METROPOLITAN ACCESSIBILITY AND INTERMETROPOLITAN COMPARISON: INDICATORS FOR POLICY REFORM

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ABSTRACT

Transportation outcomes have traditionally been evaluated with measures of mobility, including highway level-of-service, travel speeds, and person-hours of delay. This focus on mobility neglects the implications of the consensus view within the field that transportation is consumed not for its own sake, but in order to reach destinations. Viewed in this way, mobility is merely one means to achieving access. Another means is through proximity. Yet mobility and proximity exist in tension with each other, and it is unclear which exerts the larger influence on accessibility. This paper examines accessibility among 38 of the 50 largest metropolitan regions in the United States. By conducting a path analysis, paired comparisons, decomposition of metropolitan accessibility into its constituent parts, this study reveals the determinants that contribute to high overall accessibility at the metropolitan scale. We find that high residential density best explains high metropolitan accessibility, suggesting substantial transportation benefits can be derived through land-use policy.

Keywords: accessibility, proximity, transportation, land use, urban form

ACCESSIBILITY AND MOBILITY IN TRANSPORTATION POLICY

"An experienced Australian traveller once said that on business trips to Australian cities he could reckon to make four meetings in a day," writes Thomson (1977:48). "In Europe he could manage five; in the United States he could manage only three." The reason behind the variations in this traveller's itineraries was not an American propensity for long meetings, or the speed of travel in American cities, which is in any case faster than in Western Europe or Australia (Kenworthy and Laube 2002). Instead, his schedules were determined by the great distances—and hence long travel times—separating his business contacts in metropolitan areas of the United States. What the traveller wanted was interaction in the form of personal contact with the people with whom he did business. The speed with which he was able to travel was relatively unimportant to him; much more central was the amount of interaction he could accomplish in a given time.

This traveller was unwittingly expressing a view of transportation policy based in accessibility, in contrast to the mobility-centred view so dominantly reflected 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 (Ewing 1995). Common indicators include delay per capita, dollars wasted while waiting in traffic (Schrank and Lomax 2007) and highway level-of-service (U.S. Department of Transportation 2002; Transportation Research Board 1994; Edwards 1992). This 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 (Schrank and Lomax 2007) 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 as definitive success.

These mobility-based evaluations suffer from a distinct logical flaw. Pursuit of congestion relief through added transportation capacity can induce destinations to move farther and farther apart (Transportation Research Board, 1995). A paradox can thus arise: increased mobility can be associated, over the long run, with more time and money spent in travel, rather than less. Travel to more remote shopping or work locations might be accomplished at a high speed, but the spread of these destinations can demand more travel than in more compact and clustered urban arrangements in which travel is slower.

An axiom of modern transportation planning is the notion that transportation is a "derived demand" (Meyer and Miller 2001; Stopher and Meyburg 1975; Morlok 1978); that is, people rarely consume transportation for the pleasure of movement per se, but rather travel in order to reach opportunities available at destinations. Thus the direct demand for access drives the derived demand for mobility.

If travellers do not consume transportation for its own sake but in order to access destinations, then policies that lead to increased costs per destination would be counterproductive because they would leave the travellers with less time and fewer resources to spend at their destinations. This formulation implies a rejection of "mobility" or congestion relief per se as an independent goal for transportation policy. The goal is more properly specified as accessibility, which has been defined as the "potential of opportunities for interaction" (Hansen 1959, 79) or the "ease of reaching places" (Cervero 1996, 1). Mobility is properly seen as one means to accessibility; other means would include remote connectivity (e.g., via Internet or other electronic means), and proximity (Figure 1).

But mobility and proximity exist in tension with each other: places with many origins and destinations near one other tend to be places where surface transportation is slow; conversely, areas of rapid surface travel tend to be areas where origins and destinations are more spread. It is thus not immediately apparent which urban forms offer higher accessibility: areas of rapid surface travel and low densities, or areas of high densities but slower travel. Accessibility impacts would be the result of the net effect of speed and distance change as one moves from one urban form to the other.

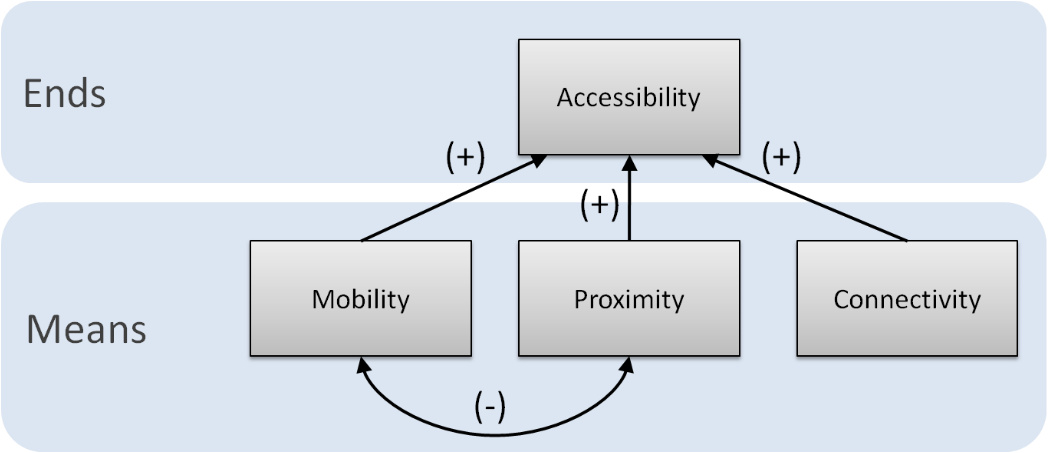

Figure 1: Relationships among mobility, proximity, connectivity, and accessibility

Nearly all empirical research on accessibility has been focused on case studies of single metropolitan regions. This paper seeks to support policy reform by developing and estimating measures of accessibility that enable a meaningful comparison between multiple metropolitan areas of the United States. The indicators, which can be analyzed both within and between regions can help gauge the progress of policy on infrastructure and the built environment toward environmental sustainability.

URBAN DENSITY AND AUTO USE

U.S. Metropolitan Areas are notable both for their low average densities and for their high auto use. For example the, densest U.S. urbanized area, Los Angeles, ranks 125th in density in the list of the 150 largest metropolitan areas of the world, less than half the density of London (Demographia 2009). And U.S. metropolitan car use is approximately 2.5 times greater than that of European cities on a per capita basis (Lyons et al 2003). Nevertheless, significant variation in both metropolitan densities and auto use per capita are observed in U.S. metropolitan areas. For example, daily vehicle kilometers travelled (VKT) per capita ranges from a low of 26 in metropolitan New York to a high of 63 in the Houston region (Figure 2). To people familiar with U.S. cities, the forces behind the auto-use gap between these locations will seem clear: New York is an older, denser, transit-oriented metropolis, while Houston is an exemplar of low-density auto-oriented urban form.

