# Plan the Optimal Locations for Mobility Hubs in Gainesville, FL

*Kelly Zheng, Jacob Yan*

*University of Florida*

## 1. Introduction

Mobility hubs serve as centralized locations where multiple transportation options, which allow travelers to seamlessly switch between various modes of transportation such as buses, bicycles, and e-scooters. The objectives of mobility hubs include the followings:

1. Provide transit supply and serve multimodal travel needs.
2. Enhance first-/last-mile connectivity and facilitate transfers.
3. Promote socioeconomic equity.

With these objectives, this study proposes an analytical framework for identifying the optimal locations for mobility hubs in Gainesville, Florida. The proposed methodology can score and weight different criteria that can decide mobility hub suitability, taking the transit supply, first-/last-mile connectivity, accessibility, infrastructure and socioeconomic equity into account in the weighting.

## 2. Methods and data

**Commented [YX1]:** Divide this section into several sub-sections.

Need to have a figure to describe the technical approach. Something like this: bus stop clustering -> buffer -> compute variables & developing indexes -> get mobility hub index --> select neighborhood-level hub --> district/regional-level hub.

### 2.1 Methodology framework

The planning of mobility hubs requires careful consideration of factors such as land use patterns, accessibility, infrastructure availability and socio-economic factors. This requires a multi-criteria decision analysis (MCDA) for identifying the location of mobility hubs, which is implemented in most studies. There are still some key research gaps in these studies. While it is widely recognized that mobility hubs are most effective when located at or near transit stops with high ridership activity, few studies have considered the location and quantity of transit stops as primary criteria for determining the placement of mobility hubs. Furthermore, there is a limited number of studies that specifically target the first mile/last mile gaps and enhance transit connectivity. Additionally, mobility hubs can be built at various levels, including the neighborhood, district, and regional scales. However, existing methods often overlook the typology of mobility hubs and instead focus only on one level.

To address such research gaps, this study proposed a multicriteria evaluation framework for quantitatively analyzing the suitability of a given location for sting mobility hub, which involves the following four steps:

1. Define the spatial unit: this study define buffer zones around bundles of transit stops as spatial units for siting mobility hubs.
2. Define criteria and weights:  Based on the stakeholder objectives, the siting of mobility hubs considers five criteria: transit supply, first-/last-mile connectivity, accessibility, infrastructure, and socioeconomic equity. Each of the criteria is assigned with different weights and has several sub-

criteria, which are weighted sums of scaled continuous variables. The weight scheme and chosen variables were decided according to the literature and discussion with stakeholders.

3. Overall analysis and ranking: Five index scores of different criteria are calculated and aggregated into the mobility hub index score for a given spatial unit. These scores are ranked to select the top amount as most potential sites for identifying the neighborhood level mobility hubs.
4. Expansion of mobility hub size: This study considers the hierarchical expansion of mobility hubs from neighborhood to district and regional levels. Step 1-3 are repeated with a revision of buffer size in step 1, weights and variables in step 3.

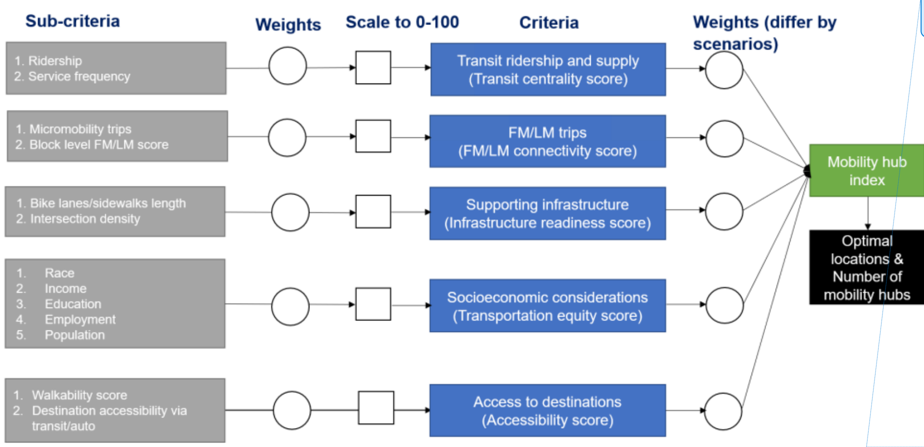



Figure 1. analytical framework for identifying the optimal location of mobility hubs based on multi-criteria.

**Commented [YX2]:** Delete the five 0.2 from the "weights" column. Revise "weights" to "Weights (differ by scenario)."

## 2.2 Data and Variables

As mentioned, we consider five criteria in deciding the mobility hubs. Each criteria have several sub criteria, which involve different continuous variables to be calculated. The criteria, its associated variables and weights are summarized in table 1.

The goal of mobility hubs is to provide transit ridership and supply to satisfy multimodal travel needs. The related data is mainly collected from Gainesville Regional Transit System (RTS)[1], the local transit bus service in Gainesville. The bus routes and stops information are collected from the General Transit Feed Specification (GTFS) dataset, a public dataset for public transportation schedules and associated geographic information. The bus ridership data (including passenger counts, on-board wheelchair and bicycle amount at stops) are collected from city of Gainesville.

