Access for Performance

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Abstract

This paper urges that policy decisions be based on important and reliable performance measures. Robust measures that assess the performance of the transportation *and land use* dimensions of cities, however, are typically missing from such discussions—they typically focus on congestion and mobility. The heart of approach suggested herein lies concept of accessibility: the ability of people to reach the destinations that they need to visit in order to meet their needs. By focusing on accessibility—rather than congestion or mobility—this approach produces a more complete and meaningful picture of metropolitan transport and land use. We place accessibility in a position of prominence as a performance measure by (a) describing the use and measurement of accessibility for metropolitan areas, (b) identifying robust, concrete and practical issues about measurement of the concept, (c) and offering prescriptions for resolving measurement issues.

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Introduction

Annually, traffic weary residents across the U.S. eagerly wait by their radio or for their newspaper to learn about the latest congestion report card from the Texas Transportation Institute. This urban mobility report makes headlines, especially in places with worsening congestion. Even smaller areas, possibly not yet victims of high levels of congestion, lament their annual increase in levels of congestion, but secretly enjoy their emerging big city status. Traffic engineers, planners, and politicians take more than feigned interest because to date, such ratings are the only available measure to assess progress toward an issue central to livability that is front and center on the front of the minds of many residents.

Congestion is a serious issue, undoubtedly. But is congestion the problem or the solution? Taylor [1] argues that traffic congestion is a solution to the problem of how to allocate scarce road space. Even if we agree that congestion wastes time, is minimizing congestion the most appropriate public policy goal [1]? Do measures of congestion provide the basis for policy prescriptions? We argue elsewhere [2] that mobility (or lack thereof because of inadequate networks or congestion) is an element of the larger goal—ensuring accessibility.

Recent years have witnessed more than a handful of conferences or workshops whose central themes focused on the concept of accessibility. For example, the University of Minnesota sponsored two conferences, producing an array of recent scholarly publications on the topic in 2004 [3] and 2007 [4-9]; the European Science Foundation hosted a workshop, How to Define and Measure Access and Need Satisfaction in Transport, in 2007 [10]. The Network on European Communications and Transport Activities Research (NECTAR) continues to sponsor activities focusing on accessibility. Accessibility has also become a civil rights issue [11].

As judged by the level of discussion, mention, and focus in specialized workshops, interest in the topic is high. Previous writings have focused on defining the concept of accessibility generally, starting from Hansen [12], but also involving other extensions [13-16], measuring the concept using different approaches [17], various data needs [18] or its use in explaining behavior [3, 19].

This paper urges that policy decisions be based on important and reliable performance measures. Robust measures that assess the performance of the transportation *and land use* dimensions of cities, however, are typically missing from such discussions [20]. The heart of approach suggested herein lies concept of accessibility: the ability of people to reach the destinations that they need to visit in order to meet their needs. By focusing on accessibility—rather than congestion or mobility—this approach produces a more complete and meaningful picture of metropolitan transport and land use.

Our intent in this paper is less about reviewing and commenting on the wealth of past research and more about adapting such research into means useful for informing and influencing policy. We aim to place accessibility in a position of prominence as a performance measure. This paper has three functions, to:

- Describe the use and measurement of accessibility for metropolitan areas,

- Identify robust, concrete and practical issues about measurement, and
- Offer prescriptions for resolving those issues.

Definitions

Accessibility has been a familiar concept in the transportation planning field since the 1950s when it was defined as the ease of reaching desirable destinations [12]. This represented one of the first efforts by planners to develop measures that linked land use and activity systems with the transportation networks that serve them. Hansen presented a hypothetical model showing how differences in accessibility—constructing an express highway—could be used as the basis for a residential land use model. In this context and others [21], highways (and other transportation infrastructure) provide accessibility that affect location decisions.

