Measuring job accessibility in urban and suburban region: the cases of Philadelphia

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Abstract

Job accessibility, one important indicator of socioeconomic context and urban spatial structure, functions with transportation systems and land-use pattern. It is crucial for urban planners to understand how spatial job accessibility varies by different transit modes and different census tracts. This study presented a GIS-based network that can evaluate the job accessibility across different census tracts in Philadelphia. Measurements for pedestrian and transit job accessibility were developed and compared in and across urban and suburban census tract. The transit network of urban core, where job sites distributed evenly, is well developed, which provides both higher pedestrian and transit job accessibilities for job seekers than the suburban. Public transit is proven to be more effective and efficient in saving worker's commuting time and expanding their mobility and accessibility to jobs. The findings of the study suggest a series of urban planning and land-use issues that policy makers should further analyze their socioeconomic mechanisms.

1. Introduction

Accessibility to job is a key indicator in the field of land use, transportation planning practice and urban management (Geurs & Wee, 2004). The improvement of job accessibility copes with social inequity, which brings people more employment, economic and social opportunities (Wang & Chen, 2015). As the interface of transportation, workers and workplaces, job accessibility depends on the degree of their interactions in both space and non-space aspects (Cheng & Bertolini, 2013). Public transportation, a fundamental component of transportation system, plays a positive role in connecting people who have little access to private vehicles with labor markets, improving the mobility and accessibility of workers. People choose public transits as means of commuting to work for its high efficiency, low cost, reliability, and more benefits to environments (Vishwanath, et al. 2014). The transit road network is one most important infrastructure in the city, which not only guarantees commuting and transportation of goods, but also contributes to the social, policy, economic development, and integration between different regions (Aldagheiri, 2009). Nowadays, many urban scientists and scholars analyzed job accessibilities based on the road network with Geographic Information System (GIS) applications. Since the concept accessibility accounts for spatial patterns for activities and the associations between these activities, spatial analysis of accessibility fits well with GIS (Liu & Zhu, 2004). GIS plays crucial role in advanced spatial analysis and making geo-decisions to support transportation planning among numerous empirical studies. For example, the shortest travel distance between the origin and destination can be determined through GIS-based network analysis. Wang et al. (2015) analyzed the GIS-based job accessibilities with transport-based spatial autoregressive (SAR) models, which can account for the spatial autocorrelations of job accessibility. Luo & Wang (2003) developed floating catchment area (FCA) with GIS techniques to examine the spatial accessibility to primary health care in the Chicago.

It is important to explore the job accessibility, as one indicator of different socioeconomic, demographic context and built environments (Wang & Chen, 2015). To explore the relationship between job accessibilities and different travelling modes as well as urban spatial structure, this study developed and

compared pedestrian and transit networks in two census tract, one urban core and one suburban in Philadelphia. By integrating and analyzing the transportation and geographical data, the GIS-based network can build a O-D travel time matrix, which evaluate the travel time from origin to employment, and can identify the spatial accessibility to jobs. The findings can provide a framework for applying GIS techniques in transportation planning for urban decision makers.

2. Methods

2.1 Data collection

This study focused on two census tracts in Philadelphia, the center city (Census Tract 5) and Manayunk (Census Tract 210). To compare the job accessibilities across urban and suburban, the former is urban center core while the latter is suburban. The boundaries of these two census tracts are gathered from OpenDataPhilly (2015). A comprehensive road network, including all types of roads, buildings polygons and points data, which shows the type of this sites, of Philadelphia are downloaded from OpenStreetMap (2021), are used to define the road network of pedestrians and destination for jobs. The transit road network is different from the pedestrians' road network, since public transit, such as bus and trolleys, drive along bounded routes. To define the transit road network, data for bus and trolley stops and routes are collected from SEPTA (2021).

By comparing the transit road network and job distributions in Figure 1, the transit road network for urban core is clearly more integrated than the suburban census tract. The bus routes for MFL, BSL, etc. transverse through the urban core. The bus stops are evenly distributed so that people can access the public transportation conveniently. The job opportunities in urban core are obviously greater than the suburban tract. In contrast, there are just two bus routes in suburban and very limited job opportunities concentrating in the northwestern corner, which suggest that the public transit is not dominant in this region.

