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16. Abstract

This research develops a framework to evaluate pedestrian improvements such that the transit system can be supported by the proposed pedestrian infrastructure in a way that can boost transit ridership and improve safety and access for riders.

The research has three main spatial data inputs, which are available in most cities: transit bus stop location, pedestrian infrastructure configuration, and land use data (population density, income etc.) paired with transit boarding data from fare boxes at those bus stops as available. Using these data, one can optimize investment in pedestrian infrastructure that likely has the greatest impact on transit using network connectivity metrics like Pedestrian Route Directness (PRD) or similar metrics, weighted to account for the influence of existing and potential demand (e.g., socioeconomic and land use data and bus boarding data).

The results are seen in two guidebooks demonstrating GIS-based methods. These provide approaches to optimize investment in pedestrian infrastructure with a focus on accessing transit, which has compounding benefits (e.g., increasing ridership and fare revenue etc.). Indeed, pedestrian infrastructure improvements could be more cost effective than transit service improvements or other ridership strategies in some cases.

17. Key Words	18. Distribution Statement
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DISCLAIMER

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Walk-to-Transit
Commercial Parcel Implementation Guide

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INTRODUCTION

This implementation guide describes the process of calculating pedestrian attraction to non-residential parcels from transit stops, and the use of Geographic Information Science-based (GIS) software to present the results.

An adapted gravity model will be applied to each route based on building area size and travel time in order to generate an attraction measure.

$$A_{ij} = \frac{S_j}{T_{ij}^{\beta}}$$

Where:

A_{ij}: The potential attraction measure of a nonresidential destination, j, by a pedestrian, i, from the nearest bus stop via the road network

S_j: The floor area of nonresidential building destination, j, per 1,000 square feet

T_{ij}: The travel time, in minutes, experienced by the pedestrian in reaching the nonresidential destination

β: An empirically estimated parameter, which reflects the effect of travel time or distance based on land use type of destination

GENERATING THE MEASURE

The attractiveness measure based on the gravity model can be calculated for each pathway solely on GIS software, although one may use a spreadsheet program to assist in calculation.

Data Requirements:

- Property ownership (vector shapefile)
- Transit stops (vector shapefile)
- Transit network (vector shapefile)
- Road network (vector shapefile)
- Tabular property data including building area size of non-residential properties

Step 1: Preparing Non-Residential parcels

1. Open the property ownership shapefile and transit stops shapefile. Create a 1 mile buffer using transit stops shapefile as input features.
2. Clip the property ownership shapefile with the buffer layer to include only the parcels within the buffer area. Use the property ownership shapefile as input features and the buffer layer as the clip features. Figure 1 shows the results of this process.

Figure 1: Example of a buffered and clipped region

3. Open the attribute table of the property ownership shapefile. Through [Table Options → Select By Attributes…], select non-residential parcels from the property ownership shapefile using the LANDUSE attribute, as shown in Figure 2. Examples of non-residential LANDUSE values are listed in Figure 3.

Figure 2: Landuse types

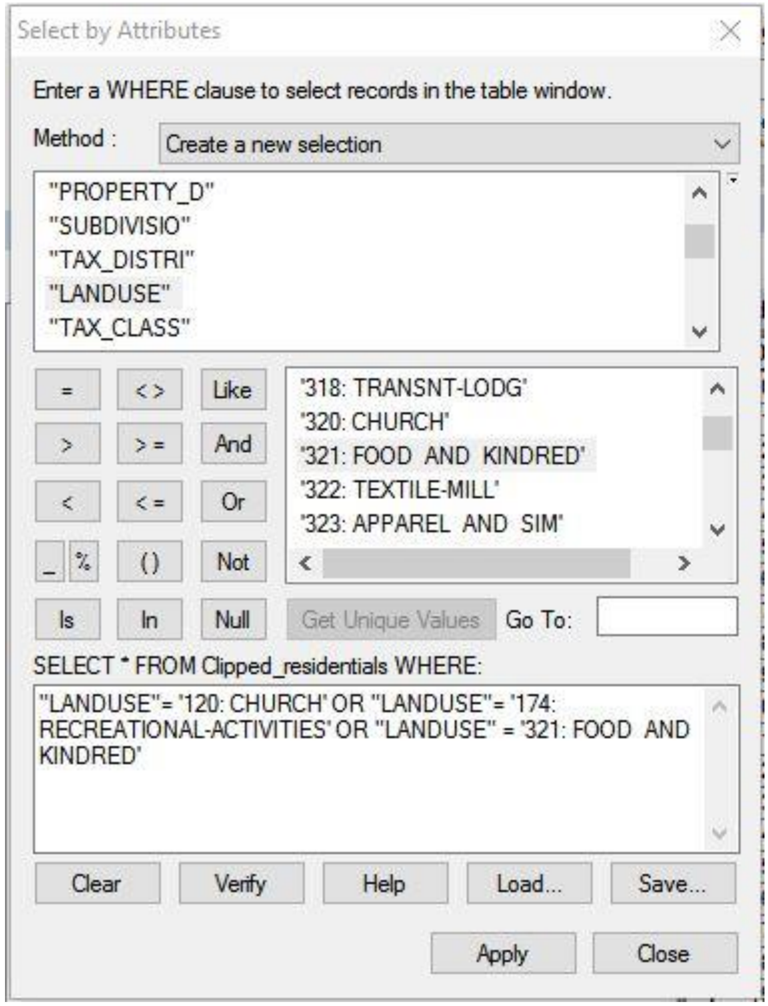

Figure 3: Selecting parcels by landuse

4. Export the selection to a shapefile by [Right-clicking the shapefile → Data → Export Data…]. The shapefile will be referred as NON-RESIDENTIAL.
5. Join building area from tabular property data to the NON-RESIDENTIAL shapefile by [Right-clicking the “non-residential” shapefile → Joins and Relates→Join…]. Base the join on PARCELID, as shown in Figure 4.

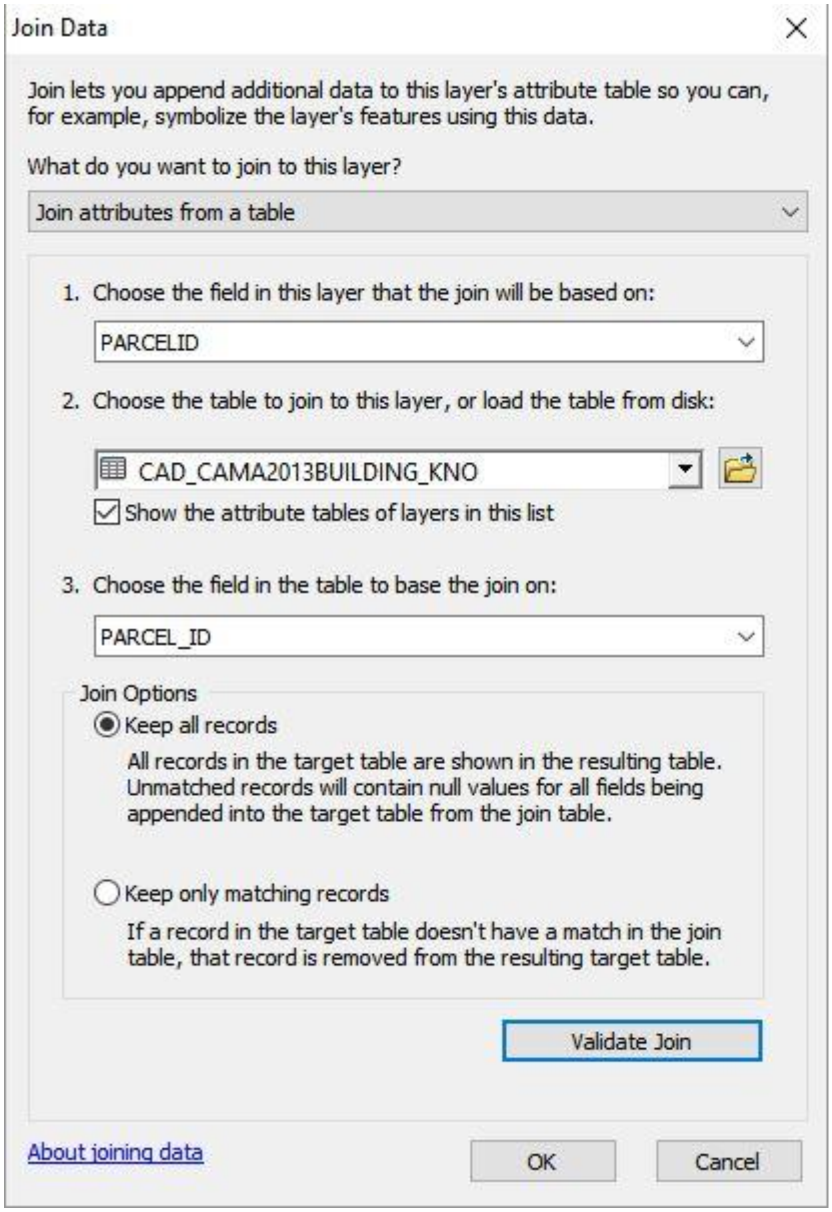

Figure 4: Joining building area data

6. Generate geometric centroids for the non-residential parcels by following the standard process as outlined by ESRI (http://support.esri.com/en/knowledgebase/techarticles/detail/32988). Make sure to export the resulting centroid data into a shapefile. Figure 5 shows the parcels with the addition of centroids.

