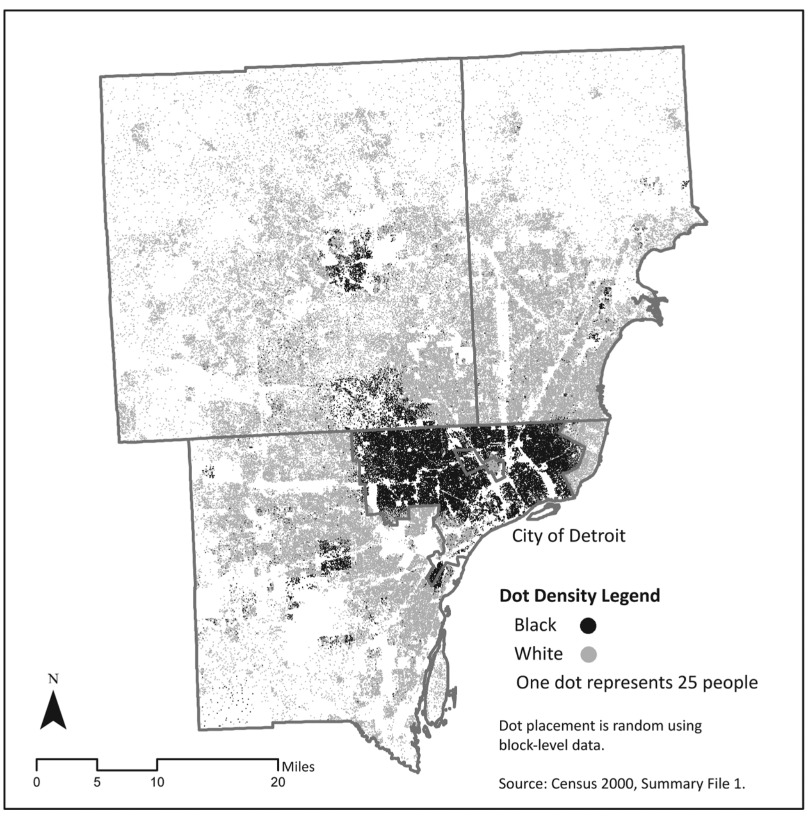

Fig. 1. Residential segregation between Blacks and Whites, Detroit three-county region, 2000.

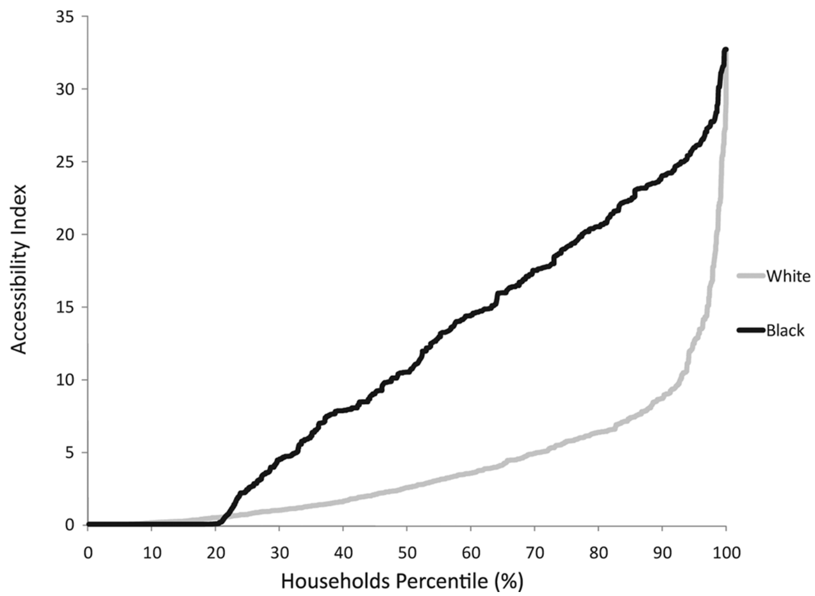

Fig. 2. Accessibility to convenience stores, by race, 2005.

rising slope. This means that accessibility is not evenly spread among whites. Instead, a very small share of whites experiences high accessibility while the vast majority of whites experiences relatively low accessibility.