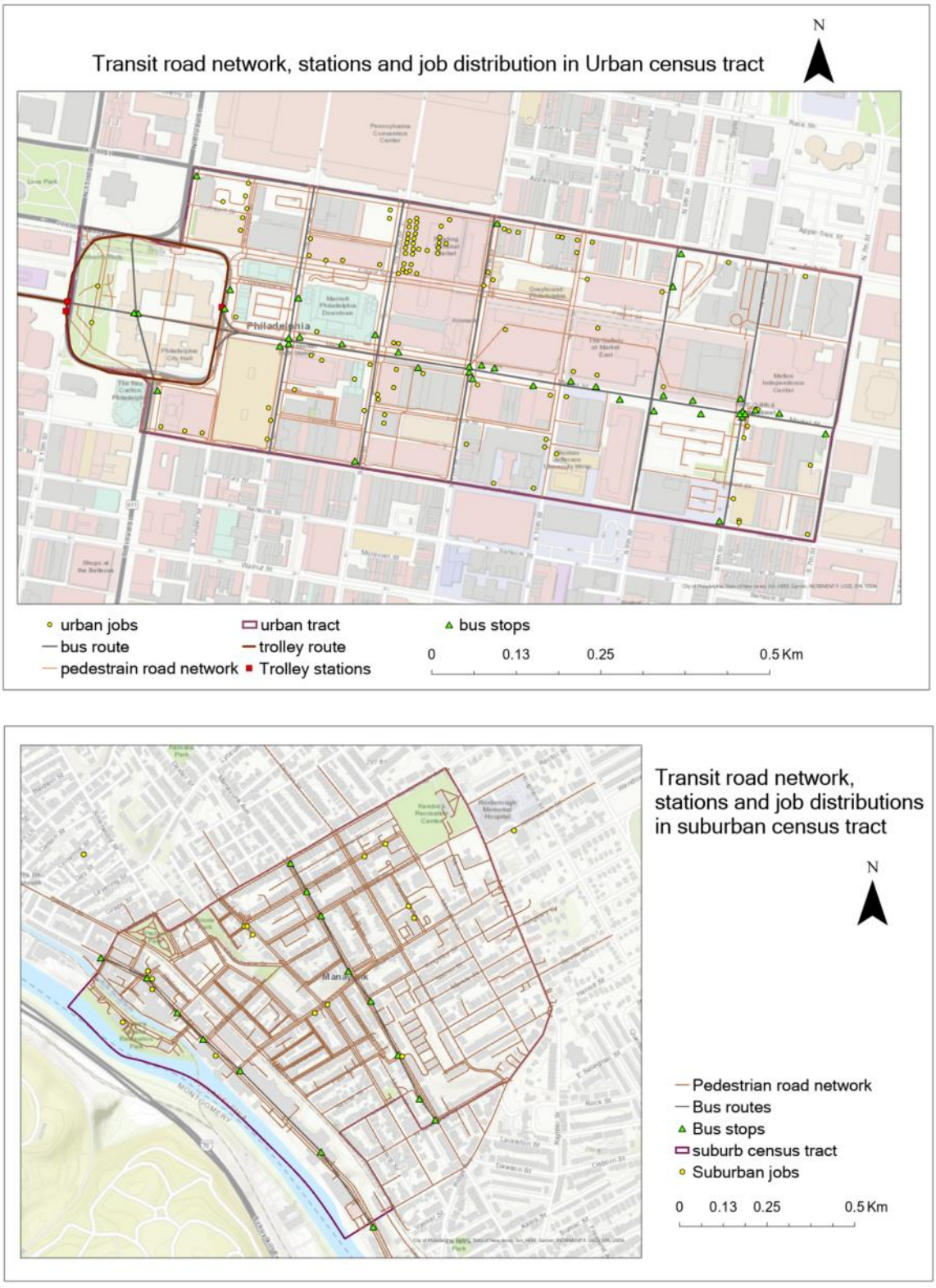


Figure 1. the transit road network stations and job accessibilities in urban and suburban census tract

2.2 Measure of Accessibility in GIS

The measure of job accessibility is conducted through network analyst in ArcGIS following the workflow in figure 2. Network is a type of linear vector data that consists of edges, junctions, and nodes. The network dataset can model the spatial accessibility by calculating the distance from nodes (Silalahi et al., 2020).

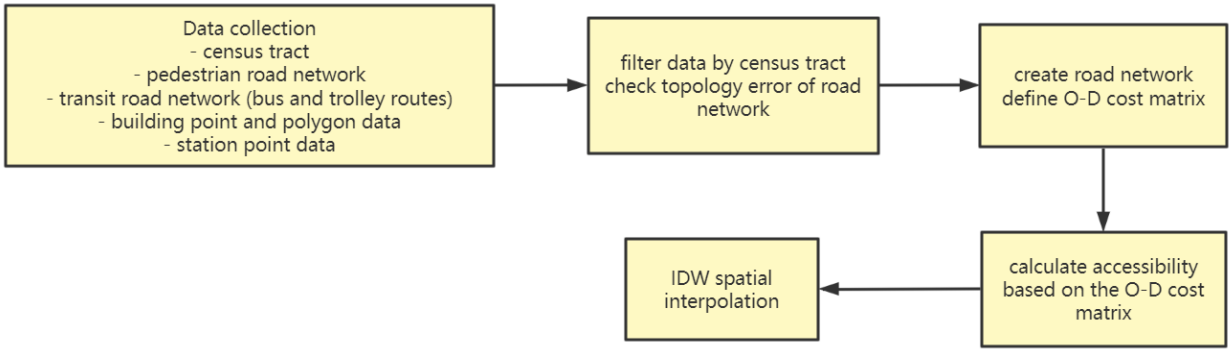


Figure 2. workflow for measuring job accessibility in ArcGIS

The O-D time travel time matrix, generated from the transportation network analysis, is the estimation of travel time between a set of origins and destinations (Wang & Xu, 2011). Based on the O-D time matrix, the measure of job accessibility can be calculated as follows (Geurs & Wee, 2004):

