An In-Depth look at the Piedmont Triad Freight Model

Overview

- Decision Framework
- Model Structure
- Model Components
  - Firm Synthesis
  - Freight Demand
  - Freight Truck Touring Model
  - Commercial Vehicle Touring Model

Decision Framework

Decision Framework

- Disaggregate modeling vs. aggregate modeling
- What is the decision framework we are modeling?
- What is a tour?

Decision Framework

- Disaggregate modeling vs. aggregate modeling
  - Firm synthesis models, shipment models and truck touring models are “disaggregate” in that they represent individual businesses and their shipments and the travel behavior of individual trucks
  - This compares to aggregate truck models that model a quantity of commodity flow and/or truck travel between aggregate spatial units (e.g. TAZs)
  - The models are a simulation: they use draws from distributions (of, for example, choice probabilities from a logit model or observed values in an empirical distribution) to establish a point value for each business, shipment, or truck

Decision Framework: Firms and Shipments, and Service Demand

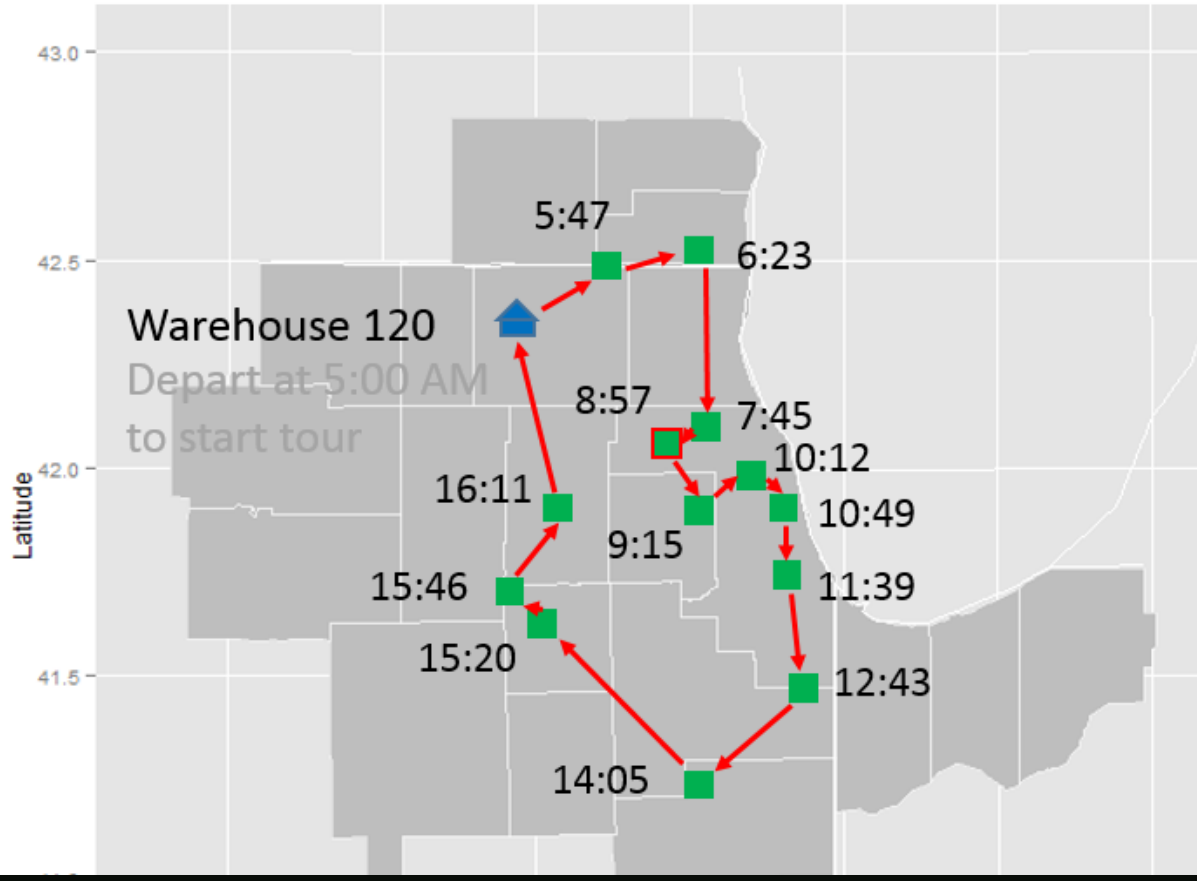
- What is the decision framework we are modeling?
  - General concept is to match the way businesses trade commodities and which leads to daily outgoing and incoming shipments, and also the way business and households require on site services.
  - Which commodities are required as inputs for production, where can those be bought, and who can production be sold to?
  - How can annual production and consumption needs by divided into daily incoming and outgoing shipments?

