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FEDERAL TRANSIT ADMINISTRATION

Evaluating Transportation Equity: An Intermetropolitan Comparison of Regional Accessibility and Urban Form

JUNE 2013

FTA Report No. 0066
Federal Transit Administration

PREPARED BY

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liter	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

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13. ABSTRACT

The concept of accessibility is used as the measurement tool to assess the link between social equity and the built environment because it simultaneously accounts for both land-use patterns and a transportation system. This study compares 25 metropolitan regions to identify those regions that best support high accessibility for transit-dependent populations, racial minorities, and low-income households. Comparing across metropolitan regions enables a better understanding of which regions offer greater geographic equity in accessibility, and what factors underpin these differences. The analysis demonstrates that accessibility can be evaluated across multiple dimensions.

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ABSTRACT

Transportation accessibility—the ease of reaching destinations—is influenced simultaneously by mobility and proximity. Several vulnerable social groups—such as blacks, Hispanics, low-income households, and households in poverty—are well known to experience mobility disadvantages. Yet, in the United States, these social groups also tend to experience distinct patterns in their residential location of metropolitan space that might offer proximity advantages relative to the rest of the population. To what degree do disadvantaged social groups experience proximity to essential destinations in ways that offset their mobility disadvantages? Do some metropolitan regions offer patterns of urban form with regional accessibility advantages for vulnerable social groups? The concept of accessibility is used as the measurement tool to assess the link between social equity and the built environment because it simultaneously accounts for both land-use patterns and a transportation system. This study compares 25 metropolitan regions to identify those regions that best support high accessibility for transit-dependent populations, racial minorities, and low-income households. Comparing across metropolitan regions enables a better understanding of which regions offer greater geographic equity in accessibility, and what factors underpin these differences. The analysis demonstrates that accessibility can be evaluated across multiple dimensions. With some exceptions, findings suggest few common outcomes running across all three dimensions of vehicle availability, race, and income, yet the method provides a basis for exploring desirable land-use and transportation policies for improving accessibility, which will, in turn, improve the prospects for more equitable urban development.

SECTION 1

Introduction: Accessibility Promotion as the Goal of Transportation Policy

Imagine it is a Saturday morning and you have an appointment to speak by telephone with a good friend at noon, but first you need to run three errands: you need to drop off one of your kids at the high school for theater rehearsal, go to the bank to get cash, then pick up a prescription for your partner from the pharmacy. Strangely, it turns out that your friend, who lives in another city, has to accomplish the exact same set of errands. Both you and your friend have all of these destinations within reach of your homes. But your friend lives in a city where travel is faster than where you live, with smoother-flowing highways and less congestion on local roads.

Is your friend better off than you? Which of you will accomplish all the tasks quickest, leaving more free time to enjoy your Saturday morning before the telephone appointment at noon? It seems that your friend might need less time for these tasks, because, all else being equal, traveling faster is preferable to traveling slowly. But it depends: what really matters to you is the sum total of time it takes to accomplish all three tasks. If you can complete all three errands in less time by traveling more slowly than your friend, that would be fine with you. But how is it possible to accomplish these errands in less time by traveling slowly? The answer is in land-development patterns. If the destinations in your city are closer together than in your friend's city, you can travel more slowly while still accomplishing tasks more quickly.

Your city would be an example of a high *accessibility* place, where you have the capacity to achieve a great deal of interaction with people and places in a given amount of time. Your friend's city, by contrast, would be an example of a high *mobility* place, where infrastructure and services are aimed at making it easy to move around.

Your city would stand in sharp contrast to the mobility-centered view that has dominated transportation policy and practice for over half a century, a trend evidenced in current policy and in the physical form of the built environment in metropolitan areas in the United States and many countries around the world. This mobility-oriented view extends to the metrics by which transportation systems are assessed. When evaluating the performance of a transportation system, the fundamental criterion for success has long been faster vehicle operating speed [1]. Common indicators of this include delay per capita, dollars wasted while waiting in traffic, and highway level-of-service [2-4]. These mobility metrics are not simply ex post facto assessments, but rather are used proactively to guide policy toward transportation investment and land-use regulation [5, 6]. The mobility-based perspective of transportation policy dominates the view of the general public as well. The widely-publicized congestion measures that routinely appear in newspapers nationwide when the Texas Transportation Institute publishes its annual Urban Mobility Report [2] have helped to elevate the alleviation of traffic congestion to a top public policy priority. Under all such mobility-based evaluation measures, planners, engineers, and the general public deem rapid movement to be a definitive indicator of transportation-policy success. On the ground, this often translates into a singular focus on fast and wide highways and zoning regulations targeting traffic congestion through reductions in density.

Accessibility gauges the potential for interaction rather than the quality or amount of movement alone [7]. If the demand for transportation is "derived"—meaning that travelers do not consume transportation for the sake of movement but to reach destinations [8, 9]—then consistent transportation-policy evaluation would be based on assessments of accessibility rather than mobility in isolation [10]. Derived demand implies that higher accessibility is the core objective of transportation planning [11]. Means to promoting accessibility include both improving mobility by achieving faster travel speed and also increasing proximity by promoting higher-density land-use development [12].

Moreover, the very purpose of cities is the access they provide to help people gain economic prosperity by offering a wide range of jobs, a variety of goods for consumption, and an assortment of amenities and services to satisfy diverse desires. Where people live has a powerful effect on their capacity to achieve a high quality of life [13], in part through the accessibility that a place provides. Accessibility represents a measure of choice—as an indicator of a person's potential for seizing available opportunities. And having choice in one's life is a highly-valued quality in and of itself [14, 15]. Advancing policies that broaden the scope of choice has become a central principle in the field of urban planning. Following the "equity planning" movement [16, 17], many professional planners now espouse providing "a wider range of choices for … residents who have few, if any, choices" [18], a tenet now codified in the ethical standards of the American Institute of Certified Planners [19].

Nearly all empirical research on accessibility has been focused on case studies of single metropolitan regions, which fail to capture the effect of region-level decisions. Intermetropolitan comparisons are essential for understanding the region-level decision tradeoffs between mobility and proximity in producing accessibility. 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 more equitable regional accessibility outcomes. This study supports a transportation policy shift by evaluating the social equity implications of accessibility through a comparison between multiple metropolitan areas of the United States. The comparative analyses of metropolitan regions enable a better understanding of which regions offer greater geographic equity in accessibility, and what factors underpin these differences. This improved understanding provides a basis for exploring desirable land-use and transportation policies for improving accessibility, which will, in turn, improve the prospects for more equitable urban development. The study compares 25 metropolitan regions to identify those regions that best support high accessibility for transit-dependent populations, racial minorities, and low-income households.

SECTION 2

Accessibility as an Indicator of Social Equity

The concept of accessibility provides the needed measurement tool as the critical link between social equity and the built environment as it is shaped by land-use and transportation decisions. The field of transportation has not yet put into practice sound methods for measuring and evaluating social equity [20, 21]. The transportation planning and engineering professions largely retain a mobility-centered view of current policy, under which success is assessed as the capacity of moving more vehicles more quickly. Planners and engineers assess their success primarily through their ability or inability to alleviate roadway congestion, reflected in their mobility-based measures such as "level of service" indicators [22].

Adherence to mobility-based measures of transportation outcomes raises two problems for evaluating transportation outcomes for racial minorities and low-income households. First, mobility-based measures such as levels of congestion are attributes of transportation links, not of people. As a consequence, all users of a roadway (for instance) are assessed to have the same level of mobility, a fact that hides variations in people's ability to reach their destinations. Aside from the fact that measuring attributes of transportation links offer little help in understanding equity among social groups, such measures are of little relevance to households without cars, the people who are most disadvantaged by the cities we build today.

Second, achieving success in providing congestion relief through added highway capacity may induce destinations to move farther and farther apart [22]. Travel to increasingly remote shopping or work destinations might be accomplished at higher speeds, but the geographic spread of these destinations demand yet more travel. Thus, transportation policy may be contributing to the sprawl that has been shown to disproportionately harm racial minorities and low-income people who tend to live near the urban core and have fewer resources to adapt to spreading land use patterns [23-25].

Accessibility is a useful tool for equity analysis because it properly places emphasis on people and their relationships to places. The capacity to interact with others influences a person's engagement with society: fulfilling needs for companionship with family and friends; participating in activities such as work, learning, and worship; gaining access to resources such as food and clothing; and enjoying visits to places such as symbolic sites, recreation locations, and open space. Recent theories of poverty suggest that the disadvantage that vulnerable people experience is largely about an inability to participate actively in society. These theories claim that poverty is best understood in terms of relative deprivation rather than by some absolute measure of money or material resources: "Their resources are so seriously below those commanded by the average individual or family that they are, in effect, excluded from ordinary living patterns, customs, and activities," writes Townsend [26]. Accessibility metrics allow for evaluating social conditions in a relative manner, to compare the capacity to interact with destinations across space and across social groups.

Accessibility metrics capture the effects not only of transportation infrastructure but also the spatial arrangement of destinations that are important to people in their lives. Accessibility is inherently multidimensional, and to measure it is to gauge directly the outcome of transportation policy. For this reason, some scholars are beginning to argue that accessibility is the appropriate "good" to be considered in questions of just distributions [27, 28]. As Wachs and Kumagai [9] argued decades ago, accessibility indicators should be used regularly by policy makers—along with more commonly used measures of income, health, and education—to assess conditions among social groups.

SECTION

3 Empirical Study of Accessibility and Social Equity

Several studies have focused on the transportation accessibility experienced by disadvantaged populations. For example, Shen [29] examined job accessibility of low-wage workers in Boston; Grengs [30] compared the job-accessibility outcomes between employees with and without the availability of a car; Hess [31] studied the job accessibility outcomes of adults in poverty in Buffalo; Kawabata [32] focused on job accessibility of low-wage workers without vehicles in Boston, Los Angeles, and San Francisco; and Apparicio and Seguin [33] investigated the ability of public housing residents in Montreal to reach a wide range of services and facilities.