$$A_i = \sum_j O_j * d_{ij}^{-b} \quad (1)$$

Where A_i is the job accessibility from a starting point of pedestrian or transit i, O_j is the number of job sites at a distance j from starting point of pedestrian or transit i, d_{ij} is the travel time between i and j by walking or taking the transit, and b is here the value of 1, which measures the extent accessibility decreases as the distance increases.

The key of network analysis is to define the origin and destination points for O-D travel time matrix. Considering the flexibility and the wide range of pedestrians' mobility, here instead of just choosing residential places to define the starting points of pedestrians, the junctions of pedestrian's network, calculated through the network analysis in GIS, are chosen as the origins that pedestrians start. By filtering the workplace from points data downloaded from OSM, and selecting points that intersects with the building polygons, the results points are chosen as the job sites as well as the destination for this matrix. Given the average speed of pedestrian as 5km/h, travel time between origin and destination (d_{ij} in equation (1)) will be calculated. By summarizing the number of job sites that can be reached from each origin, then multiplying the reciprocal of O-D travel time, the accessibility of each origin can be generated. Based on that, the IDW interpolation can be utilized to estimate the accessibility of the whole study region.

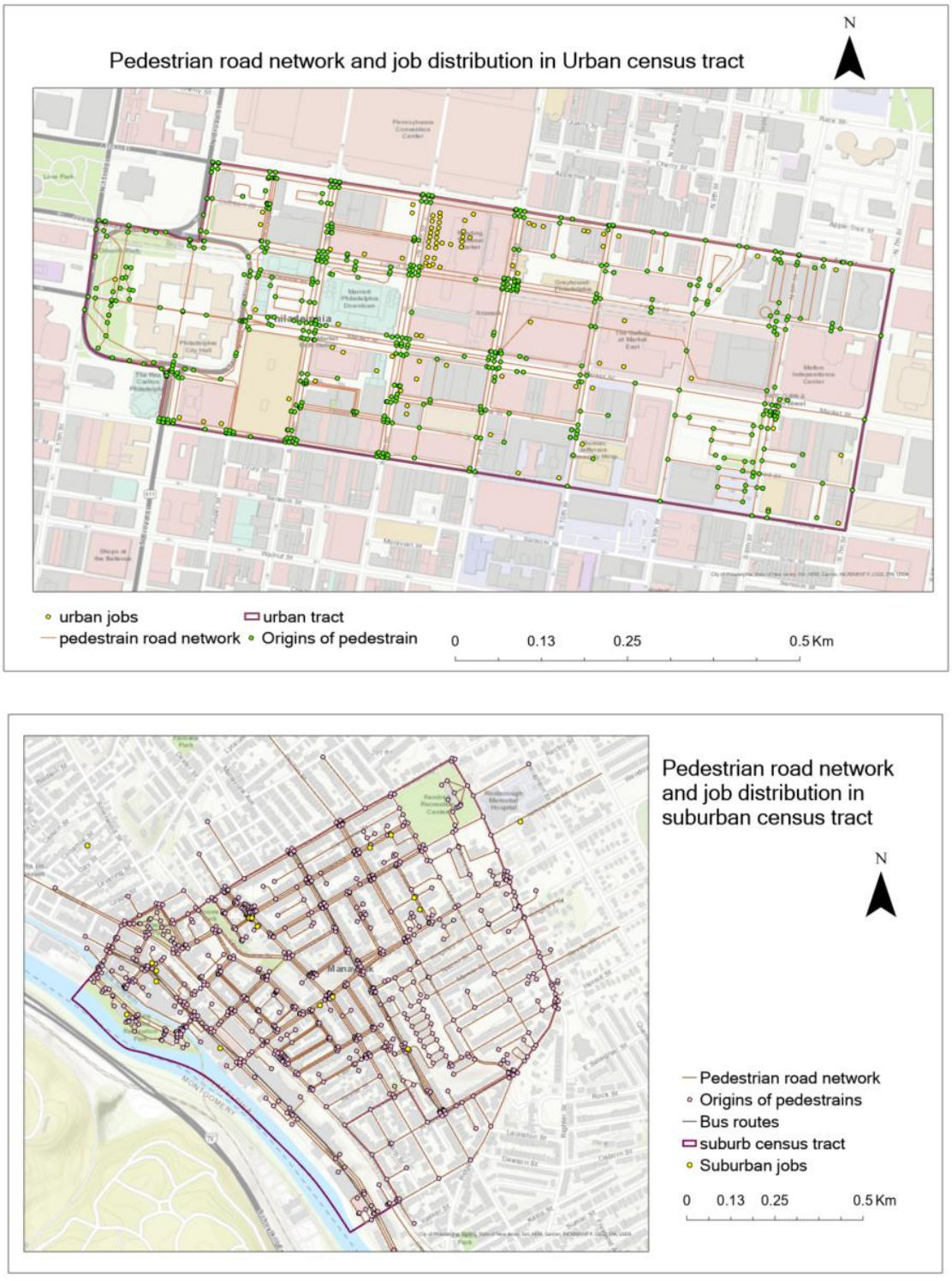


Figure 3. origins of pedestrians and destination of jobs in urban and suburban census tract