Other trip purposes that conform to this general pattern, besides the case of convenience stores shown in Figure 2, include childcare facilities, religious organizations, and hospitals. For these cases, the charts indicate that in the aggregate blacks are better off than whites: About 80% of black households experience higher accessibility than white households. Indeed, about half of black households reside in places where the accessibility indicator is very high,

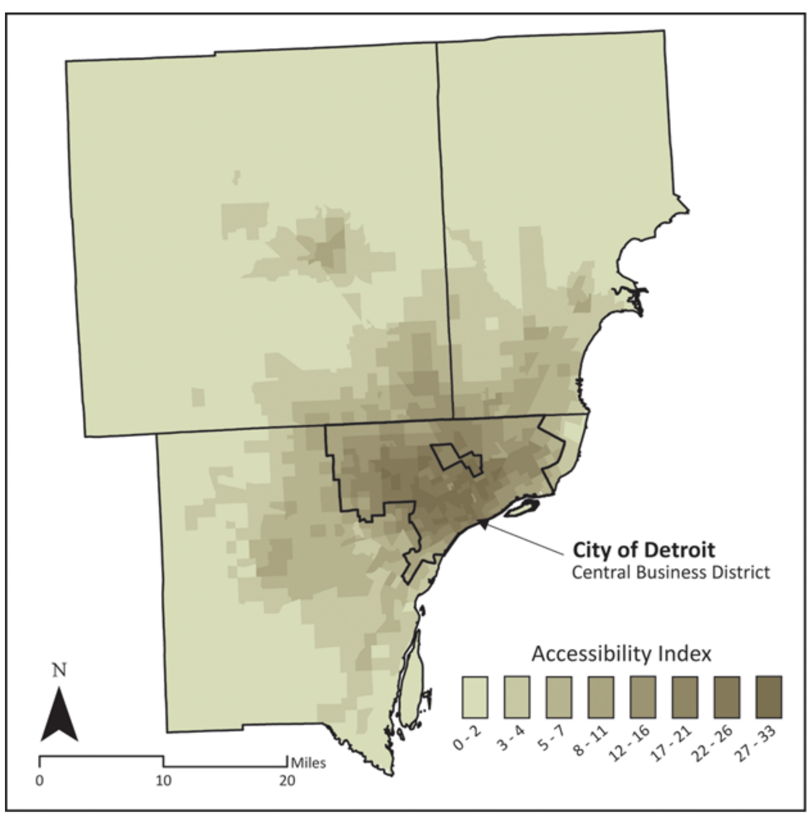

Fig. 3. Accessibility to convenience stores by auto, Detroit three-county region, 2005.

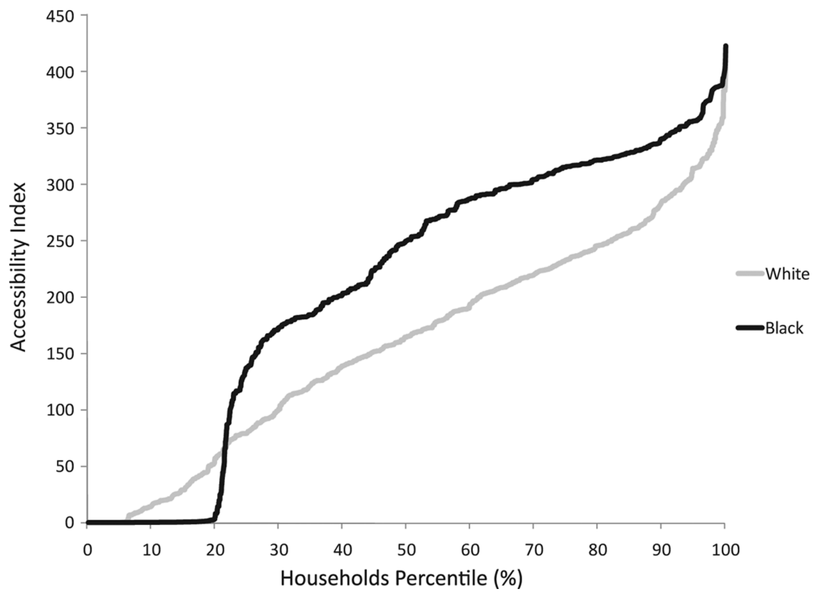

Fig. 4. Accessibility to banks, by race, 2005.

compared to only about 5%–15% of white households experiencing the same degree of accessibility. This high level of accessibility among blacks can be explained by their central location. However, even though about 80% of black households are better off than white households, the remaining 20% of black households experience extremely low accessibility. The zone with the 20th percentile of black households is located near the central business district in the central city. Among the 20% of households with the lowest accessibility in the region, nearly all reside within the central city: 84% of these households live within the Detroit boundary while the remaining 16% are scattered among various parts of the suburbs.