But only a few studies have explicitly evaluated differences among social groups in transportation accessibility. Most such studies focus on accessibility to jobs. Wachs and Kumagai [9] provided one of the earliest applications of directly comparing social groups with the concept of accessibility by evaluating differences in job accessibility by household income and occupation in Los Angeles. This early study found that higher income groups lived in places that are more accessible to high-income jobs, and that professional, technical, and managerial employees lived in more accessible locations to their jobs than do workers in other occupation categories. Black and Conroy [10], in a study of accessibility to jobs in the suburbs of Sydney, compared accessibility between men and women and found that accessibility was generally higher for men mainly because women tend to rely more heavily on the slower mode of public transportation than men. Helling [34] compared accessibility to jobs by race in Atlanta and found that overall accessibility in the region improved between 1980 and 1990, but that accessibility declined on average for African Americans. Grengs [35] compared social groups by race, ethnicity, poverty, and income in Detroit and found that a majority of racial minorities and low-income persons were advantaged in their ability to reach jobs because of their disproportionate location near the center of the metropolitan region, but that, nevertheless, a troubling share of vulnerable households experienced extreme disadvantage by virtue of lacking an automobile in spite of residing in advantaged locations.

Several studies have compared social groups in their ability to reach non-work destinations. Helling and Sawicki [36] compared accessibility by race in Atlanta and found that African American neighborhoods experience lower accessibility to retail trade and personal services than predominantly white neighborhoods, and furthermore discovered that differences in incomes failed to explain lower accessibility among blacks. Scott and Horner [37], in a detailed study of Louisville using a variety of destination types and accessibility measures, unexpectedly discovered that people in four out of five at-risk socioeconomic groups did not experience disadvantage in their ability to reach a wide range of important destinations such as grocery stores, hospitals, and post offices. Grengs [38] found that vulnerable social groups in Detroit experience an advantage in physical accessibility over more privileged groups for several trip purposes (including convenience stores, childcare facilities, religious organizations, and hospitals), but that they experienced a distinct disadvantage in accessibility to shopping and supermarkets. Despite the type of trip purpose, vulnerable social groups experienced a substantially larger share of households with extreme levels of low accessibility, as a result of disproportionately low availability of private vehicles.

SECTION 4

Method: Accessibility Metrics for Social Group Comparison

This study bases it accessibility metrics in the gravity model [39, 40] that simultaneously accounts for both the transportation network and its surrounding land-use conditions [41]. We use a common form of the gravity model, proposed by Hansen [7], and modified to account for two types of trip purposes (work and non-work destinations) and for two travel modes (auto and transit):

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

where:

> (A_i) is the accessibility index for people living in zone i, whereas our larger study examined both work purposes and both travel modes, this paper focuses exclusively on work travel via auto.
>
> O_j is the number of opportunities in destination zone j; for work travel the value is the sum of jobs in a zone.
>
> $F(c_{ij})$ is a composite impedance function capturing travel conditions across multiple metropolitan areas, associated with the cost of travel c for travel between zones i and j.

The $F(c_{ij})$ function requires some explanation in the context of intermetropolitan comparisons. The term is equal to $\exp(-\beta T_{ij})$, where exp is the base of the natural logarithm, β is a parameter empirically derived to maximize the fit between predictions of the gravity model and observed distributions of travel times. The β term ordinarily varies between metropolitan regions and has an important interpretation. People's willingness to travel a given time differs from region to region: in some, a 20-minute trip would be considered long and would be avoided if possible; in others, it would be considered to be a short trip. The value of β would be lower in the latter region than in the former, indicating a higher impedance of travel.

Variations in willingness to travel are a function both of opportunities nearby and those farther away. Regions in which many destinations were close by and few far away would presumably demonstrate greater reticence to travel (and thus a higher value for β) than those with few nearby destinations and many farther away. To compare accessibility between regions, we considered two possibilities: a β term that varies between regions and a single β term across all comparison regions. The former would have accounted for interregional variations in propensity to travel; the latter would aid consistent comparison of accessibility between regions.

We use the unitary β option.[1] This research project primarily seeks to assess the effect of land-use patterns on accessibility. Variations in β are largely endogenous to land-use patterns, as described above. For this reason, using region-specific parameters would have the effect of giving accessibility "credit" to a region in which people readily take long trips. But if their propensity to take long trips is a function in part of lack of nearby destinations, then the region-specific parameter would tend to overestimate the accessibility of these places compared to others where long-distance trips were less necessary.

Our gravity model results in four accessibility indices at each zone in a metropolitan region: travel to work by auto; travel to work by transit; travel to non-work destinations by auto; and travel to non-work destinations by transit.[2] We use an "attractiveness factor" as a measure of the number of opportunities at destination zones, reflecting the geographic distribution of land-use development, and not dependent on the travel mode. For work accessibility, we use the number of jobs in each zone. For non-work accessibility, we calculate a "non-work attractiveness index," the details of which are not provided here but can be found in Grengs, et al. [12].

As typically applied, a gravity model produces an accessibility indicator for a spatial zone rather than for individuals. As a place-based measure, it attributes the same level of accessibility to every person in a zone, regardless of their personal preferences for travel. It is a measure of the potential for people living in a spatial zone to reach destinations, but it does not address whether people actually choose to seize the potential.

Method of Comparing Social Groups by Accessibility

This study follows the common approach of calculating accessibility indicators separately by travel mode, using one indicator for travel by auto and another for travel by transit. The reason for calculating separate indicators is primarily

---

[1]To develop a shared β parameter, we estimated individual β values for 16 metropolitan regions for which we had complete data. Values of the parameter were negatively correlated with metropolitan population, and we estimated a regression with individual values β dependent and metropolitan population independent. The best-fitting regression: estimated β = 0.109*exp(-3.52*10 - 8*Population) was then used to predict the value of β for the 20th largest metropolitan region, roughly the median in our sample in size terms. The search for a single aggregate β was necessary to reach meaningful comparisons of accessibility between regions. We note that even a single regional β term is, in effect, a composite of numerous and varying β terms for individuals within the region. Thus, the process of aggregation here is not new; where most travel modeling suffices with a β aggregated to the regional level, this project required a higher level of aggregation.

[2]Accessibility indicators are calculated at the geographic unit of analysis of a Transportation Analysis Zone (TAZ), a spatial division designed for tabulating transportation-related data. TAZs typically consist of one or more census blocks, block groups, or tracts and range in number from 859 to 4,109 for the metropolitan regions in this study.

because the travel time difference between the modes is so substantial that to combine the modes into a composite accessibility index would be highly misleading. Because travel times between the modes is so considerable, travel mode is a decisive factor in evaluating accessibility among people. The ability to reach destinations varies substantially depending on whether a person can use an automobile or not.

The equity approach used here is to assign households to one of two accessibility conditions: either all persons in a household experience accessibility by auto, or all persons in a household experience accessibility by transit, depending on the availability of a vehicle to the household. Any household without a vehicle is presumed to be dependent on public transportation, and such a household experiences only transit accessibility. Conversely, any household with a vehicle available will experience auto accessibility. This is an assumption driven primarily by data availability and suffers from certain shortcomings. How someone in a household experiences accessibility is clearly more complicated than this assumption suggests. For example, people in carless households are not necessarily dependent on transit; they may share rides with car owners or restrict their housing locations to be within walking distance of work. By contrast, people who live in a household with a car do not necessarily use that car. For instance, a household where the number of workers exceeds the number of cars may force some to rely on transit.

Social Groups and Data Sources

This section introduces an approach to evaluating the equity of accessibility distribution by (a) Vehicle Availability (households without vehicles compared to households with vehicles); (b) Race (restricted to the three races as defined by the Census Bureau of African Americans, Asians, and Whites); and (c) Household Income (three categories of Low, Medium, and High).

These separate analyses—by vehicle availability, race, and income—require data at varying geographic units from several sources, as summarized in Table 4-1. Both race and household income must be cross-tabulated with vehicle availability to assign households to either auto or transit accessibility. Vehicle availability is a household-level variable taken at the block-group level of geography from the 2000 Census of Population and Housing [42]. Household income is also a household-level variable, but to make a cross-tabulation with vehicle availability requires data at the geographic unit of a Transportation Analysis Zone (TAZ) and from the 2000 Census Transportation Planning Package (CTPP). Race is not a household-level variable because members of a household may be of multiple races or ethnicities. But to cross-tabulate with vehicle availability (a household-level variable), members of a household are assumed to share the race of the householder.[3] Furthermore, race is not available cross-tabulated with vehicle availability from the CTPP, but

[3]In census data collection, one person in each household is designated as the householder. The householder is usually the person in whose name the home is owned, being bought, or rented.

it is available at the census-tract level from the 2000 Census of Population and Housing [42]. TAZ-level accessibility values are assigned to block groups and census tracts with a spatial join procedure in Geographic Information Systems (GIS).

Table 4-1

Summary of Equity Analyses and Data Sources

Analysis	Number of Metropolitan Cases	Comparison Groups	Geographic Unit	Data Source
Vehicle Availability	27	Households with no vehicle available; Households with a vehicle available	Black Group	2000 Census of Population and Housing, Summary File 3, Table H44
Race	26	African American Asian White	Census Tract	2000 Census of Population and Housing, Summary File 3, Tables HCT33A, HCT33B, HCT33D
Household Income	25	low Medium High	Transportation Analysis Zone	2000 Census Transportation Planning Package, Part 1, Table 079

The table also shows the number of metropolitan cases that have sufficient data for each analysis. Collecting data from MPOs on transit travel proved more difficult than for automobile travel. Because transit data are central to equity analysis, the lack of sufficient transit data limits the number of cases available for analysis, ranging from 25 cases (for the analysis of household income) to 27 cases (vehicle availability).