Compared with pedestrian road network, the transit road network structure is simple with stable routes and bounded stations. For urban census tract, bus routes and trolley routes are combined as transit road network in this study, because the stations of other ways of transit, like highway or railroad, do not locate in the urban census tract and the origins of highway or railroad network can't be decided. The origins of

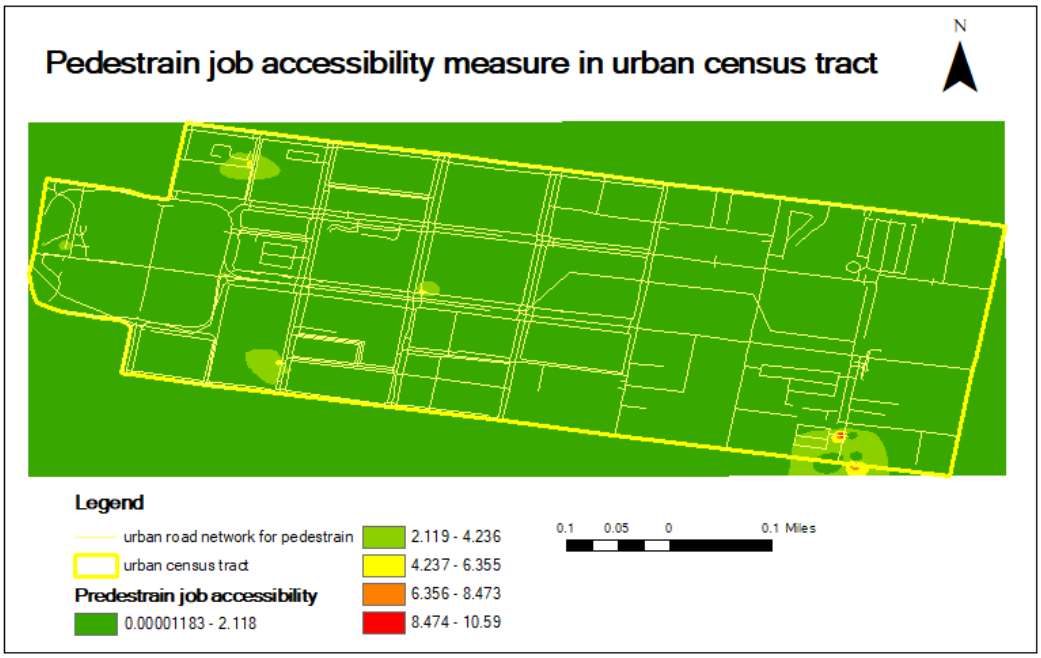
transit road network should be close or overlap transit stations, meanwhile, locate in road network. Since most point stations do not locate on the network, 10m buffer zones are created around these stations. The junctions on the network, covered by these buffer zones, will be considered as origins for transit road network.

Due to the difference speed of bus (50km/h on average) and trolley (30km/h on average), the accessibility to job by bus and trolley are first calculated separately. Then their IDW interpolation layers are merged as the results of transit job accessibility network in urban census tract. Except for bus, there is no other means of public transportations that have both routes and stations in the suburban census tract in this study. So in this study, bus is only considered to build an integrated transit road network in this suburban census tract.

3. Results

3.1 Job accessibilities in urban

In comparison with the transit job accessibilities, the pedestrian job accessibilities for most region in urban census tract is low, ranging from 0 to 2.118. From table 1, on average pedestrian spend 5 minutes walking to work and their average job accessibility is 1.1. In Pennsylvania Convention Center, the Gallery at Market East and 11th Chestnut St, pedestrians are more accessible to jobs. For pedestrians, jobs reachable by walking for a while is located at 8th Ranstead St. Transit-accessed jobs cluster spatially in the 11th and 12th Arch St, where job opportunities highly concentrated, with the accessibility value of around 25.8, then decreases gradually from the center to the edges of this tract. In urban core, jobs become more reachable when taking the public transit, since public transit, especially bus, is a dominant commuting pattern in urban core. Overall, the job accessibilities in urban are even for pedestrians.



