Developing a Census Block Level Accessibility Measure for St. Louis Metropolitan Area

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ABSTRACT

This study is an effort to develop an accessibility measure for St. Louis Metropolitan Area. Accessibility measures are commonly calculated at the Traffic Analysis Zone (zones) level, due to computational burden and data limitations. Zones, however, are generally large and prevent from evaluating accessibility at a finer scale. This paper utilizes improved computation capacity and demonstrates the potential for higher resolution analysis through the use of census blocks as the spatial unit. A gravity based accessibility measure is defined to estimate walk and transit accessibility score to Points of Interest (POIs). The scores are visualized on maps to compare accessibility for the entire region. The higher resolution provides us with the opportunity to identify low accessibility hot-spots that were not identifiable using large zones as the unit of analysis. The approach proposed in this study can be replicated in most other metropolitan areas. The approach can be implemented in scenario analysis to evaluate the impacts of change in land use, transit service, and transportation network on accessibility. The results can also be used along with the socio-economic data to study vulnerable population.

Keywords: Accessibility, Activity Center, Land Use, Policy, Census Block, Walk, Transit

INTRODUCTION

The traditional method of transportation planning in the U.S. has aimed to accommodate a growing population and increasing demand for travel and movement. Such an approach primarily focuses on improving vehicle mobility by reducing congestion, improving roadway level of service, and reducing travel time. However, the leading goal of transport activity is not mobility but quality access to destinations of interest including services, activities, and jobs (Litman, 2007). Improved vehicle mobility does not guarantee increased access to end destinations, especially for the population that uses transit and active modes of transport including walking and biking. In cases where improved mobility is achieved by roadway expansion, these other modes are negatively impacted.

With the increased emphasis at the federal level on data driven multimodal performance-based planning and programming, it is necessary for Metropolitan Planning Organizations (MPOs) and other planning agencies to incorporate additional objectives in their planning process. These additional objectives must not be aligned towards improved mobility rather towards improved accessibility, which includes land use component as well. Generally, there are two important components that constitute accessibility measures: land use or destinations and mobility (Geurs and Ritsema van Eck, 2001). Destinations are assessed in terms of cumulative number and/or type of opportunities it provides, while mobility is the ease with which one can get to the desired destination and is usually defined as a function of travel time or distance (Bhat et al., 2002).

Detailed review of current accessibility measures is available in literature (Geurs and Ritsema van Eck, 2001; Bhat et al., 2002). Bhat et al. (2002) broadly categorize available accessibility measures; some of the most important ones are explained as follows. The simplest measures are *Spatial Separation* measures that estimate the average distance from an origin to all other Traffic Analysis Zones (zone), and generate an accessibility measure for the origin (Baxter and Lenzi, 1975). Such measures do not incorporate the land use component of accessibility and do not take into consideration the availability of destinations of interest. Another way to measure accessibility is with *Cumulative Opportunities* measures. A threshold is defined for travel time or distance from an origin and the number of destinations of interest within the threshold are usedto define the accessibility measure for the origin (Hardcastle and Cleeve, 1995). The main criticism of cumulative opportunities measures is that they neglect the mobility component of accessibility; every destination within the threshold is treated equallytoward the accessibility measure. *Gravity* measures are a third way to measure accessibility. This measure incorporates the concept of travel impedance in calculating travel time to each destination of interest from an origin. Thetravel time or distancefrom the origin to all destinations (usually within an arbitrary threshold) is then summed to generate an accessibility measure (Iacono et al., 2010). Unlike spatial separation and cumulative opportunities measures, gravity measures incorporate both land use and mobility components of accessibility. *Time-Space* measures add a third component of scheduling daily activies to the accessibility measures: individual constraints such as the minimum time required to to eat and sleep; and authority constraints such as transit working hours, office hours, and curfews are also considered (Kwan, 1998). The problem with these last group of measures, as Bhat et al. (2002) puts it, is that they have a high level of disaggregation and are difficult to be used as aggregate performance measures.