Evaluating accessibility by household income presents a challenge because the “cost of living” varies substantially by metropolitan region; a $50,000 annual income means something very different to a household in New York than it does to a household in Des Moines. This study’s approach is to divide all households of a region into three categories of “Low,” “Medium,” and “High,” with each category containing about one-third of the households in a metropolitan region. The three categories are defined on a relative basis with respect to a particular region’s income distribution. Under this relative approach to defining income categories, the cutoff values between categories must go up as the average, or median, income in a region increases, on the assumption that the resources necessary to participate in that region’s social life increase as well. This approach facilitates comparison of social groups on income within a metropolitan region, but the categories themselves are not strictly comparable across metropolitan regions. Table 4-2 provides the income groupings for the metropolitan regions.

Table 4-2

Definition of Low-, Medium-, and High-Income, by Income Category, by Metropolitan Region

Region \ Income Category	<$10,000	$10,000 $14,999	$15,000 $29,999	$30,000 $39,999	$40,000 $49,999	$50,000 $59,999	$60,000 $74,999	$75,000 $99,999	$100,000 $124,999	>$125,000
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
San Francisco	4	7	18	26	35	44	56	71	81	100
Boston	8	13	27	36	45	54	65	79	87	100
Chicago	5	8	22	33	44	54	67	81	89	100
Philadelphia	5	9	23	34	45	54	67	81	89	100
Atlanta	6	10	25	36	46	56	68	82	89	100
Minneapolis-St. Paul	5	10	25	36	46	56	69	83	90	100
Denver	6	10	26	37	48	58	70	83	90	100
Seattle	6	11	27	38	49	59	71	85	91	100
New York	10	16	31	40	49	57	68	80	87	100
Detroit	8	13	29	40	50	59	70	83	91	100
Baltimore	9	13	29	41	51	60	72	84	91	100
Dallas	7	11	29	41	52	61	72	84	90	100
Los Angeles	9	15	33	44	54	62	73	84	90	100
Houston	9	14	33	45	55	63	74	85	91	100
Richmond	8	12	30	42	53	63	75	87	93	100
Portland	7	12	29	41	53	63	75	87	93	100
Charlotte	7	12	30	42	54	64	75	87	92	100
Cincinnati	8	14	32	44	55	64	76	87	93	100
Columbus	8	13	31	44	55	64	76	87	93	100
Las Vegas	7	12	31	44	56	66	77	88	94	100
Cleveland	9	15	35	47	58	67	78	88	94	100
Kansas City	8	14	33	46	57	67	78	89	94	100
Memphis	11	17	37	49	60	68	79	89	94	100
Virginia Beach	8	14	33	47	58	69	80	90	95	100
Tucson	10	17	40	54	65	73	82	91	95	100

Note: Purple indicates low-income households; light red indicates medium-income households; brown indicates high-income households. Percentages represent the share of households with an annual income of less than the upper bound of the corresponding income category. Groupings aim for the nearest cut points for 33.3% and 66.7%.

FEDERAL TRANSIT ADMINISTRATION

Accessibility Equity, Vehicle Availability, and Residential Location

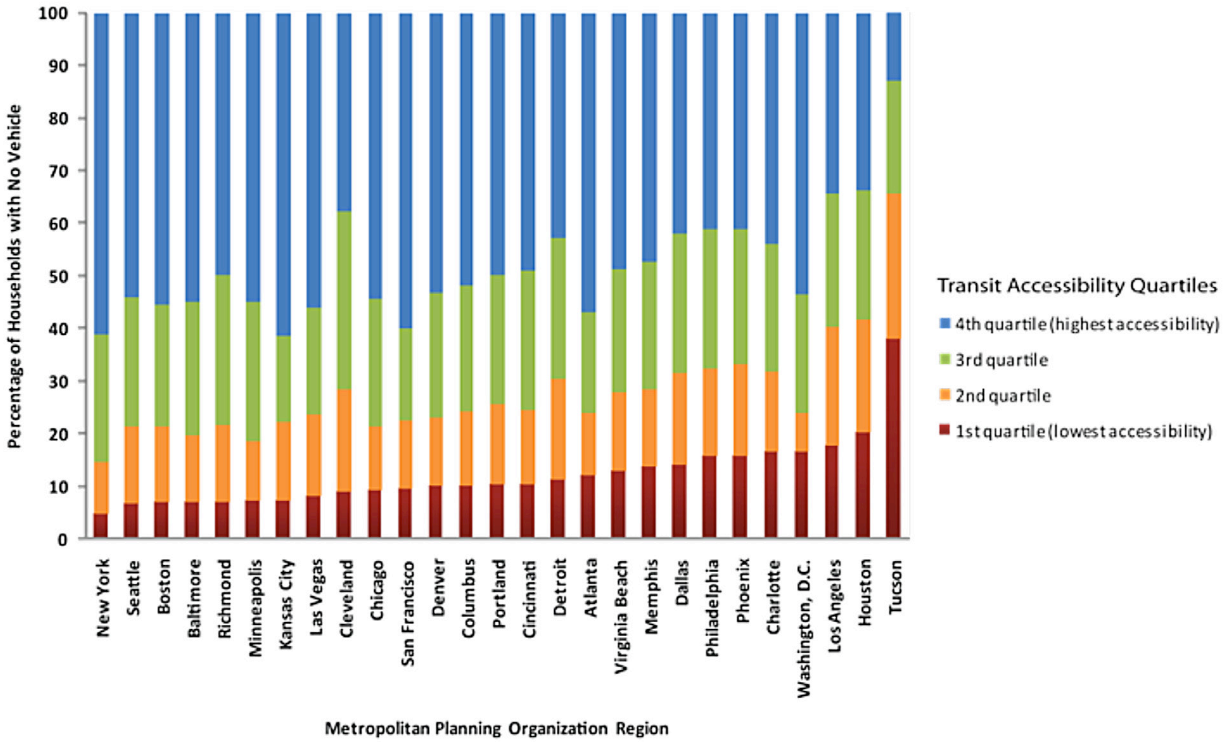
Lack of access to a private vehicle in a metropolis of the United States constitutes a severe accessibility disadvantage relative to those with cars [30, 43]. This section evaluates the degree to which "transit-dependent" households—including all persons who live in a household with no private vehicle available—experience accessibility compared to their counterparts who can drive.

Three main factors contribute to the equity of the accessibility distribution among a metropolitan region's residents. First, regions where transit accessibility is high relative to automobile accessibility will be more equitable than others. Second, regions with a small share of transit-dependent residents will be more equitable than regions with large shares of transit-dependent residents. Having access to a car is an advantage even in regions with exceptionally high transit accessibility. Finally, a region will be more equitable if a larger share of transit-dependent people is capable of living in zones where transit accessibility is high. Under this approach, land-use regulations and housing policies might contribute to improving transportation equity by relaxing restrictions on where people live.

This section focuses on the locational factor. Dependence on public transit usually constitutes an accessibility disadvantage; dependence on public transit while living where transit accessibility is low is a double burden. In this regard, Figure 4-1 shows the metropolitan regions sorted in increasing order of the share of transit-dependent households residing in the highest transit accessibility quartile. New York performs best on allowing transit-dependent households to avoid living where transit accessibility is lowest, with only about four percent of households with no vehicle available living in the lowest transit accessibility quartile. By contrast, in Tucson, one in five transit-dependent households resides in zones of the lowest transit accessibility quartile.
Note that the quartiles of transit accessibility are defined internally to each metropolitan area, such that the top quartile of Kansas City (for example) would represent much lower accessibility than the top quartile of New York City. This is to facilitate analysis of the capacity/desire of transit-dependent households to select the transit-accessible areas within their metropolitan region.

Figure 4-1

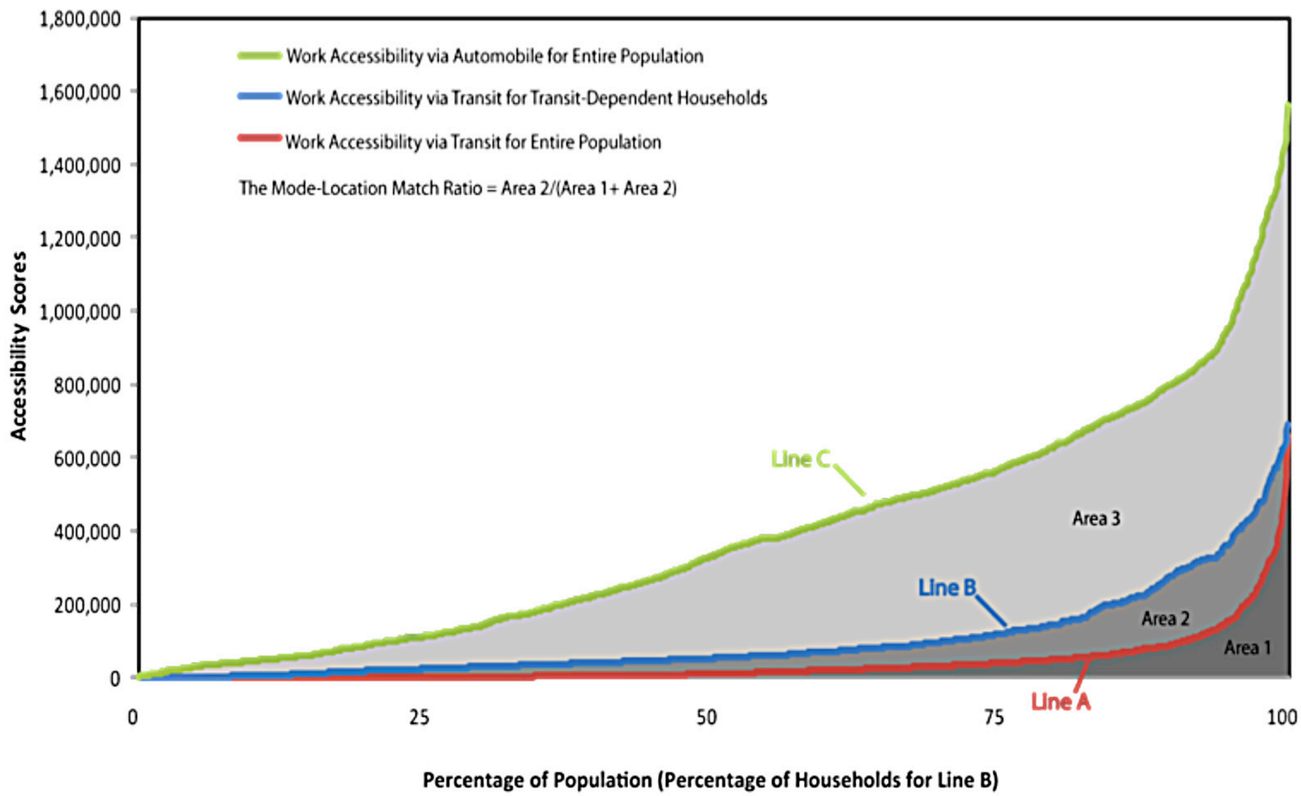
Mode-Location Mismatch: Share of Transit-Dependent Households Residing in Four Transit Accessibility Categories (sorted in increasing order on the lowest transit accessibility quartile)