The second main general pattern revealed by the charts, represented by the case of accessibility to banks by race in Figure 4, can also be found in the contrast between the shapes of the two lines. For white households, the line proceeds in a straight rise, at virtually a diagonal from the origin. The diagonal starts at about the value of 5 on the x-axis. This means that about 5% of white households experience extremely low accessibility (seen between 0 and about 5 on the x-axis). Aside from this 5%, accessibility is evenly spread among whites: about half of whites experience high accessibility, and about half of whites experience low accessibility.

By contrast, for black households, the line is in the shape of an "S". Blacks tend to experience either high or low accessibility, with little middle ground in between. This result suggests that blacks generally enjoy a positional advantage—they tend to live in close proximity of destinations—but travel speed disadvantage for the large share of

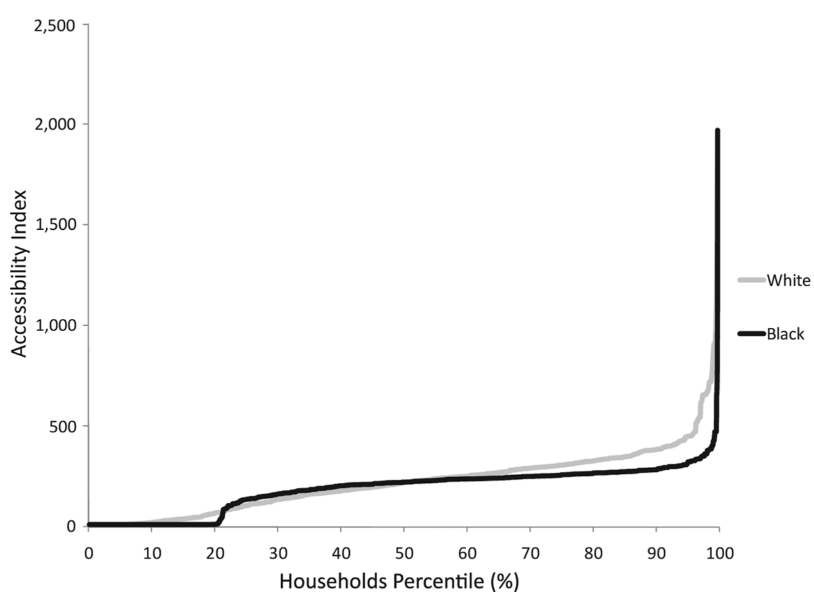

Fig. 5. Accessibility to shopping, by race, 2005.

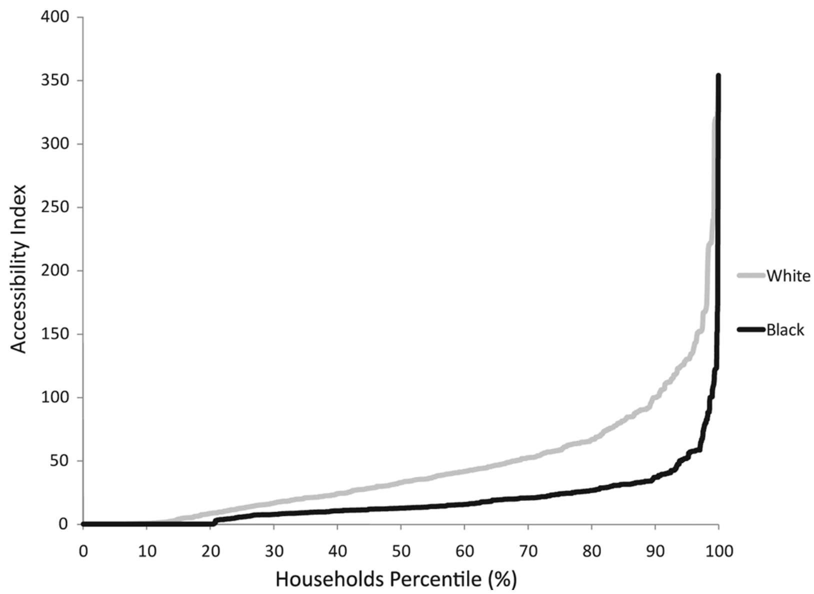

Fig. 6. Accessibility to supermarkets, by race, 2005.

blacks who are transit-dependent is so substantial as to negate any locational advantage.