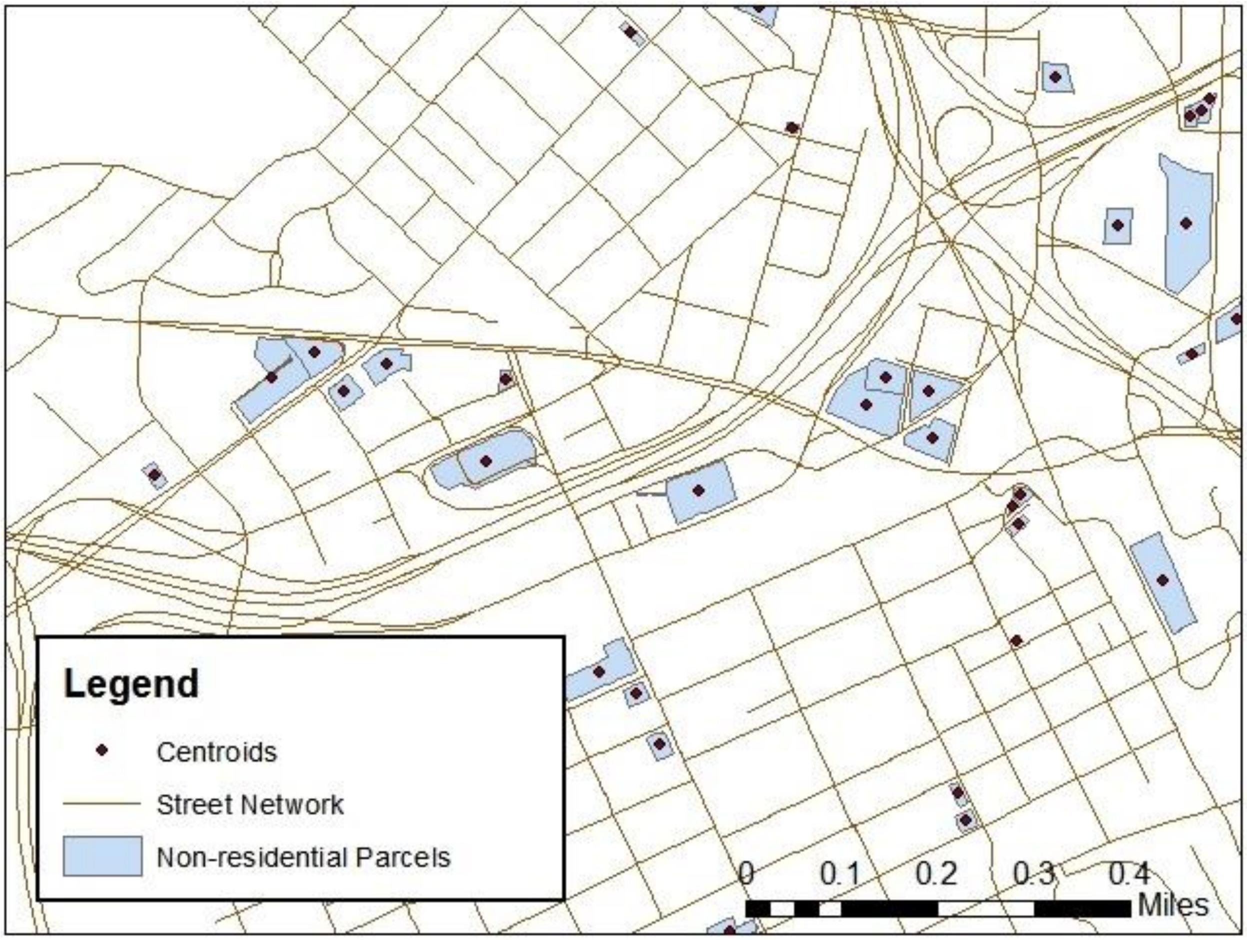

Figure 5: Non-residential parcels with calculated centroids

Step 2: Preparing and Running Network Analyst

1. The Network Analyst extension in ArcMap must be enabled. To enable, [Customize > Extensions… > Network Analyst.
2. Prior to running the Network Analyst tool, create a new field in the road network shapefile designating streets as a highways. Through [Table Options → New Field], create a new field named HIGHWAYS. Through [Table Options → Select By Attributes…], select highway segments and streets that would not allow pedestrian travel. After making the selection, [Right-click HIGHWAY column → Field Calculator…] and designate a value of 1 to the records.
3. In ArcCatalog, generate a network dataset using the road network shapefile by [Right clicking the road network shapefile → New Network Dataset…]. Follow the steps making sure to do the following:
    a. Allow to model turns
    b. Use default connectivity
    c. Do not use an elevation model
    d. Do not use a "one-way" restriction.

e. Add a restriction for travel on high speed streets by using the HIGHWAYS field created in step 1 as an evaluator. First, add a restriction attribute called HIGHWAYS, as shown in Figure 6. Then, add an evaluator to the HIGHWAY restriction by clicking [Evaluators…]. For each source value, click Evaluator Properties and type [HIGHWAYS] = 1 in the value field. This is shown in Figure 7. This will restrict travel on the specified streets for use with Network Analyst.

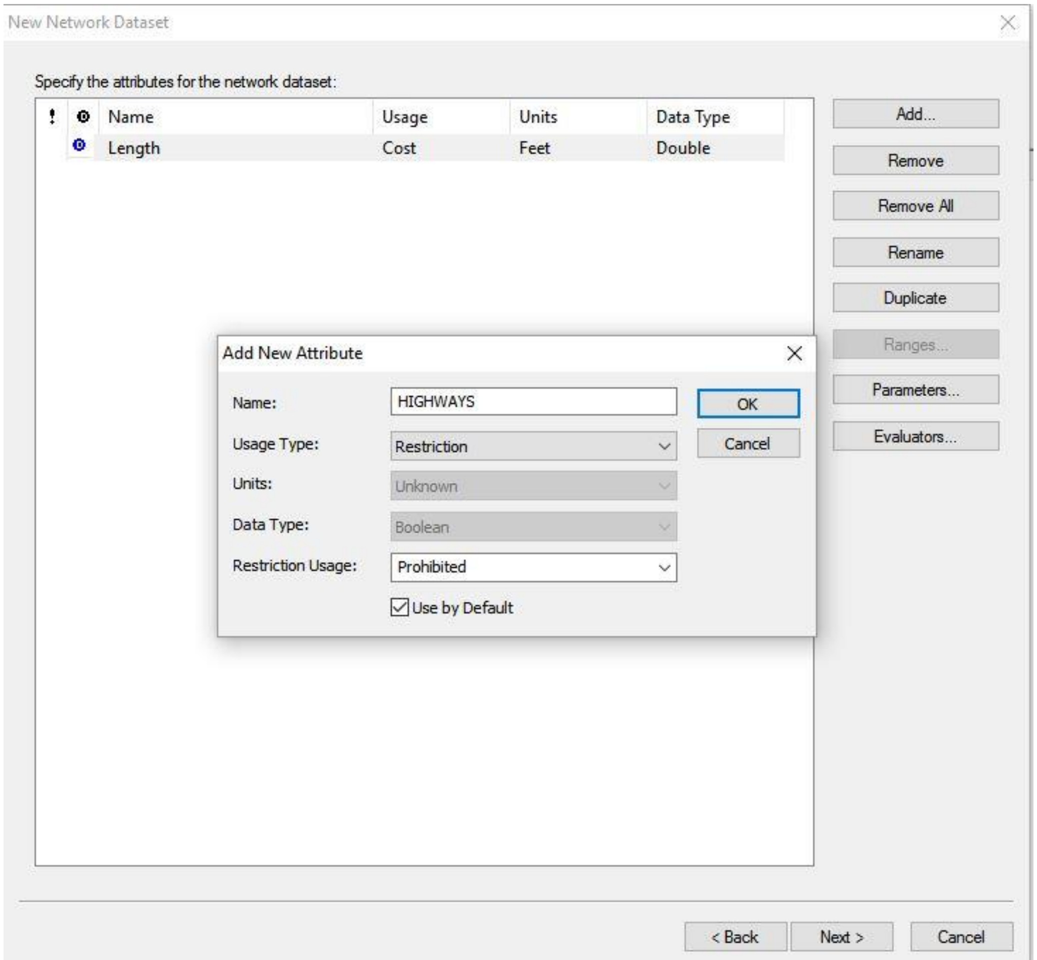

Figure 6: Creating highway restriction

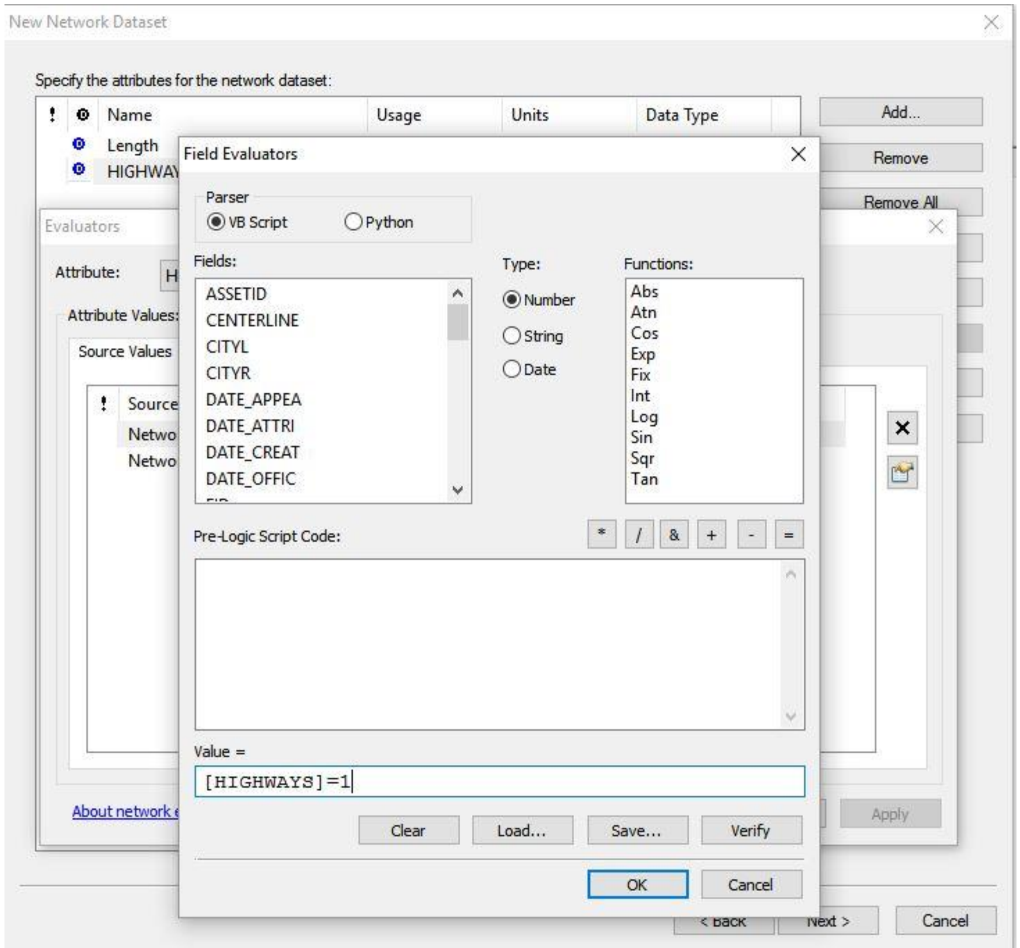

Figure 7: Creating evaluator for highway restriction

f. A travel mode is not necessary
g. Use driving directions if wanted

4. In ArcMap, open the new network dataset. Through the Network Analyst toolbar, click "Build the Network Dataset".
5. Through the Network Analyst toolbar, create a new closest facility analysis layer.
6. In the Network Analyst window, load the transit stop shapefile as "Incidents" and the centroids shapefile as "Facilities". This is done by right clicking the respective group and selecting [Load Locations…].