Mobility hubs should also solve the first mile/last mile gaps and enhance transit connectivity. The FM/LM connectivity data includes two aspects: micromobility trip and census block level FMLM gap score. The

[1] http://go-rts.com/rts-data/

micromobility trip data is collected from city of Gainesville, including the spatiotemporal information of e-scooter and micro transit trips. The data source of census block level FMLM gap score includes American Community Survey (ACS) and LEHD Origin-Destination Employment Statistics (LODES). ACS is a survey conducted by the U.S. Census Bureau and includes detailed demographic, economic, social, and housing data. LEHD provides employment and workplace characteristic data. To calculate the census block level FMLM gap, we need latest block level population data from ACS and job data from LODES.

Mobility hubs should also contain some infrastructure for pedestrian and cyclists, which includes two aspects of data: intersection density and road infrastructure for pedestrians and cyclists. The intersection density data is collected from Smart Location Database[2], a nationwide geographic data resource for measuring location efficiency that includes neighborhood design, destination accessibility and transit service. We collected intersection density at which multi-modal facilities or pedestrian-oriented facilities met and where the number of legs was greater than 4. The road infrastructure data is collected from OpenStreetMap (OSM), which provides detailed information about road networks.

Besides, mobility hubs should solve social equity issues, making sure that even disadvantageous groups can access the mobility hubs. For socioeconomic considerations, we take into account five variables regarding population, race, age, income and vehicle ownership. These socioeconomic data is also collected from ACS.

Finally, mobility hub aims at enhancing the accessibility to destinations. To measure the accessibility, we collected data regarding destination accessibility via auto or transit from Smart Location Database. To evaluate the walkability around bus stops as another measurement of accessibility, we also collected walk score from WalkscoreAPI[3].

**Commented [YX3]:** Divide this table into several: here only list the criteria and the subcriteria. Put the other components into the corresponding sections.

[2] https://www.epa.gov/smartgrowth/smart-location-mapping
[3] https://www.walkscore.com/professional/api.php

| Criteria | Sub-criteria |
|---|---|
| **Transit ridership and supply** | Ridership |
| | Service frequency |
| **FM/LM Connectivity** | Bicycle trips |
| | Microtransit FMLM trips |
| | escooter FMLM trips |
| | FM/LM gap score |
| **Infrastructure** | Intersection density |
| | Bike lanes |
| | Sidewalks |
| **Socio-demorgraphic** | Household without vehicle (%) |
| | Black population (%) |
| | People living in rental units (%) |
| | Poverty (%) |
| | Disabilities (%) |
| **Access to destinations** | Destination accessibility via auto |
| | Destination accessibility via transit |
| | walk score |

Table 1. list of criteria and sub criteria

## 2.3 Definition of spatial unit

These variables were preprocessed and scaled to the spatial unit, which refers to 1 mile buffer zone from groups of adjacent transit stops, an appropriate size for identifying a neighborhood-level mobility hub. We applied DBSCAN clustering algorithm to group all the bus stops into clusters that are in proximity based on a specified search distance. Density-Based Spatial Clustering of Applications with Noise (DBSCAN) is a base algorithm for density-based clustering. It can identify clusters of different shapes and sizes from a large amount of data, which is containing noise and outliers. The DBSCAN algorithm involves two parameters: (1). The minimum number of points clustered together for a region to be considered dense. (2). A distance measure that will be used to locate the points in the neighborhood of any point[4].

We set the search distance as 100 meters and the maximum bus stop number of each cluster as 10. This generates 628 grouped clusters among 1081 stops. We then created 1 mile buffer zone around each stop as spatial unit in our analysis.

**Commented [YX4]:** This section should be singled out. Need to describe what the DBSCAN algorithm is and what it is doing.

[4] https://www.kdnuggets.com/2020/04/dbscan-clustering-algorithm-machine-learning.html

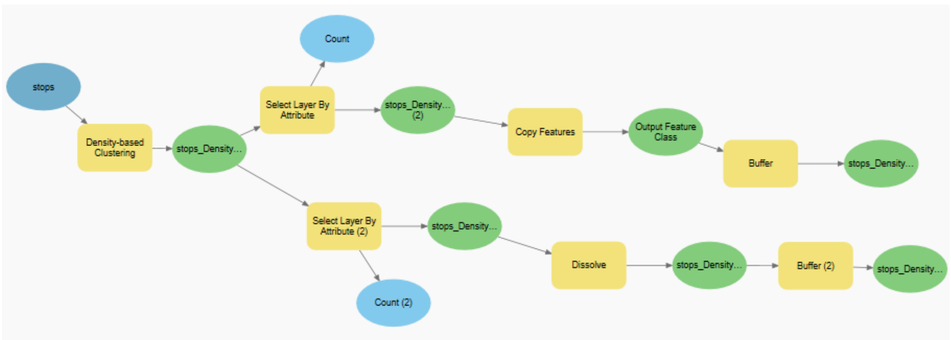



Figure 2. workflow for deciding the spatial unit in Module Builder.