People who are dependent on transit are not evenly distributed in metropolitan space but are typically concentrated near the metropolitan core [30, 44], precisely where transit accessibility tends to be high. To capture this effect—presumably a desirable effect—accessibility distributions of transit-dependent households are compared with those of the entire metropolitan population. Figure 4-2 is an illustration of the approach and compares three distributions of modes on accessibility to work: Line A (shown in red) is the distribution of the entire metropolitan population as it experiences transit accessibility; Line B (blue) is also a distribution of people as they experience transit accessibility, but rather than using the entire population, this distribution is restricted to transit-dependent households (i.e., zero-vehicle households); and Line C (green) is the distribution of the entire metropolitan population as it experiences auto accessibility.

Figure 4-2

Illustration of Mode-Location Match by Gap Analysis



In Figure 4-2, if transit-dependent households were spatially distributed no differently than the general population, Line A and Line B would coincide. But because transit-dependent households tend to live more centrally than the general population, Line B is positioned above Line A, indicating that transit-dependent households experience higher transit accessibility than the population as a whole. The Mode-Location Match Ratio is defined here as Area 2 divided by the sum of Area 1 and Area 2. The larger the gap between Lines A and B, as a proportion of the total area under Line B, the higher the "mode-location match"—or the better the ability of transit-dependent households to locate themselves in zones of high transit accessibility; this represents the gain in accessibility generated by the locational choices of transit-dependent households (compared to transit accessibility of all households in the region).

The cases of New York (Figure 4-3) and Los Angeles (Figure 4-4) are used to illustrate how the Mode-Location Match Ratio can be used to compare metropolitan regions by visual inspection. The gap between the blue line and the red line is much larger in New York (Figure 4-3) than it is in Los Angeles (Figure 4-4), constituting a larger proportion of the total area under the blue line. This larger proportion in New York suggests that transit-dependent households experience higher transit accessibility (relative to all households) in New York than their counterparts in Los Angeles. This result is the combination of two factors: the *desire* of carless households to live in relatively transit-accessible zones within their region, and their *ability* to act on these preferences. The first factor is presumably, in part, a function of the total or relative transit accessibility offered by central zones; the latter would be related to the nature of the housing market—and notably, affordable housing supply—in zones of high relative transit accessibility.

Figure 4-3

Mode-Location Match Gap Analysis (New York)

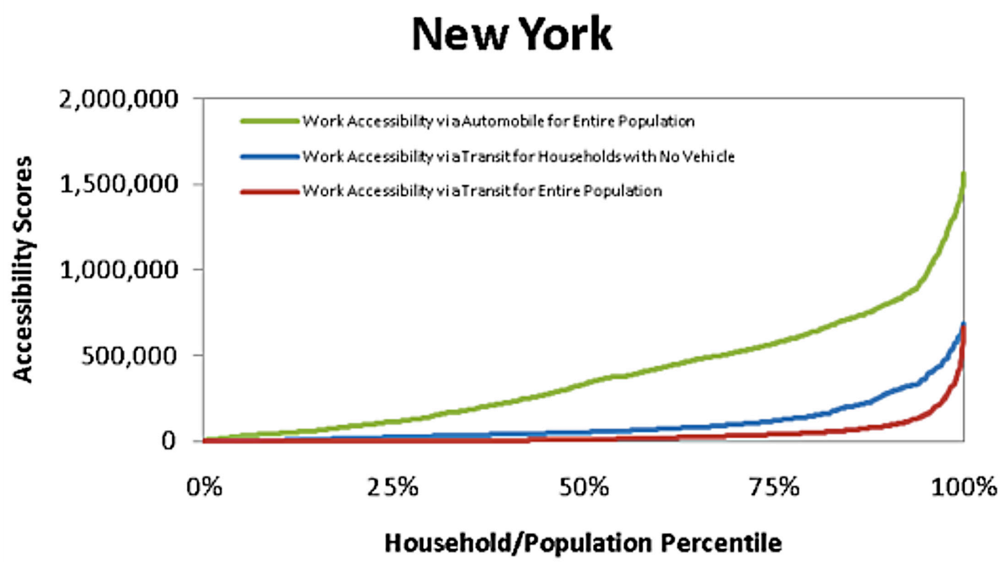


Figure 4-4

Mode-Location Match Gap Analysis (Los Angeles)

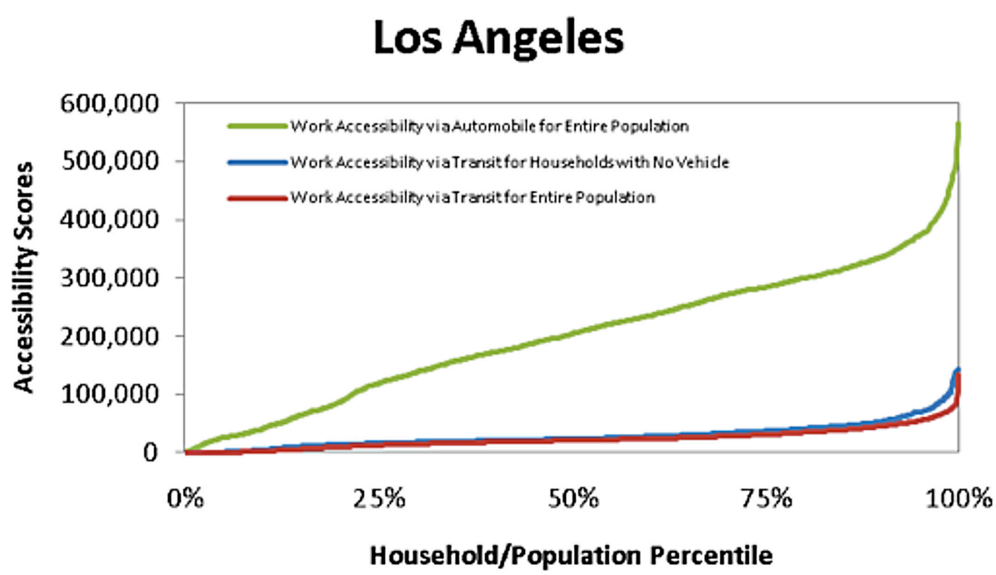
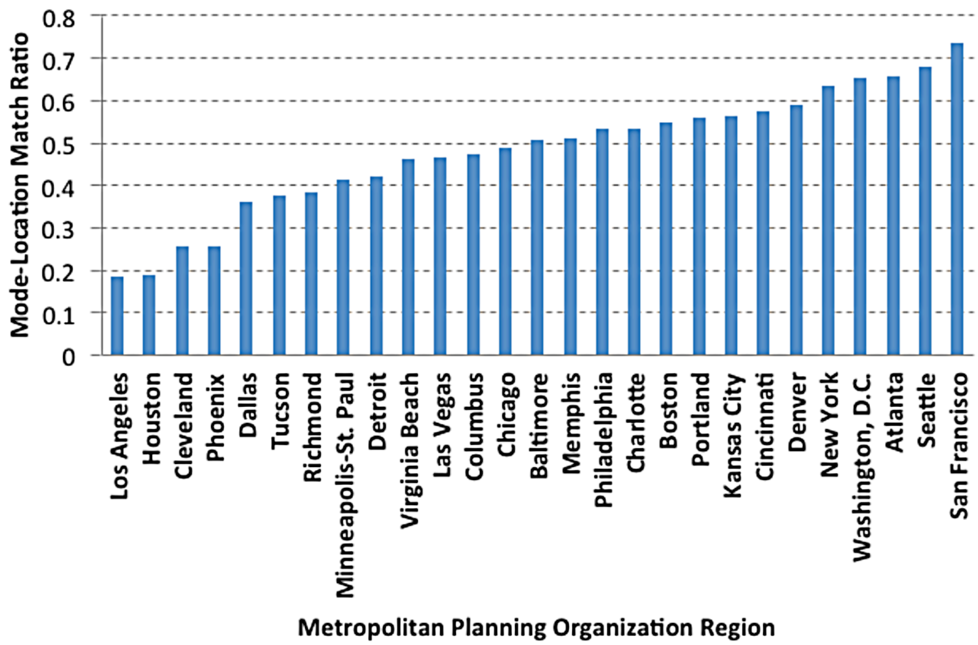


Figure 4-5 summarizes the Mode-Location Match Ratio for 27 metropolitan cases sorted in increasing order. By this measure, regions such as San Francisco and Seattle are performing best in terms of providing the ability of transit-dependent households to locate themselves in zones of high transit accessibility, while regions such as Los Angeles and Houston are performing worse among this set of metros.