CURRENT EFFORT

Although there has been a focus on the theory and formulation of accessibility measuers, the spatial unit of analysis has been a challenge. Most studies use Traffic Analysis Zones (zone) as the unit of analysis (El-Geneidy and Levinson, 2007; Benenson et al. 2011). Zones delineate large planning regions into smaller areas based on land use (Martin and Mcguckin, 1998). For each zone, a centroid node represents all travel origins and destinations as well as the socioeconomic data for the zone. The centroid links all the zonal travel activity to the roadway network or transit system using centroid connectors. The zone size is smaller where there is more activity, such as the central business district, and larger in areas with lower population and employment. Travel time and distance from an origin to destinations (OD) of interest is calculated using the centroid connectors at both ends of the trip. Since zones can be large in size, this method can lead to inaccurate estimate of the travel time and distance between ODs. Also, a zone represents the land use for the entire area it covers, not capturing the distribution of population and employment at a more disaggregate level within the zone.

Another option is the use of census blocks, which is the smallest spatial unit used by the U.S Census Bureau. This geography can be used for more detailed analysis including accessibility analysis. As an eample, there are 1,738 census zones for EWG planning area, while the number of census blocks for the same coverage is 73,217.

This paper demonstrates the potential for higher resolution accessibility measures through two enhancements to current practice. The first proposed change is the use of census blocks as the spatial unit of analysis as opposed to using zones. The second change is the use of exact location for each destination of interest, in calculating the travel time and distance for any OD pair, rather than zonal centroids. This approach provides more valid measures of accessibility at small geographies and adds the possibility of linkage to block level census data. This is particularly useful for multi-criteria analysis and permits more insightful analysis of measures like environmental justice.

This study is the first effort to develop an accessibility measure for St. Louis Metropolitan Area in a census block level. The accessibility measure used in this study is rooted in sound and well researched gravity formulation. The enhancement in spatial geography takes advantage of the increased computing power available. These changes do require signicantly greater computing power and larger memory requirements. With capable computers and efficient SQL queries, this process is likely to be available to most medium to large MPOs. The outputs of this method are easily accessible and transferable to partner agencies. When possible, this research uses open source data and software, to aid transferability.

This paper starts first with a short description of the study area followed by a discussion of the data and development of accessibility measure. In the results section, the calculated accessibility scores are presented and discussed. Finally, this paper concludes with examples on this method’s practical benefits for planning and policy, as well as its limitations and possibilities for future research.

STUDY AREA

St. Louis region is the 21st largest metro area in the nation. The 2.8 million person population is spread over about 4,600 square miles, with about 1.7 million jobs. East West Gateway Council of Governments (EWG) serves as the Metropolitan Planning Organization (MPO) for the St. Louis region, covering eight counties spread across two states. The MPO planning area is represented in figure 1.