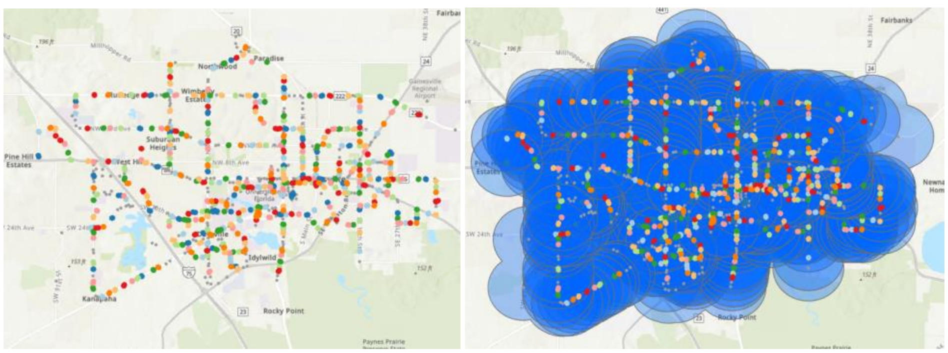


Figure 3. (a). grouped adjacent transit stops (b). 1 mile buffer zone around transit-stop clusters

## 2.4 Transit Ridership and Supply

The first criteria, transit ridership and supply, is decided by two sub criteria: ridership and service frequency, which involves some variables to be calculated as figure 4 shows (e.g., passenger count, number of bus stops). These variables are all stop-level and need to be aggregated to the spatial unit. Then they are scaled to 0-100 and the weighted sum are calculated to derive the index score of transit ridership.

| Criteria | Sub-criteria | Variable | weights |
|---|---|---|---|
| Transit ridership and supply | Ridership | passenger count | 0.4 |
| | | wheelchair | 0.1 |
| | Service frequency | number of unique bus routes | 0.1 |
| | | bus stop number | 0.1 |
| | | number of bus total passing by the stop | 0.3 |

**Commented [YX5]:** Need to have a "results" section. Section 4-9 should be sub-sections in the "data and variable" section as well as the "results" section.

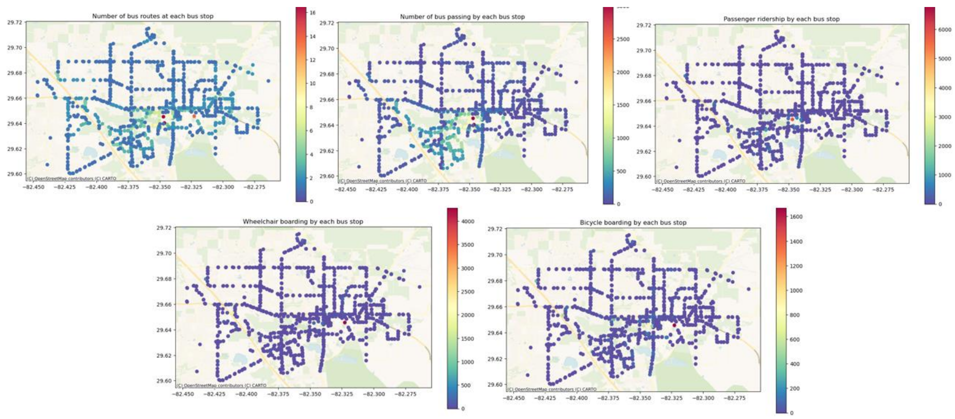



Figure 4. criteria #1 (transit ridership and supply) with associated weights and variables

## 2.5 First/Last mile Connectivity

FMLM problems refer to the gap between transit stops and travelers' origin/destination. Micromobility can solve the FMLM problems by enhancing the connectivity to transit stops. If more micromobility trips are around bus stops, then such bus stops have more needs for solving the FMLM gap. We measured the FMLM connectivity with the micromobility (scooter and micro transit) trip origin/destination trip amount within 100ft buffer zones at grouped bus stops.

Additionally, we calculated the census block level FMLM gap score as another measurement of the FMLM connectivity index score. This score is evaluated based on the distance between the centroid of each census block and the nearest bus stops, weighted the number of jobs/ the total population of the block. This involves the following steps as illustrated in figure 5:

1. Calculate the number of jobs plus the total population of each block centroid.
2. Find the distance to the nearest bus stop for each block centroid. Recode the distance into the following values: <0.25 mile: 0; 0.25-0.5 mile: 1; 0.5-0.75 mile: 2; 0.75 – 1 mile: 3.
3. Calculate the FMLM gap score at centroid level with (number of jobs + total population) * nearest distance.
4. Aggregate the total values of centroid-level FMLM gap score to the spatial unit.

Beside micromobility trip amount and block level FMLM gap score, the number of bikes passenger carry onboard at each stops is another measurement to evaluate the FMLM connectivity as figure 7 shows.