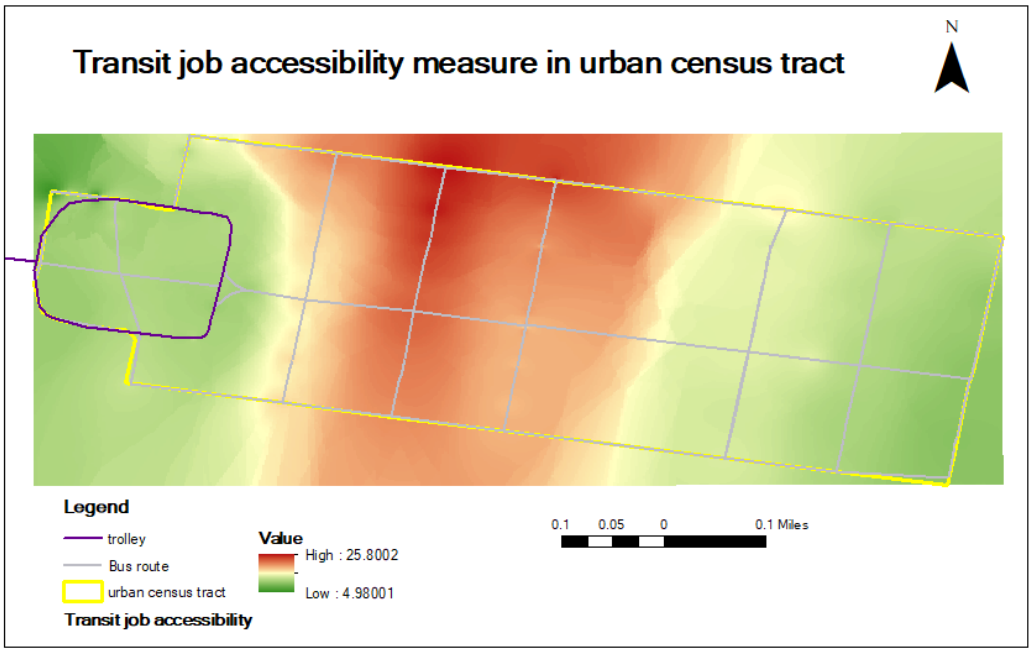
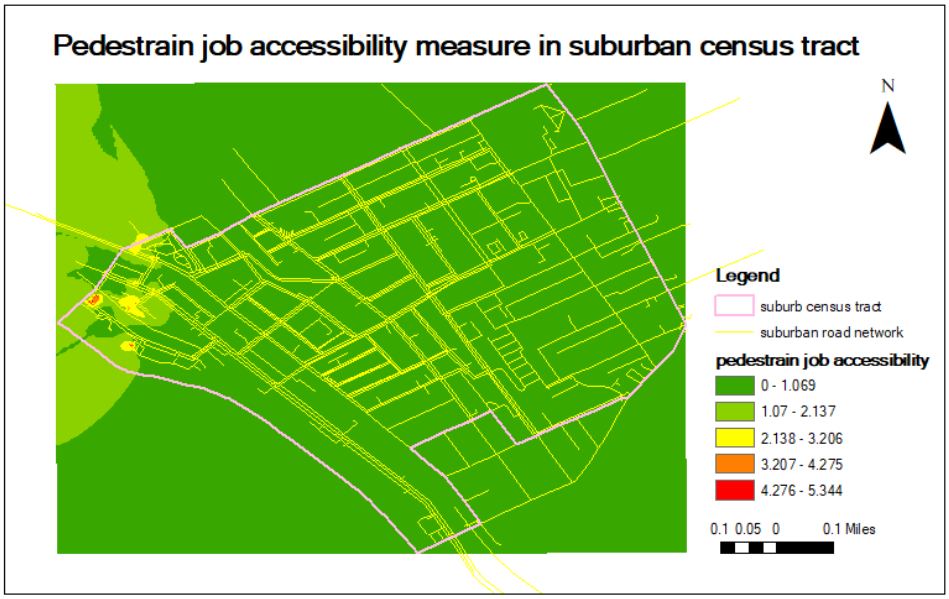


Figure 4. pedestrian and transit job accessibility in urban census tract

3.2 Job accessibilities in suburb

For pedestrians in suburban census tract, accessibility to jobs is highest in the northwestern corner, while the rest regions are low accessible to jobs, because the job sites are limited and unevenly distributed in suburbs, where most jobs locate at the northwestern corner. The transit job accessibility is also highest here. From northwestern to the southeastern, transit job accessibility decreases gradually. According to table 1, it takes people on average 10 minutes walking to the employment in suburb. Public transit has a positive effect on saving commuting time from 9.11 to 3.76 minutes and enhancing the job accessibility from 0.41 to 3.66.