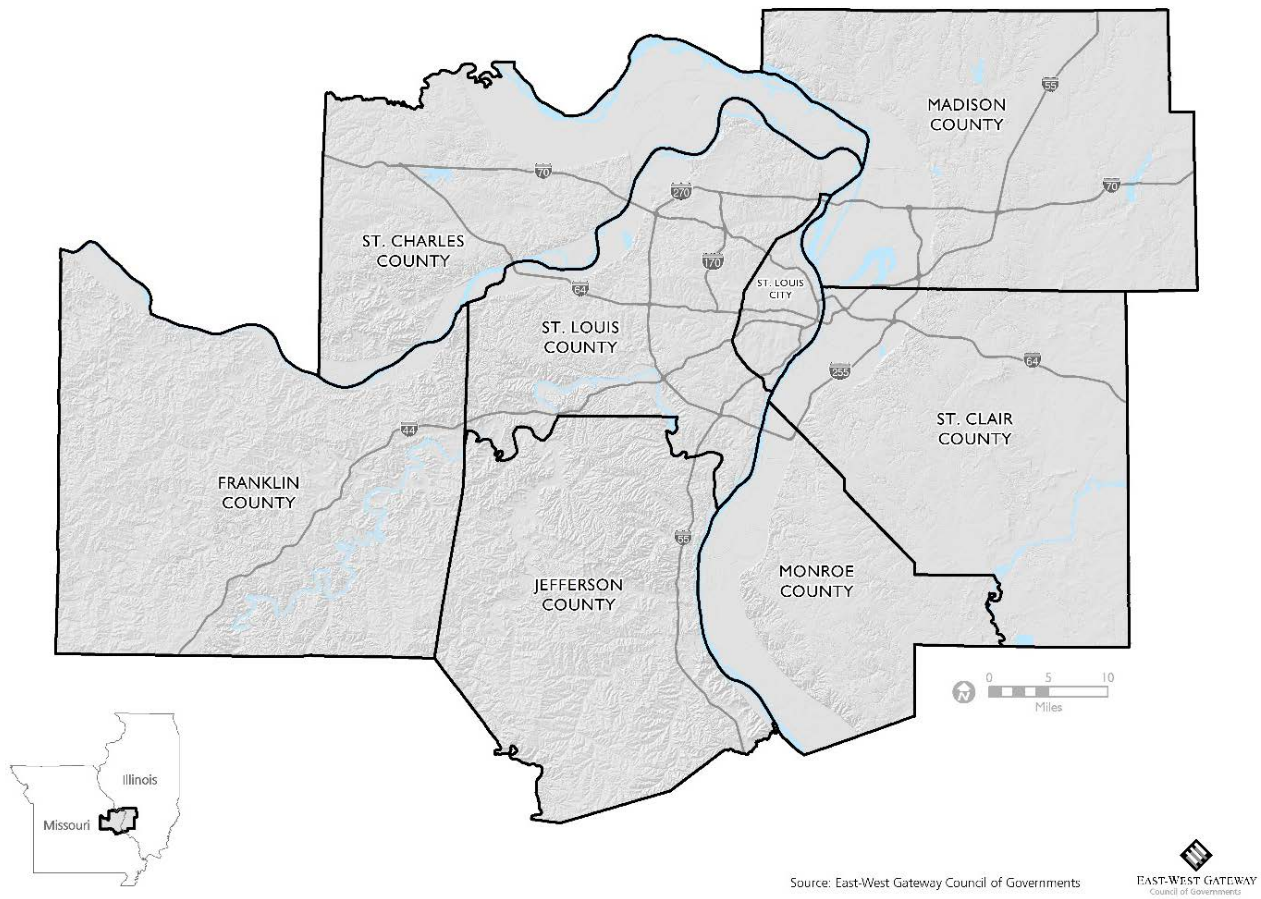

Figure 1 Study Area EWG Planning Area

The region is served by transit, including local bus, express bus and Light Rail Transit (LRT), see figure 2. The St. Charles, Franklin, Jefferson and Monroe counties are served by minimal to no transit. The dense core has mixed land use, making it well suited for walk and transit. There are a number of Universities and higher education options in the region, which attract both businesses and workers.