In these applications, accessibility weights opportunities (e.g., the quantity of an activity as measured by employment) by impedance (e.g., a function of travel time or cost). Under this framework, accessibility is typically described by the following equation:

$$A_i = \sum_{j=1}^{n} O_j f(C_{ij})$$

where A_i = accessibility from a zone (i) to the considered type of opportunities (j)
O_j = opportunities of the considered type in zone j (e.g., employment, shopping, etc.)
C_{ij} = generalized (or real) time or cost from i to j
$f(C_{ij})$ = Impedance function (exponential or power functions are most often used)

Accessibility applies within cities and between cities. The matrix depicted in Table 1 suggests one organizational schema. Most focus in the planning community has been on access for passengers to various daily activities. But access from a city to other cities is important in explaining the growth of areas as a whole; furthermore, industry depends on easy access for goods both within the metropolitan area (to distribute to customers and suppliers) and to other cities.

	Intra-metropolitan						Inter-metropolitan
Passenger		Car	Bus	Bike	…	Walk	
	Jobs						
	Stores …						
	Workers						
Freight							

Table 1. Matrix of Accessibility

New modes of transportation change each city's relative (and absolute) positioning for each type of accessibility, and this in turn helps drive the rise and fall of cities. Cities built in earlier times that could not, or did not, adapt to new modes fall by the wayside, cities that were well-located in one era may be redundant in another, faster era when primary cities need not be so close. The same applies within cities, and as intra-metropolitan transportation modes change, neighborhoods that were once exclusive or attractive lose their relative advantage, and new development rise in their wake.

The concept of accessibility was initially developed for automobile travel. To the extent that accessibility has been employed in past mainstream transportation planning circles, such measures have also typically been auto-based [22, 23]. In addition, many studies limit their focus to access to employment. The emphasis on employment accessibility is understandable, given its link to other important aspects of urban structure, such as choice of residential location, and also to outcomes hypothesized to be related to urban structure, such as social exclusion [24]. However, access to other types of destinations, such as retail, are also important because they strongly influence various dimensions of travel behavior such as trip frequency [25], destination choice [26], mode choice, and trip or tour complexity [27]. They also affect the price people will pay for land; areas with higher accessibility to desirable activities will be more expensive. The market (the collection of individual buyers and sellers) has an opinion on what is desirable, which can be ascertained through tools such as hedonic models for the price of real estate. Higher access levels to activities such as shopping and recreation are also thought to improve the general quality of life.

Different types of activities and services are associated with different sets of restrictions. Being located in a particular jurisdiction determines which government services one can legally access. Access to police, fire, and schools, e.g., depend on jurisdictional residence. Other types of activities (jobs, shops) are open to the free market, and while still subject to the capability (how far one can reach) and coupling (who one wants to reach it with) constraints of time geography [28], are not as limited by authority constraints.

As with sprawl and smart growth, the language of accessibility can be confusing and pliable as not everyone employs the same dictionary. That said, there is growing agreement among transportation scholars that accessibility refers specifically to the value of reaching destinations, while mobility simply represents the ease of moving on the network [3]. In that view, accessibility is about getting places and doing things, while mobility is just about that cost.

This identifying characteristic, the *ease* of reaching *destinations*, is often considered a suitable definition of accessibility and contains *two* important tenets. There is the land use side of the coin; the desirability of what can be reached. And, there is the transportation side; by what mode and how fast. The term accessibility is often countered with the term mobility, often defined as the "ease of movement."

Such benefits are perhaps best illustrated through examples. Imagine traveling to (or through) the prairie province of Manitoba in Canada. The traveler meets with the basic services required for daily living (i.e., food stores, shelter, employment opportunities); these services are mostly distributed across the landscape in a manner befitting relatively low density development. The result is an environment with relatively limited services but also (usually) free flowing traffic. Traffic congestion fails to exist and, when the roads are free of snow and mud, levels of mobility are quite high. People can get what they need, assuming auto-based travel, but the array of choices of things to get is relatively limited, so they are less likely to get what they want.