Figure 4-5

Intermetropolitan Comparison of the Mode-Location Match Ratio



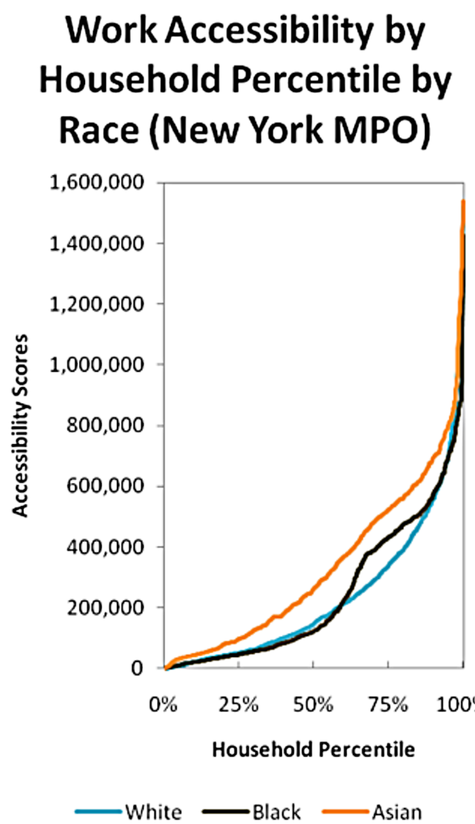
Accessibility Equity and Race

Several dimensions of the accessibility concept used in this study are known to vary considerably by race. Racial minorities tend to own fewer cars and rely more heavily on public transit [45], suggesting a disadvantage in mobility and, by extension, in accessibility. Racial minorities—and in particular, African Americans—are also not evenly spread throughout metropolitan space; they tend to be disproportionately located at the urban core of many metropolitan regions, resulting in part, from exclusionary zoning practices and historical racial discrimination in housing markets [46-49]. Residing in a central position in metropolitan space may be an advantage in accessibility. Whether a locational advantage is enough to offset the mobility disadvantages experienced by racial minorities is an open question. For instance, transit dependency is ordinarily a substantial disadvantage in accessibility. But some metropolitan regions may provide transit service at a level that nearly compensates for this disadvantage. Or, some metropolitan regions may offer more flexibility in where racial minorities are capable of, or comfortable with, living, thus allowing people in need of good transit service the option of living in accessibility-rich places. This section aims to identify the combinations of land-use forms and transportation infrastructure that may be associated with benefits for racial minorities in accessibility terms.

Analysis of accessibility by race can be carried out for any census-defined groupings by race. This section illustrates an approach by using only the three groups of Asian, black, and white. Figure 4-6 shows how the three racial groups compare in the New York region. Asians as a group experience higher accessibility than the other two groups. Blacks and whites are similar through most of the distribution, except for a small segment where blacks are advantaged in the medium to high range of accessibility.

Figure 4-6

Accessibility to Work, by Race, New York



Consider the contrast between the shapes of the two lines for blacks and whites. For white households, the line proceeds in a fairly smooth rise, suggesting that accessibility is evenly spread among whites: about half of whites enjoy high accessibility, and about half of whites experience low accessibility. By contrast, for black households, the line has a small hump in the middle, somewhat in the shape of an "S." Blacks tend to experience either of two extremes in accessibility—either high or low—with little medium-level accessibility in between. The low extreme in accessibility among blacks is likely due to their disproportionate dependence on transit. The high extreme in accessibility among blacks can be explained by their central location.

The case of Los Angeles, shown in Figure 4-7, offers a contrast to that of New York in the comparison of blacks and whites. In Los Angeles, blacks tend to experience higher accessibility than whites through most of the distribution, a pattern that is substantially different than in New York and possibly due in part to the differences in degree of centrality among blacks in Los Angeles compared to New York. The difference in car ownership rates between blacks and whites also probably plays an important role in explaining the variation found in the figures for New York and Los Angeles in the figures above. For example, as shown in Figure 4-8, a substantially larger share of African Americans in Los Angeles lives in households with vehicles available when compared to their counterparts in New York. Furthermore, the gap in vehicle availability between blacks and whites is considerably smaller in Los Angeles than in New York. It is likely that the advantage that black Los Angelinos experience compared to whites, as shown in Figure 4-7, is driven in large part by high black vehicle-availability rates, especially if a large share of metropolitan blacks are living in central locations in Los Angeles.

Figure 4-7

Accessibility to Work, by Race, Los Angeles

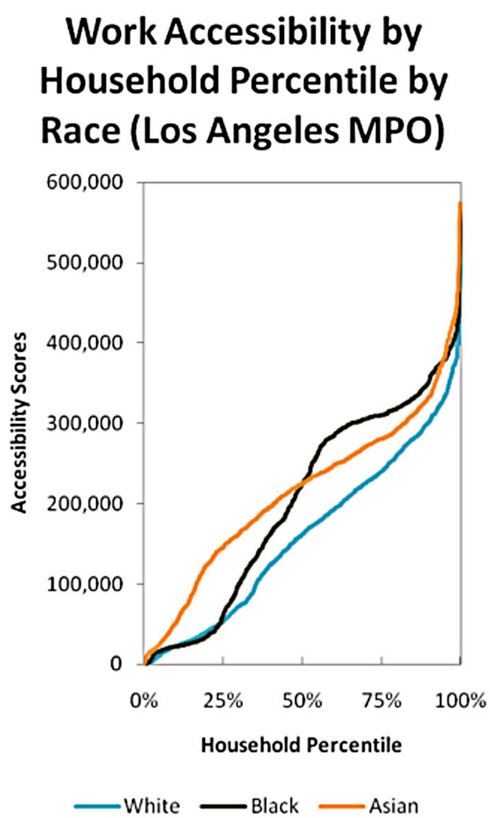
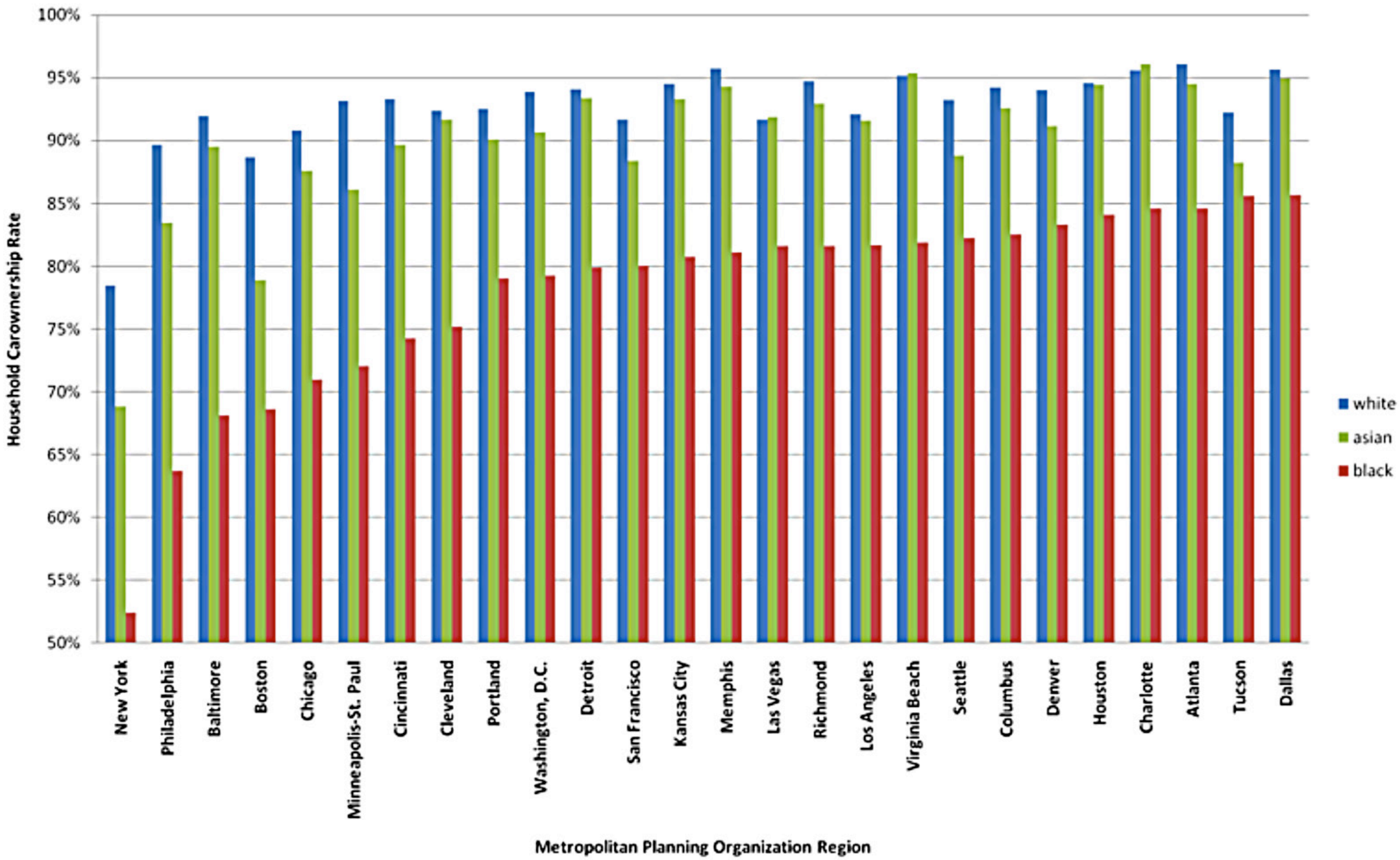


