Development of a GIS-Based Model to Examine Alternative Scenarios for Last-Mile Freight Delivery

Amy M. Moore, Ph.D.

Oak Ridge National Laboratory

ORNL is managed by UT-Battelle
for the US Department of Energy

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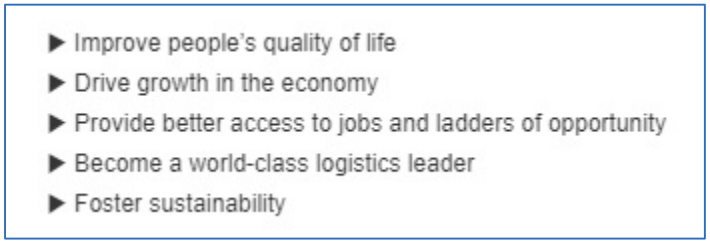
Purpose of Study

- This study is part of the Department of Energy (DOE)'s SMART (Systems and Modeling for Accelerated Research in Transportation) Mobility Multi-Modal Pillar
- Task 3.1: "Optimization of Intra-City Freight Movement with New Delivery Methods"
  - Partnership with:
    - Oak Ridge National Laboratory – (ORNL) - Lead
    - National Renewable Energy Laboratory (NREL)
    - Idaho National Laboratory (INL)
    - United Parcel Service (UPS)
    - Mid-Ohio Regional Planning Commission (MORPC)
- Focus area: SMART City Challenge Winner: Columbus, Ohio



Source: Columbus.gov

- Develop methodology for modeling intra-city truck tours and develop alternative last-mile delivery scenarios using new modes to determine energy savings

Overview of Methods

- Develop a freight delivery estimation model and tour-based freight model for Columbus, Ohio in ArcGIS and TransCAD software using :
  - UPS GPS data
  - Traffic Analysis Zone (TAZ)-level socioeconomic, business data, and locational data
  - Road network
- Provide DOE, UPS, MORPC and Columbus data on:
    - Alternative scenarios for reducing freight-related energy usage
- Create tool and methods that can be applied to other cities and regions
- Analyze energy reduction opportunities provided by new freight modes and technologies:
  - Drones
  - Parcel delivery lockers
  - Electric vehicles
  - Uber-style delivery system

Sources: Nissan, Parcel Pending, and UPS

Updating Initial Modal Energy Usage Estimates

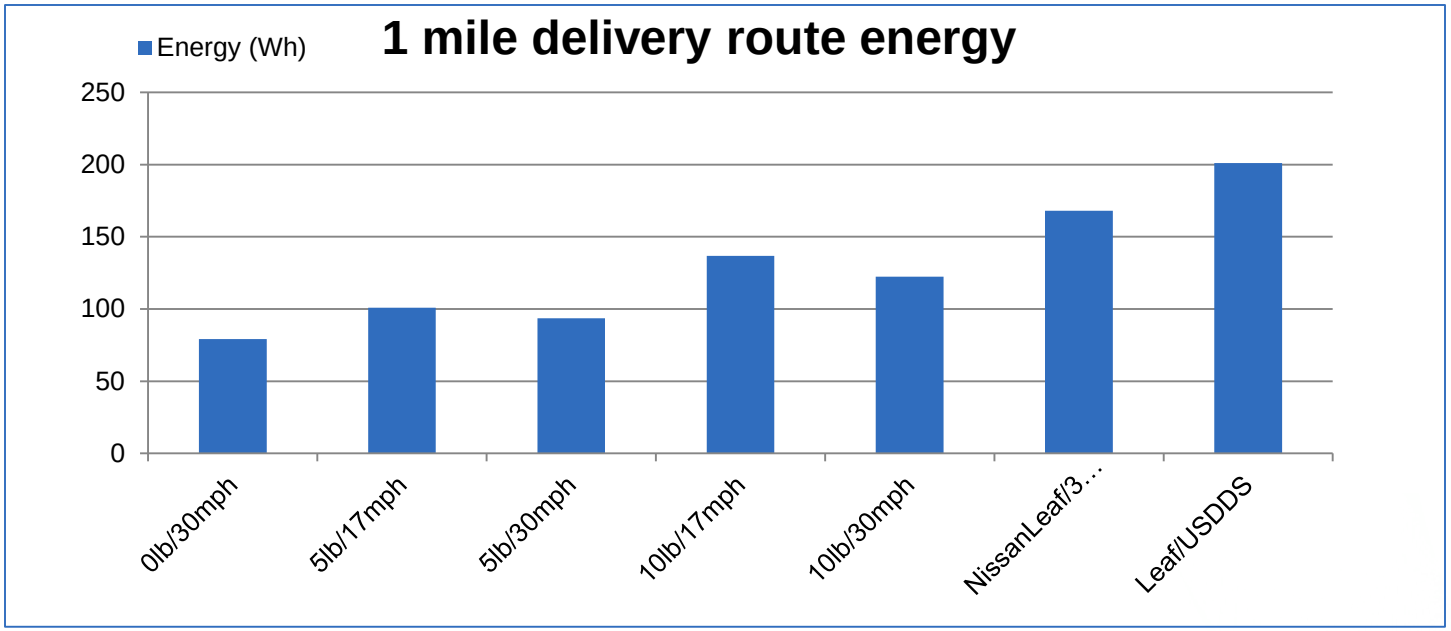
Scenario	Mode	Energy Usage kwh/mile	Source	Notes
Baseline – Class 6 UPS Truck makes Deliveries from Depot	Class 6 Truck	4.29	NREL	33.7/7.86
Class 6 EV Truck makes deliveries from Depot	Class 6 EV Truck	1	Fuel Economy	1
Class 6 UPS Truck makes deliveries to UPS stores; EV delivery van makes final deliveries	EV Delivery Van (eNV200)	.56	Inside EVs	40/72
Class 6 UPS Truck makes deliveries to lockers	Class 6 Truck	4.29	NREL	33.7/7.86
Class 6 EV Truck makes deliveries to lockers	Class 6 EV Truck	1	Fuel Economy	1
Class 6 UPS Truck makes deliveries to locker location; drones make final deliveries	Drone	.1	INL	5 lb package/30 mph (14+1.6*lbs)+((65 +2.7*lbs)*miles)
Class 6 UPS Truck makes deliveries to UPS stores; Uber-style drivers make final deliveries using passenger vehicles	EV Passenger Car (Nissan Leaf)	.34	Green Car Reports	34/100

Drone Testing at Idaho National Laboratory

Source: Victor Walker, INL

Initial drone testing at INL: November 2017

Drone Testing at Idaho National Laboratory



Preliminary Draft formula for 100ft / 30 mph:

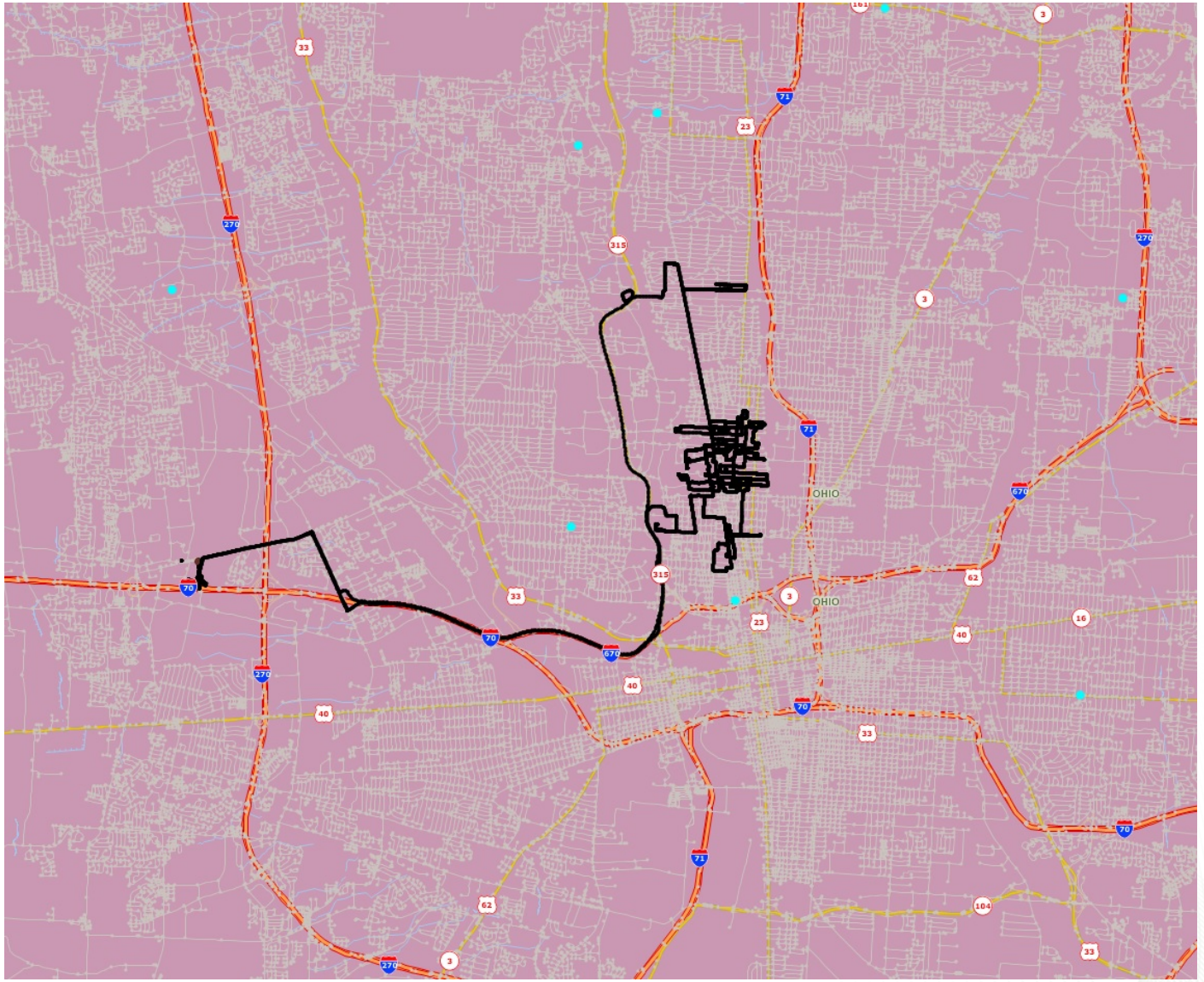
Wh= (14+1.6*lb)+((65+2.7*lb)*miles)

Source: Victor Walker, INL

UPS GPS Processing

- Combined all Excel files into one per vehicle (VBA)
  - Dataset included GPS data obtained from fleet of 19 city unit UPS delivery trucks, measured during the month of July 2017
- Removed all data points, excluding estimated "stops" – where vehicle was turned off (VBA)
  - Assumed that locations where vehicle was turned off represented a "stop" (excluding the UPS Depot)
- Imported CSV file into ArcMap; "clipped" data points from UPS Depot
- Manually processed all points in GIS – removed outliers based on time
- Manually noted dates, times, number of estimated stops, etc. for each vehicle
  - Obtained average estimated stops per day per vehicle; average start and end times
- Calculated sum of data points per TAZ in attribute table – to be used in model development

Vehicle “02” Actual GPS Tour Route July 18, 2017 (Unprocessed)