Other comparisons are more surprising. For example, Phoenix and Las Vegas generally score highly on sprawl rankings, (Galster et al. 2001; Glaeser, Kahn, and Chu 2001) yet show relatively moderate VKT per capita. Figure 2 explains this in terms overall urban densities: notwithstanding Las Vegas' sprawling urban form, it is in fact a higher-density urbanized area even than metropolitan New York, and shows a concomitantly low VKT. That Las Vegas and Los Angeles are among the highest-density urbanized areas in the United States will surprise many observers who might expect that the older cities of the Northeast to fit that description. The apparent paradox is resolved through the distinction between average and peak densities: at their centers, New York and Chicago are far denser than Las Vegas or Los Angeles. But a majority of metropolitan U.S. residents—and a large majority of U.S. metropolitan territory—are found in the suburbs. Hence suburban densities have greater weight in overall urbanized area statistics than those of downtowns. Physical constraints and water availability restrict the outward spread of a number of cities in the Southwest, leading to high overall suburban densities, and thus high metropolitan densities overall.

A negative relationship between metropolitan densities and VKT per capita has been demonstrated globally (Lyons et al 2003); Figure 2 suggests that a version of this relationship also holds internally to the U.S. context. Yet Figure 2 leaves unexplored the relationship of density to accessibility. With its low population density and high car use, does Atlanta offer its residents higher or lower accessibility than do New York, Los Angeles, or Las Vegas? It may be the case that Atlanta's higher daily VKT per capita supports a high-accessibility lifestyle in which people are able to interact with a large number of destinations daily. Alternatively, high levels of auto use may simply be the product of people trying to accomplish a set of daily activities comparable to that of other regions.

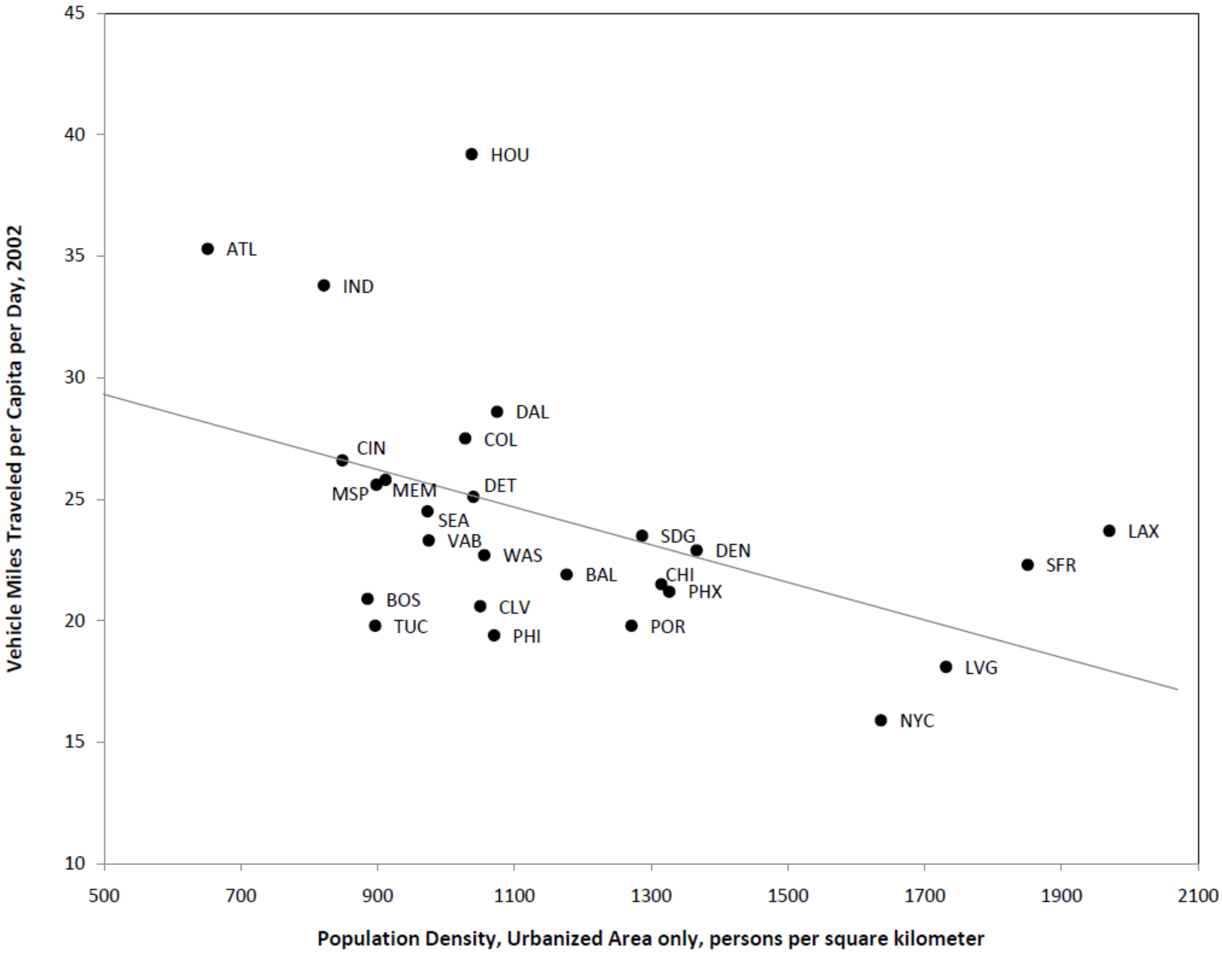

Figure 2: Vehicle Travel and Highway Provision, 30 Most Populous U.S. Urbanized Areas, 2002 (*abbreviation key provided in Table 1*)

THE GRAVITY APPROACH TO ACCESSIBILITY AND PROXIMITY MEASUREMENT

This study bases its accessibility metrics in the gravity model (Isard 1960; Wilson 1971), a powerful conceptual tool because it simultaneously accounts for both the transportation network and its surrounding land-use conditions (Handy and Niemeier 1997). Measures of accessibility derived from a gravity model are commonly used by urban planning scholars to evaluate the relative ease of reaching jobs in a metropolitan region

(Cervero, Rood, and Appleyard 1999; Grengs 2009; Shen 2001). We use a common form of the gravity model proposed by Hansen (1959), as follows:

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

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. 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, and T_{ij} is the travel time between zones i and j. 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. In order 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 chose the unitary β option. 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.

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 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 in order 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.

The measurement of proximity in this study is also derived from the gravity-based formula of equation (1), except for a change in the parameter of the composite impedance function $F(c_{ij})$. In the proximity measurement, the term is equal to $\exp(-\beta D_{ij})$, where *exp* and β are still the same parameters as defined above, while D_{ij} is the Euclidean distance between zones i and j.