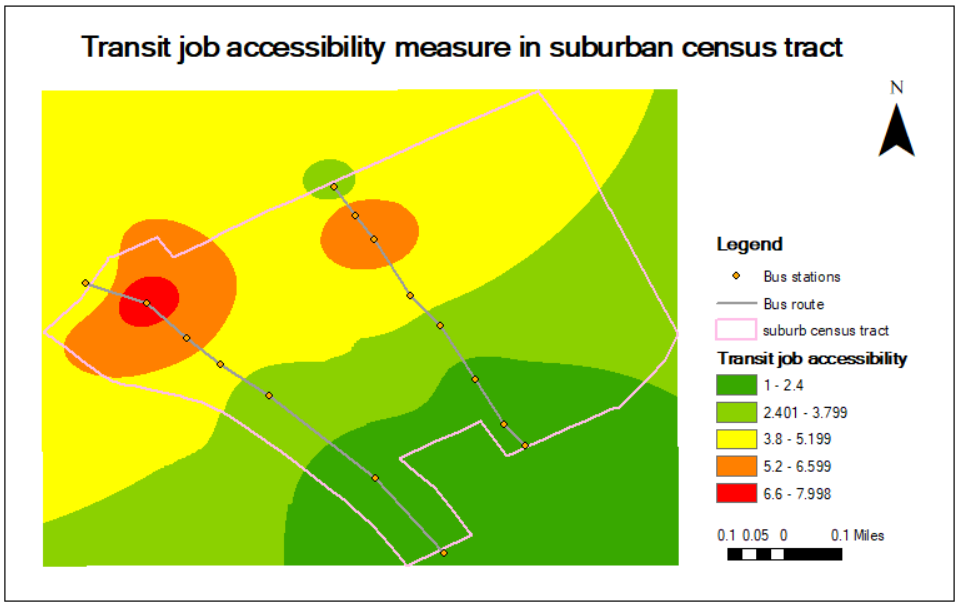


Figure 5. pedestrian and transit job accessibility in urban census tract

3.3 Compare the job accessibilities across urban and suburb

The road network structure and the spatial distribution of jobs decide the characteristics of job accessibility. Because there are greater amount and more even distribution pattern of jobs in urban, the pedestrian job accessibility in urban (1.1) is almost three times than the suburb (0.41). People living in urban spend only about half of time (5.68) in suburb (9.11) when walking to work. In urban core, there are several bus routes that connect the north and south edge of city, and one bus route traverses from the west to the east. The transit service is widely available in urban core. This spatial pattern suggests that wherever a person is in urban core, he can find and access the public transportation without walking for a long distance. Table 1 indicates that in urban core, people only spend two minutes on average taking the public transit to work and the average transit job accessibility is significant the highest (14.33). The urban transit network is much more advanced than the suburb, where there are only two bus routes that transverse the whole suburbs. Therefore, the transit job accessibility of suburb (3.66) is far behind urban significantly (14.33). Half of the suburb is low of job accessibility. If a person lives in the southeastern suburb, he will have little access to jobs unless he owns a private vehicle. From table 1, public transit plays important role in reducing travel time and enhancing job accessibilities in both regions, by increasing the job accessibility from 1.1 to 14.33 in urban, while 0.84 to 3.66 in suburbs, saving people about 60% time of commuting to work.