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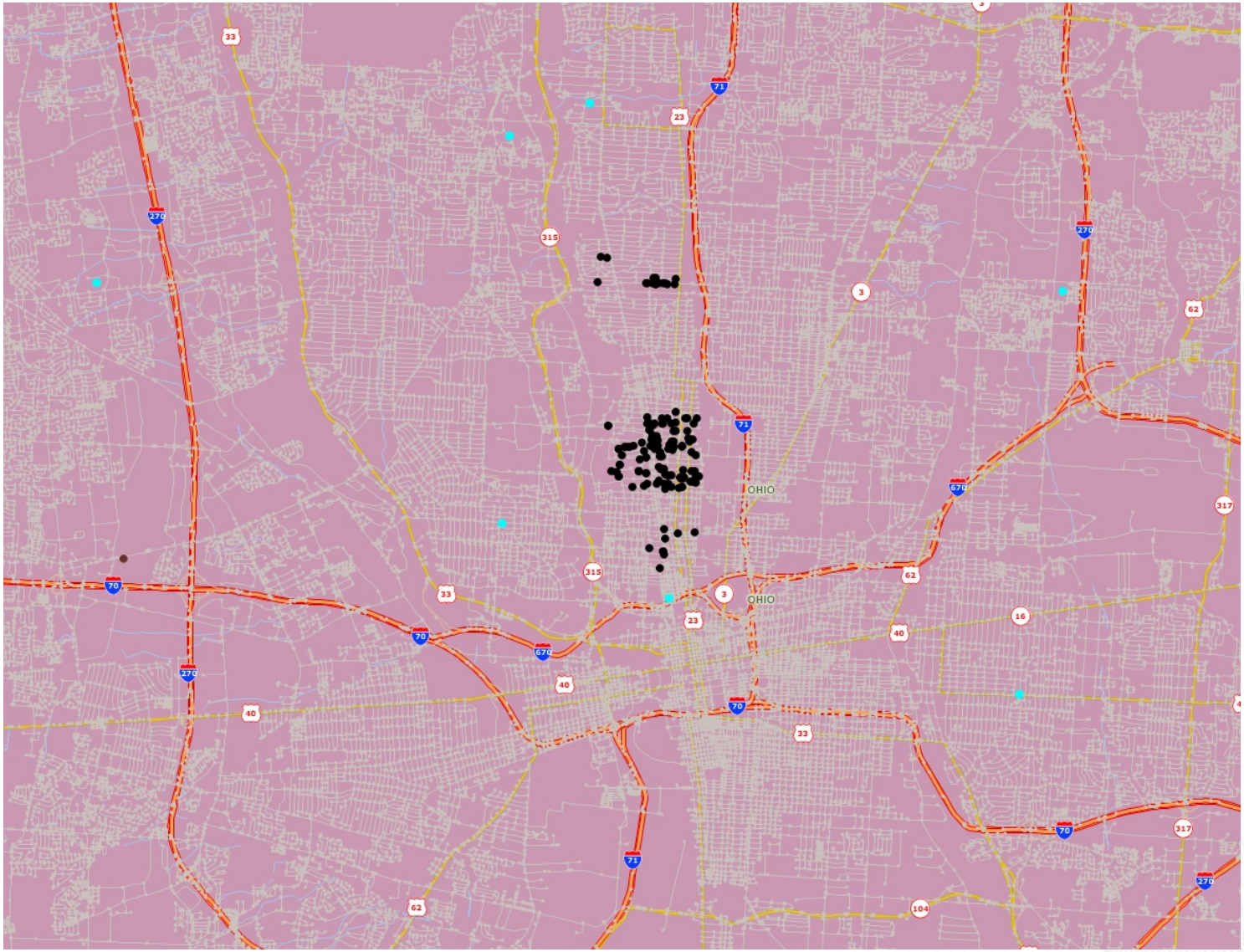
Vehicle “02” July 18, 2017 “Stop” Locations



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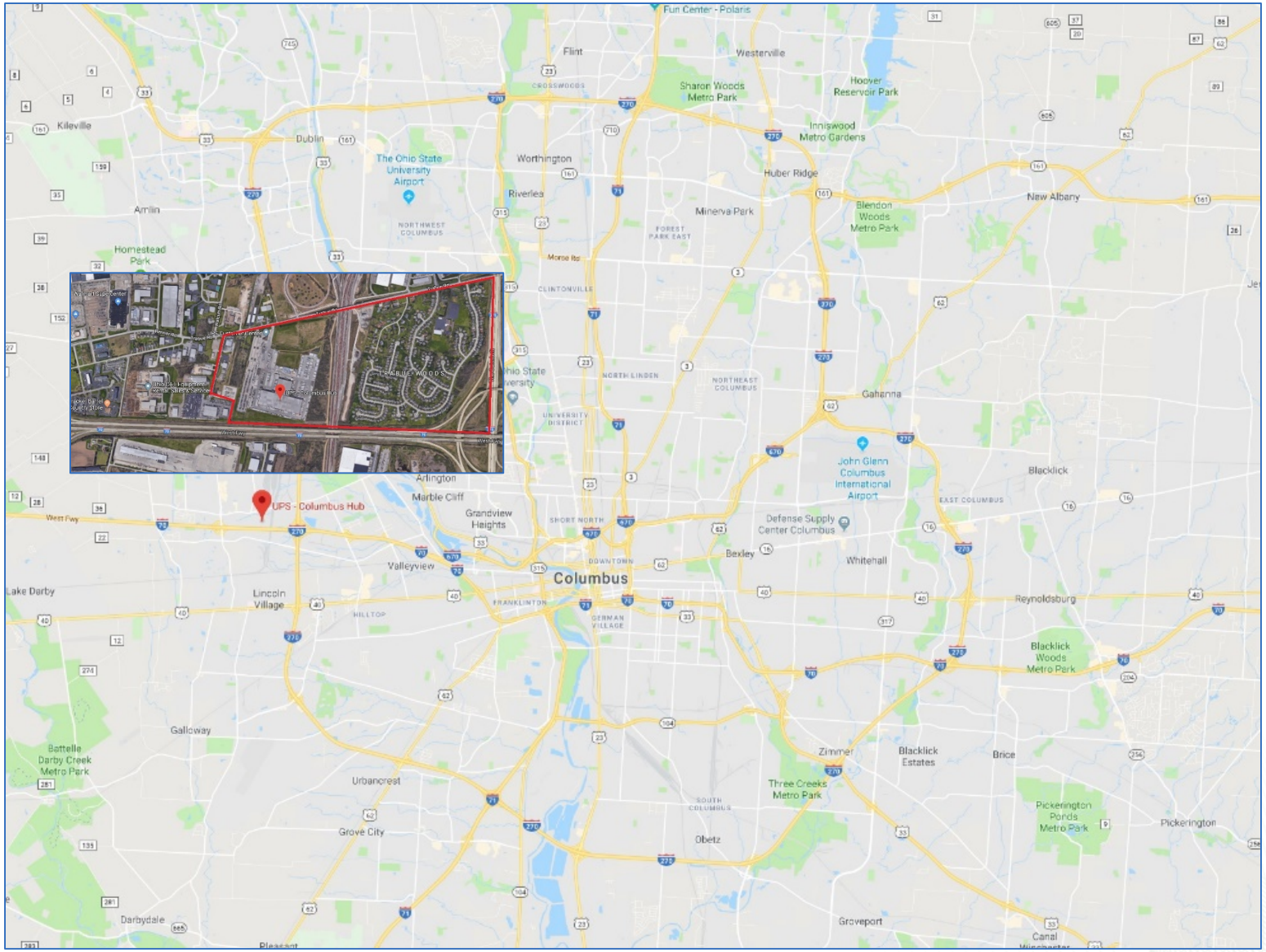
UPS Depot TAZ



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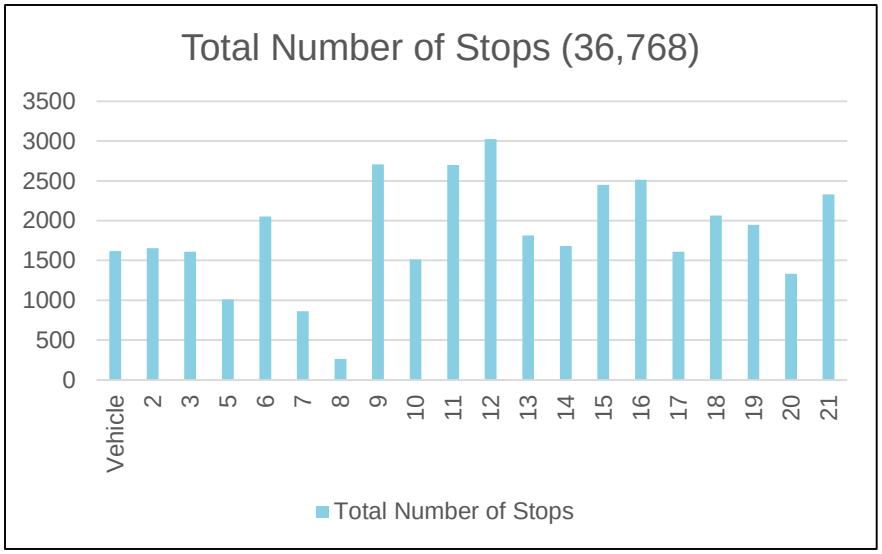
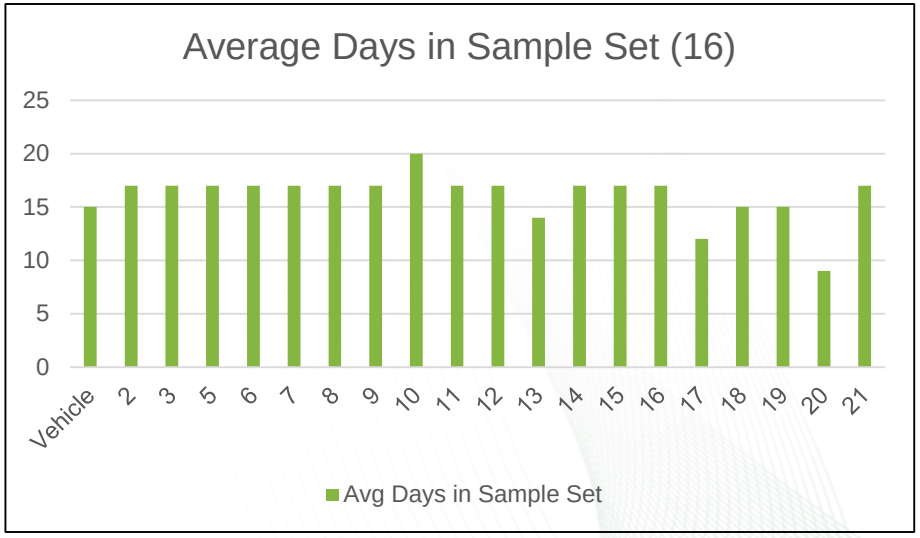
Overview of UPS Data for Model