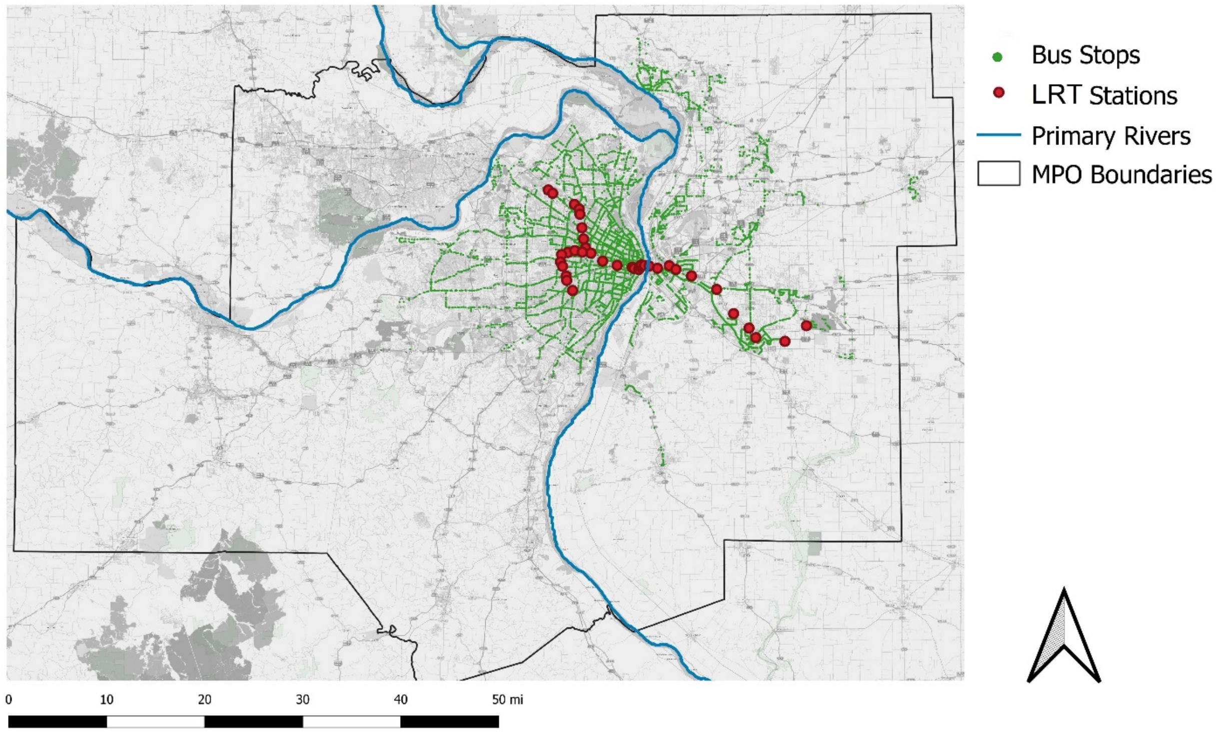

Figure 2 Distribution of Bus Stops and LRT Stations

METHODOLOGY

This section discusses the data used, terminology and how the accessibility is measured. There are four main components that are used in the methodology, and are briefly explained below.

1. Origin

This is the centroid of the census block for which accessibility is calculated. In urban areas, census blocks usually correspond to a city block, but in rural areas where there is lower population density, blocks may be bounded by roads and natural features. There are 73,217 blocks in the St Louis metropolitan area with 9,577 of them in St. Louis City.

2. Destination

Destinations or Points of Interest (POI) are locations that residents of the region need to access for daily activities. In this analysis, work accessibility was not considered, so employment was not included, rather quality of life destinations were considered. For this analysis, a wide range of destination that are used in daily life were considered. The POI file used in our analysis was obtained from NAVSTREETS Street Data. Based on this disaggregated data, there are 18,147 points of interest in the region which are represented in figure 3. For the purpose of our analysis, similar types of POIs were grouped into different categories, and are represented in table 1.

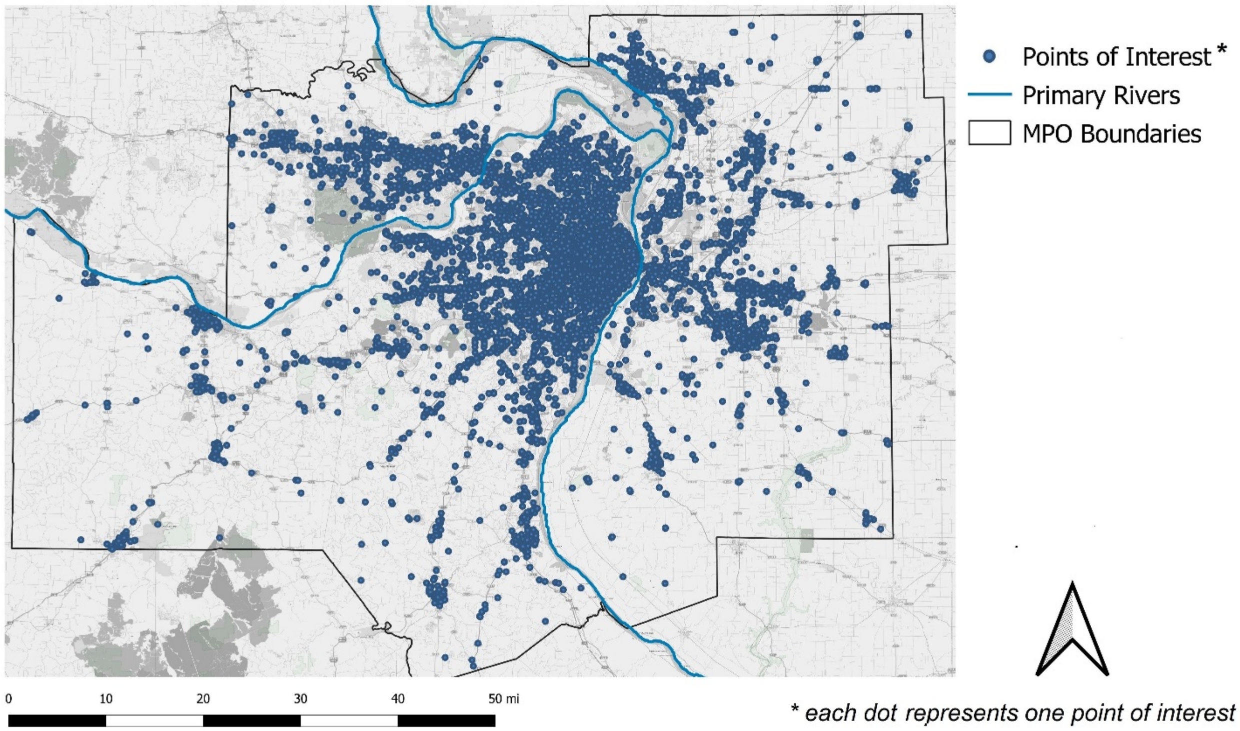

Figure 3 Distribution of Points of Interest (POI)