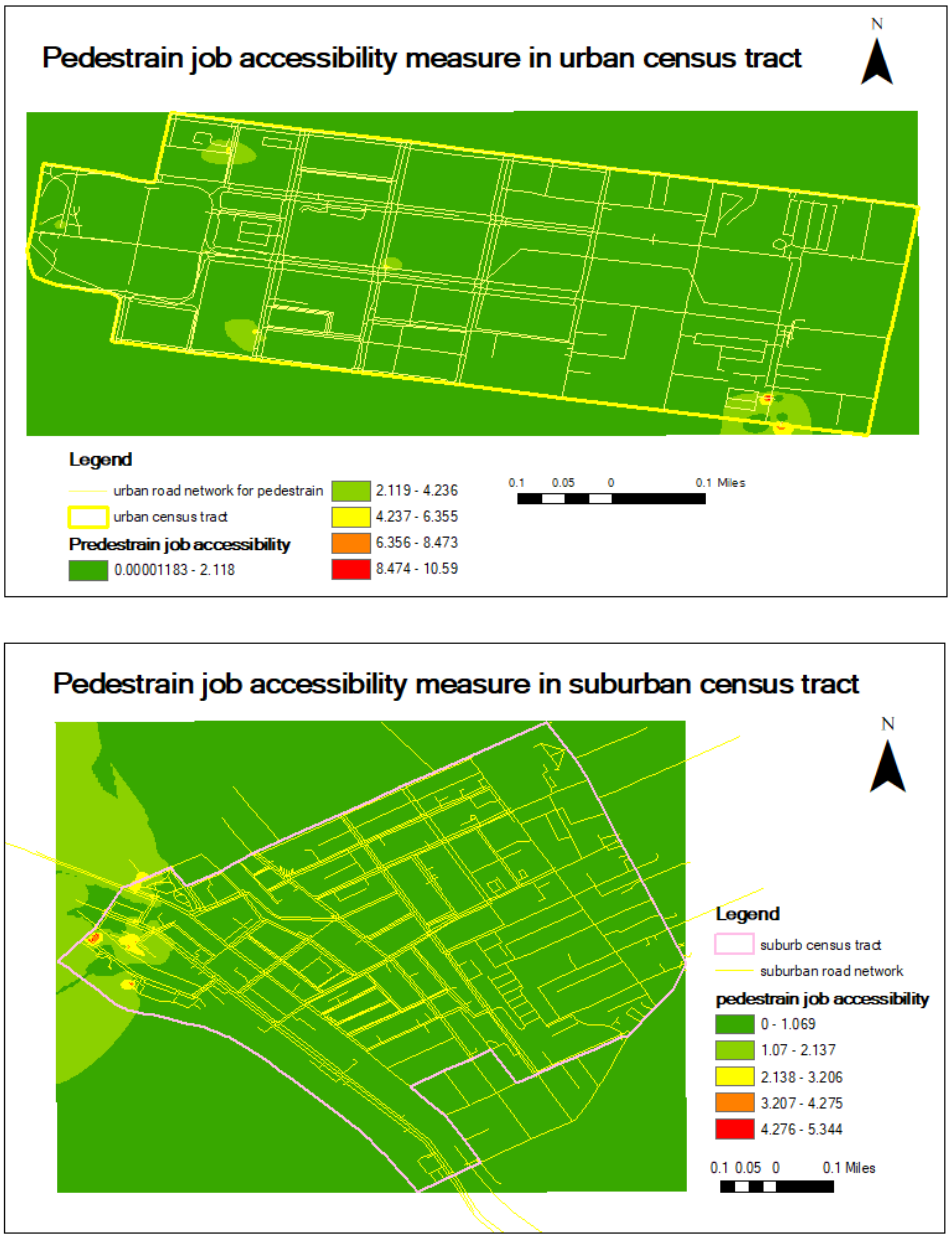
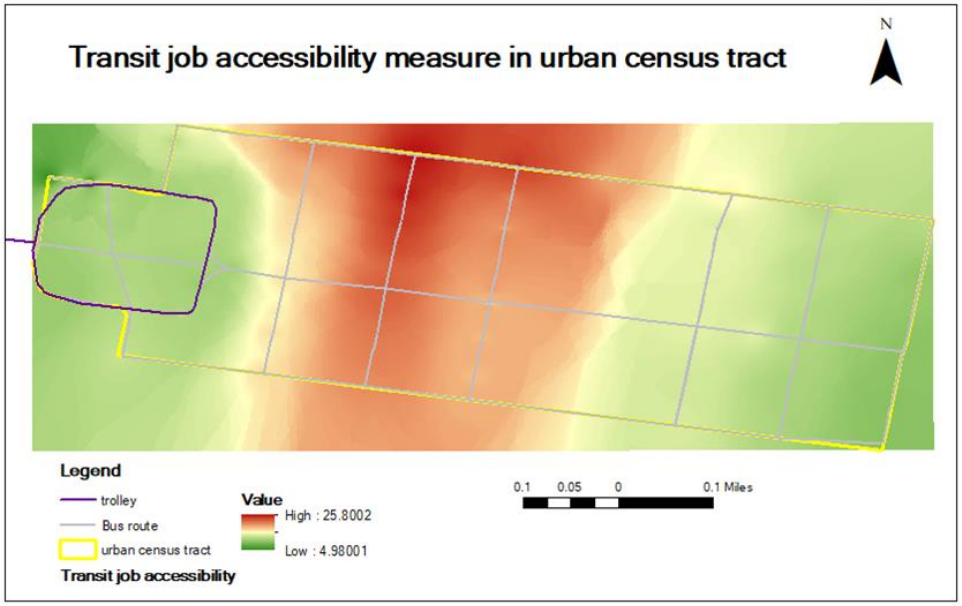