Other trip purposes showing this general pattern, in addition to the case of banks shown in Figure 4, include schools, services, medical clinics, and social visits. Comparing the races in these cases, the charts show that blacks tend to be better off than whites in terms of physical accessibility to these nonwork destinations. About 80% of black households experience a moderately high advantage over whites. Unlike with the previous pattern, where the most disadvantaged blacks were experiencing comparably low levels of accessibility relative to whites, in this case blacks experience a moderate degree of disadvantage relative to their white counterparts in this range of low accessibility.

The third general pattern in the charts is represented by Figure 5, for the case of shopping. In this pattern, which applies as well to libraries and restaurants, the shapes of the two lines are highly similar, suggesting little difference between the races. About half of white households experience a modest degree of advantage in shopping, but otherwise accessibility is fairly comparable across the races throughout the rest of the household percentiles. Although the charts are not shown here, in the case of libraries and restaurants, black households experience a small to moderate level of advantage throughout a substantial portion of the household percentiles.

Finally, continuing with the examination of charts by race, the trip purpose of Supermarkets stands alone in not fitting any of the three general patterns. As shown in Figure 6, whites experience an advantage in accessibility to supermarkets across the full spectrum of accessibility levels. And the advantage—represented by the vertical distance between the lines—is most prominent in the high accessibility range. This is confirmed by visual examination of the map in Figure 7: having high accessibility to supermarkets is entirely a suburban experience, which for Detroit means the territory where whites live in a highly disproportionate share compared to blacks. This finding about accessibility to supermarkets is especially striking in the context of the other findings of this study. All other trip purposes suggest an advantage in nonwork accessibility to African American households, because to be centrally located is to be in closer relative proximity to a wider range of destinations, all else being equal. The high degree of disadvantage to blacks revealed by the pattern of accessibility to supermarkets is highly unusual when compared to other kinds of trip purposes.

Results by Hispanic origin follow closely the findings for African Americans: on the whole, Hispanics experience an accessibility advantage compared to non-Hispanic households with the exception of accessibility to supermarkets. Hispanic households, like black households, are highly concentrated in the central city of Detroit, which explains the similar results between blacks and Latinos. Households in poverty follow patterns somewhat similar to the findings of race as well: Like African Americans compared to whites, households in poverty tend to experience higher nonwork accessibility than households not in poverty. However, a very large share of poverty households—on the order of about one-third—experience extremely low accessibility for any trip purpose (for example, less than one percentile of the full range of accessibility scores), a result explained by the 29% of households in poverty regionwide that do not have access to a private vehicle. Low-income households track fairly closely to medium- and high-income households for most trip purposes, suggesting a more random spatial distribution throughout the region among these groups. Low-income households tend to experience an advantage over the other income categories in the highest accessibility range, however, which is explained by the tendency of low-income households to live near the urban core where accessibility is high.

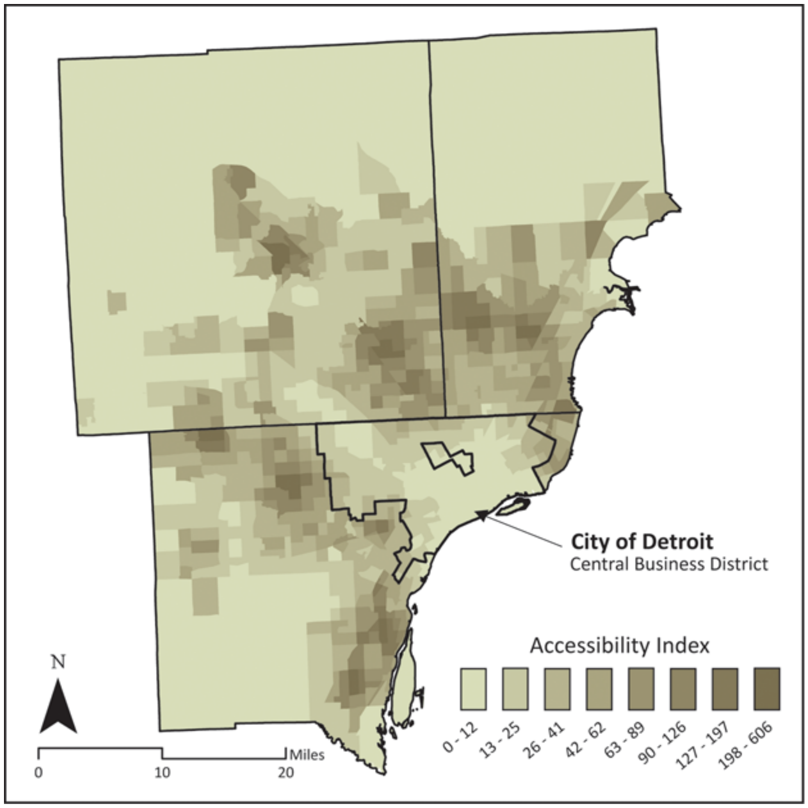

Fig. 7. Accessibility to supermarkets by auto, Detroit three-county region, 2005.