Table 1 POI Categories

Categories	POI	POI frequency in the category
Education	Higher education, school	1,362
Entertainment and Recreation	Amusement park, animal park, campground, casino, cinema, convention/exhibition centre, golf course, historical monument, museum, park/recreation area, performing arts, ski resort, sports complex, tourist attraction	1,102
Food and Drink	Coffee shop, restaurant	5,189
Grocery Stores	Grocery store	602
Hospitals	Hospital	32
Pharmacies	Pharmacy	536
Public Services and Banks	ATM, bank, city hall, civic/community centre, court house, library, police station, post office	2,938

Shopping	Book store, clothing store, consumer electronics store, department store, home improvement and hardware store, home specialty store, office supply & services store, shopping, specialty store, sporting goods store	6,386

3. Travel Time

The software TRACC was used to calculate travel time and distance between the origin and destinations using the shortest path algorithm. The software used the freely available OpenStreetMap network that includes all the roadways for the region including the local streets. It also used the latest General Transit Feed Specification (GTFS) files for transit travel time estimation. Walk trips use the OpenStreetMap road network, excluding interstates and limited access highways, with a walk speed of 3 miles per hour.

The travel time by transit includes all walking elements of the trip, i.e. the walk from the origin of the trip to the road, from the road to the public transit stops, any interchange of public transit using the road and then from the final stop to the destination via the road, and finally from the nearest point on the road network to the destination. The trip assumes arrival at the first stop one minute before the initial departure, with any subsequent interchange waiting times included as part of the final transit travel time.

4. Accessibility Measure

This work bases its accessibility measure in the gravity model formulation, which incorporates both land use and mobility. This type of measure evaluates an origin and all available destinations, with an impedence function making closer destination more attractive. An origin with higher accessibility score indicates that it has more and varied options available for interaction compared to another with a lower score. The higher score can be due to more destinations in close proximity or better mobility to the ones further away.

For this analysis, two modes were considred; transit only and walk only modes. For each mode, a catchment limit was defined. For walk only it was set at 2 miles, and due to the nature of transit routes the transit catchment was set at 30 minutes. The POIs within the catchment area contribute to the accessibility score of the origin. An impedence function was used to capture travel impedence cost and make the closer POIs more attractive and contribute more towards the accessibility score.

Accessibility also includes having access to varied types of destinations, keeping this in view the POIs were grouped into 7 broad categories, these categories are shown in table 2. The current approach also defines a parameter called 'saturation' (Sat_c), which is the maximum number of POI within a category that are counted towards the accessibility score for an origin. This is in line with the concept of decreasing marginal rate of return (Espada and Luk, 2011). Beyond saturation, additional POI from the same category do not count towards accessibility score.

Each POI category can have a maximum contribution towards the final accessibility score, with all categories contributions summing up to 100, as shown in table 2. A category's contribution represents its relative importance toward calculating the accessibility score. This is divided by the saturation (equation 1) to represent weight, which is the contribution of individual POI within the category towards the category score.

$$Category\ Weight\ (w_c) = \frac{Category\ Contribution}{Category\ Saturation\ (sat_c)} \quad (1)$$

Table 2 Saturation and weights for different point of interest categories and modes of travel

Point of interest Categories	Walk			Transit		
	Saturation	**Weight**	**Category Contribution**	**Saturation**	**Weight**	**Category Contribution**
Education	5	2.4	12	20	0.6	12
Entertainment and Recreation	10	1	10	20	0.5	10
Food and Drink	20	0.5	10	100	0.1	10
Grocery Stores	3	10	30	10	3	30
Hospitals	1	6	6	1	6	6
Pharmacies	3	2	6	10	0.6	6
Public Services and Banks	20	0.8	16	40	0.4	16
Shopping	20	0.5	10	100	0.1	10

The accessibility function formulation is as equation (2):

$$A_i = \sum_{category} \sum_{j=1}^{sat_c} f(d_{ij}) * w_c \quad (2)$$

Where,

A_i = accessibility score for origin *i*
d_{ij} = travel time/distance from origin i to the POI j within the catchment
$f()$ = decay function
w_c = the weight of the POI category
Category = POI category
J =POI
sat_c =saturation for the POI category

We choose a negative exponential decay function formulated as equation (3). Negative exponential functions were used in many other studies (Dalvi and Martin, 1976; Wilson, 1971).

$$f(d_{ij}) = \exp(-\beta * d_{ij}) \quad (3)$$

Where,

d_{ij} = travel time/distance from origin i to the POI j within the catchment

β = travel mode specific parameter

Table 3 represents catchment and β for different modes of travel. The graph representing the value of decay function for as a function of travel time or distance in figure 4.