Figure 6. pedestrian job accessibility across urban and suburban census tract



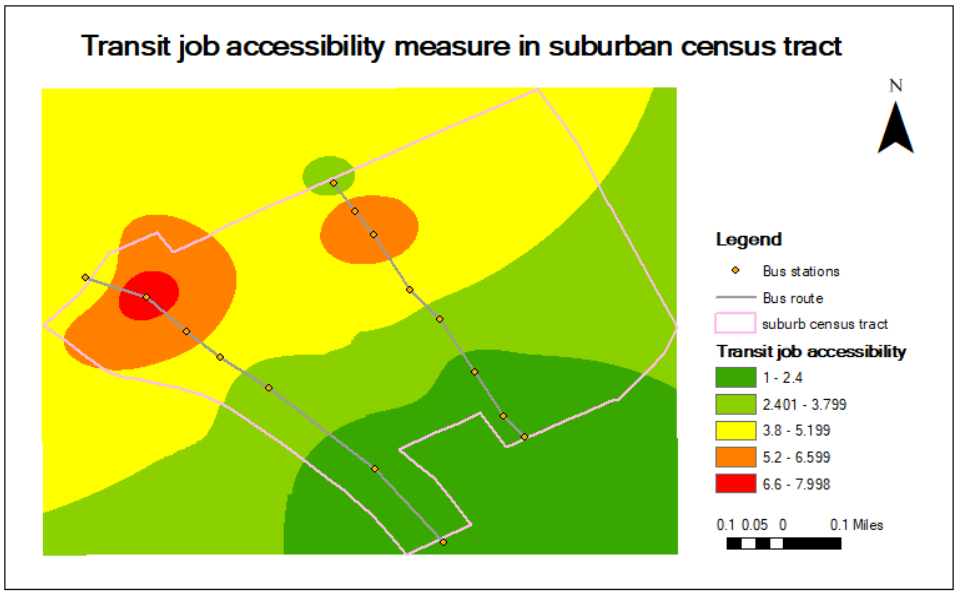


Figure 7. transit job accessibility across urban and suburban census tract

Census tract	Pedestrian travel time on average	Pedestrian job accessibility on average	Transit travel time on average	Transit job accessibility on average
Urban	5.68	1.1	1.98	14.33
Suburban	9.11	0.41	3.76	3.66

Table 1 the comparison of average pedestrian and travel job accessibility between urban and suburban

4. Discussion

With network analysis operation in GIS, this study measures the spatial difference of pedestrian and transit job accessibilities in urban and suburban census tract in Philadelphia. There are higher job accessibilities in urban than suburban, more transit-accessed than pedestrian-accessed jobs. This suggested that public transit can improve the reachability and accessibility for employment, especially for people who do not have private vehicle and suffer from poverty (Tilahun & Fan, 2014). People who live in places with high job accessibilities benefits higher employment, shorter commuting times and less environmental effects (Hu, 2019).

Job accessibility served as an important tool in understanding the urban spatial structure, since it is a measure of relationship between workers, transit systems and opportunities, fundamental elements of urban spatial structure (Huang, 2020). The disparities of transit structure and employment accessibilities between urban core and suburb reflect the socioeconomic inequality. High-income groups tend to resident in urban, where there are not only plentiful job opportunities, but also sufficient facilities and infrastructures in education, entertainment, and other services. Living in urban, though pursuing jobs are the common goal of most people, the travel demands of people diverse. Under this circumstance, high quality and well-connected transit network should be established to fulfill the needs of passengers. The rapid urbanization and the sharp growth in urban population also simulate the development of urban transit systems. On the contrary, people living in suburbs have little access to transit-oriented jobs due to the relatively behind infrastructures and low densities of employment sites. Instead of public transit, workers should own a private vehicle to improve the mobilities and accessibilities otherwise they can hardly access job opportunities. Job accessibilities is just one aspect of the distinct spatial and socioeconomic characteristics between urban and suburbs. Urban planners and scientists should focus on analyzing the driven factors of socioeconomic inequality as well as the effects generated from transit inequality. A fair, sound, and reasonable transportation system is vital for sustainable urban development since the promise of public transportation system is to provide equal access to socioeconomic opportunities everywhere.

The gap of job accessibilities between urban and suburb reveal some common challenges in urban planning, such as jobs-housing imbalance and spatial mismatch. Ideally, the supply of jobs should be reachable for workers' residence (Tao et al., 2020). The lack of transit job accessibility limits both individuals' activities and the operation of urban system. Without accessing to job by public transit, individuals can hardly benefit from the socioeconomic resources and the job attraction for a city will decrease. Since land-use pattern is a key component to job accessibility, urban policy makers should coordinate the relationship between public transportation and land-use pattern. For example, in our study, most job sites concentrated in the northwestern corner of the suburbs, where bus routes cannot reach. More job sites and residential places should be constructed and allocated along the public transit routes. The intense spatial distribution pattern of jobs and transit system, like the urban core, will shorten the distance job seekers walking to the transit stations and thus bring more job opportunities.

There are a few limitations in this study. This study consists of just two census tracts, and they are far apart. It is hard to analyze the commuting between these two census tracts. In addition, this study only considers the commuting within a single census tract, however travelling across different census tracts is quite normal, especially when passengers commute from suburbs to urban for better job opportunities. The analysis across census tract or choosing a wider range of study region will be more meaningful, since it will cover more comprehensive transit system. Public transportation system is complex with several elements, especially under urban context, so more means of public transit should be incorporated to build transit network that close to the reality. Aside for these limitations, further study should incorporate more socioeconomic factors that would influence the job accessibilities, such as land-use pattern, built-

environmental features, vehicle ownership, household size, race, and income context of different census tracts.

5. Conclusion

Using two census tracts in Philadelphia as the case study, this research utilized a generalizable GIS-based network analysis to examine the spatial distribution of access to job by walking or public transits, which demonstrates how public transportation provide people with more accessibilities to jobs. The spatial job accessibilities in census tracts of different urbanization levels are compared to reflect the socioeconomic disparities in space. The results can inform urban decision-makers combine GIS into the transportation planning and solving social equity issues. Further investigation should focus on exploring the socioeconomic mechanisms that drives people to employment in different places. Moreover, a more integrated transit network should be built at a larger scale region.

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