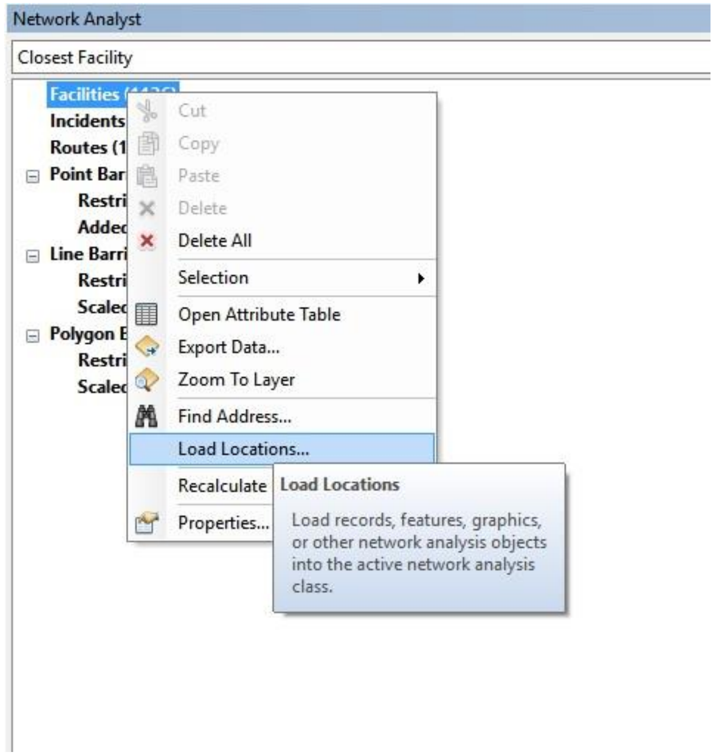

Figure 8: Loading facilities and incidents for Network Analyst

7. Solve the closest facility analysis by using “Solve” in the Network Analyst toolbar.
8. Export the generated routes to a shapefile by [Right-clicking “Routes” → Data → Export Data…]. The shapefile will be referred as “PATHS.”

Step 3: Calculating Attractiveness and Generating Results

1. Spatially join the centroids shapefile to the PATHS shapefile. This will provide building area for the destination parcel, used in calculating attractiveness [Right-clicking the “non-residential” shapefile → Joins and Relates→Join…]. Select to join all attributes to the PATH shapefile. This is shown in Figure 9.

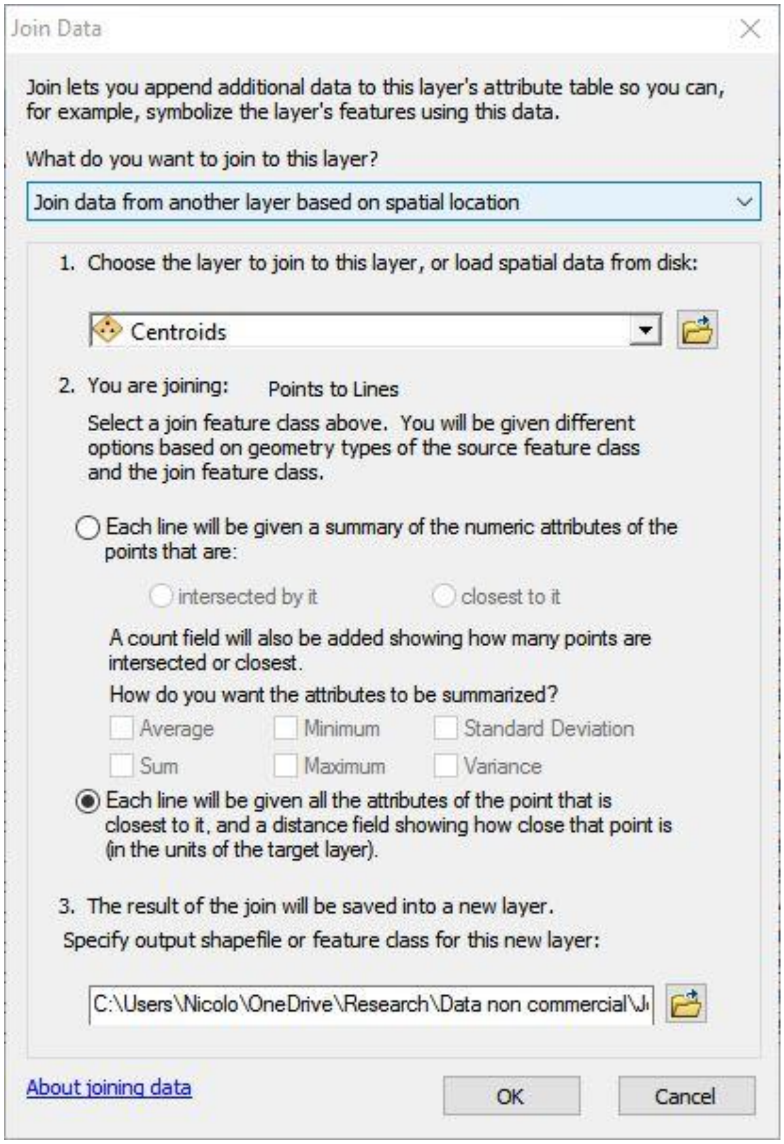

Figure 9: Spatially joining centroids to PATHS shapefile

2. In the new output shapefile, create a new field for walking time, which is calculated by running Field Calculator and using the distance of the path found in Network Analyst and a walking speed of 3.5 fps. Walking time in minutes is defined as $WALKTIME = \left(\frac{PATHLENGTH}{3.5}\right) * 60$. Figure 10 demonstrates the field calculation for walking speed using the Python parser.

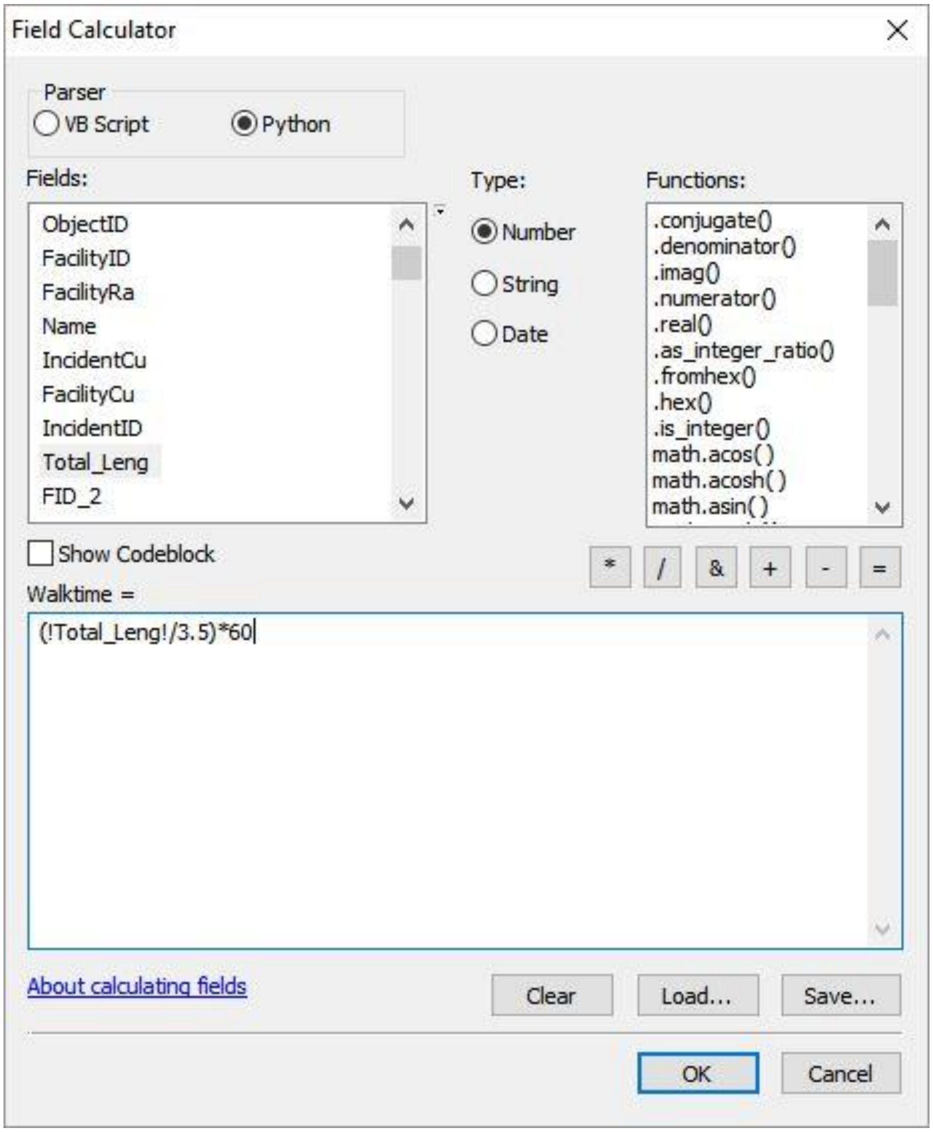

Figure 10: Calculating walktime

3. In the same shapefile, create a new field for the attractiveness A_{ij}. To calculate attractiveness, use the function:

   $A_{ij} = \frac{S_j}{T_{ij}^{\beta}}.$

   $where\ S_j\ is\ building\ area\ in\ square\ feet\ and\ T_{ij} is\ walktime$

   If available, the value of parameter β is based on an empirically calibrated term. Otherwise, use a value of 2.0. Figure 11 demonstrates the field calculation for attractiveness using the Python parser.