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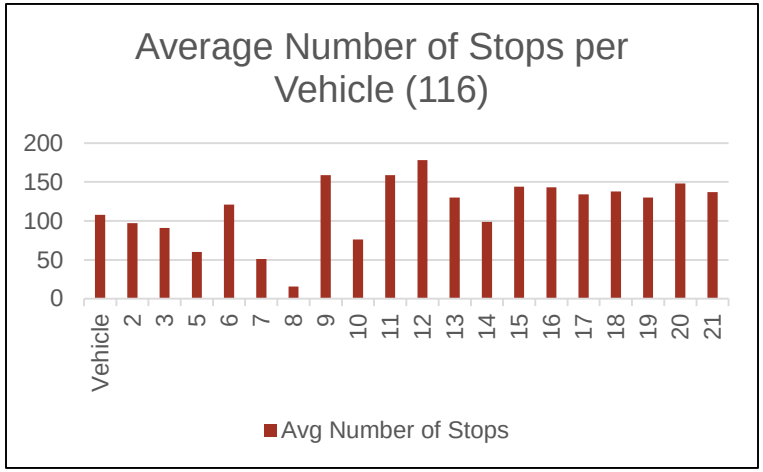
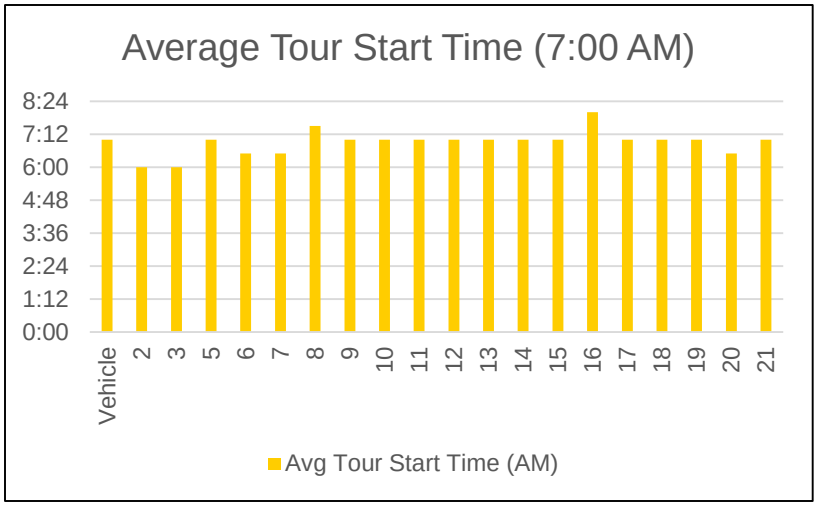
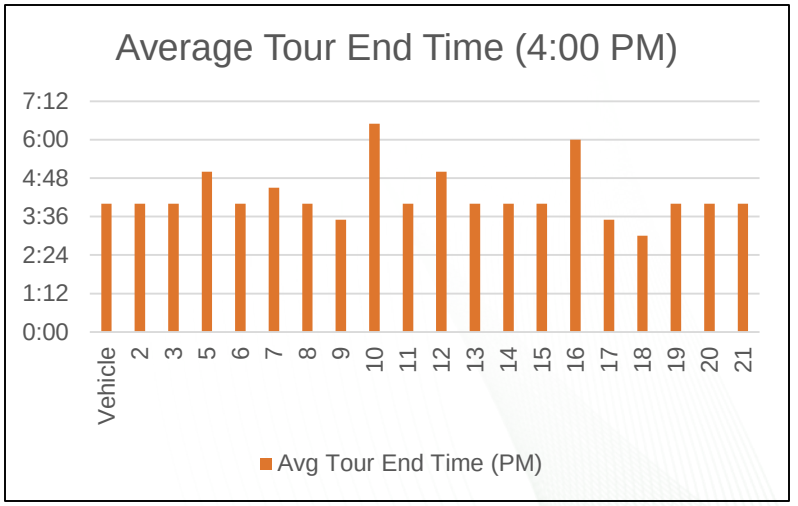
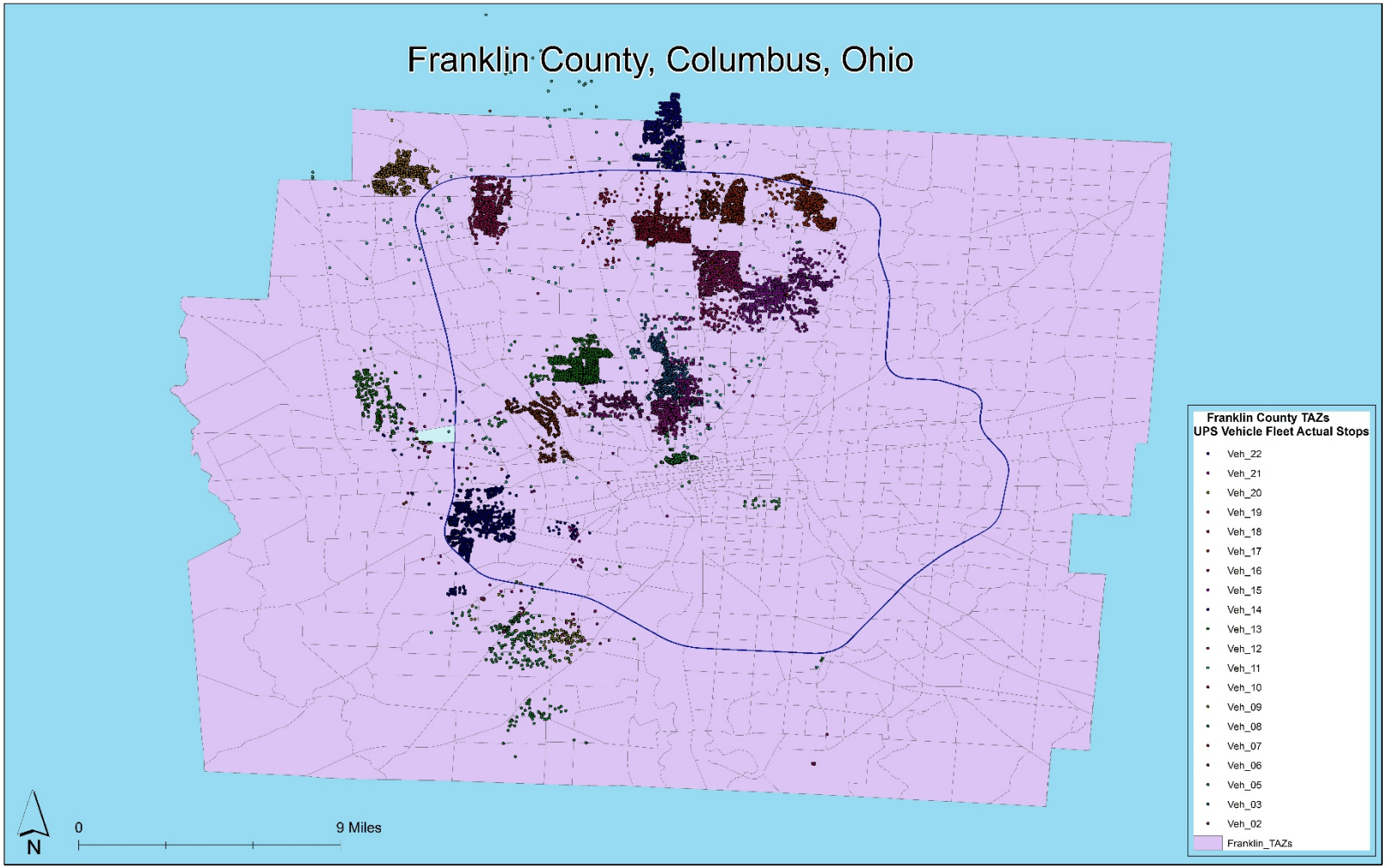






ArcGIS: Overview of All Data Points Representing Deliveries



TAZ-Level Estimation

TAZ Variables
Population
Household Population
Number of Households
Group Quarter Population
Median Household Income
Earnings
Labor Force Population
Total Jobs
Office Jobs
Retail Goods Jobs
Retail Service Jobs
Industrial Jobs
Other Jobs
Elementary Enrollment
High School Enrollment
University Enrollment

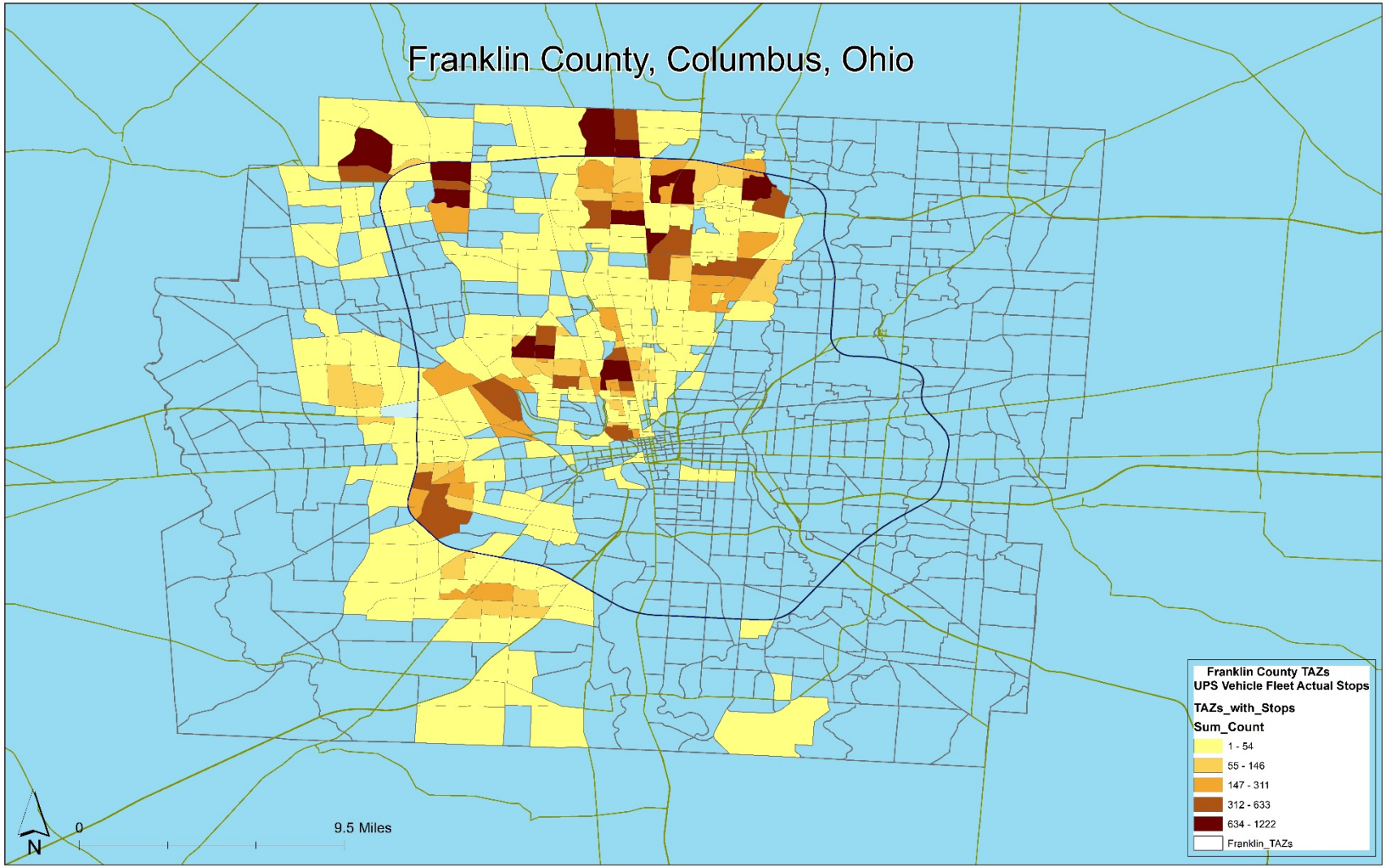
Locational Variables
Proximity to Depot
Proximity to UPS Stores
Proximity to I-270
Proximity to OSU
Proximity to CBD
UPS Stores (Dummy)
OSU (Dummy)
CBD (Dummy)

$$\hat{Y} = 16.325 + .039\beta_1 + .041\ \beta_2 + .179\beta_3 + .033\beta_4$$

Where:

$\hat{Y}$: Estimated deliveries per TAZ for July 2017
β_1 : Total number of households per TAZ
β_2 :Total number of office jobs per TAZ
β_3 :Total number of retail service jobs per TAZ
β_4 :Total number of other jobs