METROPOLITAN CASES AND DATA SOURCES

Metropolitan areas included in the current study are 38 metropolitan areas among the largest 50 regions throughout the United States for whom sufficient data on transportation conditions could be collected. Regions included are listed in Table 1. Each region was defined by the boundaries of its relevant Metropolitan Planning Organization (MPO). The most important data item is travel demand modelling data, collected from the MPO. These data contain matrices of interactions between all Traffic Analysis Zones (TAZs) in the region, including travel times and the number of trips between zones. The TAZ is the primary geographic unit of transportation modelling, and each of our metropolitan areas is divided up into these zones, with approximately one to five thousand zones per region. The zonal interactions are provided in several levels of detail, by travel mode (auto and transit), by time period (during congested peak period conditions and less congested off-peak conditions), and by trip purpose (home-based work and home-based nonwork). Travel demand modelling data employed were the latest available. These varied by MPO, depending on when their regional travel models were last calibrated and ranged from 2000 to 2009.

We purchased data on business establishments from the private vendor Claritas, Inc. (Claritas 2002). These data are collected 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. Business establishments include the number of jobs at a location in 2007, and codes from the North American Industry Classification System (NAICS) allowing us to identify businesses by industry type. We geocoded establishments to the street-address level, and then aggregated the number of jobs by TAZ.

We also collected data on population at the block group level from the 2000 Census of Population and Housing, Summary Files 1 and 3 (U.S. Bureau of the Census 2002, 2002).

Finally, for auxiliary analysis, we obtained data on VMT, total road miles, and average road speeds of metropolitan regions from the publication of 2009 Urban Mobility Report (Texas Transportation Institute, 2009).

Abbreviation	**Metropolitan Region**	**Metropolitan Population Rank**	**MPO Population**	**MPO Population Density (Persons/Km^2)**
NYC	New York-Newark, NY	1	20,974,165	1,636.11
LAX	Los Angeles-Long Beach-Santa Ana, CA	2	16,406,257	1,970.12
CHI	Chicago, IL	3	9,992,488	1,315.88
SF	San Francisco-Oakland-San Jose, CA	6	6,781,705	1,850.56
DC/WAS	Washington D.C.	9	5,739,833	1,055.92
PHI	Philadelphia, PA	5	5,383,397	1,071.07
BAL	Baltimore, MD	17	4,928,768	1,042.95
DAL	Dallas-Fort Worth-Arlington, TX	10	4,883,746	1,076.64
DET	Detroit, MI	8	4,809,619	1,039.86
HOU	Houston, TX	15	4,661,133	1,036.89
BOS	Boston, MA	7	4,299,485	885.36
ATL	Atlanta, GA	12	4,226,157	650.36
SEA	Seattle, WA	14	3,257,550	973.09
PHX	Phoenix-Mesa, AZ	11	3,189,762	1,327.25
SDG	San Diego, CA	13	2,788,097	1,286.95
CIN	Cincinnati, OH--KY--IN	28	2,692,422	848.49
MSP	Minneapolis-St. Paul, MN	16	2,620,705	898.19
DEN	Denver-Aurora, CO	20	2,591,518	1,366.57
CLV	Cleveland, OH	21	2,147,400	1,050.12
ORL	Orlando, FL	33	1,838,210	786.27
POR	Portland, OR	22	1,785,409	1,272.24
CHR	Charlotte, NC--SC	45	1,683,438	555.39
KCY	Kansas City, MO	26	1,636,400	837.29
SAT	San Antonio, TX	29	1,616,126	1,147.82
IND	Indianapolis, IN	31	1,606,810	821.63
VAB	Virginia Beach, VA	24	1,514,981	974.73
COL	Columbus, OH	34	1,442,881	1,028.21
LVG	Las Vegas, NV	27	1,308,654	1,731.20
BUF	Buffalo, NY	36	1,169,758	1,002.69
NSH	Nashville-Davidson, TN	46	1,123,570	636.55
NOL	New Orleans, LA	35	1,082,061	1,743.22
MEM	Memphis, TN--MS--AR	37	1,059,382	940.44
OKC	Oklahoma City, OK	47	990,369	870.98
HRT	Hartford, CT	43	970,483	665.59
LOU	Louisville, KY--IN	42	968,218	845.47
RCH	Richmond, VA	44	948,140	718.53
TUC	Tucson, AZ	48	830,402	896.40
ROC	Rochester, NY	50	822,534	872.87

Table 1: Population and Density of Metropolitan Areas Included in the Study

FINDINGS OF ANALYSIS

1. Density and Accessibility

This paper began by observing that even within the auto-oriented form of the U.S. metropolis, significant variations in both density and in car use exist, with metropolitan density being negatively correlated with daily VMT per capita. A question remains as to how density is related to accessibility. On the one hand, denser regions display greater proximity between origins and destinations than lower-density regions. But if travel speeds in these denser regions is slower than in their lower-density counterparts, the proximity advantage they offer may be eroded or squandered.

There is good reason to focus on speeds as a determinant of accessibility. If we assume uniform metropolitan densities, the number of destinations reachable within r minutes would be a function of the area reachable within that time; if travel were equally in all directions, this would be the area of a circle defined by πr^2. Thus accessibility would increase with the square of speed. By contrast, accessibility would increase only linearly with density. Thus if denser areas reveal slower travel, they may in fact suffer in accessibility terms.

Figure 3 suggests that this is not the case, showing that metropolitan density is positively related to accessibility for the 38 metropolitan regions of this study. These results suggest that the proximity advantage of a denser land-use pattern tends to outweigh any travel-speed disadvantage. To further explore how proximity and speed influence accessibility, we develop a path analysis as illustrated in Figure 4.