Decision Framework: Truck Touring

- What is the decision framework we are modeling?
  - General concept is to match the way that work for a truck driver's day is scheduled, e.g., by a dispatcher, fleet manager, or driver
  - What activity must be completed in a day
    - Service stops
    - Pick ups and deliveries
  - What is the best vehicle to service those activities
  - What is an efficient way to sequence and complete those activities subject to constraints such as travel time between stops and vehicle capacity

What is a tour?

A sequence of trips connecting activities that starts and ends at the same location



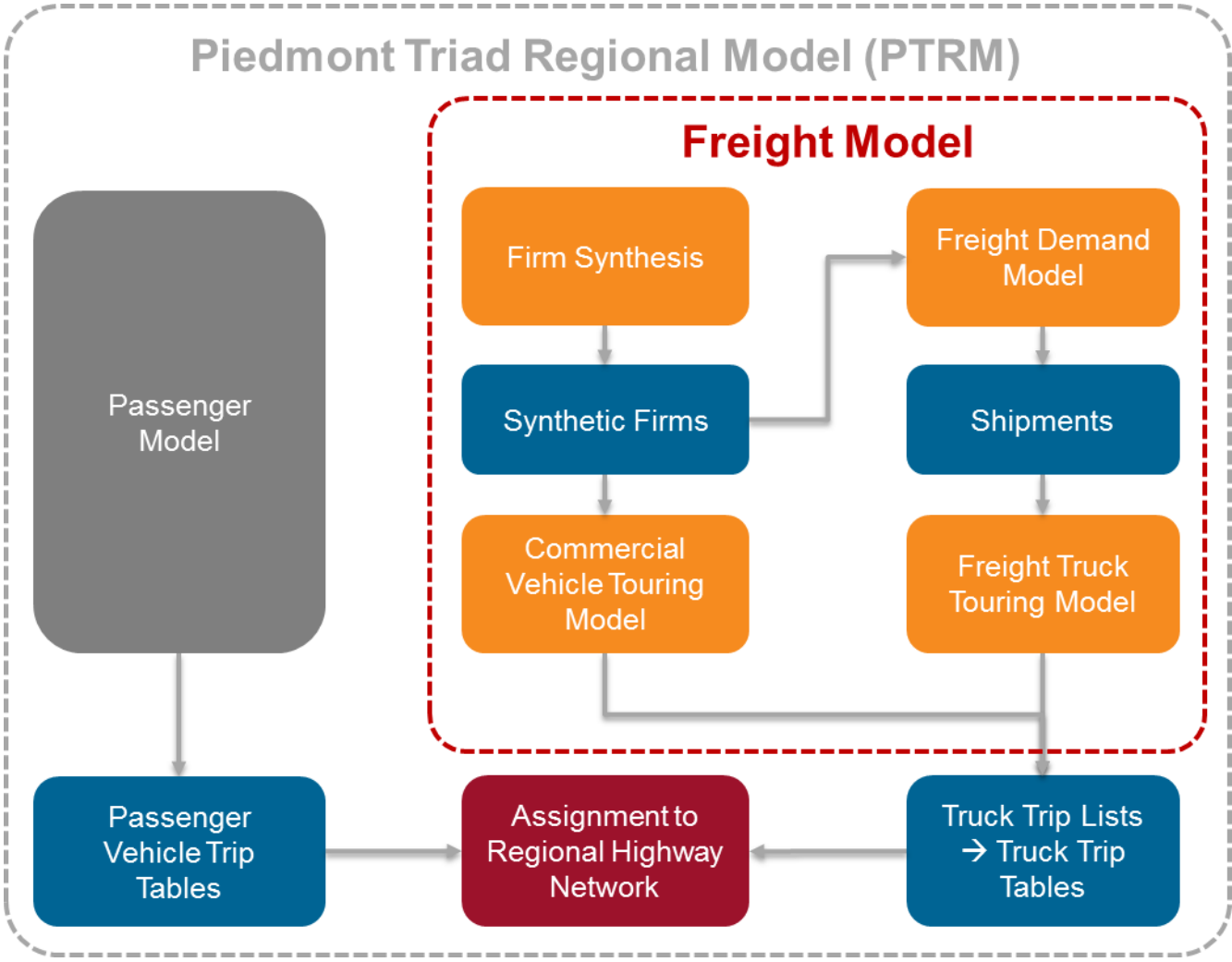
TourID	TripID	Vehicle	Scheduled	TAZ.Origin	TAZ.Destination	Activity	MAMDepart	MAMArrive	TravelTime	Distance	StopDuration
1	1	Heavy	1	4281	2011	Pick-up	400.68	478.00	77.32	51.55	10
1	2	Heavy	1	2011	2182	Pick-up	488.00	491.67	3.67	2.44	32
1	3	Heavy	1	2182	2138	Pick-up	523.67	529.12	5.45	3.63	38
1	4	Heavy	1	2138	2138	Pick-up	567.12	567.12	0.00	0.00	17
1	5	Heavy	1	2138	2686	Pick-up	584.12	589.50	5.38	4.48	21