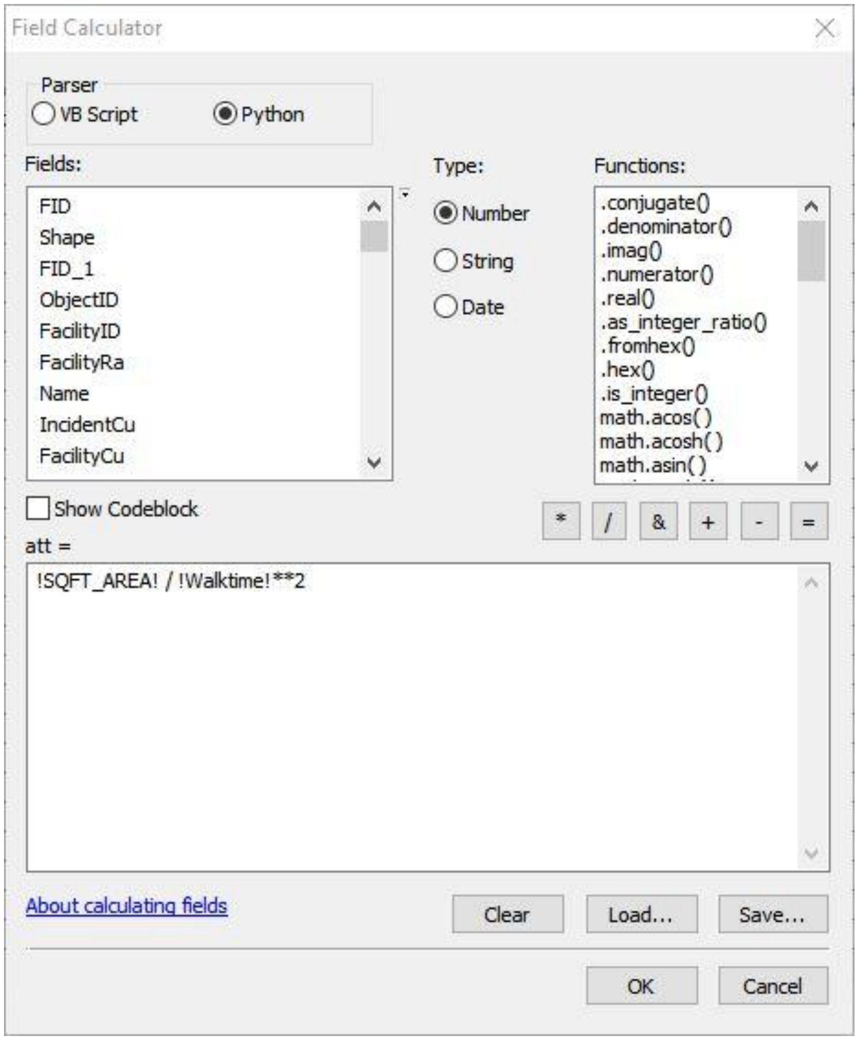

Figure 11: Calculating the attractiveness measure

4. Given the calculated values of attractiveness, use symbology to discretize the values into quintiles. This will display the paths weighted based on their desirability and allow for a comparison with the any existing pedestrian segments. Symbology is changed by right clicking the shapefile and selecting Properties. Under the symobology tab, select the value from which the paths are discretized. The attractiveness field will be the basis of the analysis. Click [Classify…] and select Quintiles as the classification method. Make

sure Figure 12 and 13 show the symbology settings to generate quintile divisions. Figure 14 shows the completed model loaded along with the existing pedestrian infrastructure.