TAZ-Level Estimation: TAZs with Assumed UPS Delivery Counts



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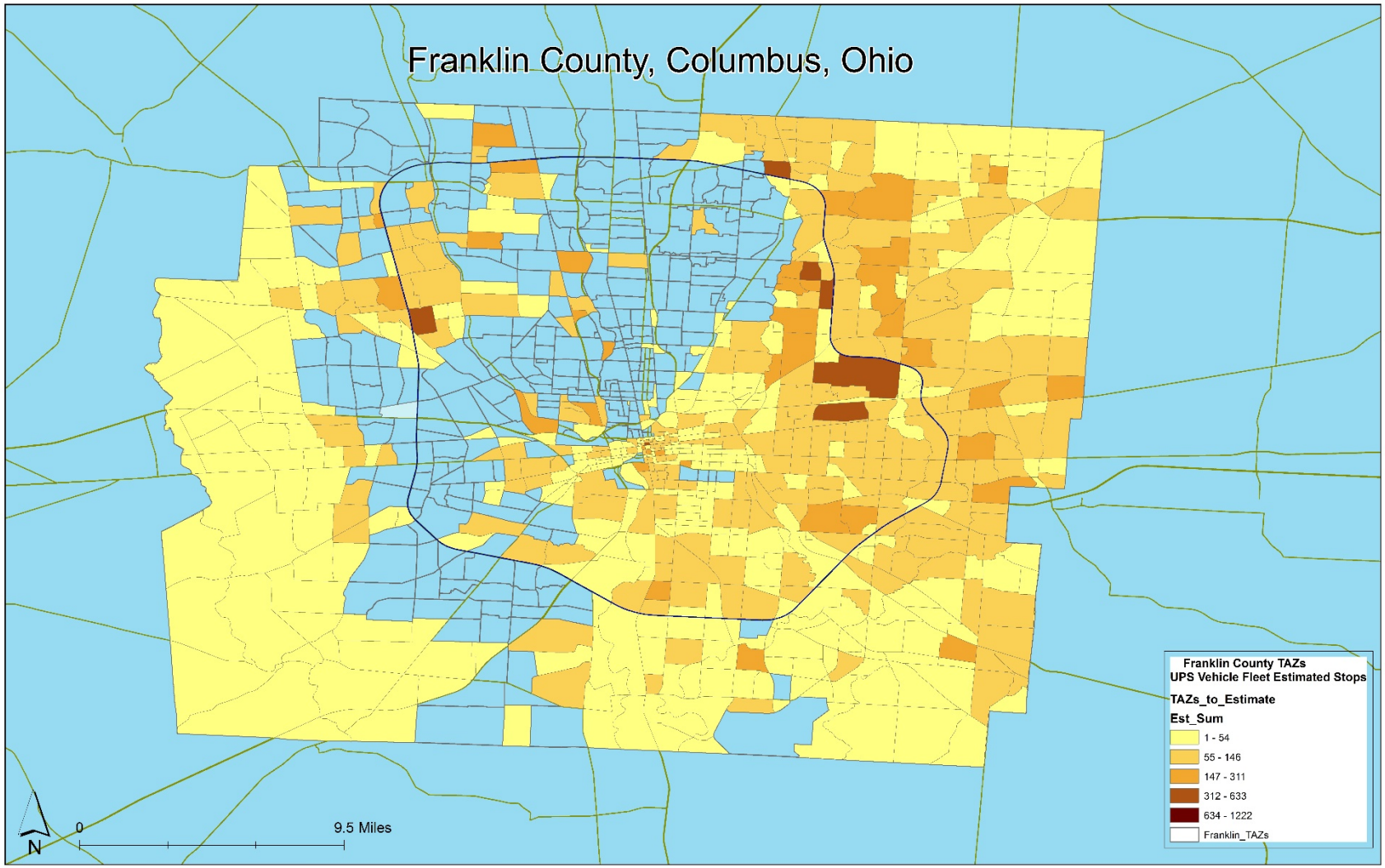
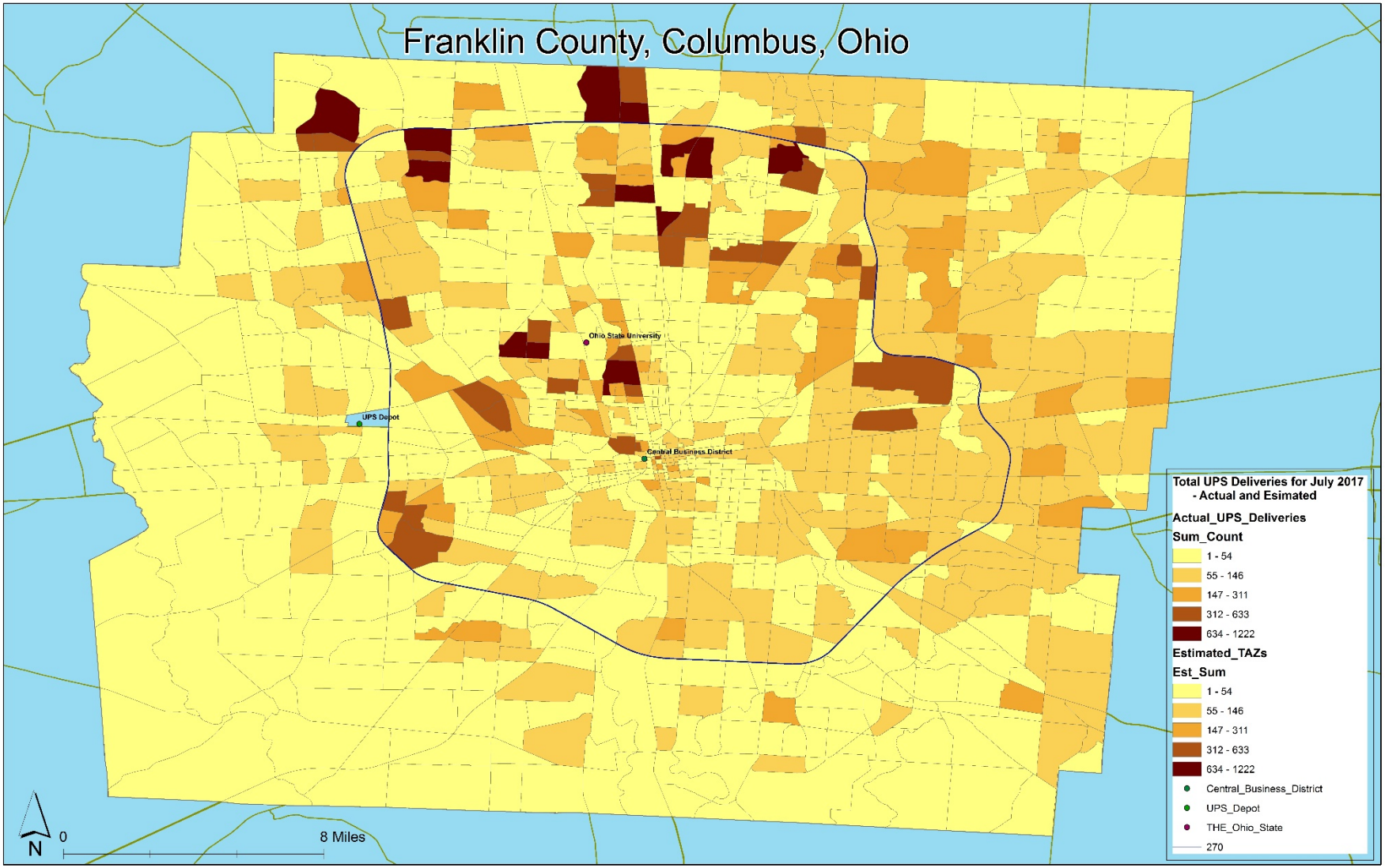
TAZ-Level Estimation: TAZs with Estimated UPS Delivery Counts