Contrast the above situation with the island of Manhattan in New York City. Often thought of as the most congested city in the U.S., its overall attraction, both culturally and economically, suffers little nonetheless. The reason is relatively simple. An endless array of services and opportunities exist for consumption accompanied by several options as available transportation modes. Despite its high levels of congestion, New York City thrives because of the extreme ease with which it enables residents and visitors to reach varied and valuable destinations.

The above exemplifies how nearby destinations produce high accessibility even with low mobility. Conversely, where origins and destinations are spread broadly, even great mobility does not ensure high accessibility. The two concepts can be readily distinguished through an understanding of the meaning of a change in each: an improvement in mobility reduces the time-plus-money cost of travel per mile, while an improvement in accessibility reduces the time-plus-money cost per (value of) destination. Land is more expensive in Manhattan than Manitoba, suggesting the market values accessibility more than mobility.

Implementation

While the concept of accessibility has received support among the academic community, its application as a planning concept has been less widespread, with just a few concrete examples to point to [29]. The reasons for limited use are myriad and not limited to the lack of: (a) consensus on a preferred and comprehensive measure (by purpose or by mode), (b) detailed, reliable and widely available travel or land use data [18], (c) consensus in understanding the different purposes for which the measures will be employed, and (d) relatively straightforward strategies for putting it all together. Below, we describe some of the difficulties associated with such reasons and strategies and, based on experience developing robust and metropolitan-scale measures [30] in the Minneapolis-St. Paul metropolitan area, prescribe strategies to address such issues.

To where?

As mentioned, most measures of accessibility center on the ease of reaching employment. This is understandable given the prominent role economic activity plays in the health of cities. But in the spirit of quality of life, diversity of goods and services, and health, it is becoming increasingly important to consider, for example, access to food, low-cost goods, parks and recreation, and medical care. Many measurement efforts may aim to be cumulative in nature, aiming to capture all aspects of the built environment in single measures. The claim is that the “whole package of accessibility” is how most residents perceive their cities, so why not measure accordingly. Other efforts claim that most policies aim to prescribe specific modifications (e.g., more housing, less commercial, more food stores) and knowing how various places fare in the disaggregate is useful. Even nominally similar destinations may not be perceived equally, see Box 1 on Taste.

By what mode?

Broadening the scope of accessibility to include additional types of destinations and non-auto modes such as walking and cycling has been proposed as an objective worthy of further study in the land use-transportation field [22, 26]. Other than Iacono et al. [23], to date, there have been few examples executing non-motorized accessibility measures for entire metropolitan areas (as opposed to smaller neighborhoods). Issues including, but certainly not limited to lack of reliable data, computational power or knowledge of non-motorized travel behavior have prevented widespread application of such measures.

Using which function?

At least three general functions have been extensively employed in past efforts. These include the cumulative opportunities function, the traditional Hansen function, and the logsum function.

Despite their historic popularity, attraction-accessibility measures have some significant weaknesses. These measures assume that the ordering of alternatives is irrelevant to the individual; this is clearly not the case when individuals have less than complete knowledge and must acquire information through a search process. Attraction-accessibility measures also deny the possibility of a hierarchical decision process where individuals mentally cluster individual choices into aggregates (e.g., making a choice between downtown versus suburban shopping malls prior to choosing individual stores). Finally, attraction-accessibility measures can be difficult to interpret. For example, researchers often interpret the Hansen measure as a gauge of "potential interaction"; however, it is unclear exactly what this means beyond simple ordinal relationships (e.g., "A has more potential interaction than B.")[31].

Box 1 Taste

Imagine a hypothetical residential neighborhood that has the following services all within 800 meters: deli, movie theatre, grocery store, veterinary, coffee shop, and a restaurant. According to most metrics of accessibility, such an environment would score exceptionally high; residents have a full array of opportunities all within convenient walking distance. Consistent with conventional theory, more places in the metropolitan area along the line of the above would be preferred over fewer places. (Too much choice may increase search and mental transaction costs however, and not be as desirable as a simple "more is better" rule would suggest, see Schwartz *Paradox of Choice*). Overall the market is likely to score a place with more access higher, (with concomitant higher rents), though for any individual, their preference structure values proximity to some different mix of destinations.