Model Structure

The Piedmont-Triad Freight Model

Main model components:

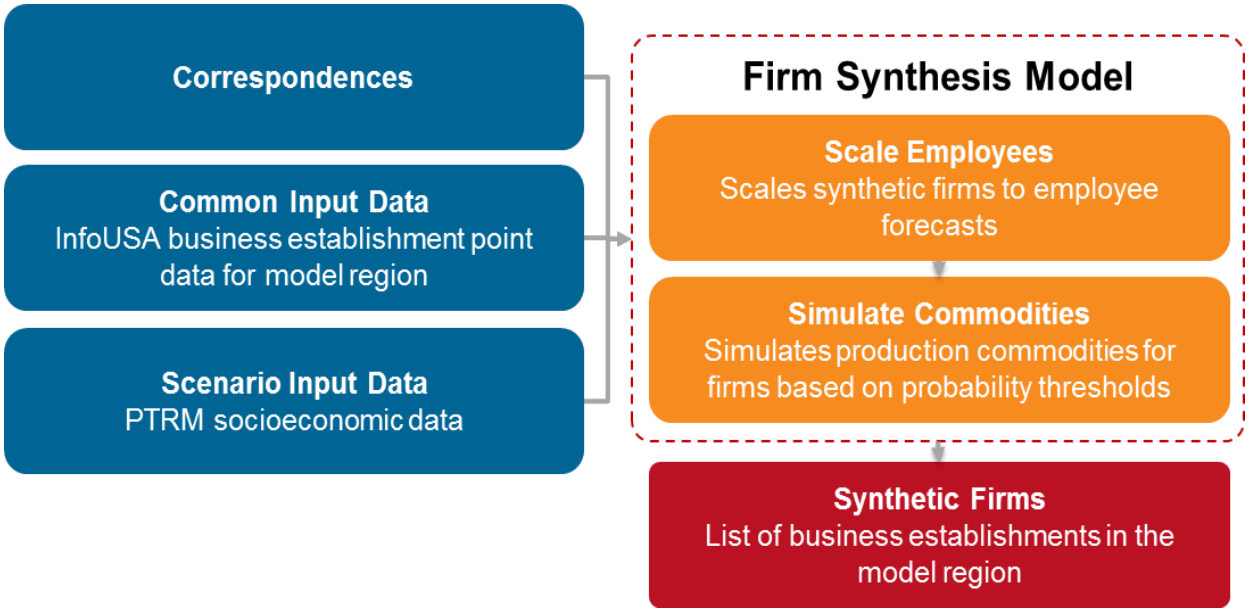
- Firm Synthesis
- Freight Truck Touring Model
- Commercial Vehicle Touring Model