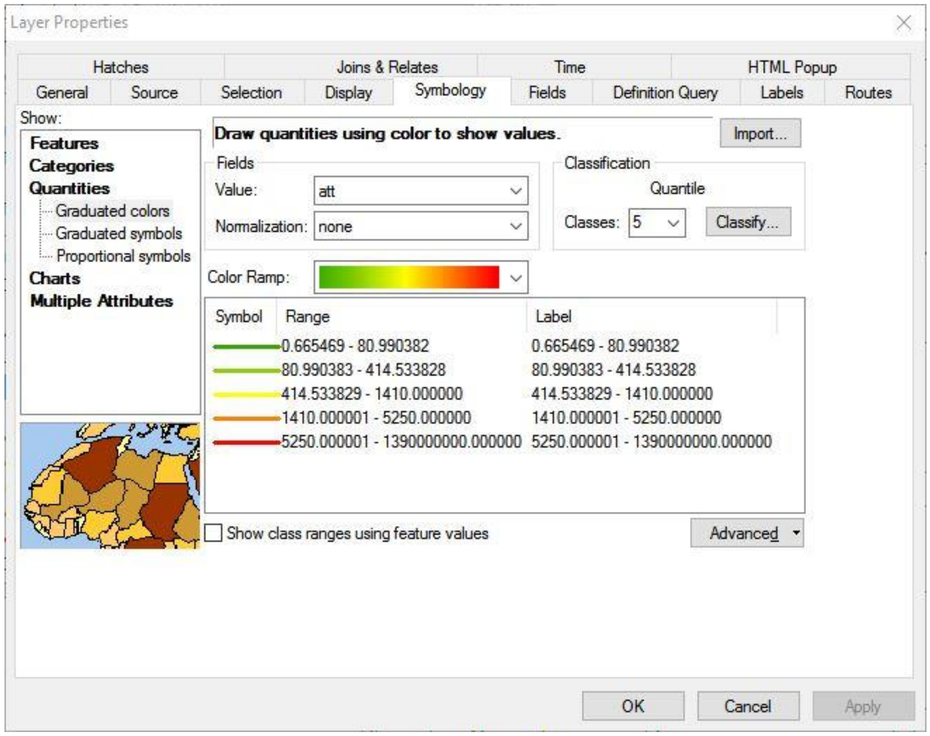

Figure 12: Selecting symbology value and color ramp

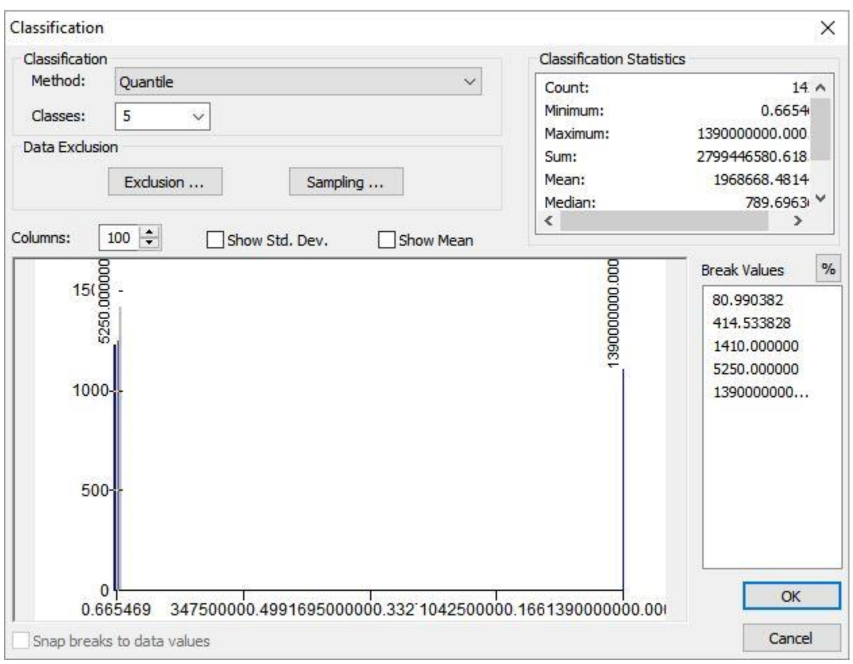

Figure 13: Selecting quintile classification

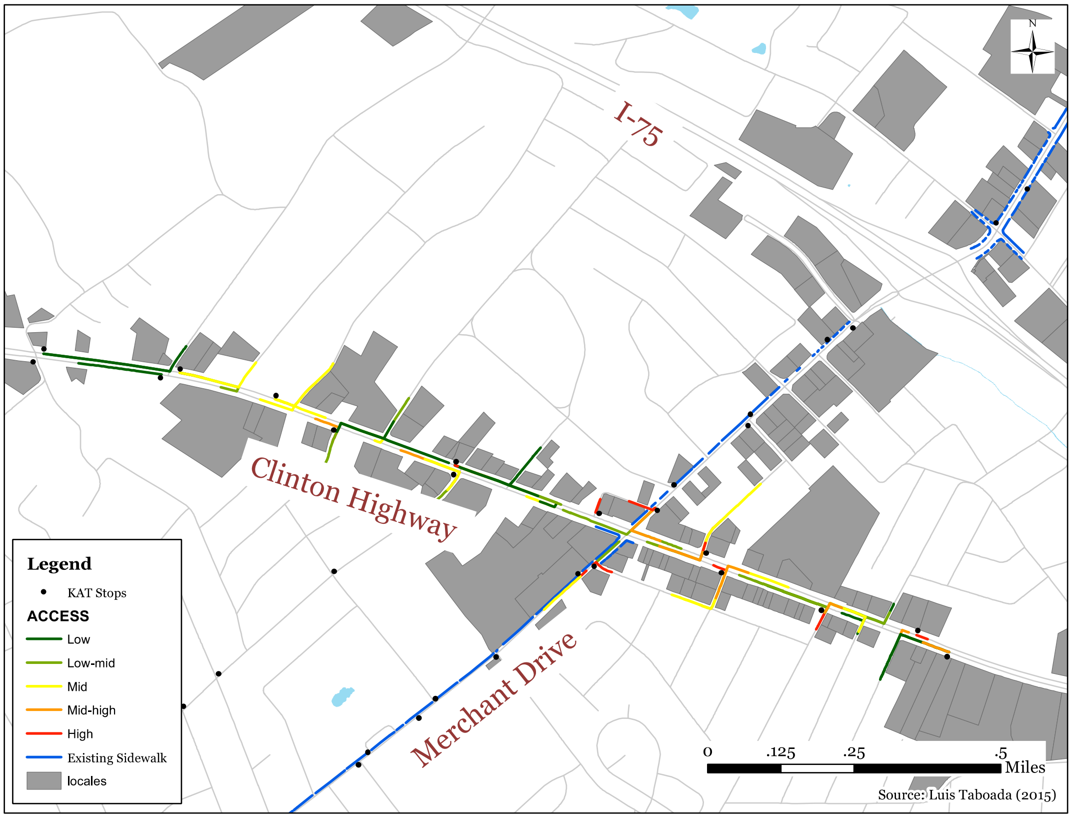

Figure 14: Resulting weighted street segments

Walk-to-Transit
Residential Implementation Guide

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INTRODUCTION

This implementation guide describes the process of calculating home-based work transit (walk access) trips at the parcel level, and the use of Geographic Information Science-based (GIS) software to present the results.

A home-based work mode-choice model is selected from PSRC (2007). This model can be used to calculate utility at the parcel-level for home-based work transit (walk access) travel. The parameters for this model are presented in Table 8.4 (PSRC 2007). The mode-choice model incorporates many factors that affect transit use. A Logit-based model is used to calculate probabilities for home-based work transit (walk access) trips. We use a home-based work trip productions model that is specified in Table 6.1 (PSRC 2007). Home-based work transit (walk access) trips are allocated from the residential parcels to the access paths from parcels to bus stops. These paths are then ranked per the number of respective trips. Finally, the results can be compared with the existing sidewalk layer using a GIS-based map.

Data Requirements:

- GIS-based road network (vector shapefile)
- Transit network (vector shapefile)
- Transit stops (vector shapefile)
- Property ownership (vector shapefile)
- Tabular property data from the property assessor's office is required, including the number of beds and number of units of each residential parcel
- Traffic Analysis Zone (TAZ) shapefile data

ESRI ArcMap 10.3, MS Excel and MATLAB were used to perform any necessary model calculations and to generate the map-based results.

Part 1: Generating the Dataset

The parameters needed to calculate the utility of a household's Home-based work (Transit Walk Access) travel are shown in Table 8.4 (PSRC 2007). One may use a combination of: the GIS attribute table and script editor, a spreadsheet program (MS Excel), or a programming language (MATLAB) to perform the necessary calculations.

Table 8.4 Home-Based Work Mode Choice Model Parameters

Variable	Drive Alone	Shared Ride 2	Shared Ride 3+	Transit-Auto Access	Transit-Walk Access	Bicycle	Walk
Level of Service							
In-Vehicle Travel Time (Minutes)	-0.0253	-0.0253	-0.0253	-0.0253	-0.0253		
Out-of-Vehicle Travel Time (Minutes) – Walk Time and Wait Time <7 Minutes				-0.0633	-0.0633		
Out-of-Vehicle Travel Time (minutes) – Wait Time>7 Minutes				-0.0506	-0.0506		
Number of Transit Boardings				-0.3060	-0.3060		
Walk time (Minutes)							-0.0788
Bicycle time (Minutes)						-0.1020	
Ratio of Drive Time to Total Time				-6.0000			
Travel Cost (cents) for Low-Income Households (Income 1)	-0.0038	-0.0038	-0.0038	-0.0038	-0.0038		
Travel Cost (Cents) for Low-Medium Income Households (Income 2)	-0.0021	-0.0021	-0.0021	-0.0021	-0.0021		
Travel Cost (Cents) for Medium-High Income Households (Income 3)	-0.0014	-0.0014	-0.0014	-0.0014	-0.0014		
Travel Cost (Cents) for High-Income Households (Income 4)	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011		
Socioeconomic							
Market Segmentation Parameter				See Table 8.3			
CBD Variable		0.199	-0.268	2.167	0.593	0.173	1.688
Alternative-Specific Constant		-2.355	-3.968	-0.169	0.351	-1.151	0.491

Source: 2000 PSRC Mode Choice Model Parameters, FTA guidelines, EPA Commuter Model.

Parameters Specific to the Transit-Walk Access Mode:

Variable	Parameter	Meaning
$INVEHTT$	B1	In-Vehicle Travel Time
$OUTVEHTT$	B2	Out-Of-Vehicle Travel Time
$BOARDINGS$	B3	Number of Transit Boardings
$COST$	B4	Travel Cost
MSP	B5	Market Segmentation Parameter
CBD	B6	Central Business District

Required data/information:

- Property ownership shapefile
- Rental property median rent values data
- Transit system routes and stops shapefile
- Transit routes headway data
- Road network shapefile
- Existing sidewalk shapefile
- TAZ shapefile
- Parcel shapefile
- Property assessor's data, including beds and units per parcel

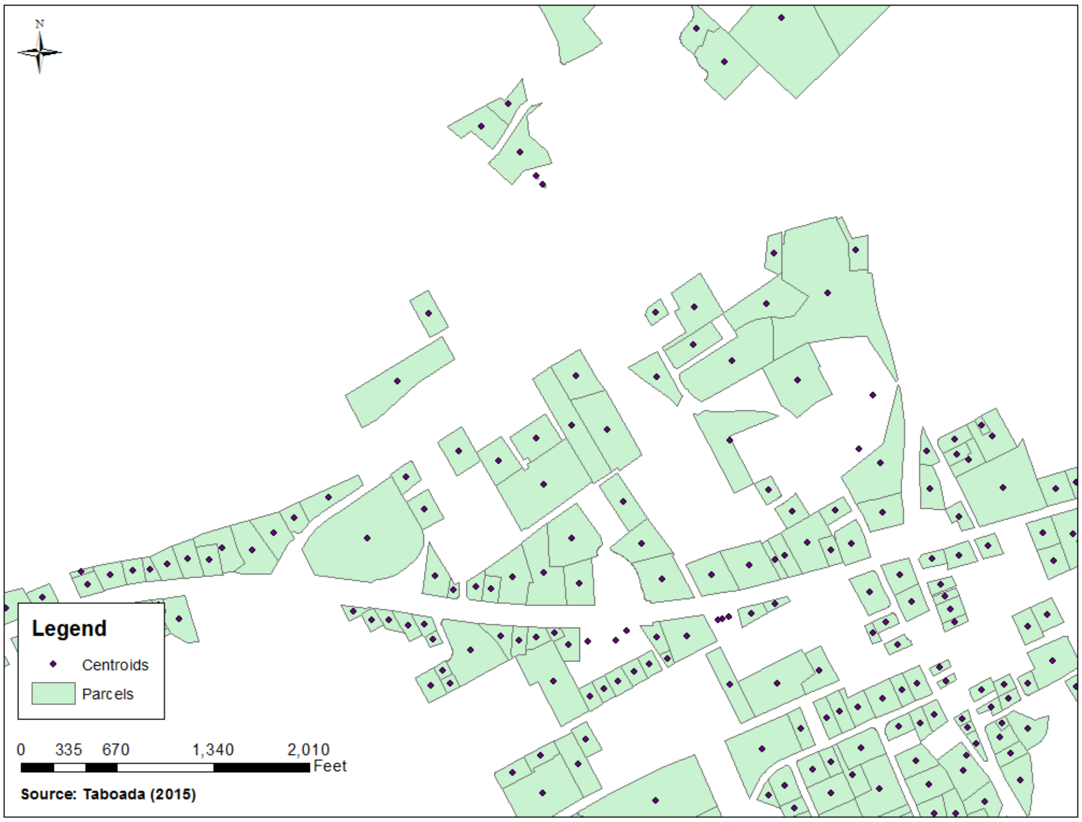
Step 1: In-Vehicle Travel Time (INVEHTT)

In the property ownership attribute table, assign an average commute time to each parcel in the Property Ownership GIS attribute table. We used ZIP code specific data, as shown in Comm_Time.xlsx. Values for the product of INVEHTT x B1 are then assigned to a new column in the property ownership attribute table.