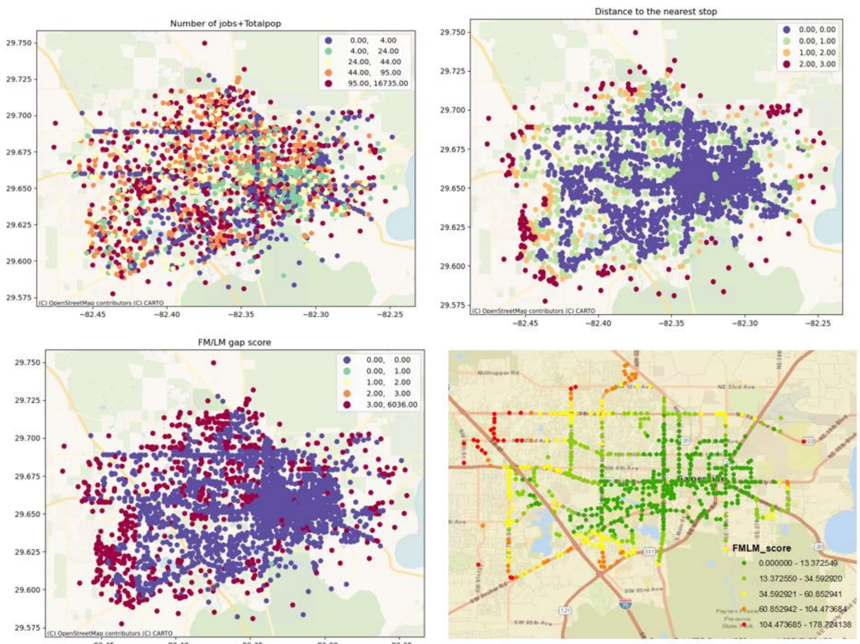



Figure 5. steps of calculating the block level FMLM score

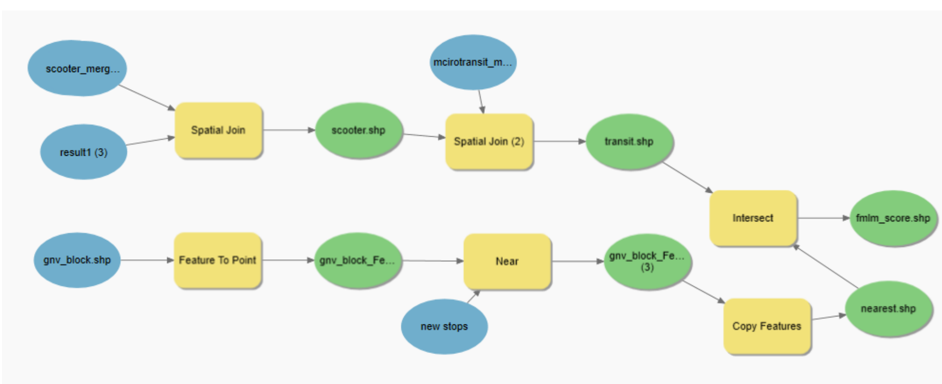



Figure 6. workflow for geoprocessing the FMLM connectivity indicators in Module Builder.

| Criteria | Sub-criteria | Variable | weights |
|---|---|---|---|
| | Bicycle trips | bicycle trips at stops | 0.15 |
| | Microtransit FMLM trips | number of trips within bus stop buffer | 0.15 |
| | escooter FMLM trips | number of trips within bus stop buffer | 0.15 |
| FM/LM Connectivity | FM/LM gap score | census block level FMLM gap score | 0.55 |