Figure 4-8

Accessibility to Work, by Race, Los Angeles



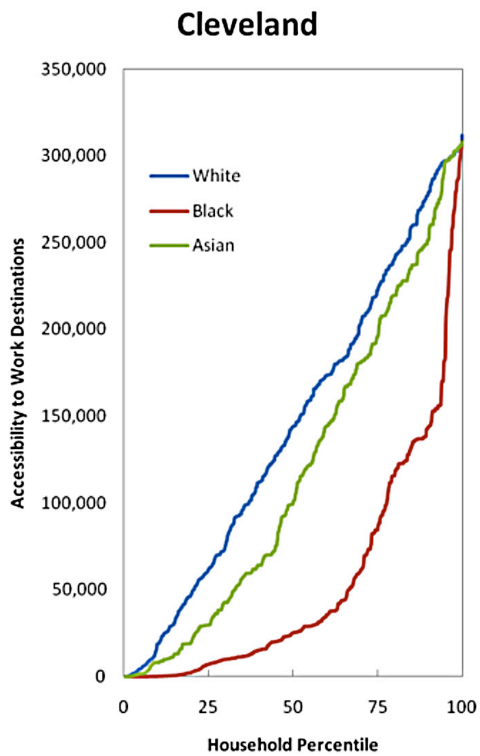
The results show that blacks as a group tend to experience an advantage in accessibility compared to whites, at least for the cases of Los Angeles and New York. This finding may run counter to the expectations of some. Indeed, the conventional understanding in social science literature is that racial minorities are disadvantaged in getting to opportunities in the United States because a growing share of metropolitan destinations are located in distant suburbs while minorities live near the center [13, 50]. Yet, from an accessibility perspective, to be centrally located is to be positioned near a wider range of opportunities than anywhere else in a region.

There are several reasons why measuring accessibility by race would be important, even if the vulnerable group is not found to be disadvantaged. First, taking an accessibility-based approach to equity analysis helps us see that the accessibility that blacks experience tends to result from systematically different reasons than for whites. The analysis suggests that, for some metropolitan regions, the majority of variation in white accessibility is a product of residential location, and a majority of the variation in black accessibility is a product of auto availability. Monitoring changes in such variables are important from a public policy perspective. Second, the finding that blacks are advantaged in Los Angeles and New York is not universal. Several cases noted below show the opposite result, and discovering explanations for these different outcomes would be useful next research steps. Third, the finding is consistent with a central question that motivated this study: Are suburbs a low-accessibility urban form? Whites live disproportionately in low-density communities, and they may be paying a price in the form of low accessibility for doing so, consistent with land-market theories that suggest that some households willingly trade-off higher transportation costs in exchange for larger homes and lots at distant locations [51]. Seen in this way, differences in the matter of choice between blacks and whites are important to recognize in evaluating accessibility outcomes.

In contrast to the findings in Los Angeles in New York, several metropolitan regions reveal patterns of accessibility disadvantage for blacks. For example, Cleveland (Figure 4-9) is an example where African Americans are severely disadvantaged throughout the entire accessibility distribution. Boston and Philadelphia (chart not shown), reveal similar patterns such that the accessibility disadvantage for blacks is not only substantial in magnitude, but also in that the disadvantage runs through the full range of the percentiles. All three of these regions are places with relatively low vehicle-availability rates among blacks (as shown in Figure 4-8), and yet other regions with comparably low vehicle-availability rates among blacks—such as Chicago and Minneapolis-St. Paul—do not reveal an accessibility disadvantage to blacks.

Figure 4-9

Accessibility to Work, by Race, Cleveland

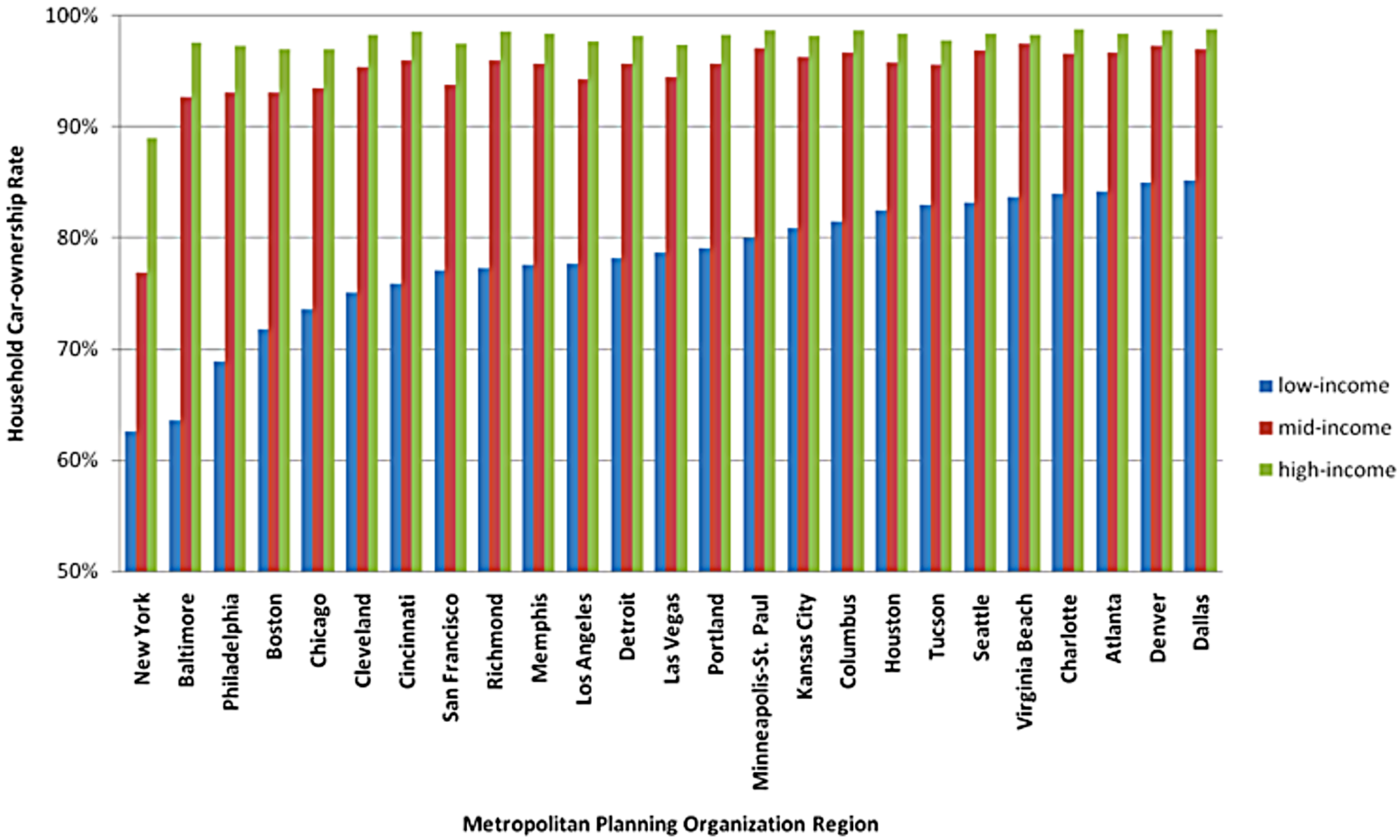


Accessibility Equity and Household Income

Evaluating accessibility in terms of income is important for reasons similar to that of race, since several dimensions of the accessibility concept vary systematically by income, such as automobile ownership and residential location. The analysis by household income proceeds similarly to that of race, except that instead of three racial groups, the three income categories of Low, Medium, and High are analyzed. A key difference among metropolitan regions on equity outcomes by income can be found in the varying rates of vehicle availability. Figure 4-10 illustrates how metropolitan regions vary in the difference between low-income households and high-income households on vehicle availability. For instance, in Dallas, the difference between low-income and high-income households (represented by the blue and green bars, respectively) is much smaller than in Baltimore. Because car ownership plays such a key role in determining accessibility, it is likely that accessibility disparities between low- and high-income households will be more severe in Baltimore than in Dallas.

Figure 4-10

Intermetropolitan Comparison of Vehicle Availability Rates, by Income (sorted in increasing order of the low-income category



A comparison between Baltimore (Figure 4-11) and Dallas (Figure 4-12) reveals a greater disparity between low- and high-income households in Baltimore than in Dallas for the low end of the accessibility range (below the 50th percentile). Low-income households at the low end of the accessibility range are mainly car-owning households located in zones at the periphery of the region and transit-dependent households located anywhere in the region. However, the low-income line crosses the high-income line in both figures. Although low-income households are disadvantaged in the low range of accessibility, at the high end of accessibility it is just the reverse: low-income households are advantaged relative to their high-income counterparts in the high accessibility range. Low-income households at the upper end of the accessibility range are likely car-owning households that experience a location advantage by residing near the center of the region compared to their high-income counterparts.