Table 3 Walk and Transit Parameters

Parameter	Walk	Transit
Catchment	2 miles	30 minutes
$\boldsymbol{\beta}$	0.25	0.01

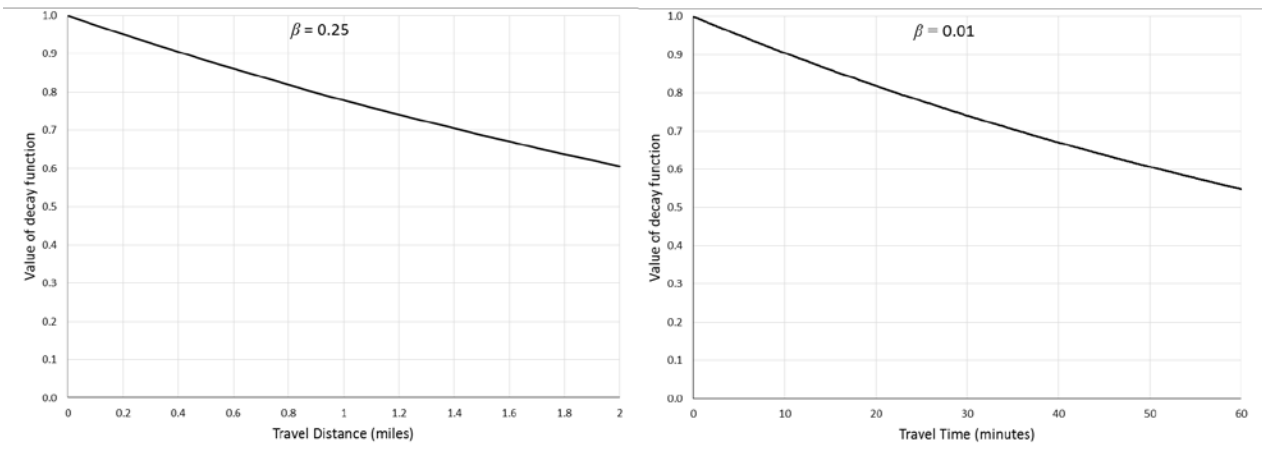

Figure 4 Value of the decay function

RESULTS

Accessibility scores calculated at the census blocks level geography are shown in Figures 5 and 6 represent walk and transit scores, respectively, with over 73,217 census blocks in the study area. As seen in these figures, except for the core urban area which includes St. Louis City, and parts of St. Louis County, the majority of the study area does not have a high walk and transit accessibility score. The results have been compared to the reality on ground and found to be representative at a level of detail not available previously.

For walk accessibility the core area scores better than the region, the accessibility changes rapidly as we move away from the core. Even in the core urban area, transit score is high only along transit corridors indicating a gap in the transit service or destinations in other parts. These figures also show that East St. Louis (located on the east side of the Mississippi river) has a significantly lower accessibility score for both walk and transit.

The significance of this effort is that we can look at the regional level or zoom in to any small area to see the accessibility at the micro level.The differences are visible at a block by block level, and knowing where the vulnerable population lives, it makes it easier to identify the holes in the network that need to be addressed or economic revitalization that needs to be addressed. This disaggregate level of analysis makes it easier to study a subarea and identify strategies for improvements. This can be a tool used in project selection, especially for STP-S and TAP bike and pedestrian projects as well.