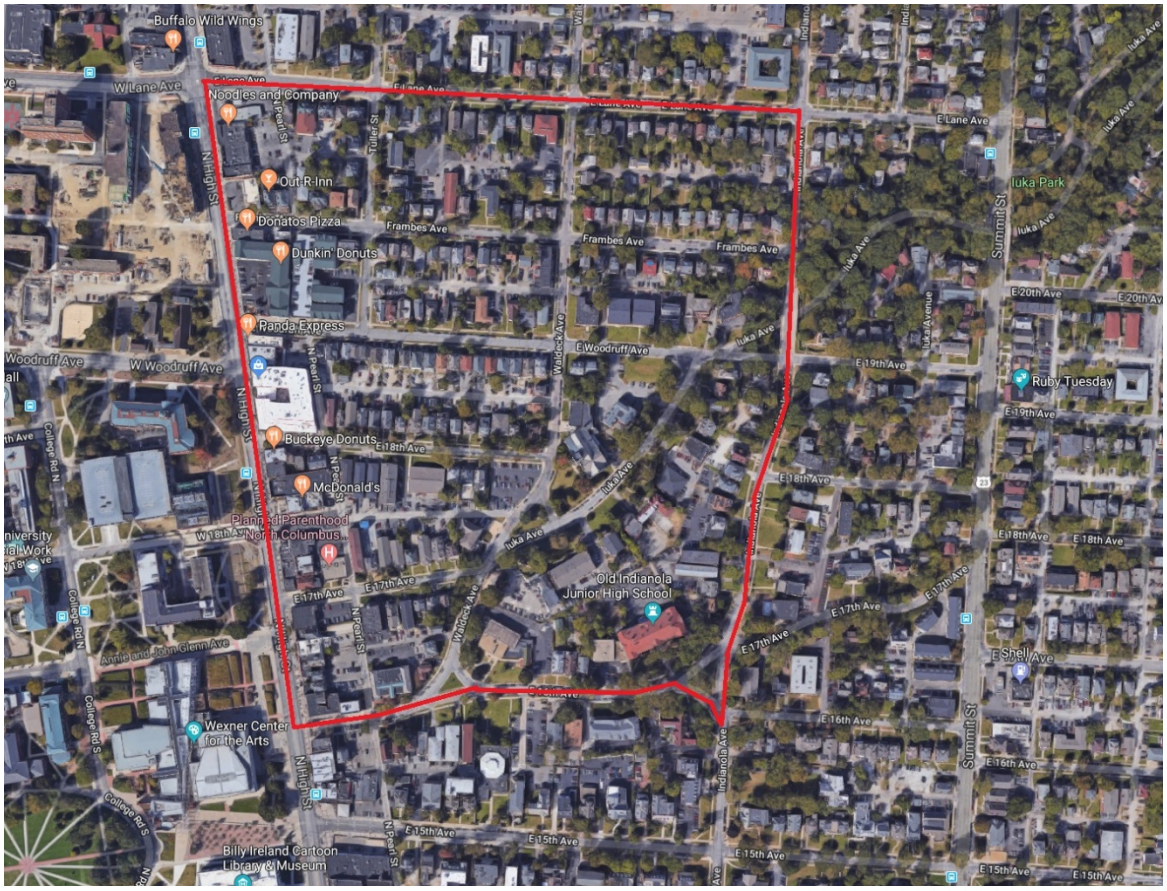


TAZ-Level Estimation: Combined Assumed and Estimated



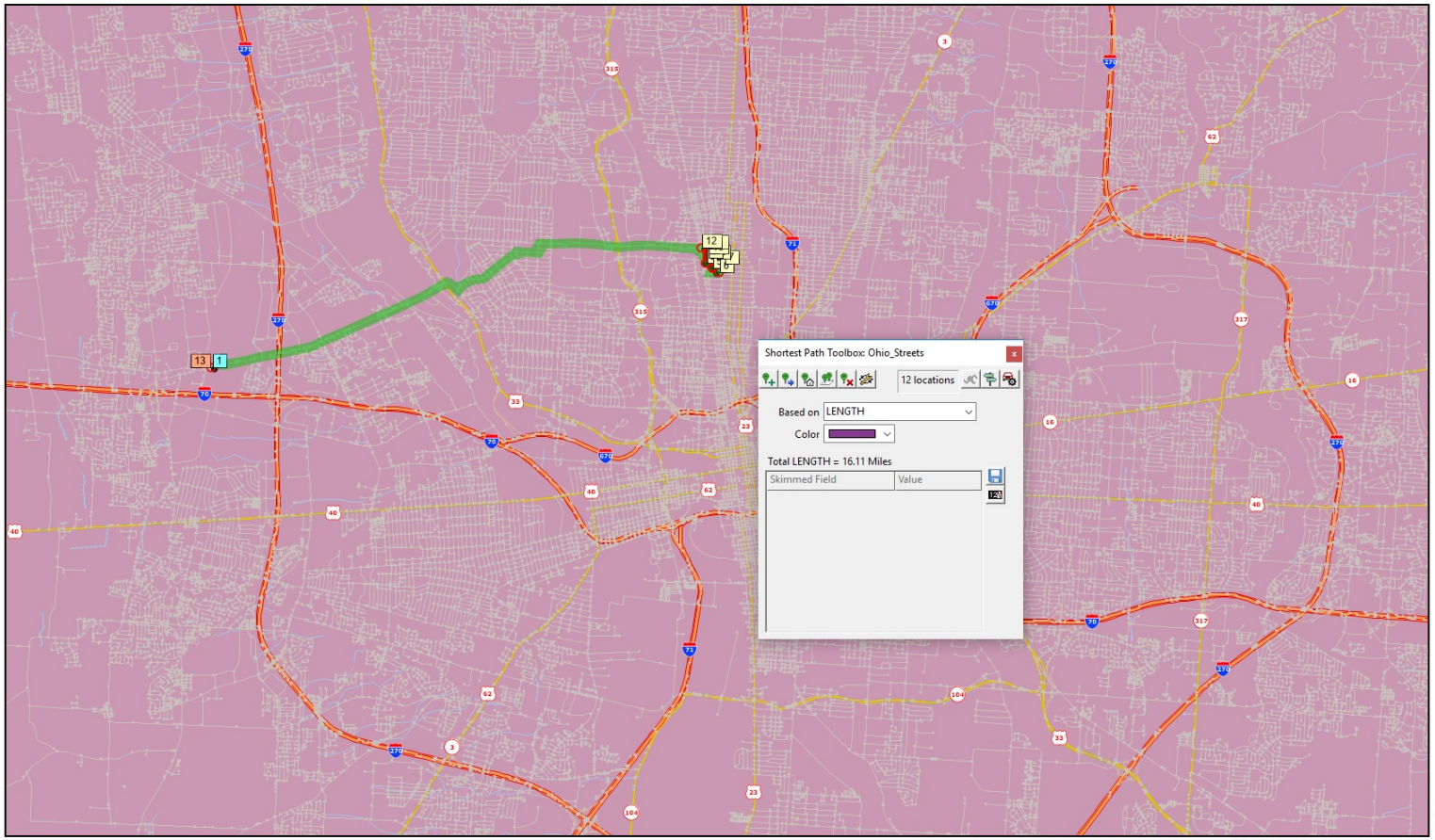
Alternative Last-Mile Delivery Scenarios

Indianola Neighborhood Case Study



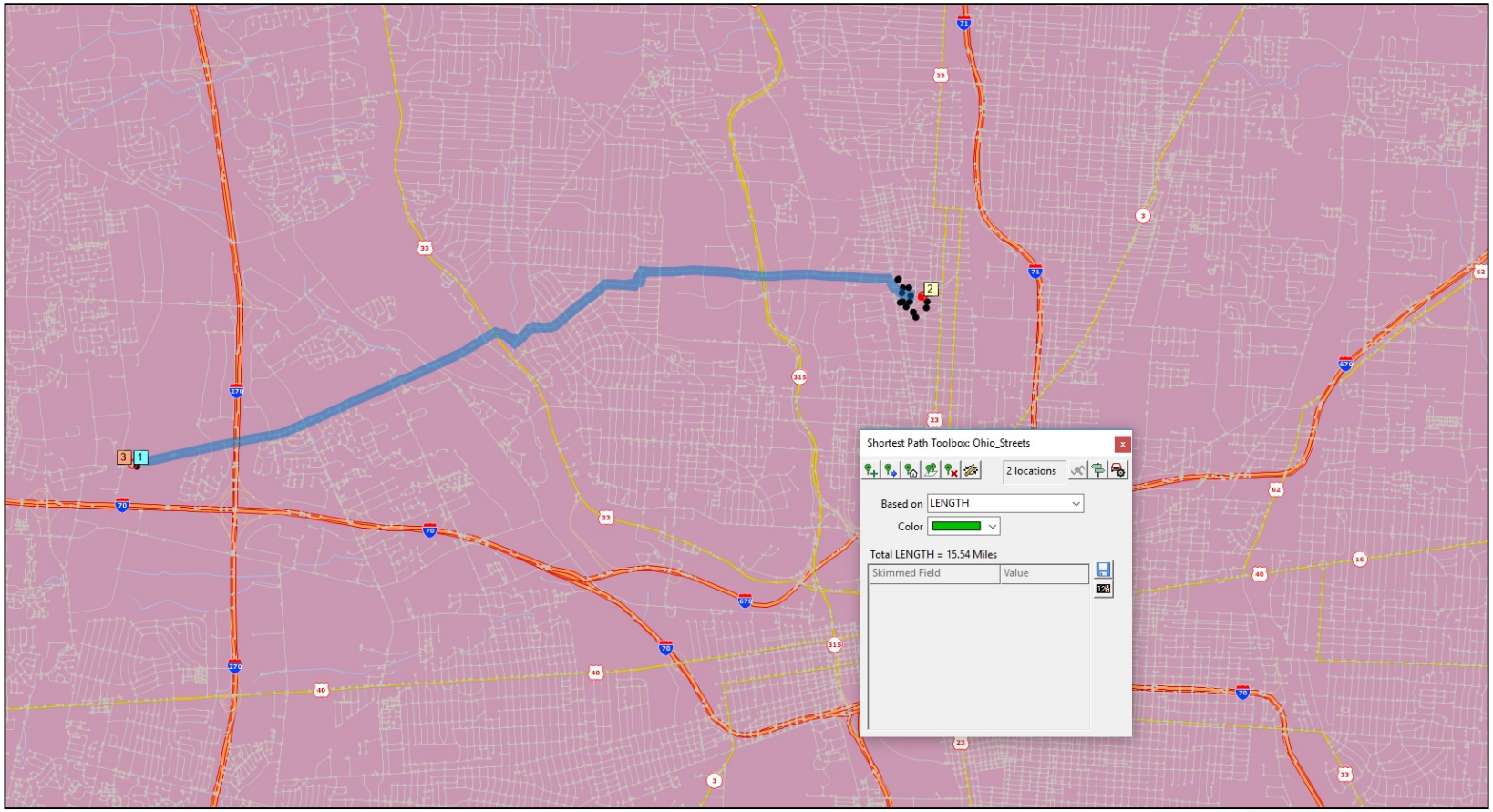
"Vehicle 02" delivery data from July 18, 2017 was used, which included and estimated 16 stops within the Indianola Neighborhood TAZ.

Indianola Case Study Tour Route



Taking the shortest path, the typical truck tour route was 16.11 miles roundtrip.

Indianola Case Study Tour Route with Locker



Locating a locker within the TAZ resulted in only a slight savings in distance traveled (15.54, compared with 16.11 miles roundtrip).

Indianola Case Study Tour Route with Lockers

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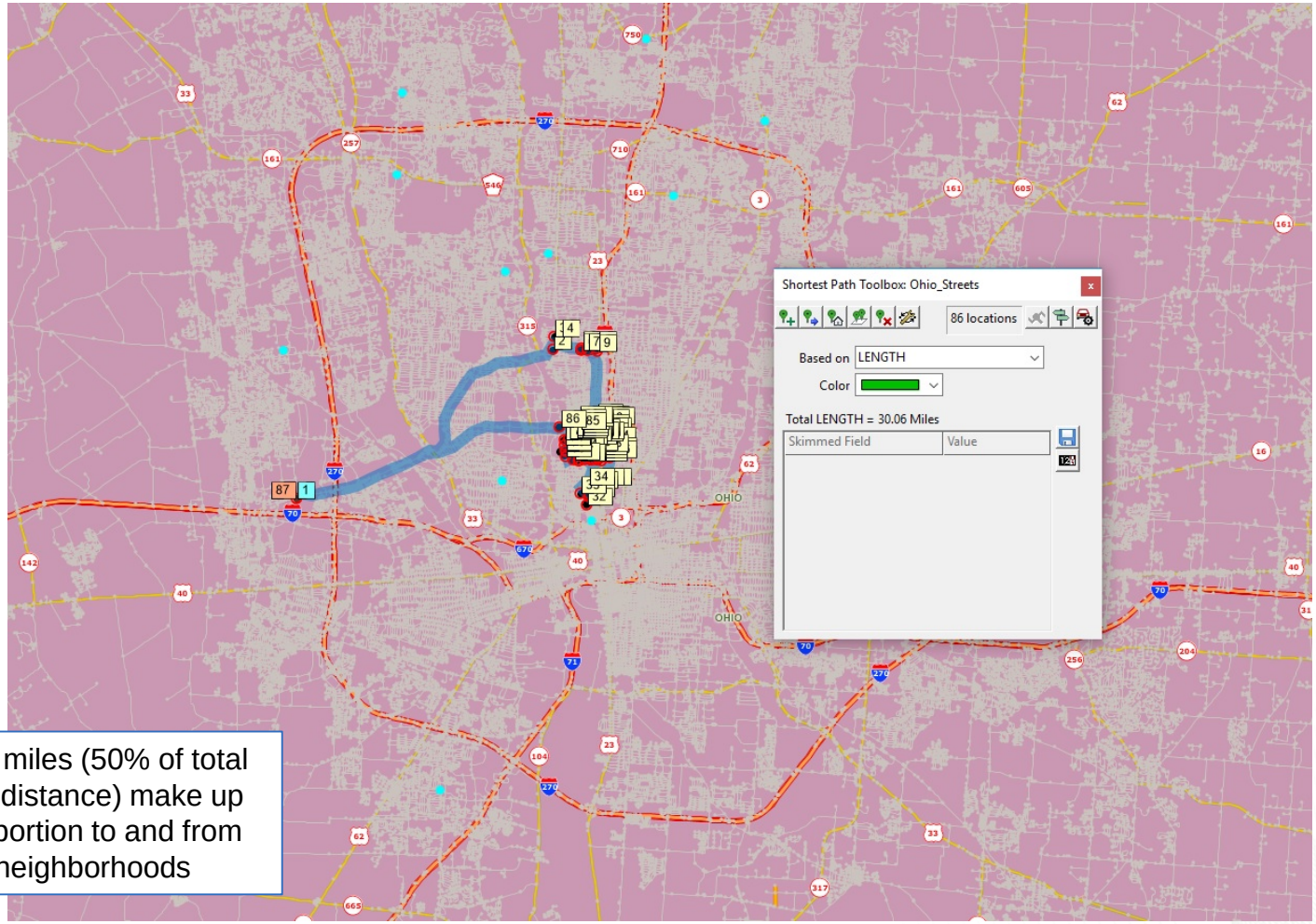
Indianola Case Study Tour Route with Drones

Incorporating the use of drones at the locker location results in 4.8228 miles traveled in addition to the 15.54 roundtrip distance traveled by the truck from Depot to neighborhood.