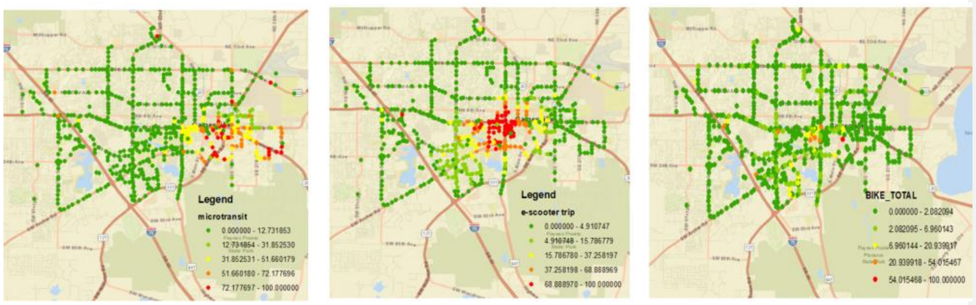


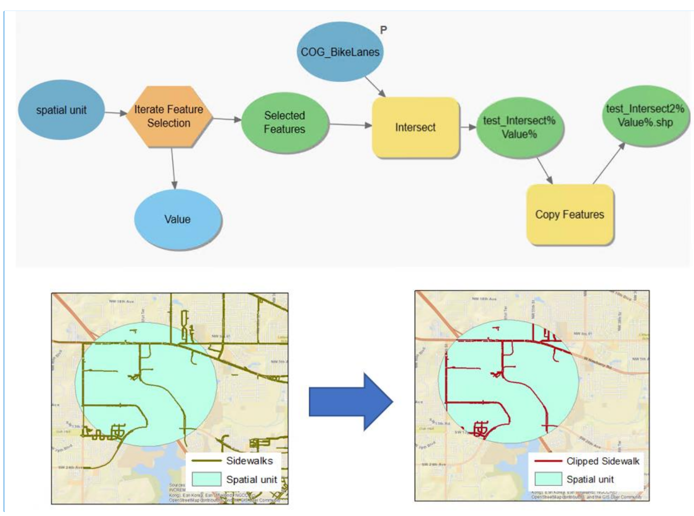

Figure 7. criteria #2 (first/last mile connectivity) with associated weights and variables

## 2.6 Road Infrastructure

The infrastructure index score is measured by three dimensions:

1. The sidewalk and bicycle lane length, the ratio between sidewalk/bicycle lane length and overall road network length within the spatial unit.
2. The intersection density at which multi-modal facilities or pedestrian-oriented facilities met.

The original data should be clipped and assigned to the spatial unit with the workflow in figure 8.




**Commented [YX6]:** Attach the model builder screenshot and perhaps some intermediate visuals in other sections as well.

Figure 8. workflow of how to clip and assign the data to the spatial unit

| Criteria | Sub-criteria | Variable | weights |
|---|---|---|---|
| | | Multi-Modal Intersection Density | 0.16 |
| | Intersection density | Pedestrian-Oriented Intersection Density | 0.16 |
| | | bike lane length/street segment length | 0.16 |
| | Bike lanes | bike lane length | 0.16 |
| | | sidewalk lane length/street segment lengt | 0.16 |
| Infrastructure | Sidewalks | sidewalk lane length | 0.16 |

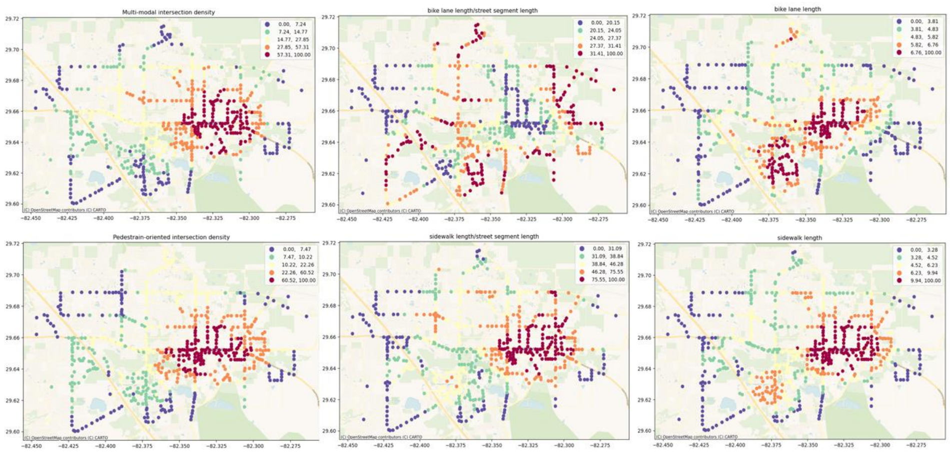



Figure 9. criteria #3 (road infrastructure) with associated weights and variables

## 2.7 Socioeconomic Considerations

The socioeconomic variables are collected at census block group level. To aggregate the socioeconomic factors to the spatial units, we selected the census block groups intersected with the spatial unit and then calculated the indicators (e.g. percentage of black people).

| Criteria | Sub-criteria | Variable | weights |
|---|---|---|---|
| | Household without vehicle (%) | | 0.2 |
| | Black population (%) | | 0.2 |
| | People living in rental units (%) | | 0.2 |
| | Poverty (%) | | 0.2 |
| Socio-demorgraphic | Disabilities (%) | Percentage | 0.2 |

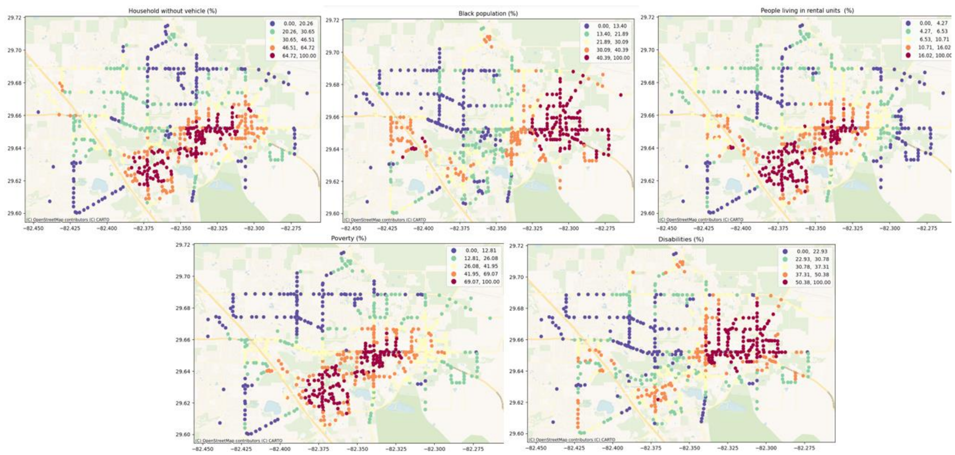



Figure 10. criteria #4 (socioeconomic equity) with associated weights and variables