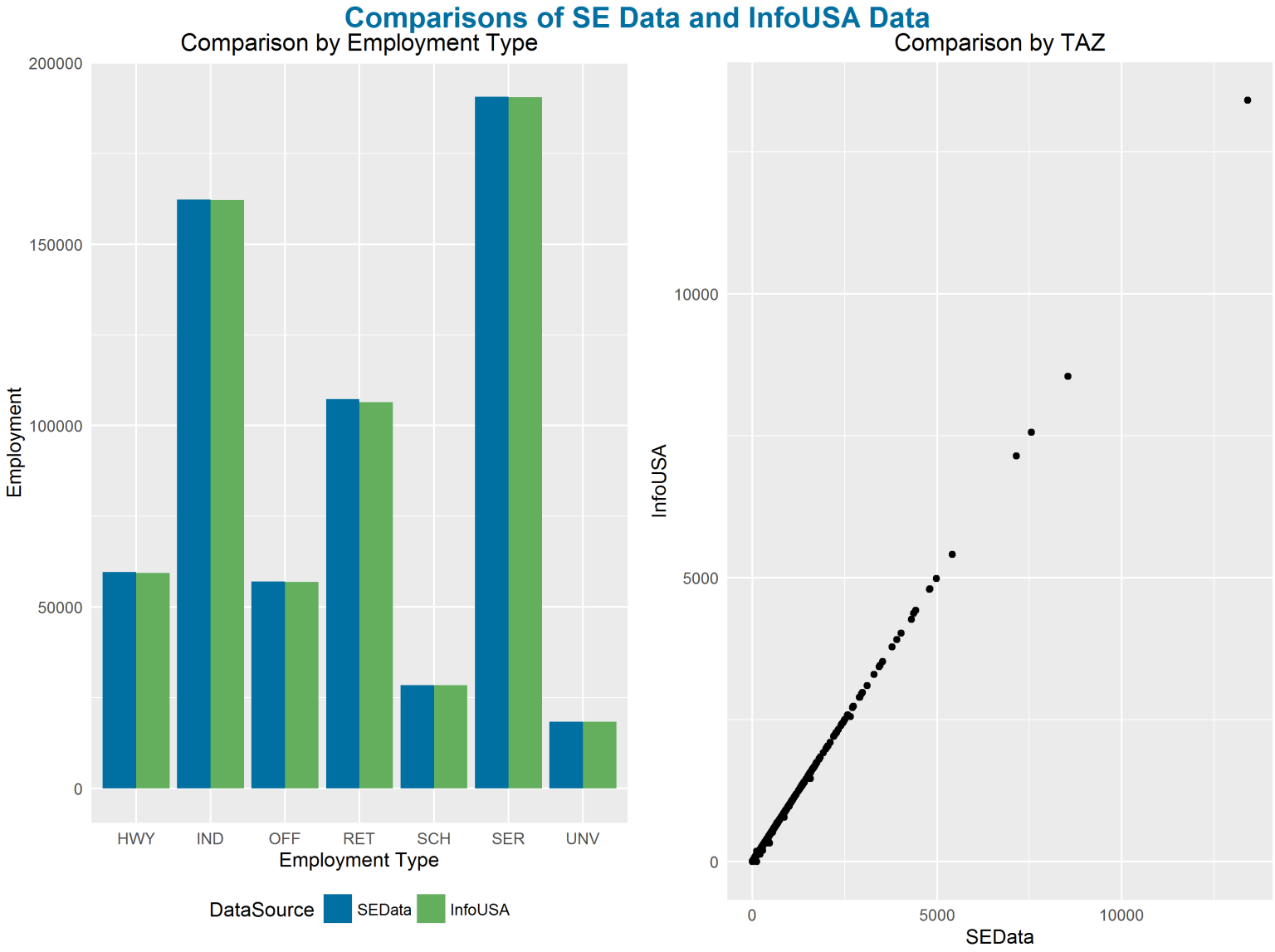
Model Components

Firm Synthesis Model