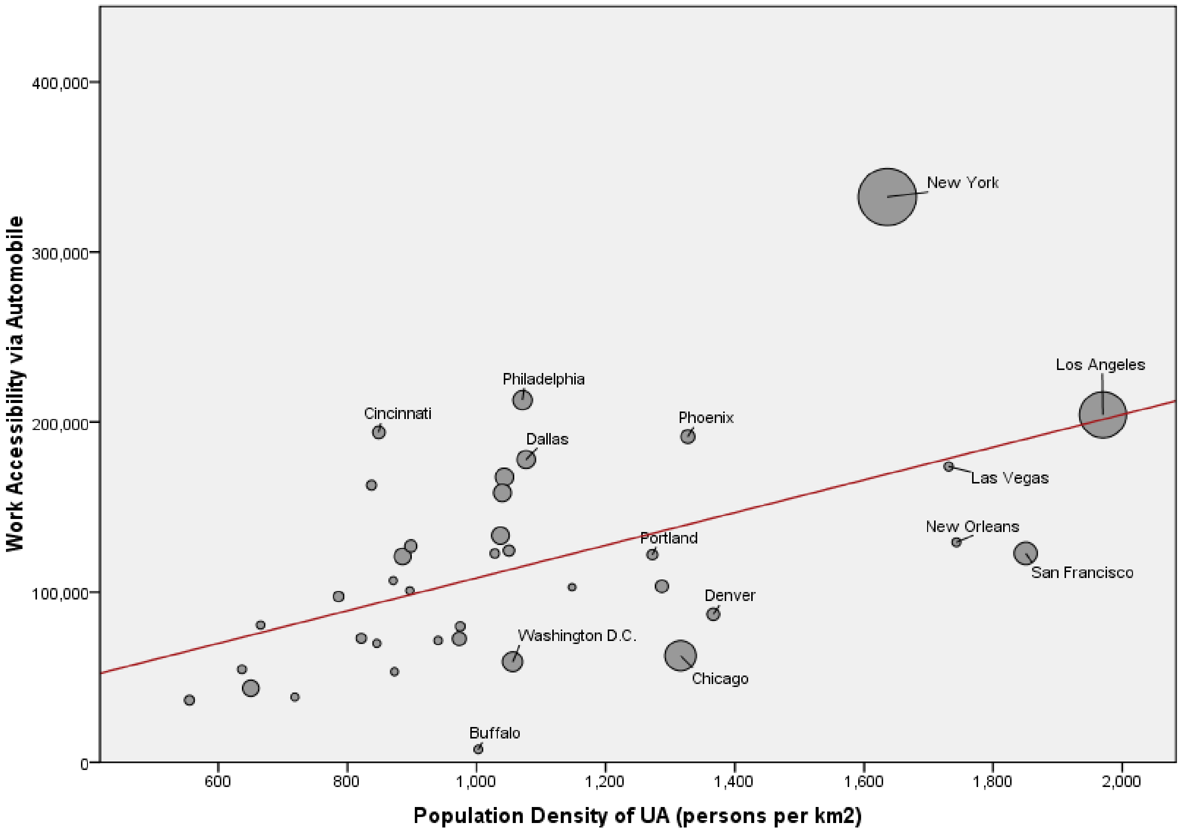

Figure 3: Median Work Accessibility by Auto by Urbanized Area Population Density
(Circle sizes proportionate to metropolitan population)

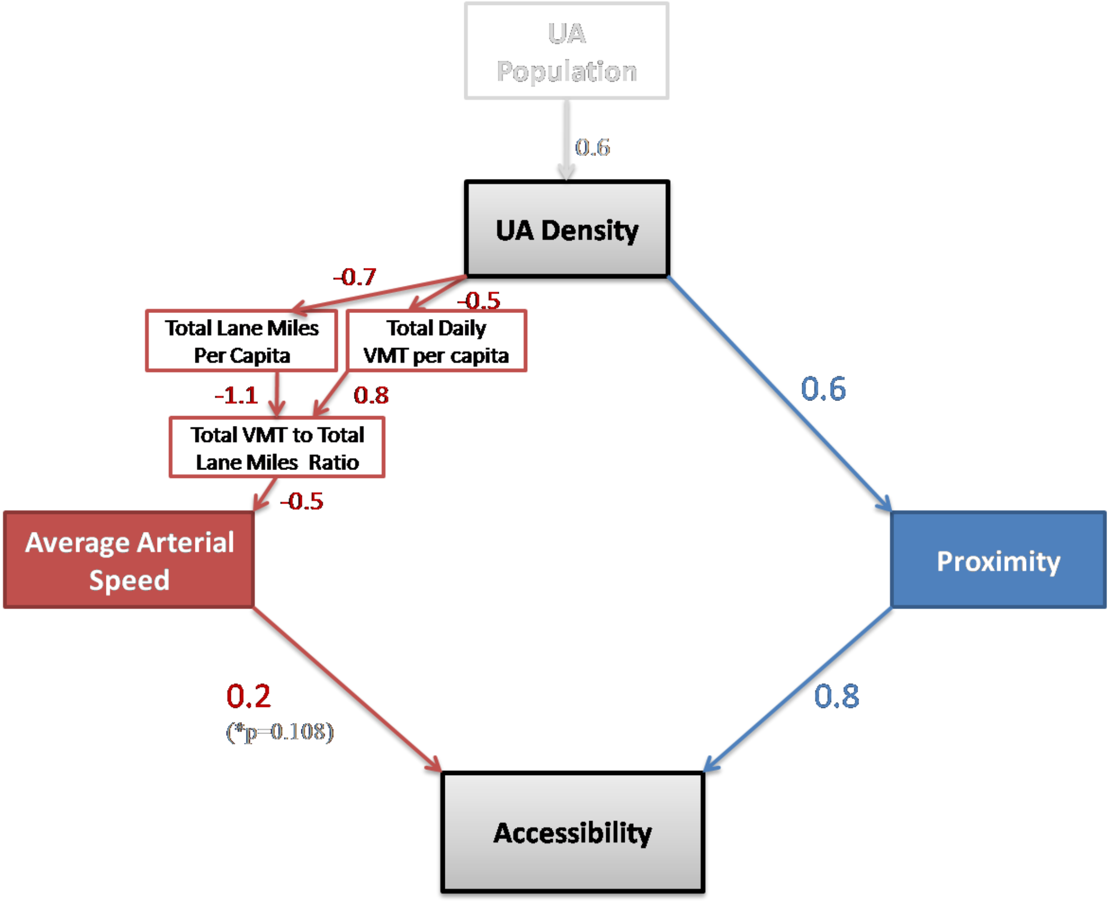

Figure 4: A Path Diagram of Factors Relating to Median Work Accessibility by Auto

The path diagram of Figure 4 represents a series of regression models intended to explain how density influences accessibility at the metropolitan scale. Arrows indicate the direction of causation between variables. The value of each arrow is the standardized coefficient of the independent variable in a regression model. All coefficients shown in Figure 4 are statistically significant at a level of α=0.01 except where noted.

Note that the path diagram of Figure 4 is consistent with the conceptual model presented in Figure 1: both mobility (in terms of speed) and proximity contribute to accessibility. Figure 4 shows that residential density influences both mobility and speed.[1] As shown in the figure, population density affects metropolitan accessibility through two paths. One path is through proximity (the blue path in the figure) such that higher density leads to higher proximity in the region and an increase in accessibility. The causal negative link between density and speed is supported by this empirical analysis. The relationship is based on a negative relationship between density and lane miles per capita; the denser areas are less roadway rich than their higher density counterparts. But this factor is countervailed by the negative association of density and vehicle miles travelled (VMT) per capita: the road-poor denser areas also exhibit less travel. This tends to weaken the relationship between density and the VMT-to-lane miles ratio, and hence the relationship between density and speeds.