Sometimes these individual-level constraints require accounting for consumer tastes. For example, most people seek access to a grocery store, but for some people that means finding the closest location for milk, while for others only a gourmet food store will suffice.

Policy

Having discussed some important theoretical underpinnings and outstanding intellectual issues in measuring accessibility, we turn to describing how accessibility measures can best inform and influence policy in metropolitan areas. In community planning initiatives, the goal of enhanced accessibility has generally garnered a welcome seat at the table [29], alongside a laundry list of aspirations and platitudes such as increased mobility, decreased congestion, and reduced greenhouse gas emissions.

However, despite a seeming consensus among land use-transportation scholars and practitioners about the merits and concepts of accessibility as a performance measurement tool, the concept has not yet been widely adopted. A fundamental issue is that accessibility measures come in all different shapes and sizes. Some are more theoretical and robust in their complexity. Others are more practical and applicable with readily available data. The advantages of each depend on the intent and purpose. Furthermore, data requirements have been relatively burdensome, thereby rendering the concept too difficult to effectively measure. Faster computational speeds and increasingly available land use data that are both detailed and reliable, however, help relax these constraints. The current outstanding challenge when approaching such a goal in metropolitan and policy confines now centers around the type—and value—of measures that would be used.

We suggest that accessibility measures have enormous potential to provide an appropriate performance measurement tool to guide *both* future land use decisions and transportation investments. But for such a measure to gain the currency it deserves in the policy process, it needs to be straightforward and appealing to users and politicians.

These stipulations require several criteria to be filled—criteria not unlike those described for measures of effectiveness in analyzing the goals or success of different policy initiatives [2], Levinson (2003). Key to the particular pursuit of measuring and furthering accessibility is that the measures be clearly understood by both residents and policy decision-makers. Towards this end, we suggest that five criteria need to be satisfied. We label these the "5 C's" of effective accessibility measures and each are briefly discussed as follows.

Cumulative – Accessibility measures need to scale well. They need to apply to a particular address, a neighborhoods or an entire region.

Comparable – Accessibility measures need to inform multiple modes on the same continuum and the same scale. In other words, it is ideal to have the associated varying networks, varying travel speeds, and varying impedance functions be as consistent as possible. Comparing an accessibility measure for walking that focuses particular attention on experiential elements (e.g., urban design amenities) with an accessibility measure for auto based solely on travel time presents outstanding challenges.

Clear – For the measures to have appeal to various constituents, they need to be understood by them. They need to be transparent in terms of where the data came from, how they were calculated, and what they mean. Politicians and citizens have a hard time relating to phenomena such as log-sum measures or negative exponential distance decay curves.

Comprehensive – Accessibility measures need to be able to clearly capture just certain domains of interest—restaurants, for example—or be able to aggregate different types of land uses.

Calculable – Finally, it is best for measures to employ data that is readily accessible, available for an entire metropolitan area, and specific enough to capture the fine-grain calculations required for pedestrian travel.

The above criteria and discussion ultimately limit the utility of some of the more theoretical, nuanced, or even robust and extended measures that have appeared throughout the literature over the past decades. As much as researchers support continued exploration of how more complex measures could and should be applied to policy environments, there are competing demands—demands which often cannot be realized. Satisfying the above five C's of effective accessibility measures, we claim, ultimately leads to a suggested and specific type of measure to be employed, the "6th C," *cumulative opportunity* measures of accessibility.

Several advantages of this measure for this purpose stand out. It is a straightforward measure for people to understand; the number of destinations within a set amount of travel time is a concept most can relate to. It scales well; it can be used in a straightforward manner for a single point or an entire metropolitan area. It compares well; it can be used in the same manner to compare different modes, different neighborhoods, and even different metropolitan areas.

Of course, a number of definitional considerations still need to be fully ironed out. Even the most straightforward of measures can be made complicated by attending to all sorts of details. For example, how should destinations be measured (e.g., by establishment, employees, or something else)? How detailed should transit schedules be consulted (e.g., what time of day, how many transfers)? What time cut-off should be imposed (20 minutes, longer or shorter)? Should more than one time band be used?