Step 2: Out-of-Vehicle Travel Time (OUTVEHTT)

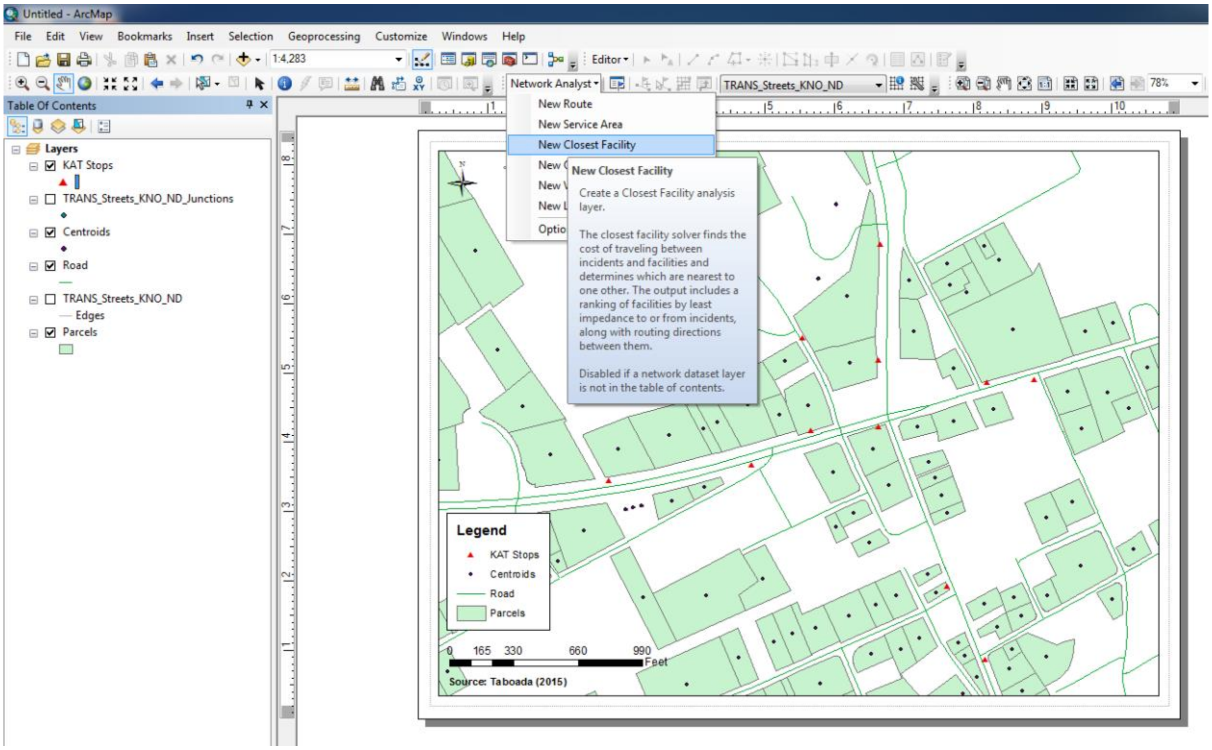
Property ownership, transit stops, and road network shapefiles are needed to generate routes from each residential parcel to the closest bus stop.

- First, the residential parcels are queried from the property ownership layer. Parcels that are too far (e.g. > 1.0 mile) from bus stops can also be erased from the dataset.
- Geometric centroids are generated for each residential parcel.



- The Network Analyst extension in ArcMap must be enabled. In the toolbar, Customize > Extensions… > Network Analyst. See Closest Facility Tool in ESRI's Network Analyst Tutorial document.
- The road network file is converted to a Network Dataset (.nd) file in ArcCatalog. This step is necessary prior to using the Closest Facility Tool in Network Analyst. Ensure to not use the "one-way" restriction when building the Network Dataset. However, create a new restriction to prevent paths from generating along roads of high-speed motorized travel (Interstate highways).

- Open the network dataset road file in ArcMap. Initiate a new Closest Facility in Network Analyst. Load the bus stops as incidents, and the parcel centroids as facilities. Solving the problem will generate one path for every parcel centroid.



- Export the paths as a new shapefile (PATHS) and relate this data to the residential parcels
- Walking time is computed in the PATHS attribute table as a new column using a walking speed respective to the area of study (we used 3.5 fps)
- Wait time is estimated as half of the headway of routes serving the bus stop respective to a residential parcel. Associate each transit stop with the nearest transit route. This can be done by spatially joining transit stop data with the transit route data.
- $OUTVEHTT = WALKTIME + WAITTIME$
- Based on the value of $OUTVEHTT$, apply the suitable coefficient B2 to each parcel using the table below:

$OUTVEHTT$	**B2**
Less than 7 minutes	**-0.0633**
Greater than 7 minutes	**-0.0506**

Step 3: Number of Transit Boardings ($BOARDINGS$)

The number of transit boardings is defined as the fare for using the transit system. For all parcels, $BOARDINGS$ is equal to the cost of a bus pass ($ 1.50). A value of 1 * **B3 (-0.3060)** is applied to each parcel.

Step 4: Travel Cost ($COST$)

1. Income:

   Yearly income can be estimated using property values and apartment rents.

   a) Property values ($PVAL$) are related to the residential parcels from the assessor of property dataset. Income is estimated to be 0.3 of the property value.
   b) For home property values, use the formula $INCOME = 0.3 * PVAL$.
   c) For apartments, collect the median rents for each ZIP-code from Zillow.com. ($RENT$).
   d) Roughly 25% of income is associated with rent. For apartments,

$$INCOME = \frac{RENT * 12months}{0.25}$$

2. Value of Time:

   The value of time is defined as the cost in dollars per hour of the time spent using transit travel.
   Household incomes are categorized as shown in the following table.
   Table 8.3 in PSRC (2007) recommends the following value of time for each income category. The values have been converted to dollars per minute:

Income Bracket	Value of Time ($/min) $VALTIME$
$ 0 to 25,000	0.067
$ 25,000 to 50,000	0.1205
$50,000 to 80,000	0.1807
> $80,000	0.233

3. For every residential parcel, calculate the value of the variable $COST$ defined as:

$$COST = B_4 * (90 + (OUTVEHTT + INVEHTT) * VALTIME)$$

4. Following are the parameters for Travel Cost from Table 8.4 (PSRC 2007)

Income Category	B4
$ 0 to 25,000	-0.0038
$ 25,000 to 50,000	-0.0021
$50,000 to 80,000	-0.0014
> $80,000	-0.0011

Step 5: Market Segmentation

The market segmentation parameter (MSP) values for Transit – Walk Access are found in Table 8.3 (PSRC 2007). The specifications for worker class and income are found in Table 8.2 (PSRC 2007).

Table 8.3 Home-Based Work Market Segmentation Parameters by Car-Worker Class and Income

Variable	Car Class 1 0-Car HH	Car Class 2 Workers > Cars	Car Class 3 Workers <= Cars	Car Class 4 1-Worker HH
Drive Alone				
Income 1	-4.0	-0.2	0.3	0.0
Income 2	-4.0	-0.2	0.3	0.0
Income 3	-3.5	0.3	0.8	0.5
Income 4	-3.0	0.8	1.3	1.0
Shared ride 2	0.0	0.9	-0.5	-0.4
Shared ride 3+	0.0	1.3	-0.6	-0.7
Transit – Walk access				
Income 1	2.4	4.4	-1.3	0.5
Income 2	1.9	3.9	-1.8	0.0
Income 3	1.4	3.4	-2.3	-0.5
Income 4	0.9	2.9	-2.8	-1.0
Transit – Auto access				
Income 1	-4.5	-0.9	-2.1	-1.6
Income 2	-4.0	-0.4	-1.6	-1.1
Income 3	-3.5	0.1	-1.1	-0.6
Income 4	-3.0	0.6	-0.6	-0.1
Walk	0.5	1.2	-1.6	-0.1
Bicycle	0.2	0.7	-1.0	0.2

Source: 1999 PSRC household travel survey.

Table 8.2 Household Classification System for Home-Based Work Mode Choice Model

Workers	Autos			
	Zero	One	Two	Three+
1	1	4	4	4
2	1	2	3	3
3+	1	2	2	3

The number of cars, number of workers, and income of each residential parcel are needed in order to correctly determine the Market Segmentation parameter of each household. If local data provides this information, additional calculations may not be required. However parcel-level data for number of workers or number of vehicles in each household may not be readily available. In this case, number of workers averages, number of vehicles averages, and other information, at the TAZ level, can be disaggregated to the parcel level.

The points below outline the process used in Abdelqader (2014) to disaggregate TAZ-level data to the parcel level.

A. The following variables can be found in the TAZ dataset:

$BEDR_{PAR}$: Bedrooms in the parcel

$UNITS_{PAR}$: Units in the parcel

B. The following variables are found in the Assessor of Property dataset:

$UNITS_{TAZ}$: Total units in the TAZ

$BEDR_{TAZ}$: Total bedrooms in the TAZ

WPH_{TAZ}: Average number of workers per household in the TAZ

VPH_{TAZ}: Average number of vehicles per household in the TAZ

C. Calculated data:

1. Total workers in TAZ:

   $TOTW_{TAZ} = WPH_{TAZ} * UNITS_{TAZ}$

2. Number of workers per bedroom in TAZ:

   $$WPB_{TAZ} = \frac{TOTW_{TAZ}}{BEDR_{TAZ}}$$

3. Total vehicles in TAZ:

   $TOTV_{TAZ} = VPH_{TAZ} * UNITS_{TAZ}$

4. Number of vehicles per bedroom in TAZ:

   $$VPB\_TAZ = \frac{TOTV_{TAZ}}{BEDR_{TAZ}}$$

The TAZ-specific WPB and VPB rates are used to estimate number of workers and vehicles for each parcel. The worker and vehicle values are then used to find the Market Segmentation parameter of each household.

D. Number of workers:

The number of workers in each parcel unit is found by multiplying the average workers per bedroom of the TAZ with the number of bedrooms per unit for each parcel.

$$WORKERS = WPB_{TAZ} * (\frac{BEDR_{PAR}}{UNITS_{PAR}})$$

E. Number of vehicles:

The number of vehicles in each parcel unit is found by multiplying the average vehicles per bedroom of the TAZ with the number of bedrooms per unit for each parcel.

$$VEHICLES = VPB_{TAZ} * (\frac{BEDR_{PAR}}{UNITS_{PAR}})$$

F. Income:

Households are categorized into four income classes. The following categories were selected for the Knoxville case study in Abdelqader (2014).

Category	Income
1	$ 0 to 25,000
2	$ 25,000 to 50,000
3	$50,000 to 80,000
4	> $80,000

G. MSP

A worksheet (MS Excel) or a program (MATLAB) should be used to calculate the Household Class (Table 8.2) and then the MSP (Table 8.3) for each residential parcel.

Record the MSP for each household as **B5**.

Step 6: Central Business District (CBD)

Parcels located within a predetermined CBD area will have a value of **B6 (0.593)**. Ignore this parameter for all other parcels. A Boolean condition is applied to the attribute table; parcels within the CBD = 1, parcels outside the CBD = 0.