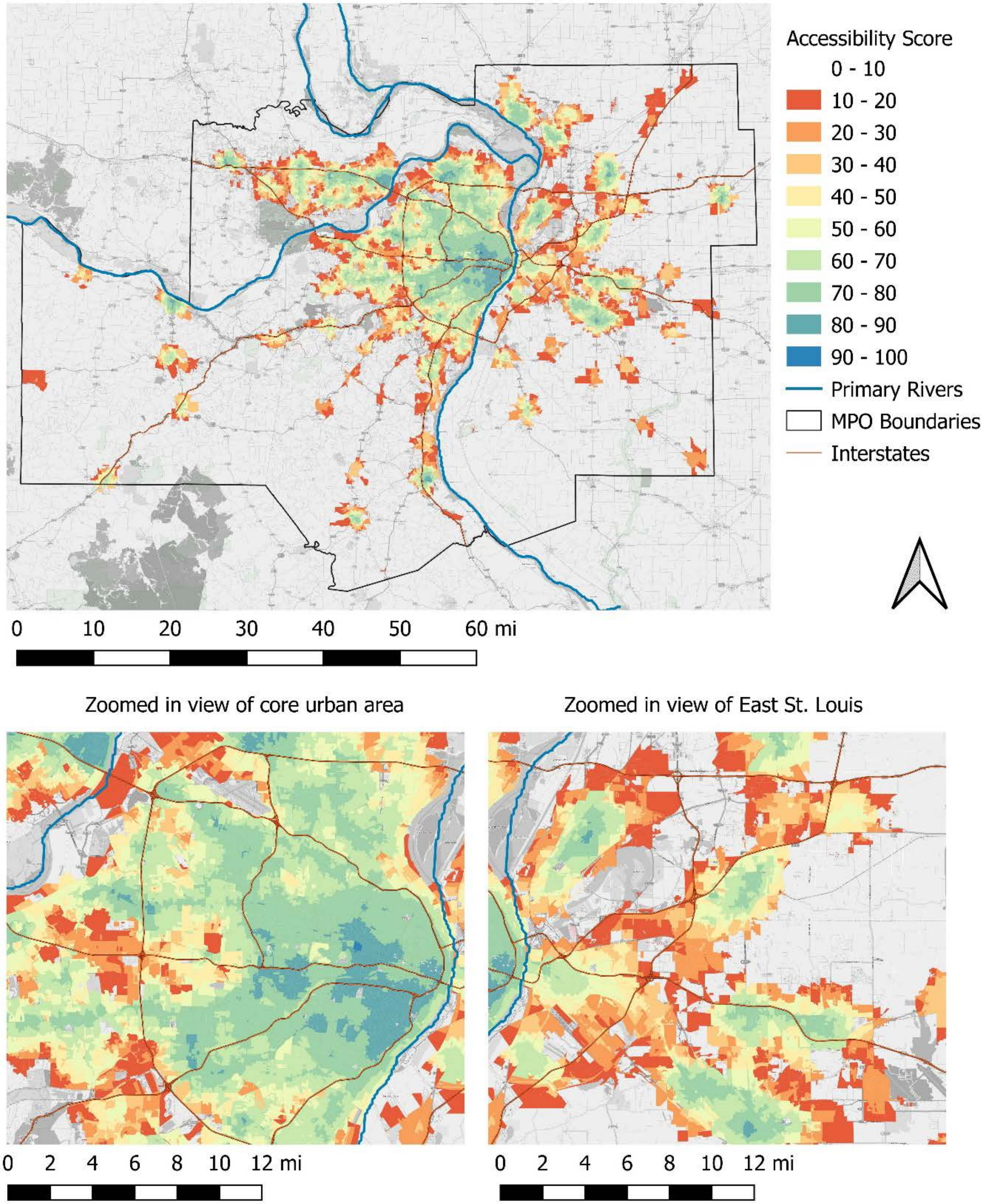

Figure 5 Walk Accessibility Score

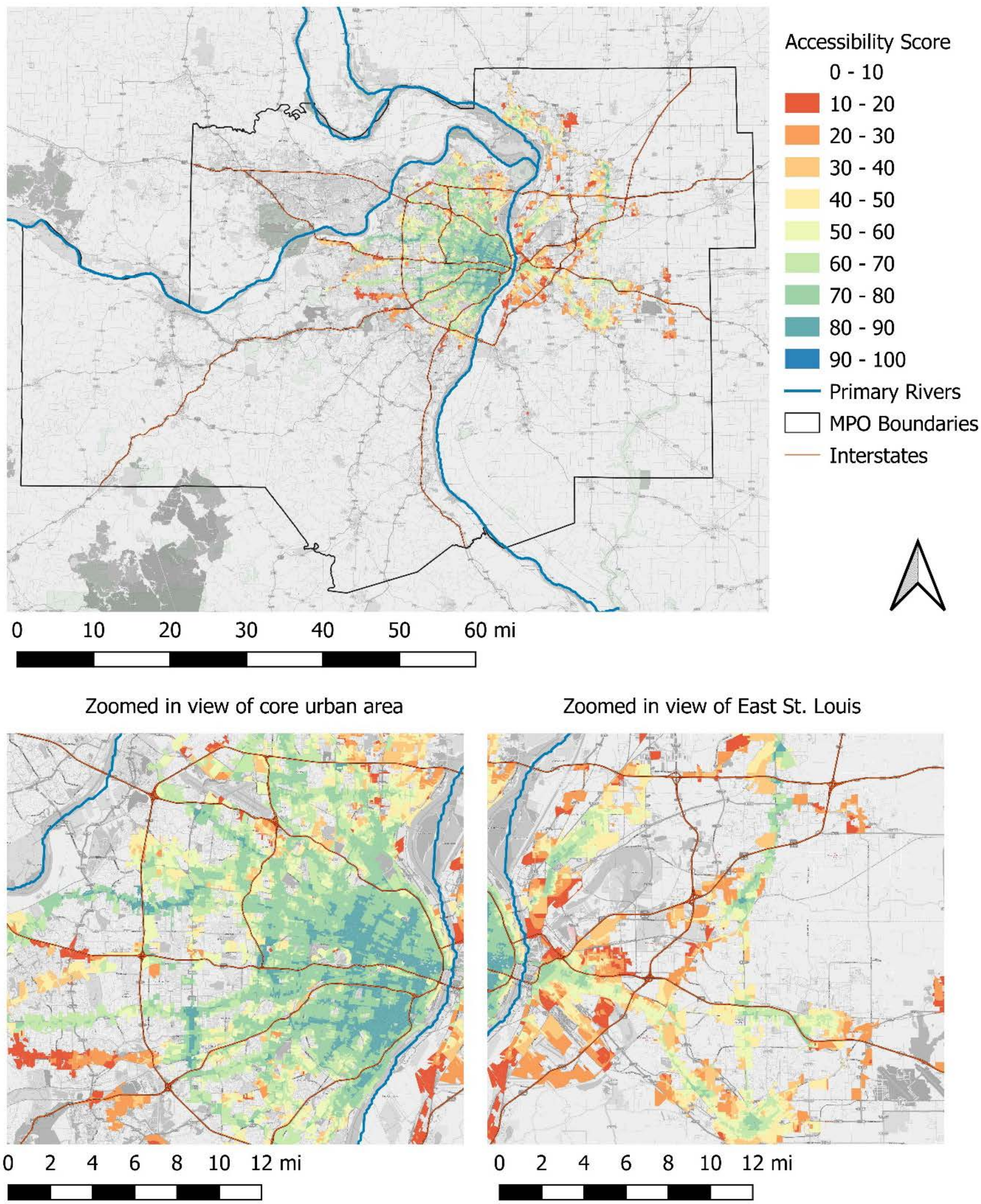

Figure 6 Transit Accessibility Score

DISCUSSION

In this paper does not consider accessibility to jobs, rather quality of life POIs. An employment opportunity requires more than having physical access to a job since the type of job must also match the worker's skills. Future plans include building on the current approach to be able to appropriately measure job accessibility. US Census Longitudinal Employer–Household Dynamics' LODES dataset can also be used to locate jobs. The aforementioned dataset provides information on the number of jobs available in each census block, this makes the current approach very suitable for further development of a job accessibility measure.

This effort assumes that walking is possible on all roadways, excluding interstates and limited access highways; this neglects the fact that some roads lack sidewalks. Having a network representation of sidewalks and developing a stress level for the attractiveness or distress for certain pedestrian walk facilities will help improve the travel time estimation for walk trips. The same comment holds for a network representation of bike facilities if the goal is to calculate bike accesibility.

Creating a composite accessibility measure that takes into account all modes of transport and socio-economic characteristics like auto ownership, and calculates a single accessibility score instead of, or in addition to separate accessibility scores for different modes, is another suggestion for future research and development.

Mapping environmental justice and title VI areas on accessibility maps provides us the opportunity to compare accessibility for different socio-economic groups and study environmental justice for low-income, racial minorities, people with disabilities, elderly, those with low English proficiency, and zero-vehicle households. The suggested framework can also be used for scenario analysis, for e.g., to study the effects of a new roadway, change in transit service or adding bikepath connecting residential area to a strip mall.

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