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[1] We conducted detailed analysis of various urban form indicators and found that average urbanized-area residential density better predicts metropolitan accessibility than does indicators such as centralization, concentration, and dispersion of population and of employment.

Thus notwithstanding the fact that accessibility tends to increase with the square of speed as discussed above, the proximity route of causation appears to be the stronger of the two. The regression models indicate that the total effect of density on accessibility along this path is 0.48. The second path is through speed (the red path): higher density results in slower travel speeds due to traffic congestion and a decrease in accessibility. Model results along this path indicate that the total effect of density on accessibility is -0.037. Figure 4, in sum, suggests that proximity has a larger effect on accessibility than does speed.

This path diagram suggests an answer to a question posed at the beginning of this paper: do low-density metropolitan areas, with their high car-use per capita, offer a high-accessibility lifestyle? Results presented here show that the opposite is the case: along the path from total daily VMT per capita to accessibility in Figure 4, the total effect is -0.08. This suggests that people living in low-density, high-VMT regions experience lower accessibility overall than people living in denser regions with less car travel. This suggests that the high VMT per capita of the low-density metros are a product of people's efforts at meeting the ordinary needs of an ordinary day.

2. Inter-Metropolitan Comparison of Accessibility

To make comparisons among metropolitan regions requires that we match similar regions. The matching of cases is performed on the basis of two variables that influence accessibility but which are largely unaffected by transportation and land-use policy: metropolitan population and metropolitan shape.

Population size was selected as a classifying variable because larger metropolitan regions offer their residents a greater number of destinations than smaller regions, an effect that would tend to increase accessibility in larger regions. By contrast, larger regions tend to have more roadway traffic congestion, a factor that would tend to lower accessibility. Our clustered comparisons thus grouped metropolitan regions of similar population size.

We also grouped metropolitan regions by shape. Some metropolitan regions are roughly circular, while others are highly irregular, usually a product of physical barriers such as seacoasts, mountains, or bays. Shape would be relevant to accessibility calculations because for a given set or origins and destinations, a circular shape will minimize travel distance (and in all likelihood, time) from all origins to all destinations. Greater deviations from circularity are associated with increasing travel distances for a given set of origins and destinations. Consider, for example, a metropolitan region around a bay, such as San Francisco. Territory that would have been close to the region's core without the physical barrier of the water is uninhabited, a fact that would tend to lower accessibility compared to a more regularly shaped region. For this reason we calculated a shape index as follows. We determined the area of average employment density or greater for each region. The circumference of that area (C_a) was measured and compared to the circumference of a circle enclosing the same area (C_c). The resulting shape index, C_a / C_c, is a measure of the circularity of a region. The statistic ranges between 0 and 1, with higher numbers indicating a more circular region.

Figure 5 shows the metropolitan clusters we derived by plotting population size versus shape.

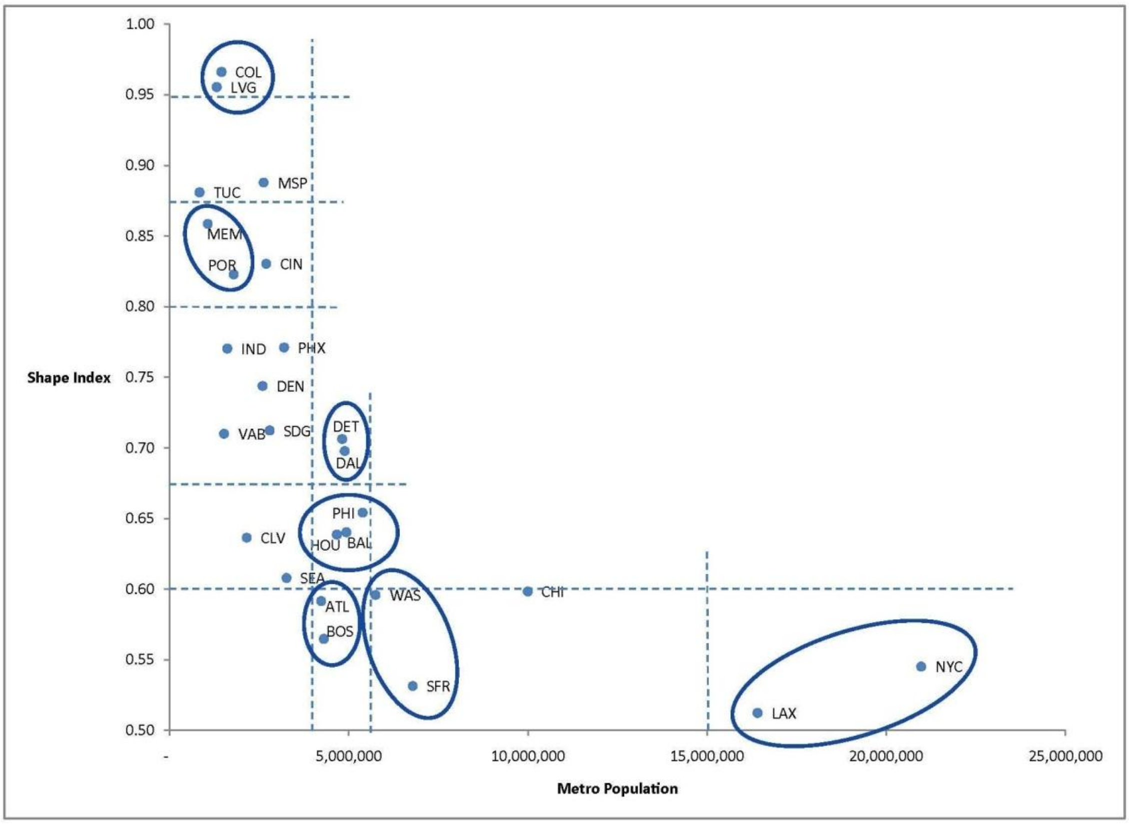

Figure 5: Size and Shape Classification to Determine Comparison Clusters

The following section compares the population distribution of work-based automobile accessibility among these various clusters. Pairs/clusters are identified in Figure 5, and include: New York and Los Angeles; Washington, D.C. and San Francisco; Atlanta and Boston; Philadelphia, Houston, and Baltimore; Detroit and Dallas; Memphis and Portland; and Columbus and Las Vegas. We have compared the population distribution of work-based automobile accessibility among all these various clusters, but for a reasonable length of this paper, we will only present two clusters as a demonstration of our methodology and analysis.