A prescribed measure we endorse would be computed using a cumulative opportunity measure that: (a) uses 20 minutes as a baseline measure for comparative purposes, (b) is performed for specific subunits for a region (e.g., transportation analysis zones to measure auto accessibility, census blocks for other modes), (c) measures various types of destinations (e.g., retail, food, health care) independently or in an aggregated manner, and (d) does so using actual measures of the phenomena rather than modeled estimates.

Accessibility measures are typically thought of in terms of locational (x-y) attributes. Their value from a policy perspective, however, is when the measures are detailed in nature, but can be scaled up to represent broader areas using a weighted average for the area under inquiry. One could present a weighted accessibility score for a particular latitude and longitude location or a sub-area (e.g., a transportation analysis zone, or block) or an accessibility measure for an entire neighborhood, community or even metropolitan area using the following equation:

$$A_{area} = (\sum A_{sub\text{-}area} * P_{sub\text{-}area}) / P_{area}$$

A = Accessibility Measure (for a particular area such as a neighborhood, district or even metropolitan area)
P = Weight (e.g., population of the disaggregate unit area)

Figures 1, 2, and 3 illustrate the accessibility to jobs by walking, biking, and transit for 1995, 2000, and 2005 respectively in the Twin Cities Metropolitan Area (Minnesota). The bar charts, compiled using the above equation, parsimoniously depict the number of jobs that can be reached in 20 minutes of travel time by each mode. As can be seen, walking is slower than biking or transit, and thus has overall a lower level of accessibility. Over time accessibility is increasing, primarily because of the redistribution and growth of land use, and in part because of changes to the transportation network. The visual map depiction combined with the bar chart—which could be computed for any geographic area—provide a clear, useful, and robust story for accessibility in the region that planners, high level policy analysts and decision makers can easily relate to.

Directions

For many years, normative work looking at cities and transportation has focused on strategies to modify transportation phenomena or behavior: how to encourage residents to drive less, use transit more, or spur walking. (In contrast with 20th century policy, which favored more driving and less transit, and spurned walking). These normative strategies are often pursued outside of an appreciation of the policy-related forces that have shaped these behaviors. Furthermore, the ways of thinking about policy prescriptions are bereft of appropriate measurement methods or standards.

For example, considerable research seeks improved models of travel behavior. Furthermore, it tries to draw close associations to environmental outcomes; alternatively, research might seek to put more accurate dollar figures on various intangibles, etc. The intent is that such research will enhance policy making. Implicit in this line of reasoning is that shortcoming in transportation policies in the past were primarily attributable to lack of accuracy in this kind of knowledge. By reducing uncertainty in these areas, it is thought, more effective policies could be uncovered.

But what if weaknesses in the policies are derived from sources other than gaps in predicted outcomes? What if they come from inferior definitions of the problems (e.g., mobility vs. accessibility)? This paper suggests that problem definitions can be reformed to bring them in line with current transportation goals and also identifies several important issues. As issues of mobile source pollutants, consumption of non-renewable resources, and global climate change rise in prominence, increasing attention focuses on urban development strategies to alleviate these concerns. Indicators to comprehensively measure the performance of the combined transport *and* land use system are valuable in such an endeavor.

The concept of accessibility operationalized using cumulative opportunities measures offers a compelling alternative basis for policy regarding the built environment. In this application we view the process of developing accessibility consistent measures for both motorized and non-motorized modes as both an accomplishment and an invitation for future work for both practitioners and academics.

Accessibility is rarely presented in units that are easily interpreted. The measures rarely have any absolute meaning in terms of costs or benefits or other values such as convenience. Thus, they are often normalized over a certain range and interpreted in purely relative terms [32]. Relativity helps users grasp differences between various places or neighborhoods but many are yearning for a concrete unit of measurement. Such is certainly one distinct advantage of the cumulative opportunities measure.