Part 2: Home-Based Work Transit (Walk Access) Trips

Utility

Utility of Transit-Walk Access travel is calculated for households as follows:

$$U = (B1 * INVEHTT) + (B2 * OUTVEHTT) + (B3 * BOARDINGS) + COST + MSP + (B6 * CBD) + 0.351$$

Probability

The probability of a household choosing Transit-Walk Access travel mode can be calculated using a Logit-based model. A value of zero is assumed for all other alternatives.

$$P_{W2T}(i) = \frac{e^{U_{W2T}}}{e^{\Sigma U} + e^{U_{W2T}}}$$

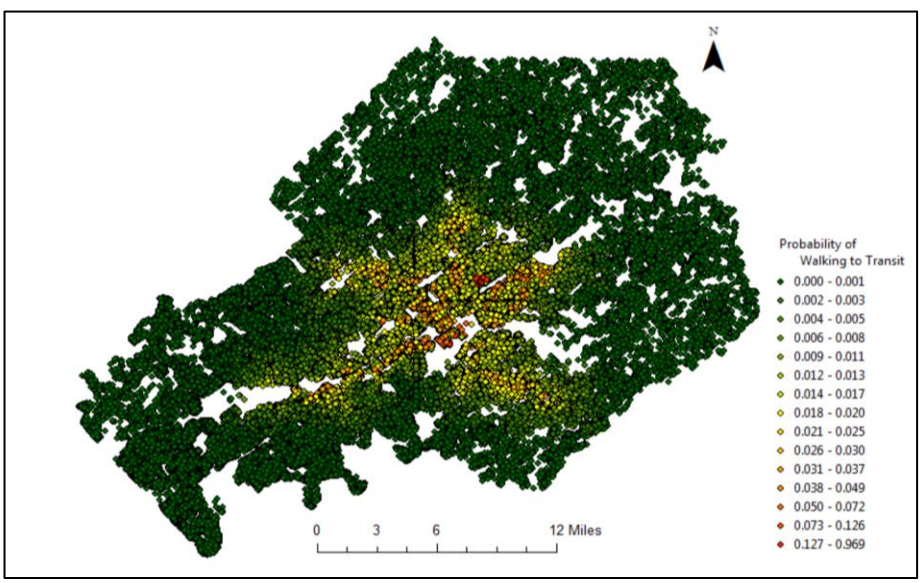
$$\rightarrow P_{W2T}(i) = \frac{e^{U_{W2T}}}{e^{0} + e^{U_{W2T}}}$$

$$\rightarrow P_{W2T}(i) = \frac{e^{U_{W2T}}}{1 + e^{U_{W2T}}}$$

Where,

$P_{W2T}(i)$: Probability of walk-to-transit trips for household *i*

$U_{W2T}(i)$: Estimated utility of walk-to-transit trips for household *i*



Trip Productions

Home-based work trip productions (HBWTP) per household are determined using Table 6.1 (PSRC 2007). Household size, number of workers, and household income are necessary for this step.

Table 6.1 Home-Based Work Trip Productions Per Household

Household Size	Number of Workers in Household	Income				
		Less than $15,000	$15,000-$24,999	$25,000-$44,999	$45,000-$74,999	$75,000 and Above
1 person	0	.02	0.01	0.07	0.26	0.19
	1	.75	1.02	1.17	1.37	1.30
	0	0.00	0.07	0.01	0.15	0.33
2 persons	1	0.08	0.41	0.62	1.06	1.24
	2	1.24	1.57	1.78	2.22	2.40
	0	0.00	0.00	0.15	0.11	0.21
3 persons	1	0.20	0.40	0.77	0.99	1.09
	2	1.33	1.52	1.89	2.12	2.21
	3+	2.52	2.72	3.09	3.31	3.41
4+ persons	0	0.00	0.17	0.09	0.22	0.17
	1	0.47	1.10	1.02	1.15	1.10
	2	1.07	1.71	1.62	1.75	1.71
	3+	2.62	3.26	3.17	3.30	3.26

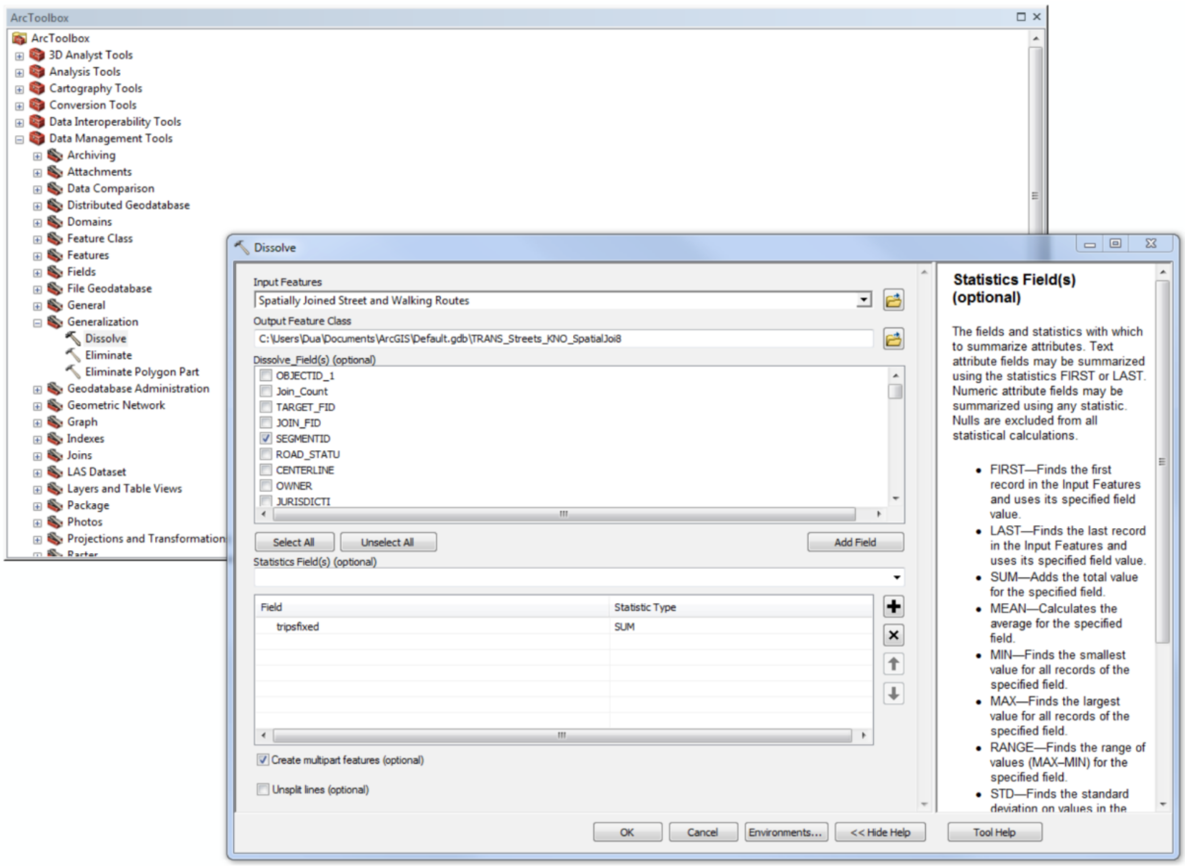
Total Trips

Total Home-Based Work Transit (Walk Access) trips are estimated by multiplying the calculated walk-to-transit probability by the tabular HBWTP value for each household. This value, TRIPS, is then joined to the PATHS (parcel centroid to bus stop) shapefile using worksheets or the Spatial Join Tool in ArcMap.

$$TRIPS = HBWTP * P_{W2T}$$

Part 3: Mapping Results

The total TRIPS variable should be related back to the PATHS shapefile. The individual PATHS are then dissolved to join any overlapping walking segments using the Dissolve tool in the ArcToolbox.



In ArcMap, apply symbology (Right click PATHS layer > Properties… > Symbology > Quantities > Graduated Colors > select TRIPS). The values can be discretized into five categories using Quantile classification. We are interested in the relative differences between paths, rather than the absolute estimated walk-to-transit trips.

The sidewalk layer is added to the map to identify gaps in the network or potential opportunities for future sidewalk infrastructure investment.

The result of this model is a road network with segments, as per the original GIS layer from KGIS. The following figures illustrate a sample of the final results showing color-coded road network segments based on the estimated weights (Total Trips).

The results represent the differences in the level of importance of the road segments. Red colors indicate higher total trips and priority for providing pedestrian infrastructure. These segments might be serving a higher number of parcels with potential walk to transit trips and/or parcels with higher numbers of walk to transit trips depending on the overall accumulated numbers associated with these segments.

Shown below is also a map that includes the existing sidewalk network. This projection helps in identifying gaps in the sidewalk system where infrastructure investments could be beneficial.

The segment of the roadway in Figure 3 represents a gap in the pedestrian infrastructure (sidewalks) where higher probabilities of generating walk to transit trips are expected due to specific demographics of the population residing in this area. The higher trip numbers are supported by the presence of a residential complex as can be seen in the street view.

After the selection of alternative locations for pedestrian infrastructure prioritization, the estimated costs for adding infrastructure will vary according to locations, topography and other variables within the construction sites. While these variables are necessary for the prioritization process, they are beyond the scope of our analysis and can be performed by public agencies as an advanced step after the application of results from this procedure.