Clustered regions are compared on the basis their population distribution of accessibility. Initially, each TAZ within a metropolitan area was assigned an accessibility score. TAZs vary in population; by assigning the accessibility score to the population residing in the TAZ, we were able to analyze the distribution of work-based auto accessibility across the population as whole. This approach to comparison can be seen in Figure 6 on the next page, which compares the population distribution of work-based auto accessibility between residents of metropolitan Boston and metropolitan Atlanta.

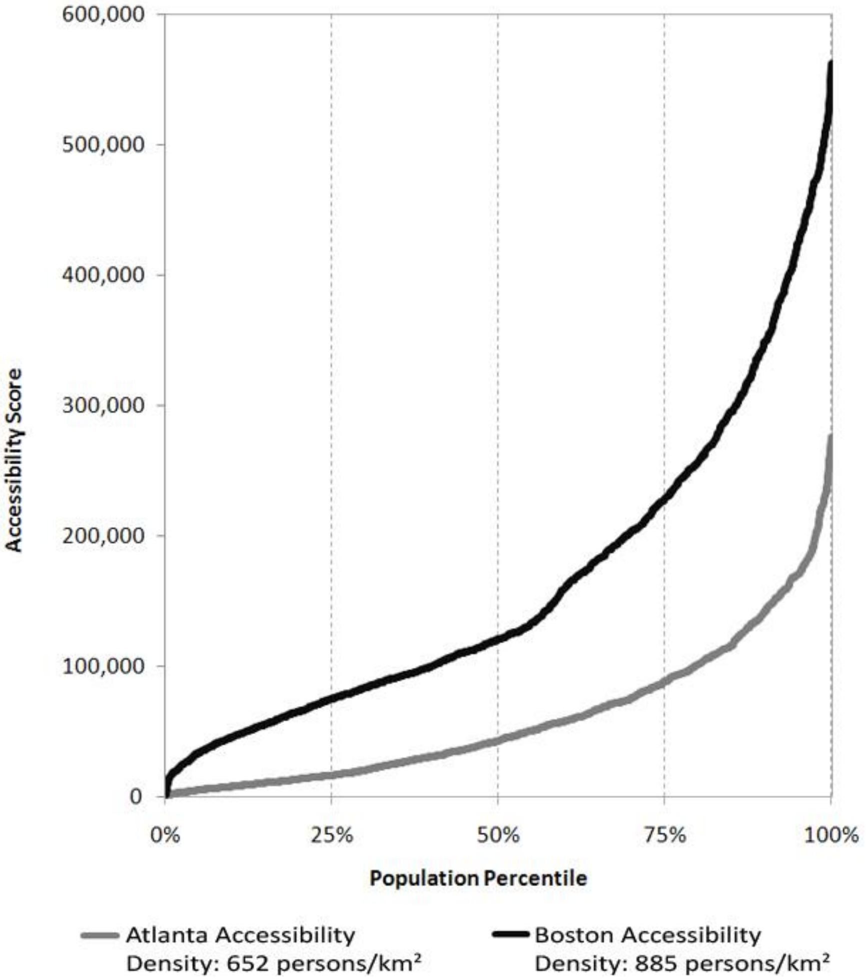

Figure 6: Accessibility Comparison between Atlanta and Boston

The horizontal axis, titled “population percentile” refers to the percentile distribution of accessibility within the population. The 1st percentile individual would be the person who has lower accessibility than 99% of the population (and probably lives in a peripheral area of his or her respective region); the 99th percentile individual enjoys greater accessibility than 99% of the residents of the region, and probably lives at the center. The median (50th percentile) individual probably lives in a close-in suburb; the values for the median resident will be used below to compare accessibility between regions. The vertical axis, labeled “accessibility score” presents the score from equation 1 above. This accessibility score is a ratio variable (thus, for example 400,000 represents twice the accessibility of 200,000), but its units have no direct interpretation.

In this pair, Metropolitan Boston is considerably denser than Atlanta, a metropolitan region of similar size and shape. Predictably, it offers higher accessibility throughout its population distribution (Figure 6). The difference is marked; throughout most of the distribution, Boston offers at least twice the accessibility of Atlanta.

For another comparison, results for the Baltimore-Houston-Philadelphia clustered comparison are much closer (Figure 7). The three are quite closely matched in urbanized-area density. Over nearly the entire population distribution, Philadelphia’s accessibility is greater than that of the other two regions. The curves for Houston and Baltimore cross between the 75th and 80th percentile, indicating Houston's greater accessibility at the high end of the population distribution.