The bottom line is that accessibility measures help planners and others better differentiate between policy variables they can control—such as trip cost or development approvals—and how individual travelers weigh and select among destinations (which planners can do little to control). Implementation of this framework would, at a minimum, permit a more straightforward comparison of access in different communities, in a given community over time, or across alternative future scenarios. A more standardized definition of what to measure is thus valuable.

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Figure 1. 1995 Total Employment

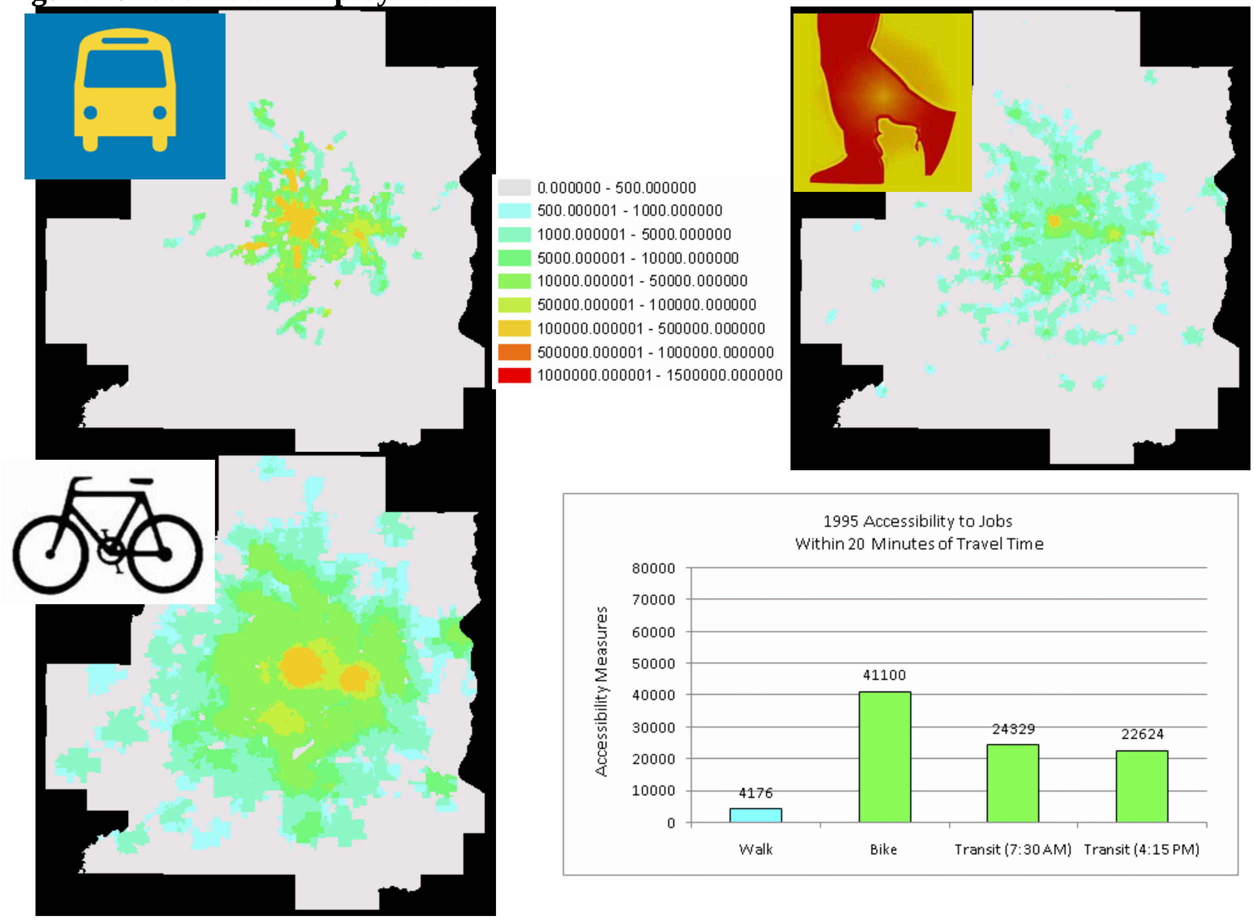

Figure 2. 2000 Total Employment

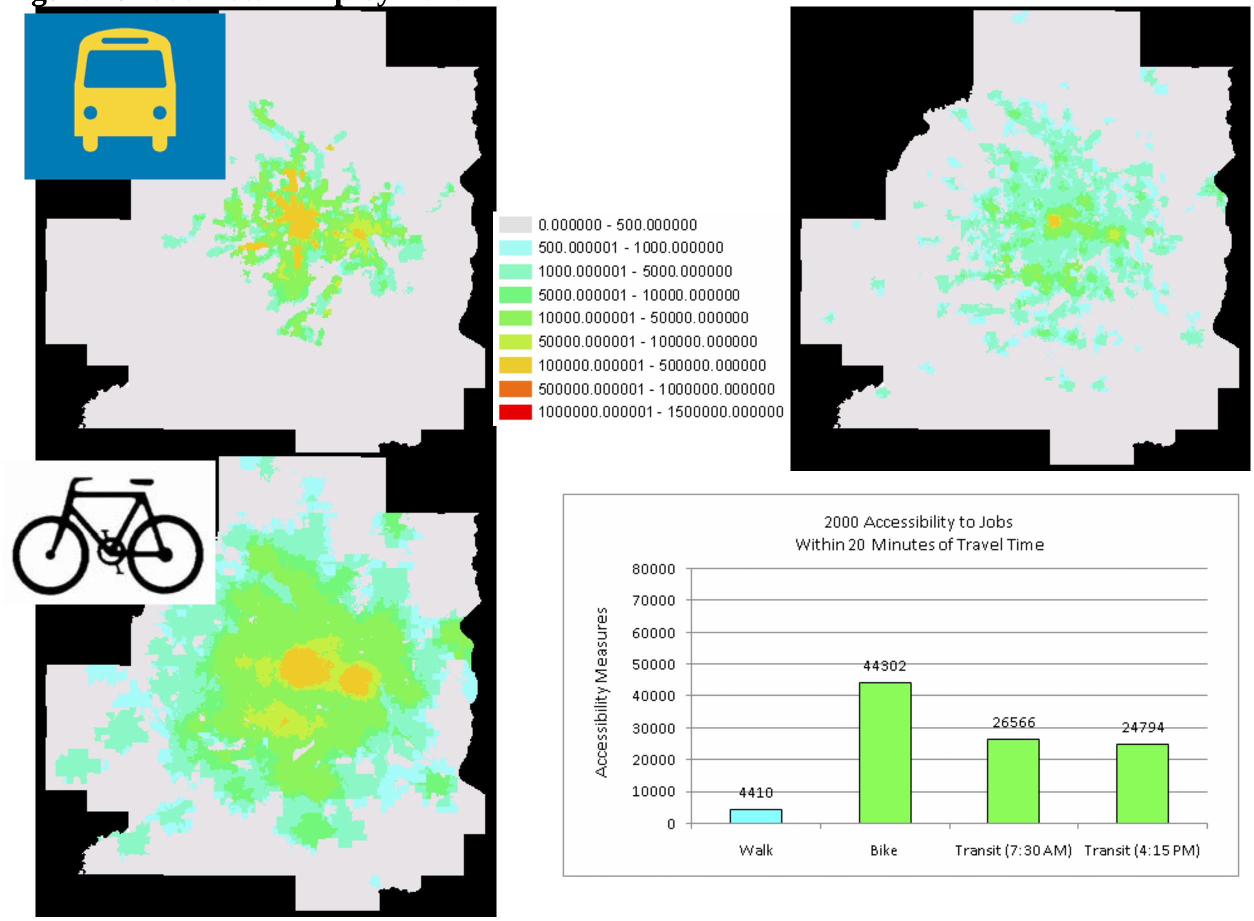

Figure 3. 2005 Total Employment