Figure 4-11

Accessibility to Work, by Household Income, Baltimore

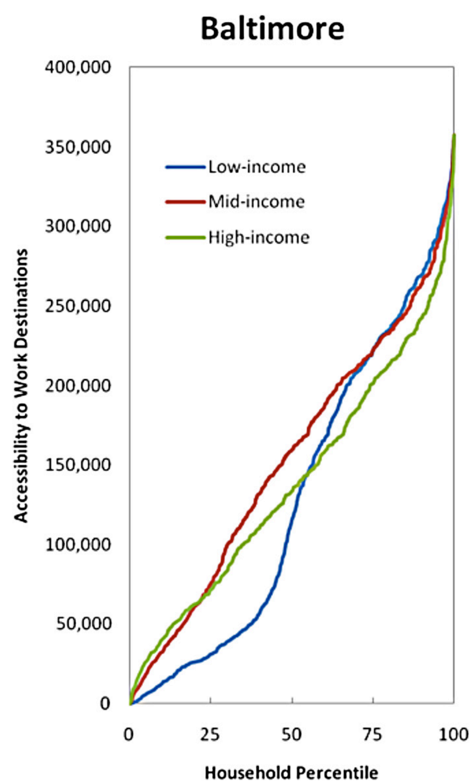
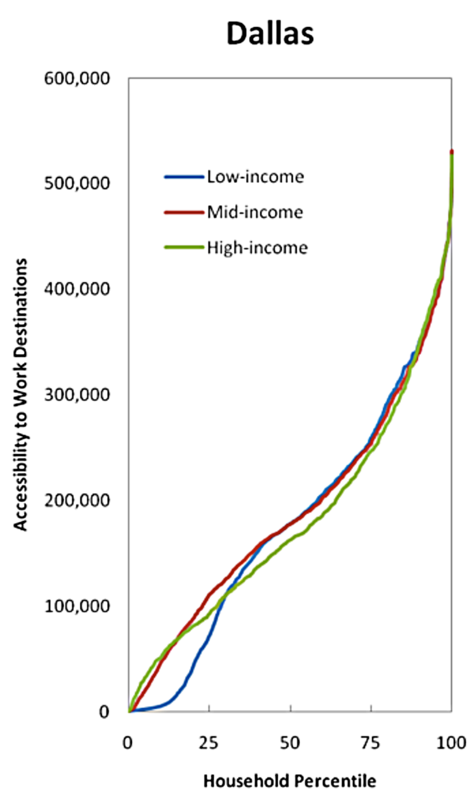


Figure 4-12

Accessibility to Work, by Household Income, Dallas



Most of the metropolitan regions reveal patterns that are largely similar to the cases of Baltimore and Dallas illustrated here. Several cases are notable for unusual patterns (although the figures are not shown here for brevity). First, some metropolitan regions have an unusually high disparity between low-income households and high-income households, including Baltimore, Cincinnati, Los Angeles, Memphis, and Philadelphia. Second, several regions show a distinctly low disparity between low- and high-income households: Atlanta, Chicago, Minneapolis-St. Paul, and Seattle. Finally, although the case of Cleveland in the previous section revealed a dramatic disadvantage of blacks compared to whites, it does not show an unusually high disparity between low- and high-income households, indicating the importance of conducting equity analysis from a variety of perspectives.

SECTION

5

The Special Case of Transit-Dependency in Regional Accessibility

In all regions studied, accessibility via transit fell far short of accessibility via automobile—even for the most transit-accessible zones. Previous studies have revealed that the magnitude of the difference between auto and transit accessibility in many metropolitan regions of the United States is substantial [29, 30, 52, 53]. Because of the central importance of having an auto available, this section focuses on people without the ability to drive a car.

In this section, the accessibility measurements described previously at the level of transportation analysis zones (TAZ) are analyzed jointly with data from household travel surveys specific to a region by geocoding household locations to their respective TAZ and attaching the accessibility attributes of the TAZ to the survey data on the individuals in the household. This enables a more focused analysis of the distribution of accessibility by persons, households, and auto availability.

For this part of the analysis, we examined seven metropolitan regions, listed in Table 5-1, that were chosen in large measure on the basis of data availability, and include Atlanta, Detroit, Los Angeles, San Francisco, Seattle, Tucson, and Washington, DC. These were regions with an MPO that was able to provide data sufficient to calculate auto and transit accessibility to both work and non-work destinations, along with a household travel survey that enabled a linkage between the accessibility characteristics of a zone and the demographic and mode-access characteristics of people. The metropolitan areas are drawn from among the largest 15 metropolitan regions in the United States, with one much smaller region (Tucson) added for comparison. The regions differ in realms relevant to accessibility calculations, including size and density. The regions also represent a geographic range with three in the West, and one each in the Southwest, South, Northeast, and Midwest. In each case, the study area was defined by the boundary of the relevant MPO. This yielded areas of roughly equal size, with the exception of Los Angeles, an enormous MPO that takes up most of southern California. The most recent household travel survey from each of these seven metropolitan regions was used for attributes of individuals, with dates of the surveys shown in Table 5-1.

Table 5-1

Characteristics of the Seven Metropolitan Regions of the Analysis of Transit-Dependency

Metropolitan Region	Population, 2000 (MPO Boundary)	Population Density, 2000 (Urbanized Area, persons/ km^2)	No. of TAZs	Travel Survey Date	Households Surveyed
Los Angeles-Long Beach-Santa Ana, CA	16,406,000	1,970	4,109	2000	16,506
San Francisco-Oakland-San Jose, CA	6,782,000	1,851	1,454	2000	18,068
Washington DC	5,740,000	1,056	1,972	1994	4,865
Detroit, MI	4,810,000	1,040	1,442	2006	4,745
Atlanta, GA	4,226,000	652	2,027	2005	2,249
Seattle, WA	3,258,000	973	938	2001	8,069
Tucson, AZ	830,000	896	859	1999	2,076

We note two observations after matching carless households with zonal accessibility scores. First, many of the households without cars reside in the central city, which tends to be the highest-accessibility territory of a region. For example, the range runs from about 17 percent of region-wide carless households living in the city of Los Angeles to about 29 percent in Seattle. Second, this center-city territory tends to be among the most auto-accessible in the region. In many regions, some of the lowest-accessibility individuals reside on the highest-accessibility territory. Despite our previous findings regarding the importance of proximity for the population as a whole, even the high proximity of the center-city carless population to work and non-work destinations often fails to lift them out of the lowest quartile of accessibility region wide.

To illustrate, Figure 5-1 depicts this phenomenon spatially for the case of Atlanta. The grayscale represents three classes of auto accessibility zones (calculated in this case for non-work accessibility). Where individuals have an automobile available, their accessibility equals that of their zone. Where they do not have a car available for their use, their accessibility is the transit accessibility for the zone. One gauge of inequity in accessibility is the presence of lowest-accessibility people in the highest-accessibility zone, observed as red dots in the dark grey zone. In all cases, the highest-accessibility zones contain carless people, but in some regions (Detroit and Seattle in this study), residence in the highest-accessibility zones is sufficient to keep people out of the bottom quartile of regional accessibility, even if they do not own cars. In others (Atlanta in this study), the highest-accessibility zone contains numerous lowest-accessibility carless individuals.

Figure 5-1

Comparing Individual Accessibility to Zonal Accessibility by Automobile (Non-work Accessibility), Atlanta Region

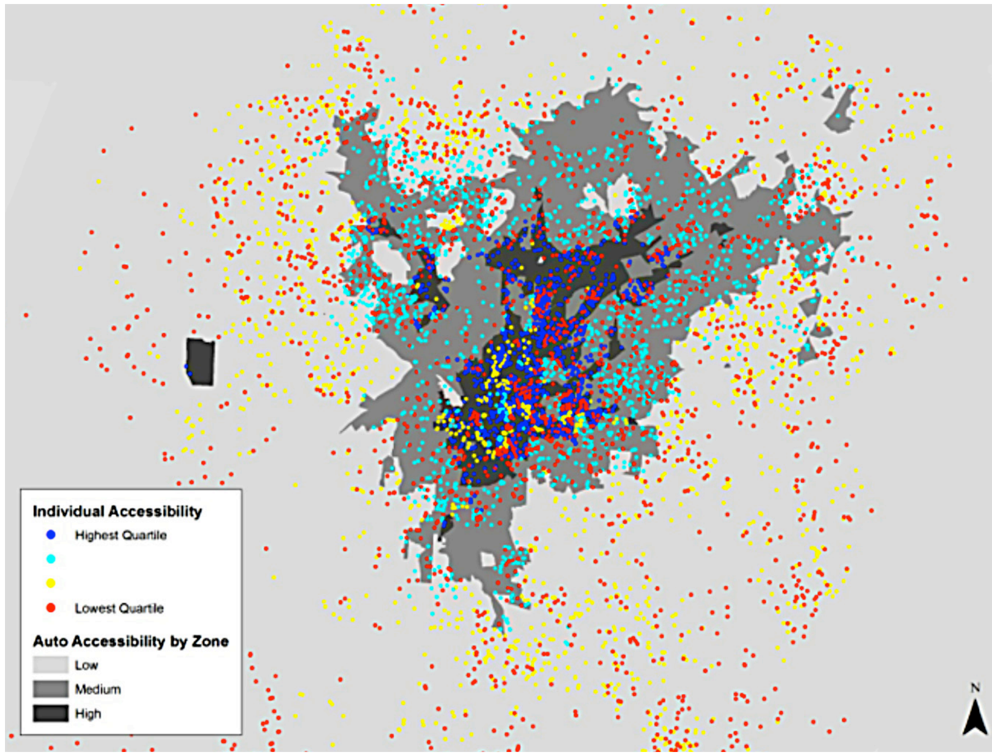


Table 5-2 summarizes the degree to which a metropolitan region achieves an equitable distribution of accessibility across all of the region's survey respondents. We use a Gini coefficient as a measure of this distribution. A Gini coefficient ranges from 0 to 1, with lower values indicating a more equitable distribution of the measured resource (in this case, non-work accessibility) across a population (the sample of individuals). Tucson offers the most equal distribution over all, with Los Angeles a distant second.