Indianola Case Study

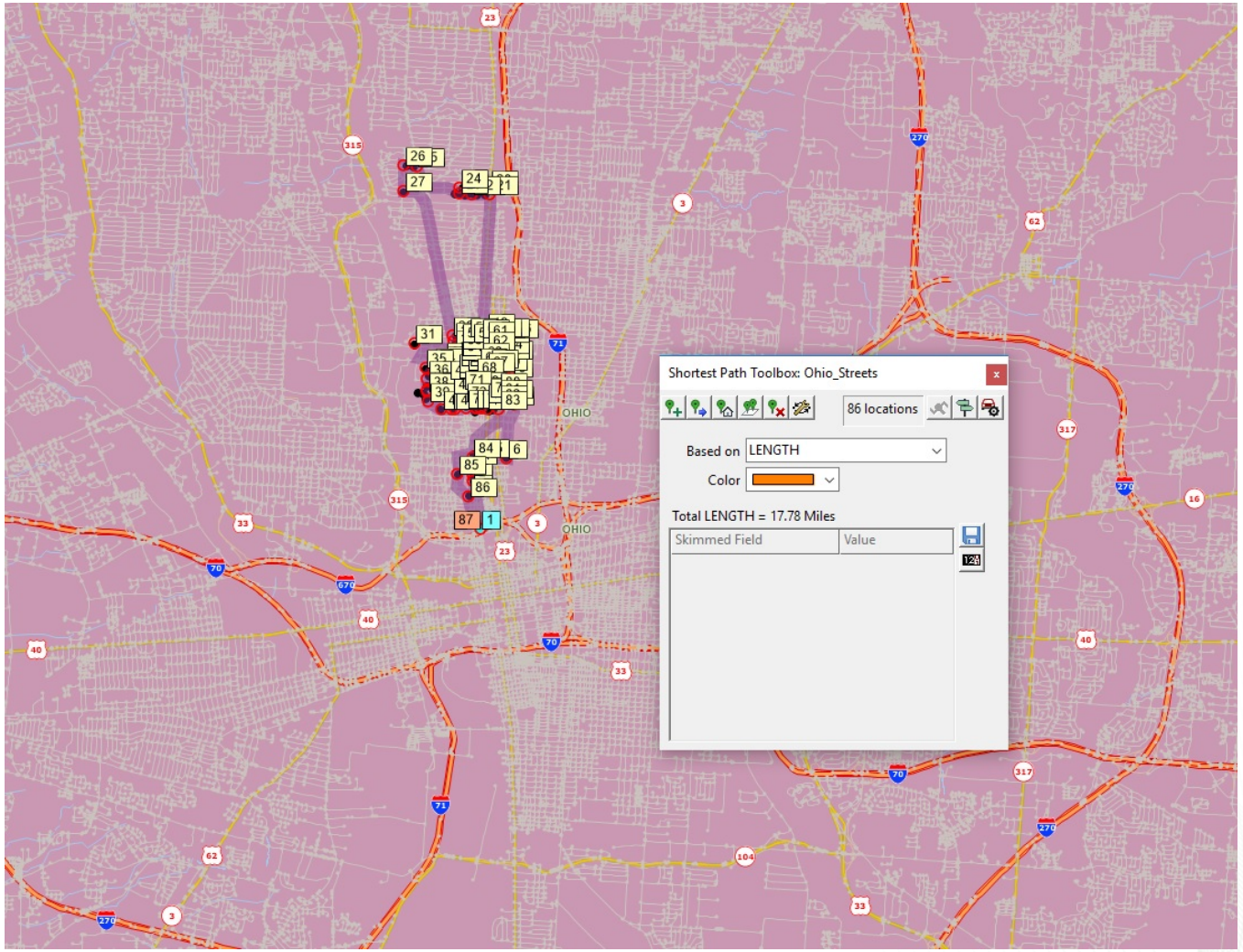
Scenario	Mode	Energy Usage kwh/mile	Total Energy Usage kwh	Notes
Baseline – Class 6 UPS Truck makes Deliveries from Depot	Class 6 Truck	4.29	69.11	16.11*4.29
Class 6 EV Truck makes deliveries from Depot	EV Class 6 Truck	1	16.11	16.11 * 1
Class 6 UPS Truck makes deliveries to UPS stores; EV delivery van makes final deliveries	EV Delivery Van (eNV200)	.56	71.13	(15.91*(4.29))+(5.14*(0.56))
Class 6 UPS Truck makes deliveries to lockers	Class 6 Truck	4.29	66.67	15.54*4.29
Class 6 EV Truck makes deliveries to lockers	EV Class 6 Truck	1	15.54	15.54*1
Class 6 UPS Truck makes deliveries to locker location; drones make final deliveries	Drone	.1	67.15	(15.54*4.29)+(4.822*0.1)
City Unit UPS Truck makes deliveries to UPS stores; Uber-style drivers make final deliveries using passenger vehicles	EV Passenger Car (Nissan Leaf)	.34	69.13	(15.91*4.29)+(2.57*0.34)

Vehicle 02 July 18, 2017 Full Tour

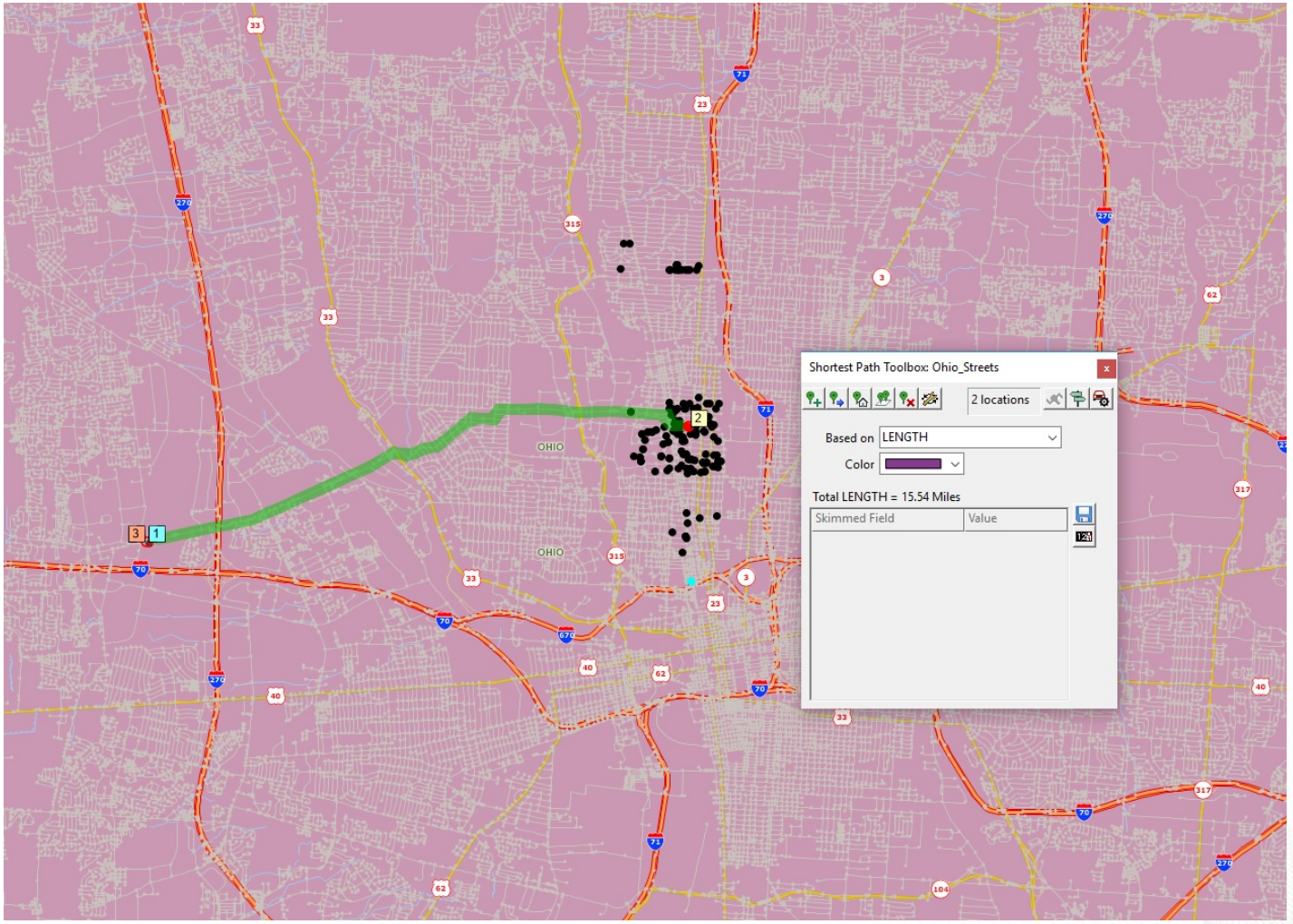


15.2 miles (50% of total tour distance) make up the portion to and from neighborhoods

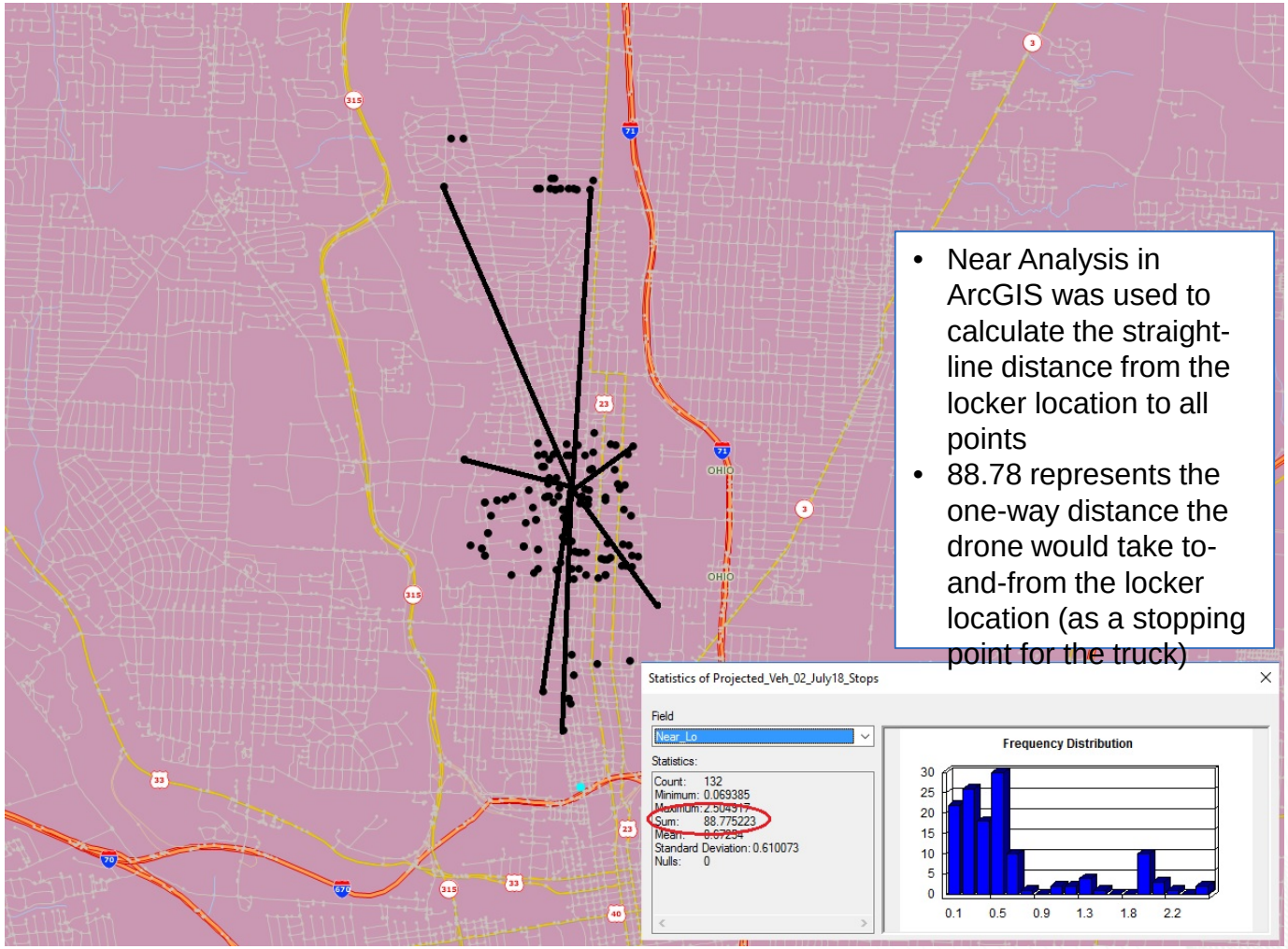
Vehicle 02 July 18, 2017 Tour from UPS Store