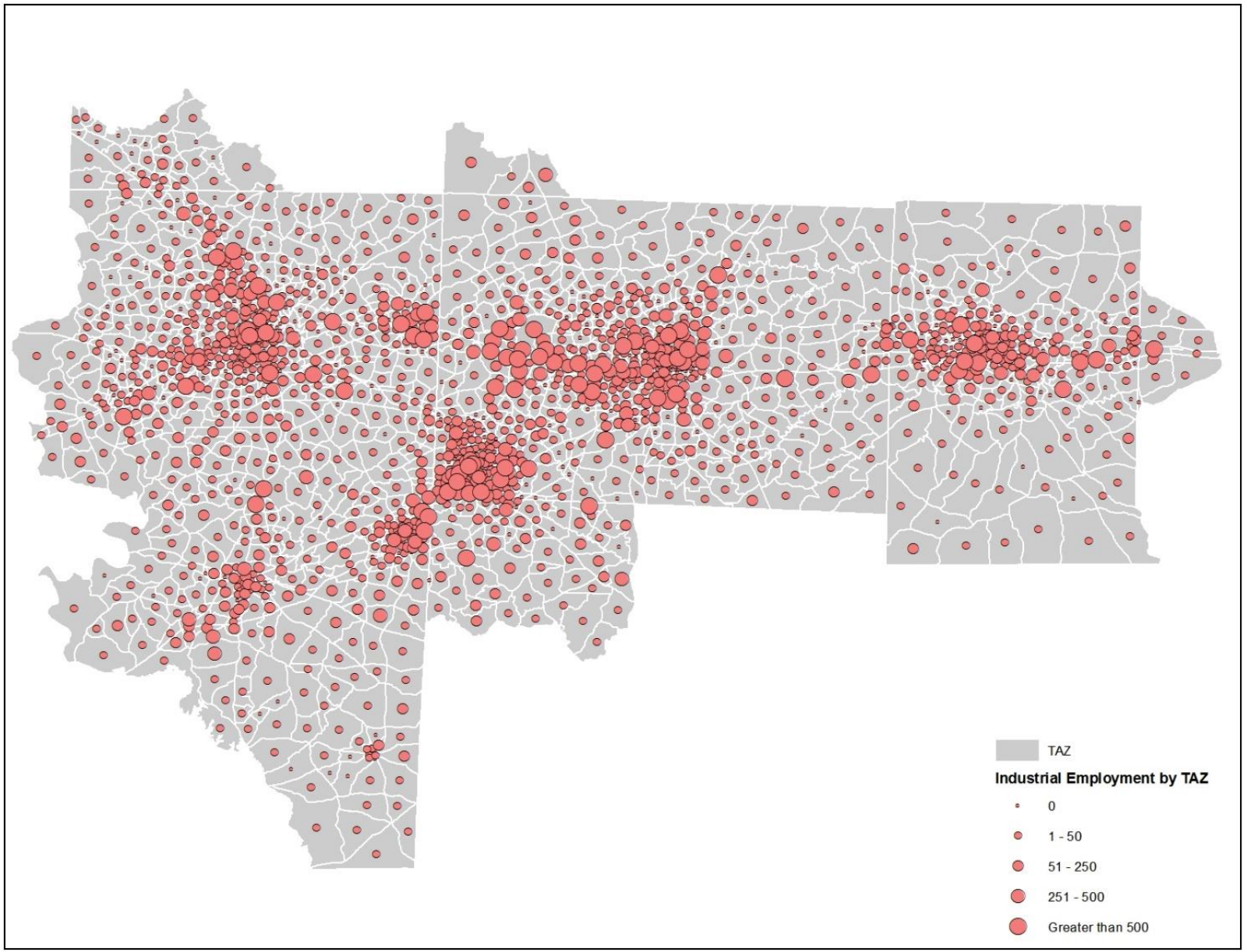
- Creates a list of business establishments within the model region