6. Conclusion

Nonwork accessibility varies substantially by the purpose of the trip. The highest accessibility zones occurred primarily in the urban core for most trip purposes, and high accessibility appears to be largely determined by the land-use arrangement of the destinations. Where the density of destinations is high, so too is accessibility. Yet several trip purposes deviated from this general pattern. Some trip purposes show a "polycentric" pattern of accessibility, and yet other trip purposes show the highest accessibility zones occurring entirely in the suburbs, including shopping and supermarkets.

The analysis of social equity found that several vulnerable social groups are not as disadvantaged in accessibility as is generally understood. Vulnerable social groups—including African Americans, Hispanics, low-income households, and households in poverty—experience an advantage over more privileged groups for several trip purposes, including banks, schools, services, social visits, convenience stores, childcare facilities, religious organizations, and hospitals. However, vulnerable groups experience a disadvantage in accessibility to shopping and supermarkets. And, even in situations where the majority of the vulnerable social group is better off than the more privileged group in the aggregate, the vulnerable social groups experience a substantially larger share of their households with extreme levels of low accessibility (for example, less than one percentile of the full range of accessibility scores), as a result of their disproportionately low access to private vehicles.

Analyzing the case of a single metropolitan region is useful for showing and describing these patterns, but to explain them adequately would require intermetropolitan comparison. Is Detroit unusual in these patterns? Are local and regional policies contributing to these patterns? Intermetropolitan comparisons would be essential for resolving these questions. Without a systematic analysis of a cross-section of metropolitan areas, policy makers have little guidance in understanding which arrangements of transportation infrastructure and which types of urban form lead to better regionwide accessibility outcomes.

Yet the analysis offers lessons for advancing the measurement of accessibility. And it lends support for making the evaluation of accessibility a standard element in assessing the success of a transportation system (Boschmann and Kwan 2008; Wachs and Kumagai 1973). First, although the finding that nonwork accessibility varies by the purpose of the trip is not surprising, the magnitude of the differences suggest that any effort to measure nonwork accessibility ought to be conducted by accounting for these differences. Unlike for the case of the journey-to-work which is commonly assessed with a single measure of "job accessibility," nonwork accessibility is not likely to be described sufficiently with a single, composite indicator that accounts simultaneously for multiple trip purposes. Instead, multiple measures of nonwork accessibility ought to be used. One approach is to use multiple measures by trip purpose. Several regional planning agencies are starting to use accessibility indicators as part of their technical analysis of environmental justice, as mandated by federal law and policy (Cambridge Systematics 2002). Although most accessibility measures focus on the journey-to-work, several notable efforts are underway to measure nonwork accessibility through multiple trip purposes. For example, the Metropolitan Transportation Commission of the San Francisco Bay Area uses a simple cumulative opportunities approach—counting the number of destinations within a threshold travel time—to evaluate accessibility by both auto and transit to schools, food stores, health services, and social services (Metropolitan Transportation Commission 2004). Similarly, the Mid-Ohio Regional Planning Commission in Columbus, Ohio also uses a cumulative opportunities approach and focuses on accessibility to shopping, universities, and hospitals (Mid-Ohio Regional Planning Commission 2012).

Another approach to calculating multiple measures of nonwork accessibility is to use various geographic scales, as suggested by the market reach of central place theory. Although research on neighborhood commercial markets is scarce, transportation planners may turn to a body of literature on the economics of retail firm location to complement future work on nonwork accessibility. In particular, a better understanding of the various travel activities may help in establishing the impedance function to use in gravity-based models. Based on this literature, stores that sell high-frequency goods locate at the neighborhood scale, but stores that sell low-frequency goods locate at the larger, regional scale. And some types of retail businesses benefit from agglomeration clustering so consumers can make multiple purchases in the same area, or can compare goods and prices from several retailers (DiPasquale and Wheaton 1996).