Vehicle 02 July 18, 2017 Tour from Depot to Locker



Vehicle 02 July 18, 2017 Drone Scenario



- Near Analysis in ArcGIS was used to calculate the straight-line distance from the locker location to all points
- 88.78 represents the one-way distance the drone would take to-and-from the locker location (as a stopping point for the truck)

Vehicle 02 Full Tour Case Study

Scenario	Mode	Energy Usage kwh/mile	Total Energy Usage kwh	Notes
Baseline – Class 6 UPS Truck makes Deliveries from Depot	Class 6 Truck	4.29	128.96	30.06*4.29
Class 6 EV Truck makes deliveries from Depot	EV Class 6 Truck	1	30.06	30.06 * 1
Class 6 UPS Truck makes deliveries to UPS stores; EV delivery van makes final deliveries	EV Delivery Van (eNV200)	.56	78.21	(15.91*(4.29))+(17.78*(0.56))
Class 6 UPS Truck makes deliveries to lockers	Class 6 Truck	4.29	66.67	15.54*4.29
Class 6 EV Truck makes deliveries to lockers	EV Class 6 Truck	1	15.54	15.54*2
Class 6 UPS Truck makes deliveries to locker location; drones make final deliveries	Drone	.1	112.03	(*4.29)+((14+1.6(5))+(65+2.27(5))*177.54)
City Unit UPS Truck makes deliveries to UPS stores; Uber-style drivers make final deliveries using passenger vehicles	EV Passenger Car (Nissan Leaf)	.34	71.28	(15.91*4.29)+(8.89*0.34)

Brookside Colony Neighborhood (Northwest Columbus)

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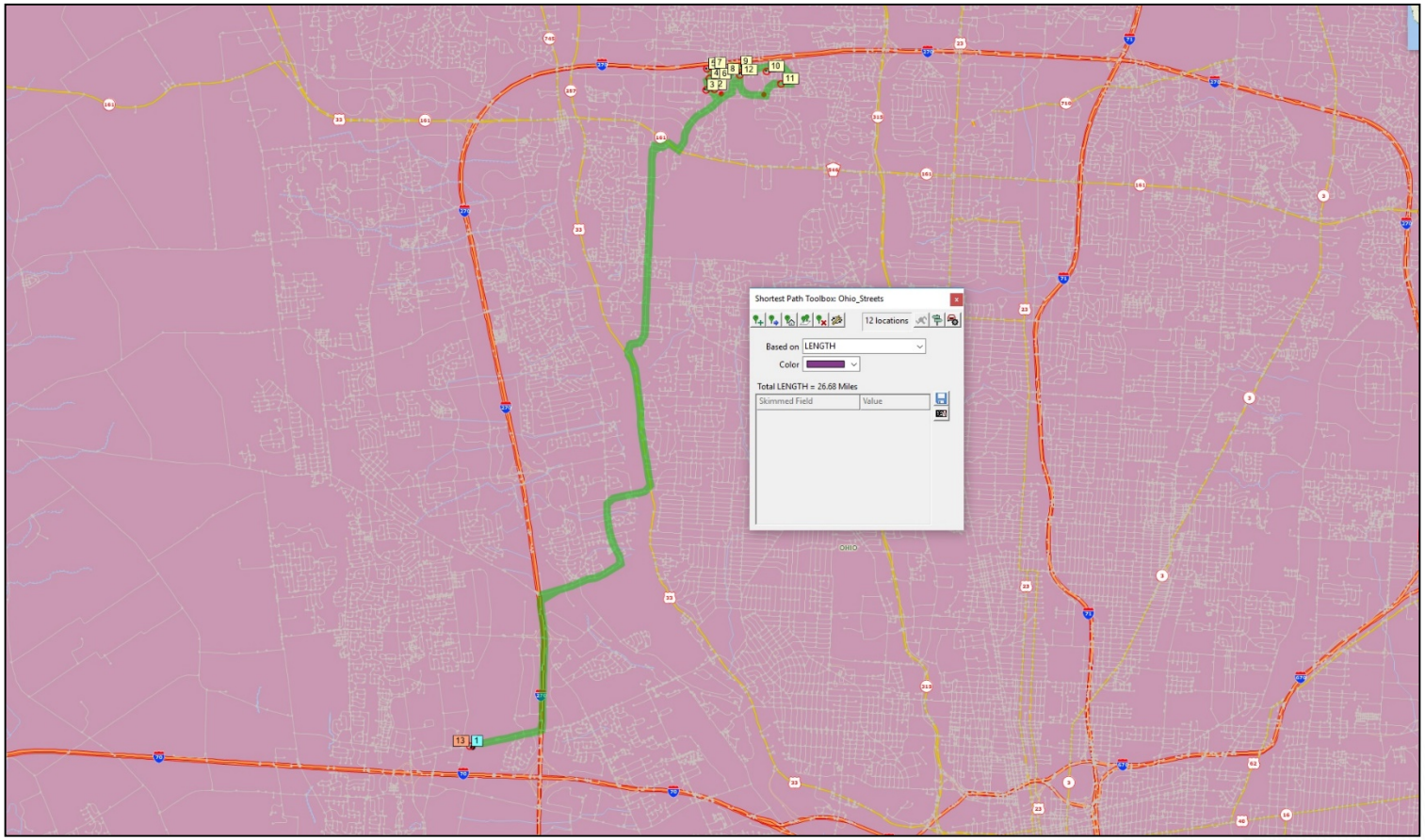
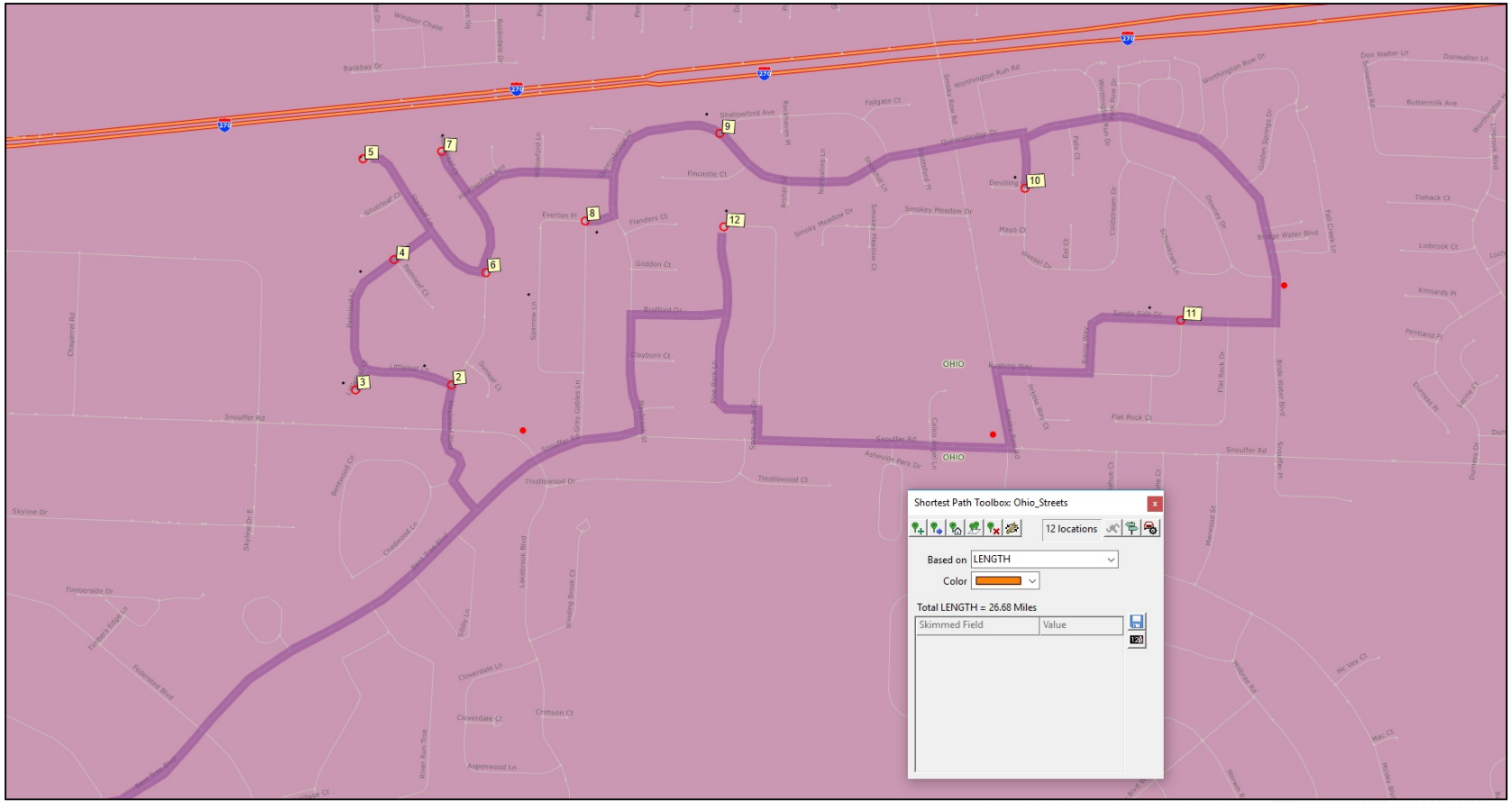
Brookside Colony Tour (Estimated from Model)



The TAZ containing the Brookside Colony neighborhood has an estimated (from the model) average number of 11 stops (deliveries) per day.

A typical shortest path tour route from the UPS depot results in 26.68 miles traveled roundtrip.