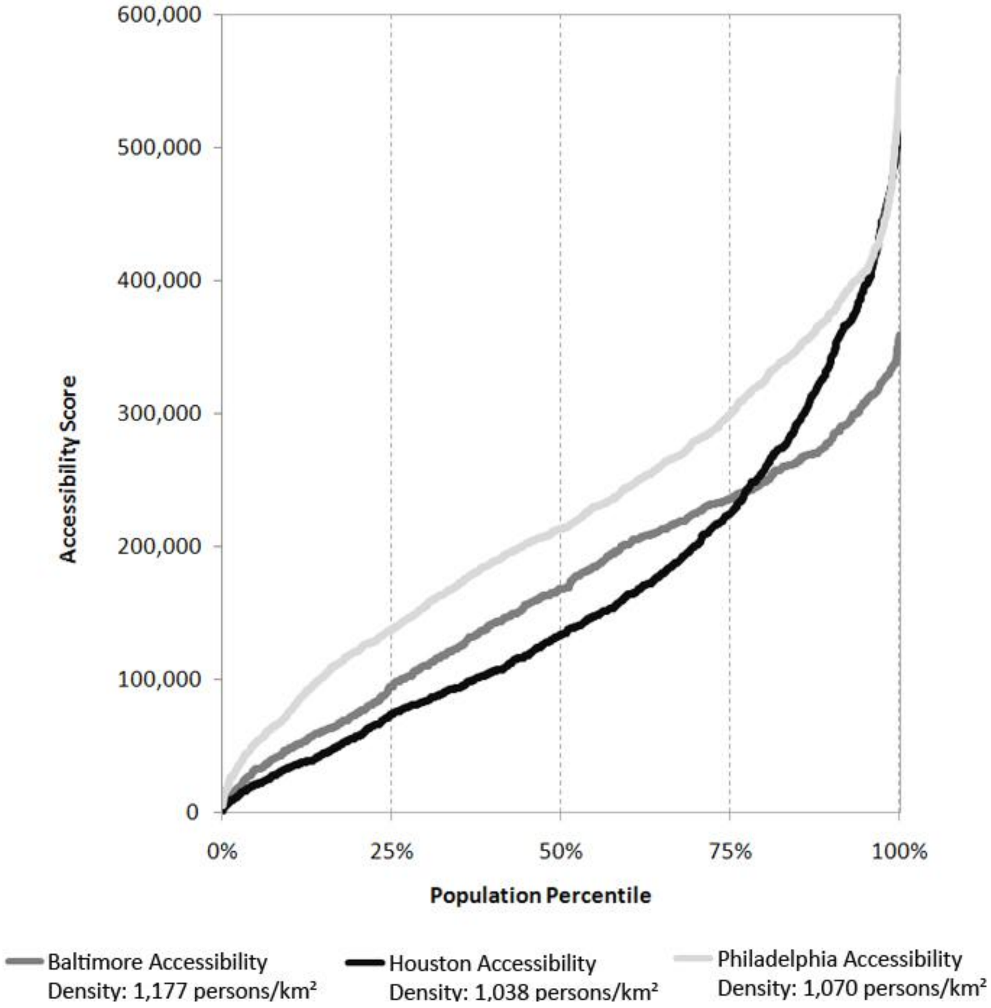

Figure 7: Baltimore-Houston-Philadelphia Accessibility Comparison

3. Decomposition of Inter-Metropolitan Accessibility Differences

In accordance with our conceptual framework that accessibility can be improved through higher speed and proximity (and our findings from the path diagram confirms it), we further conducted an in-depth analysis of our inter-metropolitan comparison of accessibility. Accessibility gaps between metropolitan areas were decomposed into those differences attributable to travel speeds and those due to differences in proximity between populations and their destinations. This is accomplished by transforming the speed distribution of metro "A" into that of metro "B."[2] The difference between the transformed and the original curves represented the speed-related advantage to metro "B." The difference between the distribution for metro "B" and the transformed curve for "A" then represents the proximity-related advantage to metro "B."

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[2] We observed that travel speeds between TAZs within a metro are approximately normally distributed. The transformation was accomplished by taking the z-score of each travel speed in the zone-to-zone trip table from metro A. This z-score was then applied to the mean and standard deviation of speeds from metro B in order to transform the speed distribution of metro A into that of metro B.

Figures 8 and 9 demonstrate this decomposition for the pairs Boston-Atlanta and Philadelphia-Houston. The Atlanta-Boston decomposition (Figure 8) shows that the proximity advantage of Boston dominates the accessibility gap between the two metropolitan areas. Boston holds a slight peak-hour travel-speed advantage over Atlanta throughout most of the population distribution. But from the remote suburbs and increasing toward the central city, Boston offers a considerable proximity advantage, leading to higher work accessibility by car overall.

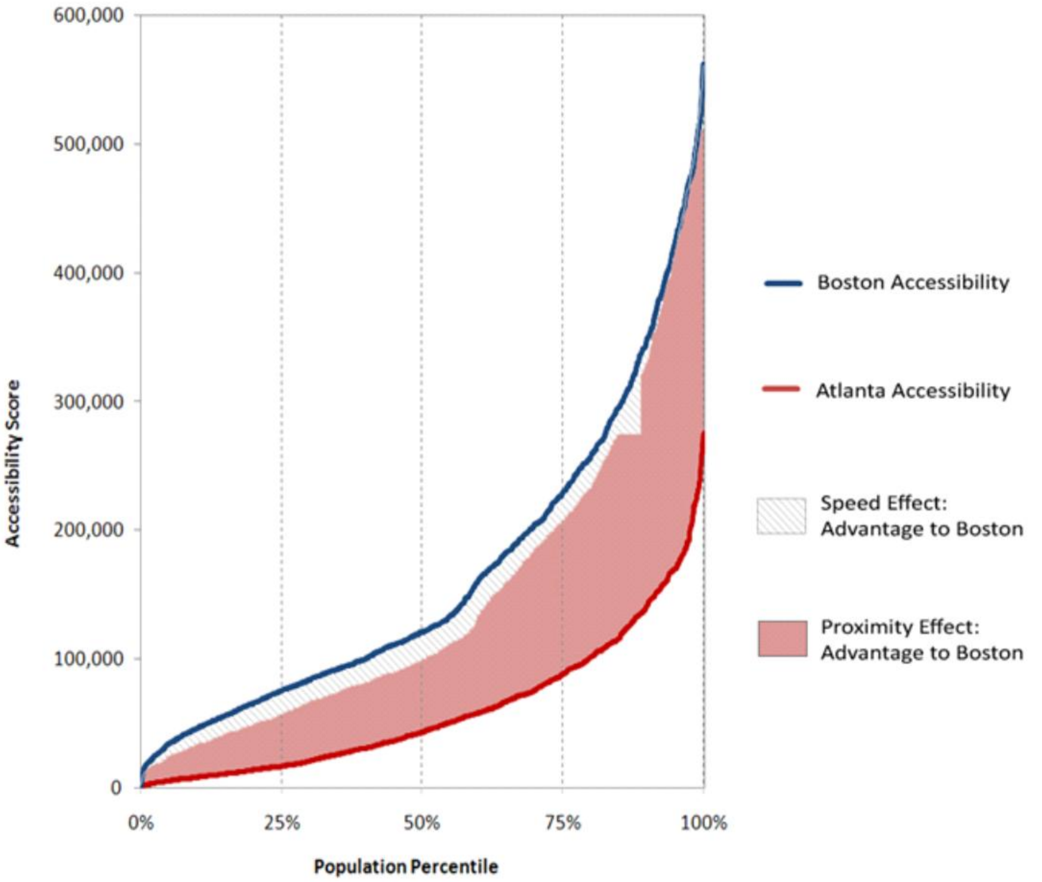

Figure 8: Decomposition of Accessibility Differences between Boston and Atlanta

Two other pairs show a similar situation: New York-Los Angeles pair and Portland-Memphis pairs, where the more accessibility (New York in the first pair and Portland in the second pair) has both speed advantage and proximity advantage over its counterpart. Moreover, in both pairs, the speed advantage is much smaller in magnitude than the proximity advantage, just like the case of Boston-Atlanta pair shown in Figure 8.

The decomposition of the comparison between Philadelphia and Houston, however, represents a different situation (Figure 9). In this pair, Houston holds some speed advantage over Philadelphia, while Philadelphia has a much greater proximity advantage which overwhelms its speed disadvantage. The result of the two competing forces of speed and proximity, in this case, is that Philadelphia wins in accessibility.