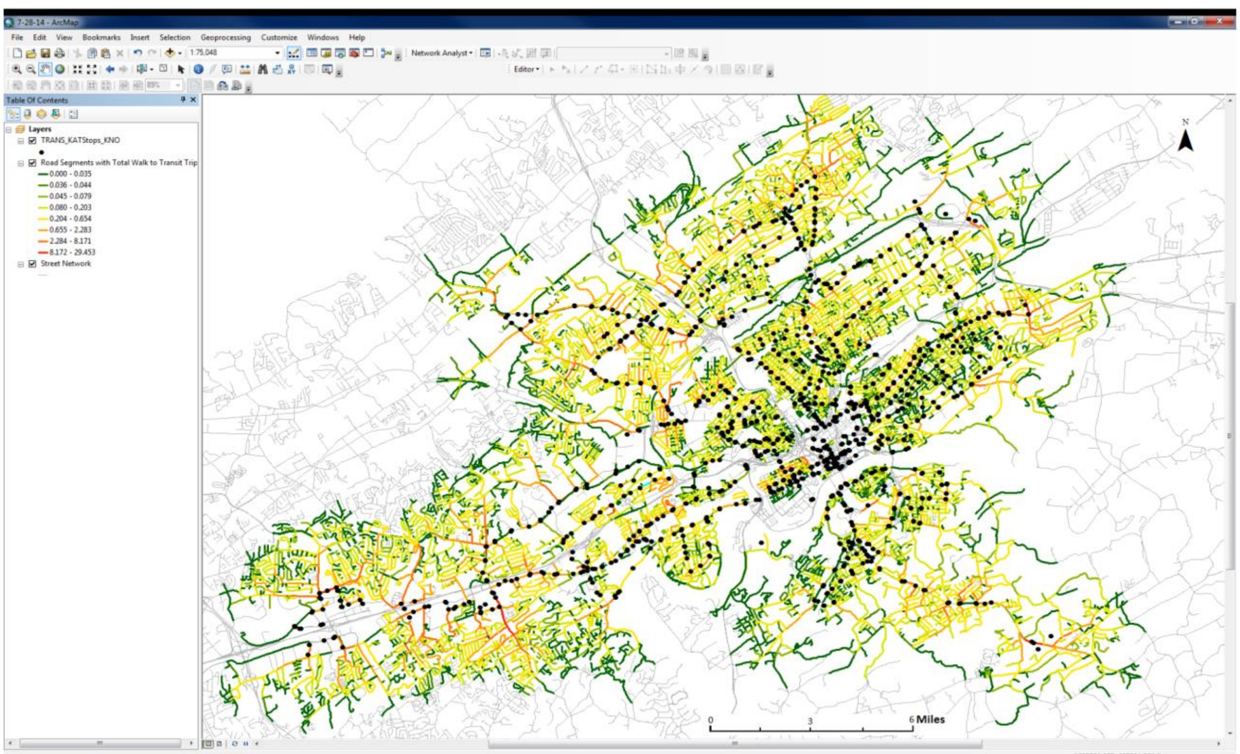


Figure 1. Walk-to transit trips result

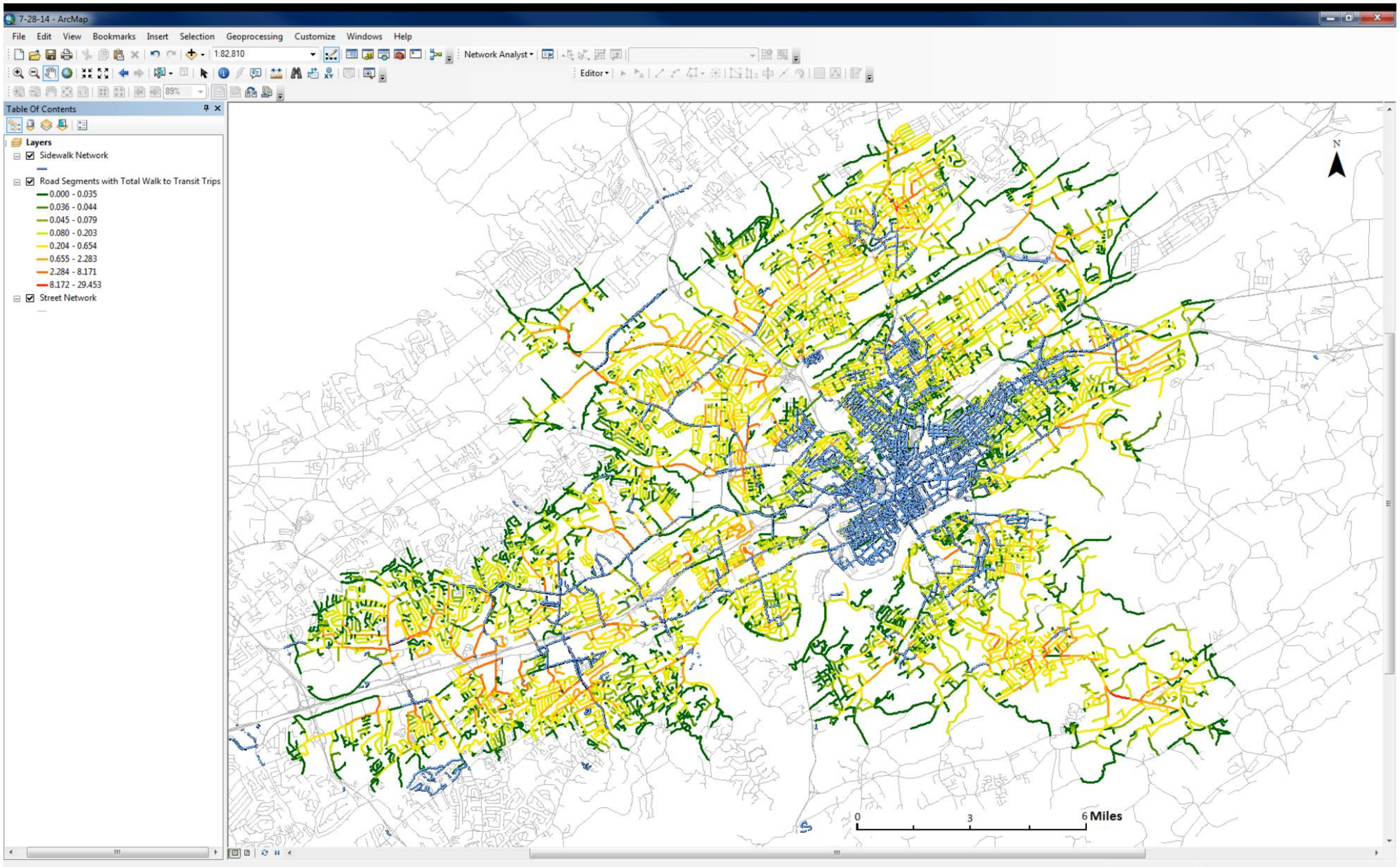


Figure 2. Results with existing sidewalk layer

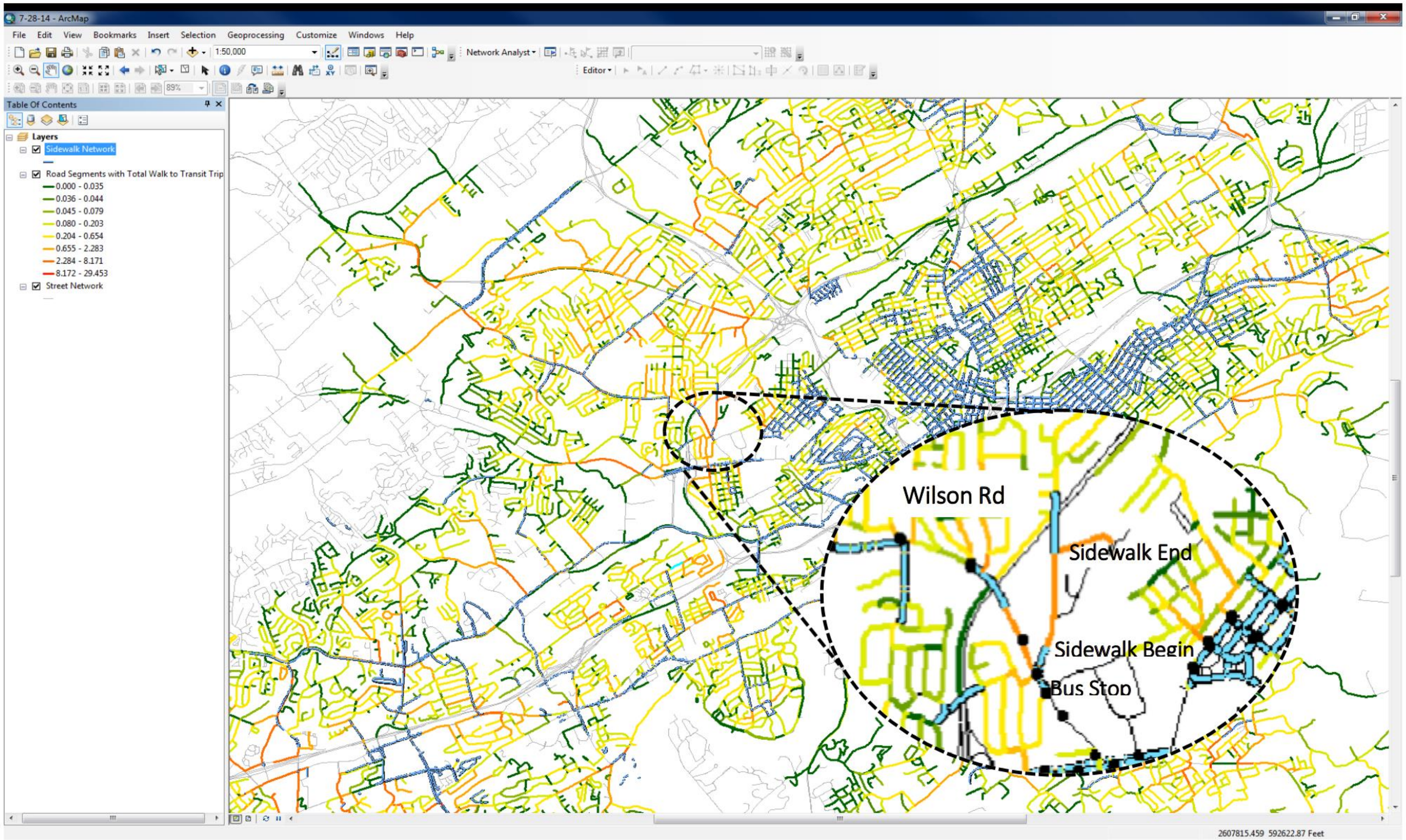


Figure 3. Detail of gap in the sidewalk network on high-priority segment

Figure 4. Street view of figure 3 example