## 2.8 Accessibility to destination

The accessibility to destinations is measured by the following two aspects: (1). destination accessibility via auto or transit; (2) workability score.

| Criteria | Sub-criteria | Variable | weights |
|---|---|---|---|
| Access to destinations | Destination accessibility via auto | Jobs within 45 minutes auto travel time | 0.25 |
| | Destination accessibility via transit | Jobs within 45-minute transit commute | 0.25 |
| | walk score | 0-100 | 0.5 |

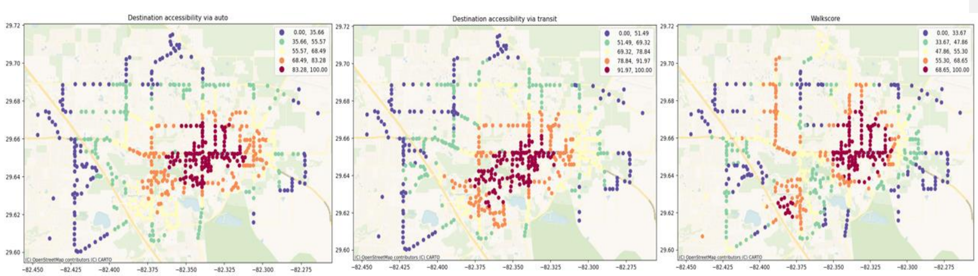



Figure 9. criteria #5 (accessibility) with associated weights and variables

## 2.9 Selection of mobility hubs

The mobility hub index is the weighted sum of index score of each criteria. We assign the same weights (20%) for each criteria, and also emphasize each criteria by assigning 50% weights, while others remained 12.5%.

| Criteria (score) | accessibility | transit supply | equity | infrastructure | FMLM | weights_equal |
|---|---|---|---|---|---|---|
| Transit Centrality Score | 0.125 | 0.5 | 0.125 | 0.125 | 0.125 | 0.2 |
| First/last mile Connectivity Score | 0.125 | 0.125 | 0.125 | 0.125 | 0.5 | 0.2 |
| Infrastructure Readiness Score | 0.125 | 0.125 | 0.125 | 0.5 | 0.125 | 0.2 |
| Socio-demorgraphic equity score | 0.125 | 0.125 | 0.5 | 0.125 | 0.125 | 0.2 |
| Accessibility Score | 0.5 | 0.125 | 0.125 | 0.125 | 0.125 | 0.2 |

Table 2. weights assigned under different scenarios.

By weighting each criterion, we can compute the mobility hub index score of each spatial unit. To identify multiple mobility hubs from the spatial units, we implemented an algorithm to choose from the spatial unit following four steps:

1. Select the existing (or planned) mobility hubs.

2. Exclude all potential hubs within 1-mile of the selected hubs from considerations

3. Select the hub with the highest mobility hub index as the next hub

4. Repeat steps 2 and 3 until the service coverage is >60% or the total number of hubs reaches N

There are three hubs planned to be sited in Gainesville as figure 10 shows: Butler Plaza Transit Center; Eastside hub; a downtown hub. These are considered at the initial stage of siting the mobility hubs.