Close-up of Brookside Colony Tour Route



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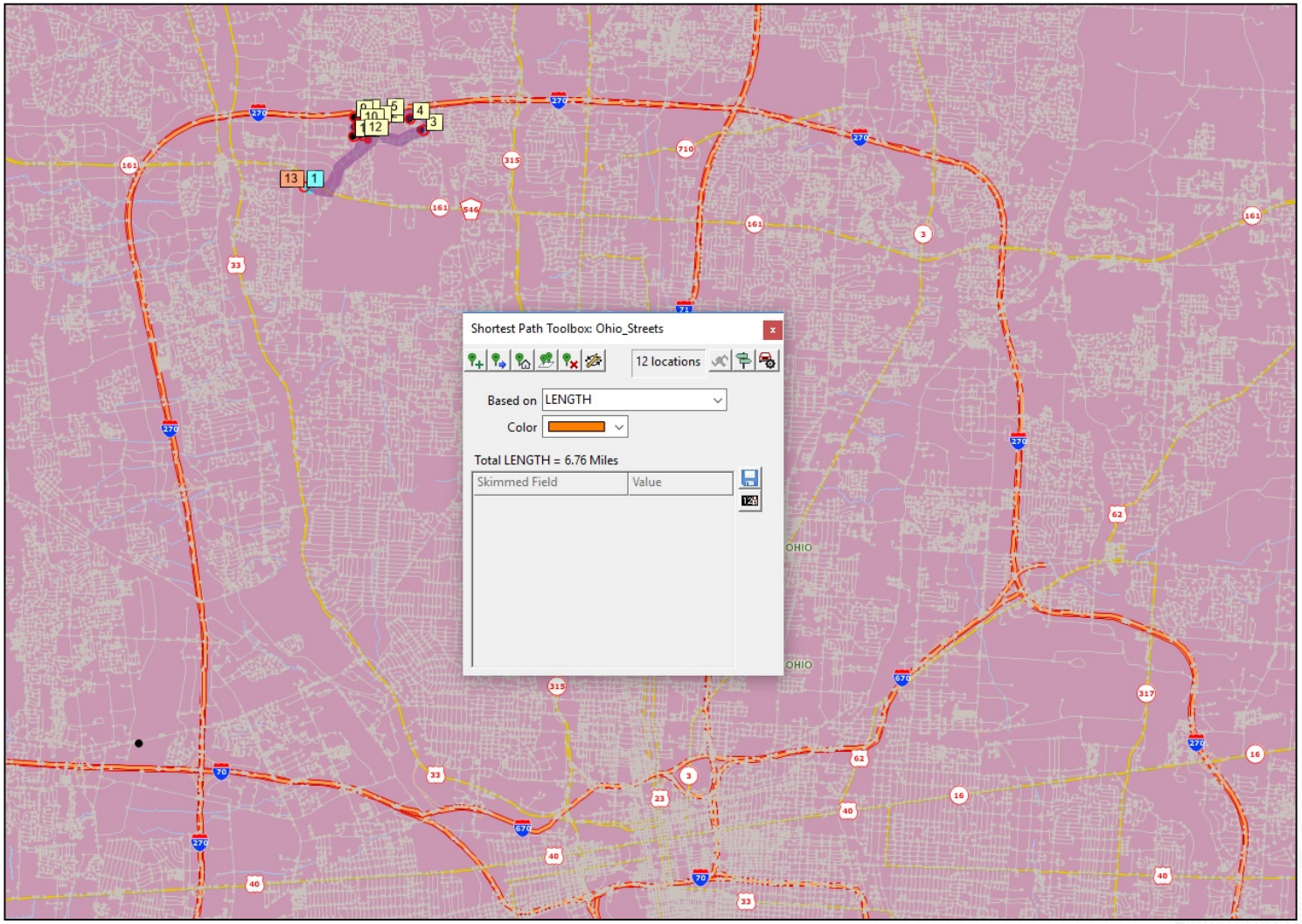
Brookside Colony: UPS Store to Delivery Locations



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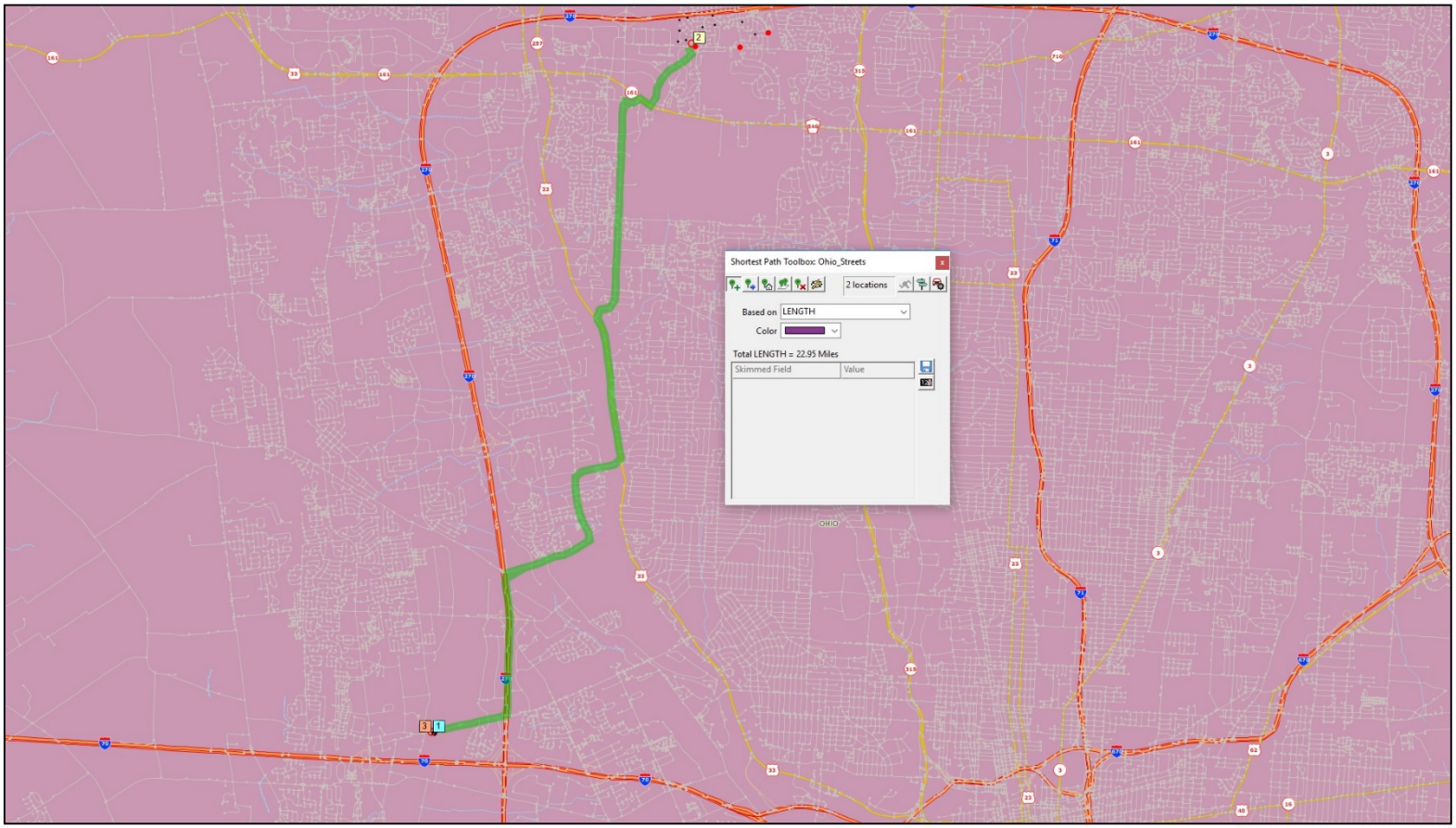
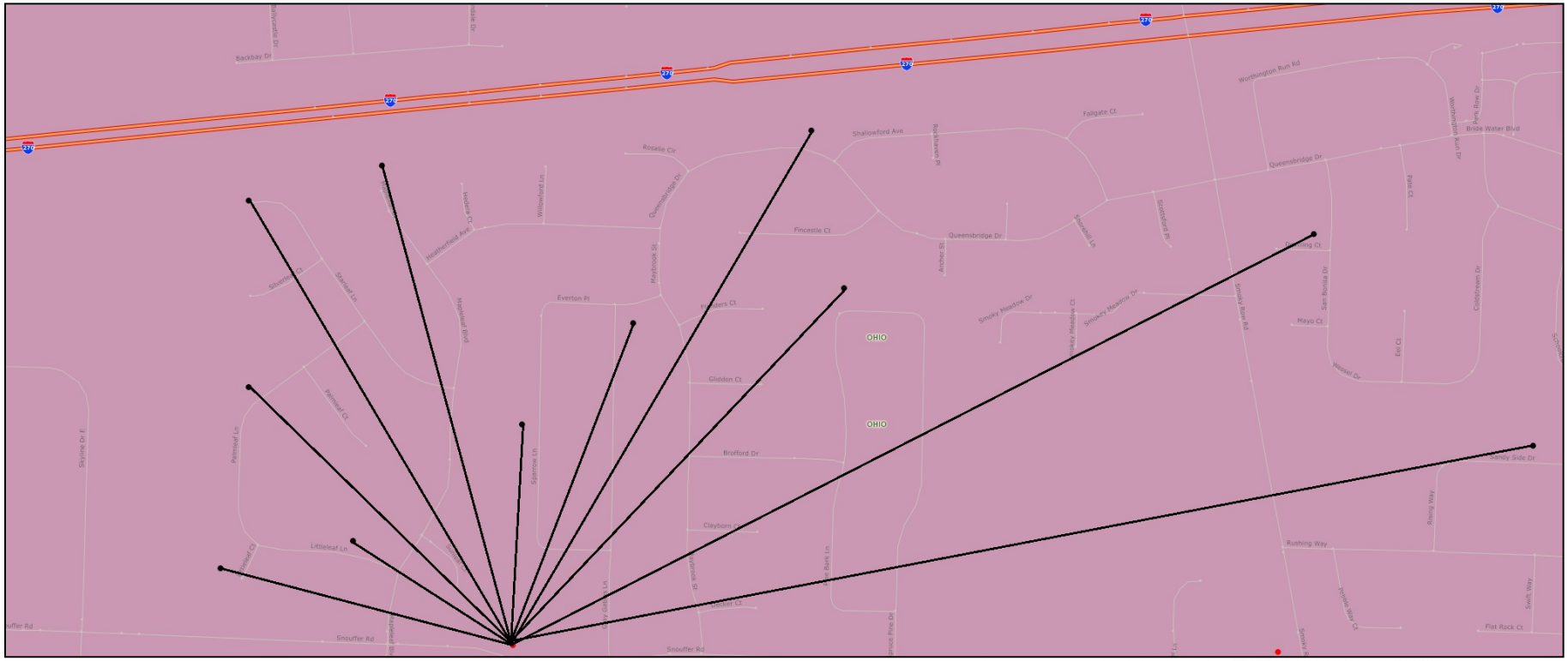
Brookside Colony: Drone Scenario



Using one of the locker locations as a vehicle stop for drone dispersion resulted in a savings of approximately four miles roundtrip (22.95, compared with 26.68) for the truck distance from Depot to neighborhood.

Brookside Colony: Drone Stop at Locker Location



Incorporating the use of drones at the locker location results in 7.902 miles traveled in addition to the 22.95 roundtrip distance traveled by the truck from the Depot to the neighborhood.

Brookside Colony Case Study

Scenario	Mode	Energy Usage kwh/mile	Total Energy Usage kwh	Notes
Baseline – Class 6 UPS Truck makes Deliveries from Depot	Class 6 Truck	4.29	114.46	26.68*4.29
Class 6 EV Truck makes deliveries from Depot	EV Class 6 Truck	1	26.68	26.68 * 1
Class 6 UPS Truck makes deliveries to UPS stores; EV delivery van makes final deliveries	EV Delivery Van (eNV200)	.56	89.24	(19.92*(4.29))+(6.76*(0.56))
Class 6 UPS Truck makes deliveries to lockers	Class 6 Truck	4.29	98.46	22.95*4.29
Class 6 EV Truck makes deliveries to lockers	EV Class 6 Truck	1	22.95	22.95*1
Class 6 UPS Truck makes deliveries to locker location; drones make final deliveries	Drone	.1	99.08	(22.95*4.29)+((14+1.6(5))+(65+2.27(5))*7.902)
Class 6 UPS Truck makes deliveries to UPS stores; Uber-style drivers make final deliveries using passenger vehicles	EV Passenger Car (Nissan Leaf)	.34	86.61	(19.92*4.29)+(3.38*0.34)

Summary

- Initial Findings:
  - EV trucks appear to be helpful in reducing energy usage for the portion of the tour from the Depot to the neighborhood (“stem” portion)
  - Parcel lockers appear to be helpful in reducing energy usage in more suburban neighborhoods with fewer through-streets and more cul-de-sacs
  - Pairing parcel lockers with EV delivery trucks or vans will likely further reduce energy usage overall
- Future work:
  - Develop additional scenarios
  - Obtain additional GPS data from UPS or other companies to represent seasonal fluctuations in delivery demand
  - Add automation by developing a program in TransCAD that will calculate estimates based on mileage and scenario types
  - Further drone testing
  - Refinement of energy estimates
    - Obtain estimate of kwh/mile/parcel