Employment Comparison Results

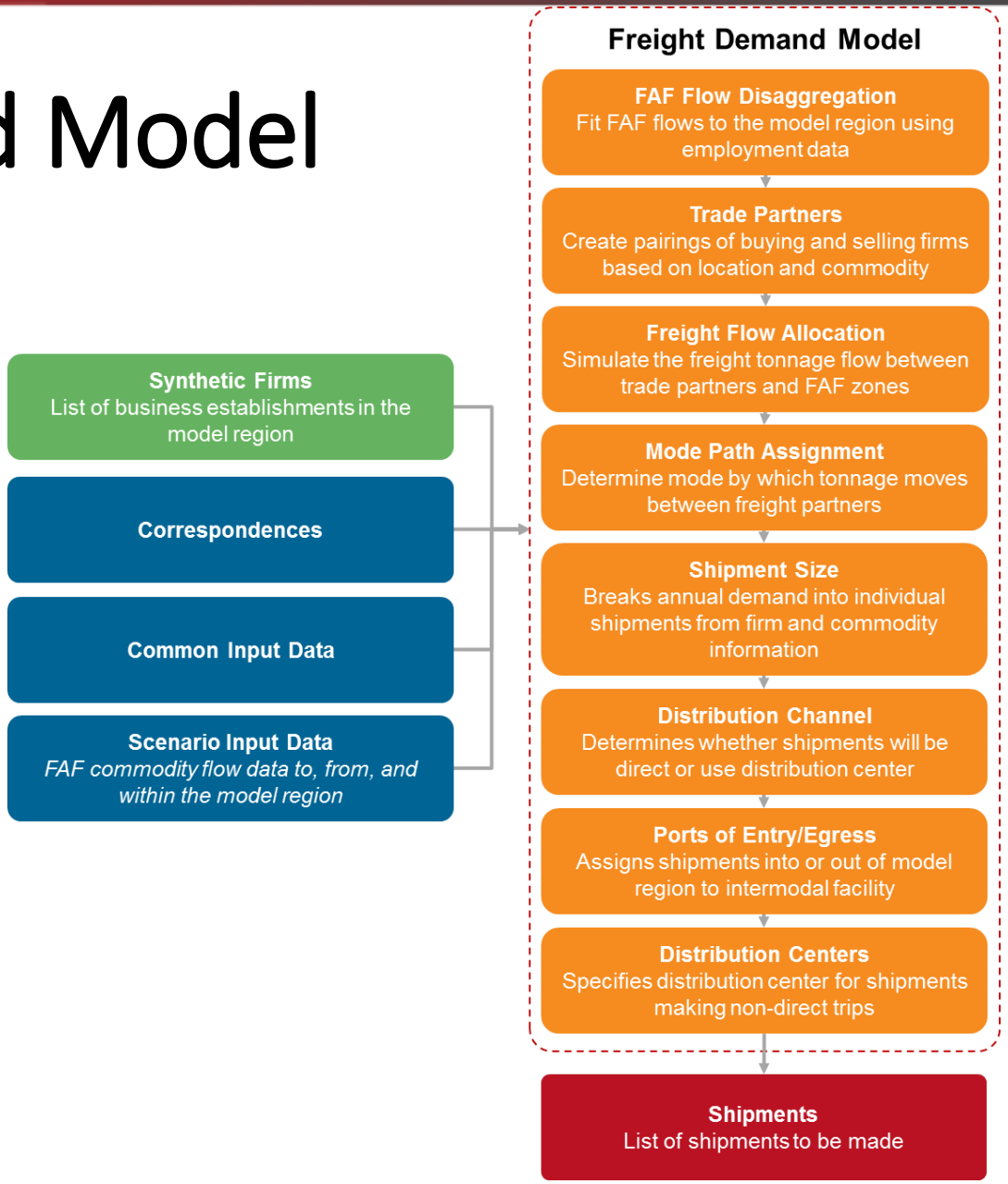


Industrial Employment by TAZ



Freight Demand Model

The freight demand model develops a list of zone-to-zone shipments, some of which are allocated to distribution centers and intermodal facilities.