A second lesson is that accessibility in this study is defined in a very narrow sense, focusing strictly on the potential for travel in terms of the cost of time. It does not address qualitative differences among destinations, such as product selection, product quality, parking availability, store hours, perception of safety and crime, and service friendliness. A more complete analysis of accessibility, especially in the context of comparisons among social groups, would also include other dimensions of accessibility. Other relevant dimensions of a person's ability to access important destinations, aside from qualitative differences, include the relative prices of goods and services and the relative ability of travelers to pay for goods and services. Another dimension that is likely to be particularly relevant in the context of a racially segregated region like Detroit is the degree of comfort that travelers experience when visiting places outside of familiar surroundings. The fear of racial hostility has a long history in Detroit (Farley, Danziger, and Holzer 2000; Sugrue 1996; Thomas 1997; Zunz 1982) and likely has a strong influence on travel patterns. Unfortunately, these other dimensions of accessibility are difficult to measure, especially at the metropolitan scale of study, and remain severely understudied by transportation scholars. The definition of accessibility in this study allows for better understanding the physical constraints on travel, but it is not sufficient for appreciating the full range of constraints on travel.

Third, the measurement of nonwork accessibility is highly sensitive to the definition of a destination. Note that the case of accessibility to supermarkets turned out to be highly atypical compared to other trip purposes. Indeed, the study approach of analyzing separately 13 different trip purposes helps to accentuate just how unusual the case of supermarkets is in the case of Detroit. The case of supermarkets is the only trip purpose where every vulnerable social group experienced substantial disadvantage in accessibility throughout the entire range of households that make up the social group. This finding is consistent with many studies, and it suggests that supermarkets may represent a universal concern with respect to accessibility disadvantages (Burns and Inglis 2007; Clifton 2004; Grengs 2001; Helling and Sawicki 2003; Moore and Diez Roux 2006; Raja, Ma, and Yadav 2008; Zenk et al. 2005). This finding about supermarkets also suggests that other trip purposes—such as services, shopping, banks, and medical clinics—would benefit from a finer breakdown in category. Had supermarkets been included with convenience stores as a larger category as "food stores," the unusual pattern of supermarkets would not likely have been detected. For example, my decision to separate out supermarkets from food stores in general was driven by the widely understood pattern whereby large chain supermarkets are abandoning central cities (Dunkley, Helling, and Sawicki 2004; Guest 2006; Raja et al. 2008; Turque 1992). Bingham and Zhang (1997) found that about 20% of the economic activities they examined declined dramatically once the level of neighborhood poverty reaches about 10%. When 20% of households in a neighborhood fall below the poverty line, the presence of supermarkets in neighborhoods is scarce and small convenience stores are taking their place. The finding here that accessibility to convenience stores is highly centralized is consistent with what was found by Bingham and Zhang.

Fourth, even though a core objective of transportation policy is to increase accessibility, planners and policy makers ought to begin accounting for differences in *kind* of accessibility. The findings that African Americans are disproportionately advantaged in their accessibility to convenience stores while being decidedly disadvantaged in accessibility to supermarkets is supported by studies of "food deserts" (Raja et al. 2008). Numerous studies claim that high-poverty neighborhoods of central cities are disadvantaged compared to other neighborhoods in their ability to obtain healthy, affordable food because grocery stores are not located nearby and transportation options are limited (Chung and Myers 1999; Gordon et al. 2011; Larson, Story, and Nelson 2009; Moore and Diez Roux 2006; Raja et al. 2008; Smith et al. 2010; Zenk et al. 2005). Other studies go further to claim not only that appropriate food stores are not available, but that convenience stores have filled the gap and in ways that are sometimes exploitative and harmful to neighboring residents (Cannuscio, Weiss, and Asch 2010; Gebauer and Laska 2011; Lucan, Karpyn, and Sherman 2010). Finding ways to refine measures of accessibility to account for varying degrees of quality among trip purposes has so far received little attention among transportation analysts

(Witten, Exeter, and Field 2003), yet should become an important element of evaluating nonwork accessibility.

In conclusion, the findings here are consistent with one of the suggestions by Porter (1995) in a highly influential article that argued that central cities have competitive advantages. Porter argued that underserved markets in central cities justify commercial redevelopment based solely on economic grounds. To the extent that accessibility as a vital ingredient in determining the value of land is overlooked by policy makers and private developers, the finding that central locations continue to provide high levels of accessibility to many nonwork destinations even in a place as distressed as Detroit suggests promise for much-needed investment. More likely, however, is that accessibility is but one of multiple influences on such decisions, and transportation planners ought to find accessibility's role in revitalization development.

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