Table 5-2

Equity of Distribution of Non-work Accessibility Across Survey Sample

Metropolitan Area	Gini Coefficient of Non work Accessibility Distribution	Share of People in Survey Sample with Auto Availability (%)
Tucson	0.214	84.4
Los Angeles	0.483	80.5
Seattle	0.520	90.0
Atlanta	0.658	86.5
Detroit	0.666	85.8
San Francisco	0.694	87.1
Washington, DC	0.727	87.7

Note: The lower the Gini coefficient, the more equitable the distribution.
Source: Household travel surveys.

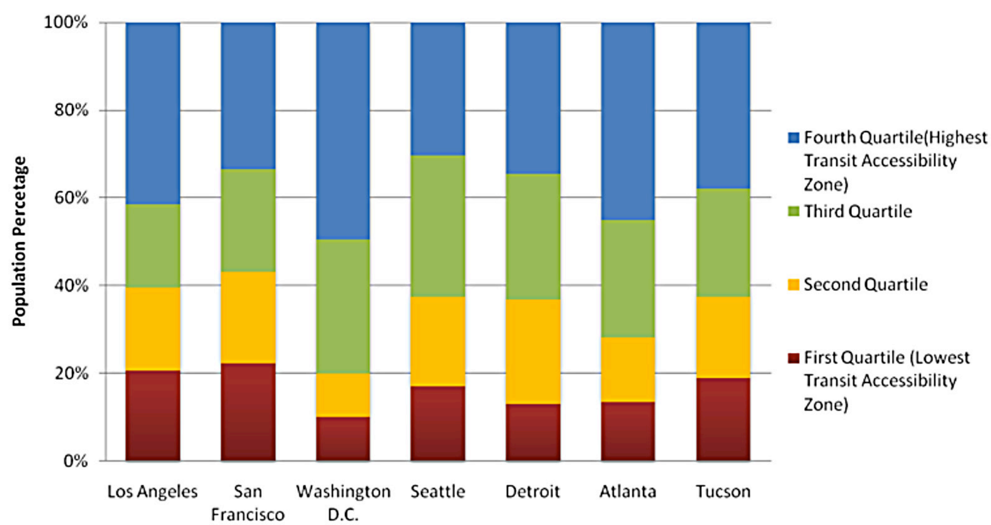
Do Transit-Dependent People Live in Accessibility-Rich Zones?

Regardless of the level of transit accessibility provided in a region, carless individuals can always increase their accessibility by locating in zones of higher transit accessibility. Ideally, the modal disadvantage of the transit-dependent population would be compensated by their location advantage if they reside in zones of exceptionally high transit accessibility. Depending on the level of accessibility provided by the highest-accessibility transit zones, such people may still experience reasonable accessibility relative to the rest of the population. In this way, we might say that their travel modes "match" their home locations. By contrast, for the transit-dependent people who live in low transit accessibility zones, their accessibility would be extremely poor because of both location disadvantage and mode disadvantage. We might say that there is a "mismatch" between their travel mode and their home locations.

For an example of an analytical approach to examining how travel mode relates to spatial location, we plot the severity of this mismatch in Figure 5-2, for the case of older adults age 75 and older. To detect the mismatch problem, all TAZs in each metropolitan area are grouped into four classes based on their non-work accessibility scores by transit. The first quartile class includes the TAZs with transit accessibility lower than 25 percent of the survey sample in a metropolitan region. The quartiles are thus determined internally to a metropolitan region and differ in their levels of accessibility between regions.

Figure 5-2

Figure 5-2 Share of Transit-Dependent People (Age 75+) Living in Four Classes of Transit Accessibility



The mismatch—shown in the figure as the share of older people without cars living in the class of the lowest transit accessibility—is most severe in San Francisco and Los Angeles. In these regions, at least 20 percent of carless older adults reside in areas of the poorest transit accessibility for their regions. Around 40 percent of the carless older-adult population of the California regions live in areas of lower-than-median transit accessibility for their regions. By contrast, fewer than 20 percent of the carless older population of metropolitan Washington, DC live in areas of lower-than-median transit accessibility.

With only seven cases studied, it is beyond the scope of this project to determine the causes of these variations. It may be, however, that the high transit accessibility of Washington, DC both attracts carless populations and enables even those who might be able to afford cars to choose a car-free lifestyle. Furthermore, the fact that the two California regions display the greatest mismatch—carless older adults on low-transit-accessibility territory—may stem from obstacles to relocate to higher accessibility zones that are unique to the situation of California.[4]

[4]One of those obstacles may be the property tax regime put in place in California under Proposition 13, under which property taxes are held relatively constant as long as owners remain in their homes, but are reassessed at the time of sale. For older Californians who have owned homes for many years, a move to a more transit-accessible neighborhood invariably results in a large increase in property taxes paid. In this way, this tax regime may impede locational decisions based on transit accessibility, effectively encouraging carless older adults to remain in areas that are a poor fit for their current transportation capacities.

SECTION 6

Conclusion: Social Equity and Urban-Form Dimensions of Regional Accessibility

This study was designed, in part, to show that intermetropolitan comparisons of accessibility are feasible. The metrics for comparing transportation outcomes between regions presented here stand in contrast to the strictly mobility-based evaluation approaches that typify traditional transportation planning. Accessibility metrics, while increasing in importance in transportation practice and research, are rarely used to compare between metropolitan areas. Intermetropolitan comparisons are key to moving accessibility to a more central position in transportation policy for two main reasons. First, the general public—along with the public officials that serve them—finds comparisons to other metropolitan regions helpful in understanding the outcomes in their home region. Second, intermetropolitan comparison is also central to inferring the determinants of accessibility and accessibility change.

In carrying out this study, we found two key obstacles to conducting intermetropolitan comparison. The first is a lack of data availability and consistency. The principal data sets required for the current analysis are zone-to-zone travel times and travel flows for peak- and off-peak periods by each metropolitan area. Even though these data are developed by virtually all large U.S. metropolitan planning organizations as part of their regional transportation planning process, the data are collected with a hodge-podge of categories and definition. Much of the work of the current study was devoted to resolving intermetropolitan discrepancies in these data sets—a task that necessarily led to a comparison that is less reliable than it might be. Progress in accessibility evaluation will be facilitated by consistent definition of these model outputs across regions, and perhaps even the development of a nationwide repository of this information. This would have precedent in the National Transit Database, (NTD) which requires standardized reporting on the part of transit agencies receiving federal funding—a standardization that facilitates meaningful comparison between agencies.[5]

[5]Transit agencies are required to submit annual reports of their performance to FTA as part of the Uniform System of Accounts to remain eligible for federal funding. Transit agencies are highly diverse—in their size, mission, and technical capacity—and yet they are capable of providing consistent data that meet the same accounting and reporting requirements. More than 660 transit agencies report data on their transit activities each year. The NTD, as the repository for these data, serves as a primary tool for planning, policy, investment decisions, and apportioning FTA funds for transit purposes. By using consistent data standards, the NTD allows transit agencies to compare their performance with peer agencies and to track progress over time.

The second obstacle to intermetropolitan comparison of accessibility is methodological. Whereas in standard transportation planning practice an individual impedance distance-decay function is estimated for each region, this study has relied on a single pooled factor. The approach is both necessary for intermetropolitan comparison and justified as a method, yet there are many approaches to estimating such a factor. Significantly higher or lower factors could not only raise or lower accessibility levels overall, but could alter the ordinal ranking between metropolitan areas.

The study focused substantively on social equity outcomes of regional accessibility. A long history of scholarship that evaluates equity in the delivery of urban services has resulted in highly mixed evidence, with some studies demonstrating that disadvantaged populations receive lower levels of services and others showing the opposite [54-57]. These and other studies make clear that evaluating equity is a highly complex exercise and the technical problems are severe.

Rarely is the concept of equity easily defined; it is highly contingent on a variety of factors. The best studies of equity in urban service provision use multiple indicators [58, 59]. One approach to evaluating equity is to describe patterns using a variety of measures across multiple dimensions, and then to test them against multiple evaluation criteria [55].

The analysis presented here has demonstrated that accessibility can be evaluated across multiple dimensions. Using three dimensions—vehicle availability, race, and income—patterns in the distribution of accessibility are described across metropolitan space. These patterns can be compared among metropolitan regions which, in this case, were done primarily by visual inspection of charted data. With some exceptions, there are few common outcomes running across all three dimensions. Notable exceptions are Boston, Cleveland, and Philadelphia, all of which suggest disadvantages in accessibility to work to work for African Americans and low-income households.

The concept of accessibility offers important insights into questions of social equity in transportation. In particular, the concept underscores the importance of residential location in a determining a household's ability to access opportunities. Transportation planners have typically focused on providing effective transportation infrastructure and services, essentially determining the spatial distribution of auto and transit accessibility. This study shows that even given a particular distribution of auto and transit accessibility, the location of carless people still matters. The ability of transit-dependent households to locate in transit-rich zones varies substantially from one region to the next, as this study has demonstrated by developing the Mode-Location Match Ratio. This and other indicators developed in this study can assist in the evaluation of transportation policy by tracking the distribution of transportation equity over time and by comparing between regions, as demonstrated here.

This study also aimed to demonstrate the relevance of accessibility metrics—and, more broadly, transportation policy focused on accessibility promotion—to urban planning practice, particularly as such practice shapes urban form. Ultimately, reform of transportation planning towards an accessibility-oriented practice is about getting more of what people want out of transportation. This accessibility-based perspective brings transportation planning practice in line with transportation research that finds that the demand for travel is derived from the demand for reaching destinations. A shift from mobility-based to accessibility-based practice holds the promise of altering the tradeoffs that have gripped the transportation field for years, whereby the multiple goals of mobility, environment, and social justice are viewed as being in competition. With compact metropolitan regions being associated with both lower VMT and higher accessibility [12, 60], transportation and land-use policy may be able to promote these multiple goals simultaneously.

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