Long haul and short haul freight demand

- Truck touring model at the heart of the PART model design starts from commodity-defined shipments into, out of, and within the model region: EI/IE/II
  - Direct pick up / delivery
  - Peddling tours based at warehouses and distribution centers
- NCSTM allocation of truck trips to SWTAZs duplicates market coverage of these demand segments and commodity info is not included in outputs
- Fractional allocation approach used by NCSTM is not consistent with simulation approach of truck touring model
- Simulation-based long-distance freight model is needed to provide the commodity-defined EI/IE/II inputs to the truck touring model

Overview of approach

- Based on US BEA Input-Output (IO) tables ("make" and "use") specifying quantities of commodities consumed as inputs to commodities produced
  - Consistent with IO table methods found in NCSTM
  - Uses simulation methods from National Supply Chain models from Chicago (CMAP), Florida DOT, and Baltimore (BMC)
- Rooted in synthetic firms used in truck touring model simulation
  - Firms are producers and consumers of commodities
  - Firms choose suppliers for their consumption needs (in/out of region)
  - Firms are chosen to supply commodities to other firms (in/out of region)
  - FAF commodity flows are allocated to buyer-supplier pairs
  - Commodity flows converted to annual/daily shipments by truck (and other modes)
  - Truck shipments are assigned to either direct pickup/delivery or warehouse and distribution centers

Inputs from firm synthesis

- Firms are created for both the freight and commercial vehicle model
- Defined by industry classification and employee-size distribution for the region (from InfoUSA data)
- For each firm producing a transportable commodity (SCTG), project annual production (dollars, tons) proportional to firm size (BEA “Make” tables)
- For each commodity produced, project annual consumption of input commodities (BEA “Use” tables)
  - For every $1 produced, what fraction of that dollar is spent on each input
  - Many input commodities for each output commodity—model top 90% by value (typical range: 10 – 30)

Choose suppliers

- For each synthetic firm in the model region, choose a supplier for each input commodity, using a 2-stage approach:
  a. Choose among FAF zones that ship the commodity to the model region FAF zone, including intra-regional FAF flows
     - There are parts of two FAF zone representing the Piedmont-Triad region
     - Choice is a single FAF zone from which to receive the input commodity
     - Choice probabilities are proportional to FAF flows by dollar value (not mode specific)
  b. For firms that have chosen the model region FAF zone…
     - Choose another synthetic firm that produces the commodity as a supplier
     - Choice probability is proportional to each supplier's annual production amount, discounted by distance-decay relationship
- End product is either an external supplier (identified only by FAF zone), or a specific firm within the region

Choose external buyers

- For each external consumer of commodities produced within the region, choose synthetic firm in the model region as suppliers
  - Internal consumers of commodities produced within the region have been identified in previous step
  - External customers are represented in aggregate form by the FAF flows going from the model region to external FAF zones
  - For each external FAF zone consuming a particular commodity from the model region FAF zone, choose a synthetic firm in the region as a supplier
    - Probability of choice of supplier is proportional to each firms' annual production amounts of that commodity
    - Since there are many FAF zones trading with the Piedmont-Triad region, regional producers may have multiple external and internal customers
- End product is the pairing of each external FAF zone flows of a particular commodity type with a single producer (synthetic firm) within the region

Allocate the FAF flows between buyer and supplier pairs

- External-Internal:
  - For each external FAF zone, allocate FAF flows *to* the model region to the synthetic firms choosing an external supplier.
  - Proportional to each firm's annual consumption requirements
- Internal-External:
  - For each external FAF zone, allocate FAF flows *from* the model region to the synthetic firms chosen to supply a particular commodity to a particular FAF zone.
  - Proportional to each firm's annual production amounts
- Internal-Internal:
  - For each buyer-supplier pair identified earlier, allocate a portion of the intra-FAF zone commodity flows
  - Proportional to the product of the buying firm's annual consumption and the supplying firm's annual production
- End product are tons of commodities being shipped (annually) between synthetic firms in the model region and external buyers/suppliers, and between pairs of buyer-supplier firms within the model region

Mode paths

- EI and IE flows may arrive and depart the region using different mode paths:
  - Truck only
  - Rail-truck
  - Air cargo-truck
- Assume percentage of flows by each mode in FAF
- Non-truck flows are not modeled in Phase 2 but the truck portion of intermodal flows within the region are modeled (otherwise those truck trips would be missed)