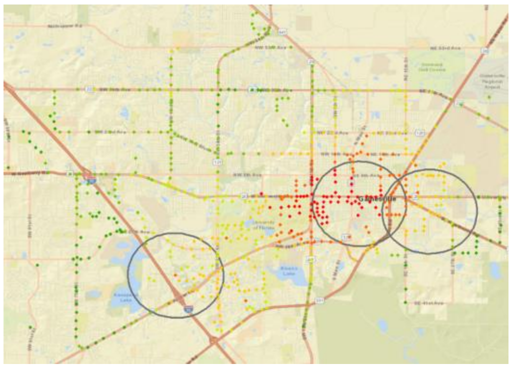


Figure 10. three mobility hubs planned to be sited in Gainesville

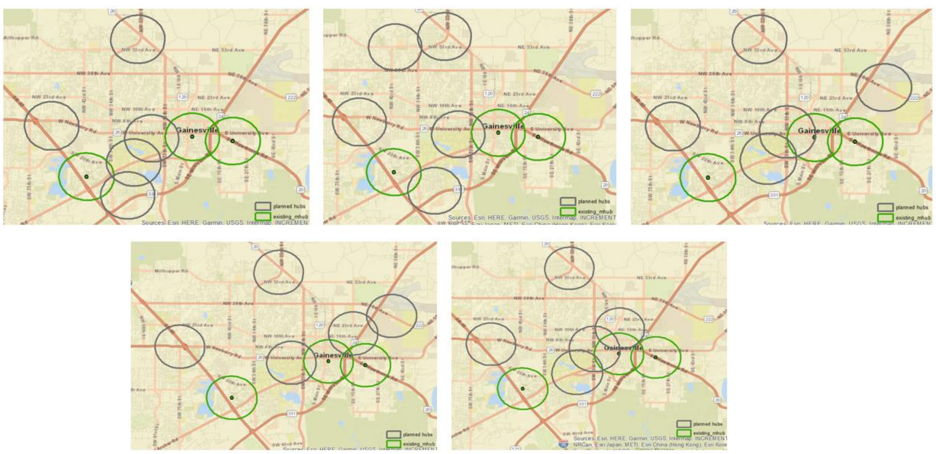


Figure 11. demonstration of the algorithm planning the mobility hubs

## 3. Results

By analyzing and quantifying the variables, each score associated with different criteria is calculated as figure 12. UF campus has the highest transit ridership index score and highest accessibility score. This means that UF campus has the most abundant transit supply and ridership. In contrast, north and east Gainesville has the lowest transit supply and ridership. Southwestern Gainesville has the most serious FMLM gap problem where limited bus stops cluster. East Gainesville has the highest infrastructure score, suggesting more plentiful cyclist and pedestrian infrastructure was provided. It also has the highest transportation equity score, suggesting that most disadvantage people (e.g., black, poverty population).

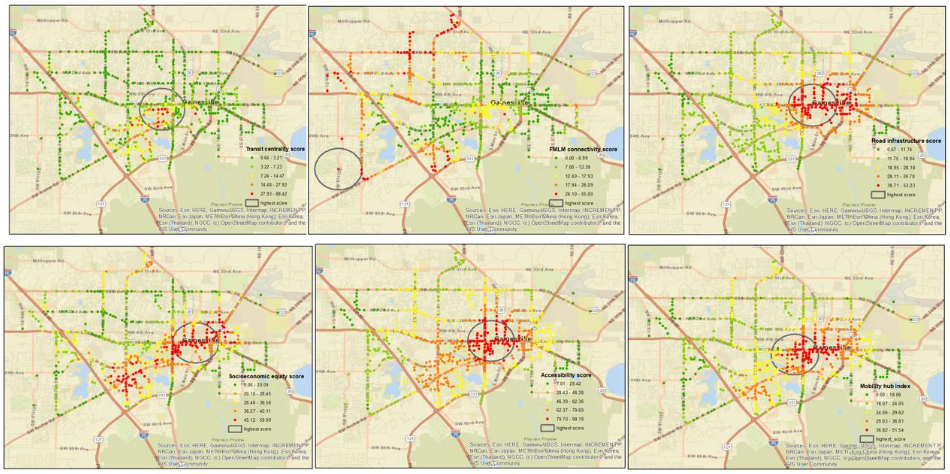
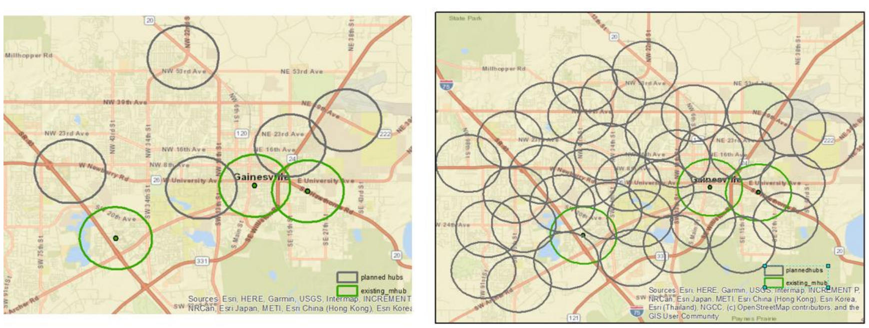


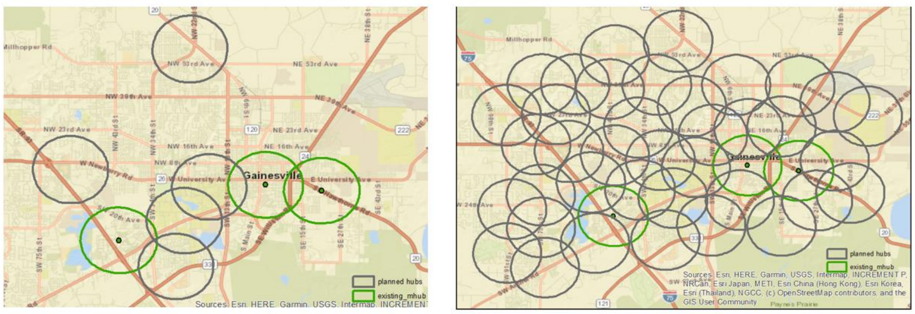
Figure 12. five scores associated with different criteria and the mobility hub index score (with the same weights of each criteria)

We also adjusted the weights of different criteria and visualize the outcomes of planned mobility hubs. Figure 13 shows how 8 mobility hubs and the maximum number of hubs to be planned in Gainesville given different scenarios.