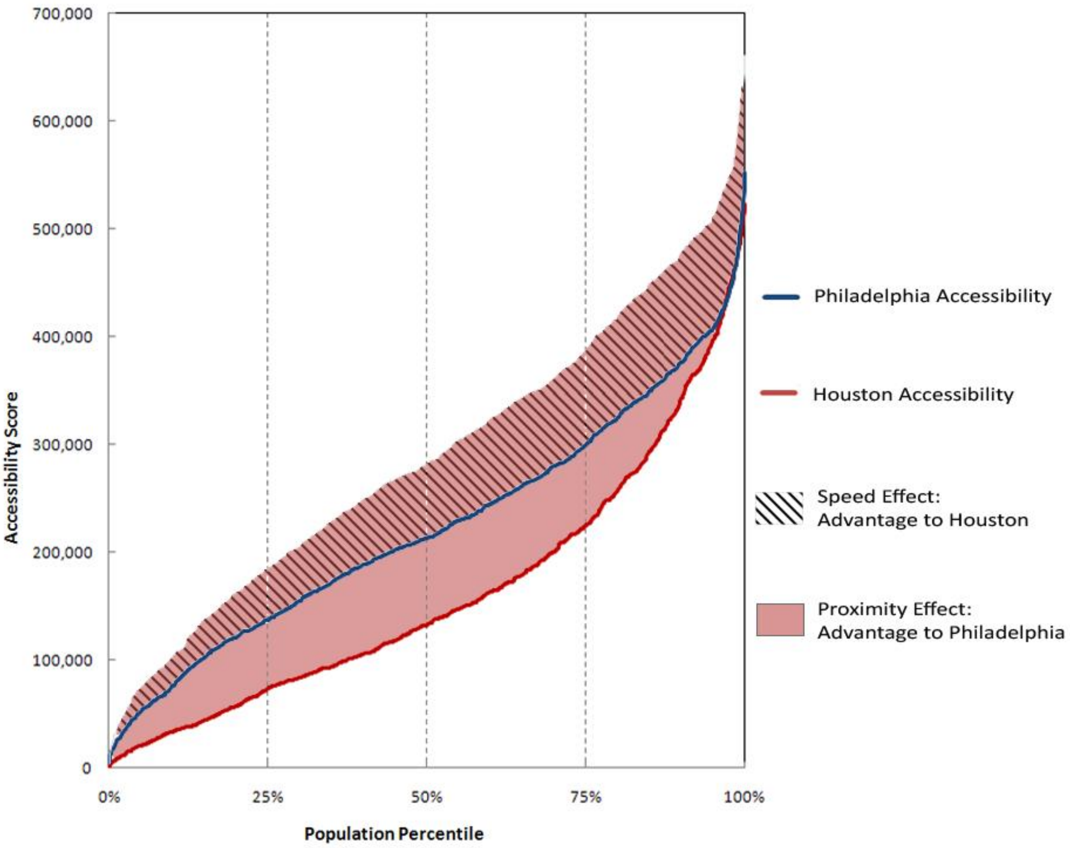

Figure 9: Decomposition of Accessibility Differences between Houston and Philadelphia

The Las Vegas-Columbus pair shows a similar pattern of decomposition like the Houston-Philadelphia pair. Columbus has some speed advantage over Las Vegas, yet such advantage is outweighed by the much larger proximity advantage of Las Vegas. Therefore, the result of comparison is that Las Vegas has a higher accessibility overall.

Our analysis of decomposing the accessibility differences between two metropolitan regions is a practice that shows the possibility of quantifying the different determinants of accessibility in a case-specific way. The findings from decomposition analysis are quite consistent with our findings from the path analysis: although both speed and proximity are important factors that affect accessibility, proximity plays a more important role in general. This contrasts sharply with a traditional transportation planning view that presumes, whether explicitly or

CONCLUSIONS AND INTERPRETATION

Much current transportation and land-use research seeks to identify urban forms that can curtail auto mobility by reducing (or reducing the growth in) VMT per capita. Research in this tradition tends to focus on the external costs of transportation, including carbon emissions, regional air pollution, and energy dependence. Underpinning this research is a view that reductions in automobility are likely more than counterbalanced by environmental gains.

While similarly inspired by the potential to reduce transportation's environmental harms, this study takes a different approach. Rather than presuming that people must inherently accept some costs in constrained mobility as a trade-off for environmental gains, this study asks whether accessibility—transportation's ultimate purpose—and sustainability might go hand in hand.

Results presented in this paper suggest that this approach has promise. In the U. S. context, metropolitan density is associated both with lowered VMT per capita and with higher work accessibility by car. Thus people living in higher density regions are not sacrificing transportation benefits for reductions in carbon emissions; they are simultaneously reaping the benefits of accessibility and driving less than their counterparts in lower-density regions.

That sheer urbanized-area density, rather than finer-grained metrics of urban form, seems to predict accessibility might seem surprising at first blush. Urban planners often like to focus on nodes of high-intensity activity, transit-oriented development, and other forms of walkable urbanism. Few are likely to get excited about high-density urban sprawl. Yet an auto-oriented region like Las Vegas can in fact exhibit, higher accessibility, and lower VMT per capita than regions with dense cores but lower densities overall. This is not to suggest that the auto-oriented, highly decentralized Las Vegas is in any sense a model for urban form. We do argue, however, that with the majority of Americans living in suburban zones, efforts to densify the broad suburban expanses are needed in order to increase accessibility overall.

In the near term, concentrated nodes of walkability and transit orientation will suffer from the "drop-in-the-bucket" problem: while they provide excellent accessibility via multiple modes to their residents, they are too small to affect overall metropolitan averages appreciably. This should change over time as demographics and tastes shift towards urbanist lifestyles (Nelson 2006) and these urban forms begin to gain critical mass. In the meantime, suburban densification through redevelopment and development of passed-over sites at higher densities is an important element of accessibility-oriented planning. Where U.S. land use planning has begun to create special zones for mixed-use development, this development is unlikely to affect U.S. metropolitan accessibility in the near term because these areas remain tiny relative to the metropolitan region as a whole. This suggests a more broadly based approach to policy reform that can include the redefinition of the spatially dominant single family zone itself to allow for ancillary commercial uses, accessory apartments, and even some forms of attached dwelling (Hirt 2007).

In the more immediate term, this research is designed to demonstrate the feasibility of using accessibility metrics to evaluate transportation outcomes between multiple metropolitan regions. In contrast to traditional metrics of mobility, the measures demonstrated here are consistent with the basic understanding that the purpose of transportation is not movement, but access. Though transportation evaluation remains largely mobility-based, current transportation discourse has begun to shift, referring frequently to "mobility and accessibility" as the twin goals of transportation planning. While we applaud the spread of the accessibility concept, the pairing of these goals as if they were co-equal still fails to acknowledge the fundamental implications of the derived nature of transportation demand: mobility is a means and accessibility is an end. The accessibility concept simultaneously subsumes both mobility and proximity, rendering the "mobility and accessibility" formulation both redundant and incomplete for its neglect of the central role of proximity in shaping the accessibility of cities and metropolitan regions. Perhaps the frequent pairing of "mobility and accessibility" indicates that we are on an evolutionary path towards a more fundamental transformation in our understanding of the purposes of transportation and transportation planning. The approach to inter-metropolitan accessibility comparisons presented here is offered as a step in that direction.

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