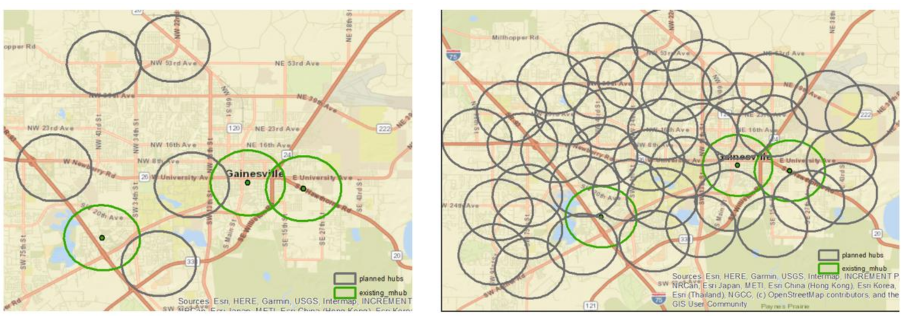
38 hubs, 87.74%

Figure 13 (a). planned mobility hubs given same weights of each criteria.



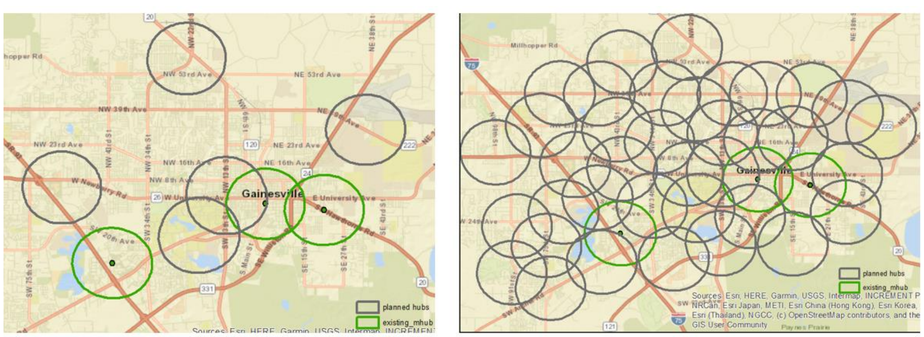

41 hubs, 89.5%

(b). planned mobility hubs emphasizing on the transit ridership and supply.



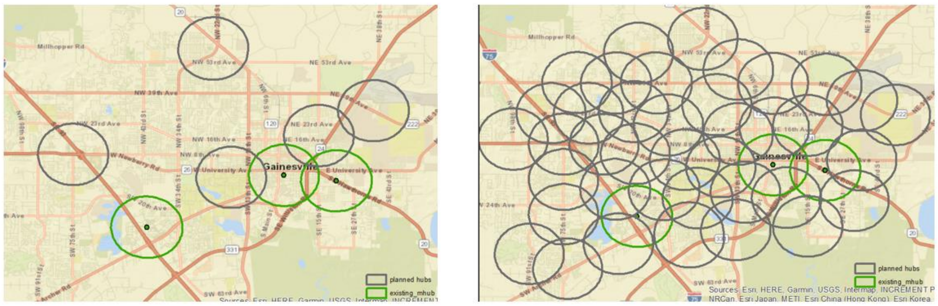

43 hubs, 90.9%

(c). planned mobility hubs emphasizing on the FMLM connectivity.



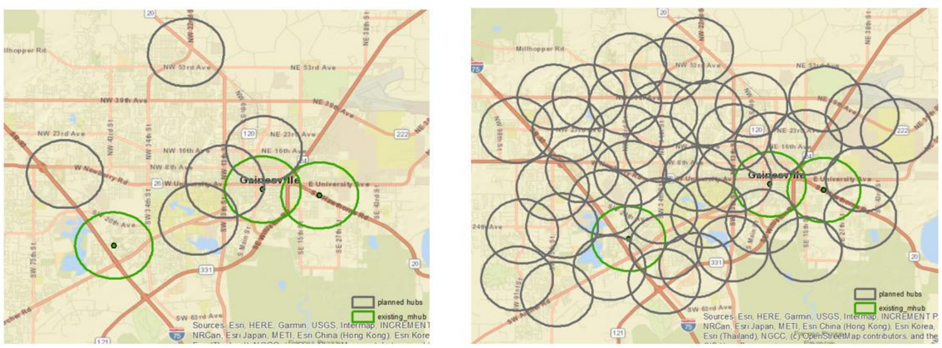

40 hubs, 89%

(d). planned mobility hubs emphasizing on the road infrastructure.




42 hubs, 88.8%

(e). planned mobility hubs emphasizing on the socioeconomic equity.




43 hubs, 89.5%

(f). planned mobility hubs emphasizing on the accessibility.