Shipment size

- For each allocation of commodity flows between shipper and receiver, break into individual shipments by choosing an average shipment size
  - Use Commodity Flow Survey distributions of shipment size by commodity
  - Annual amount divided by average shipment size implies frequency

Distribution channel choice

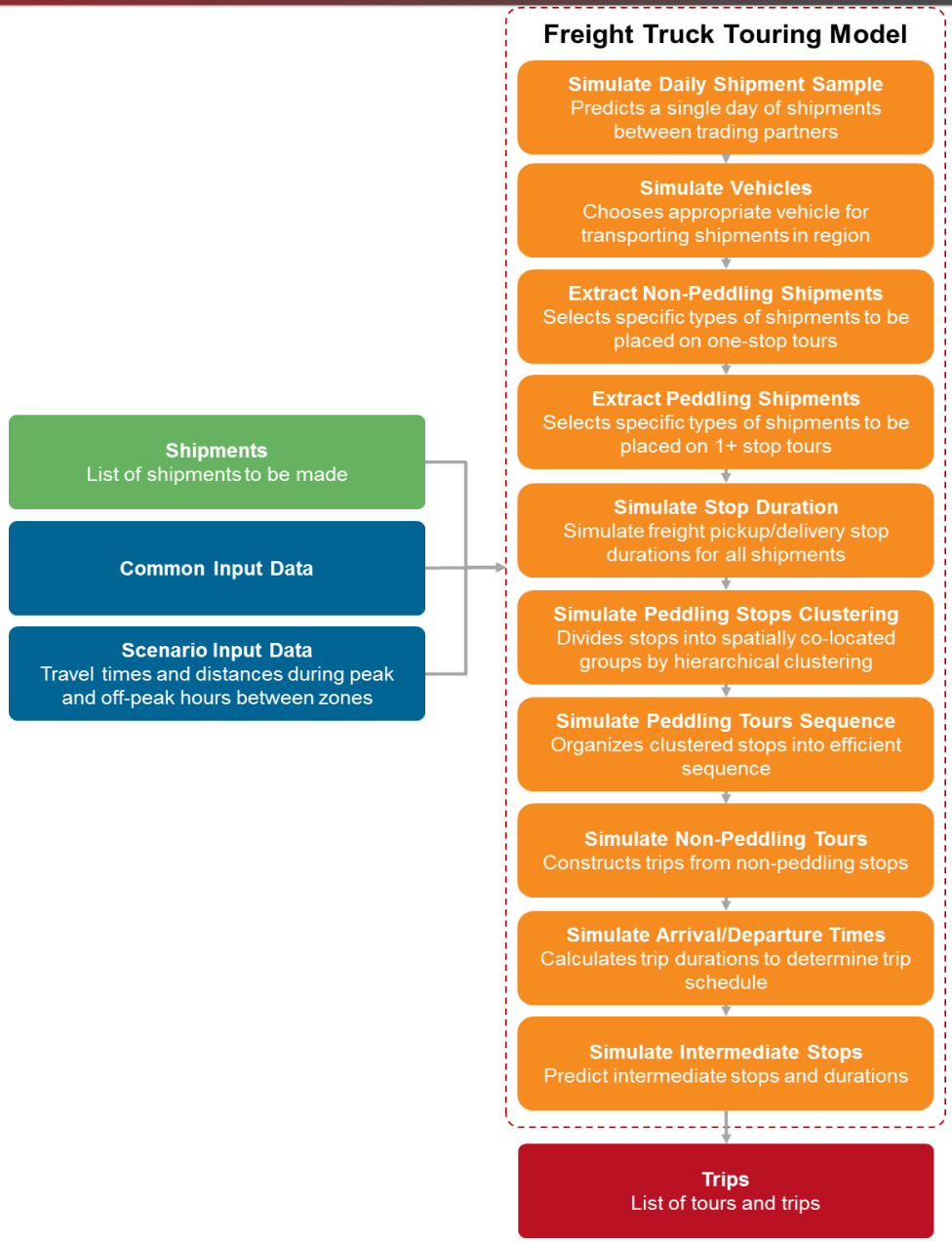
- Shipments by truck and commodity type are allocated to either
  - Direct pick up / delivery, or
  - Peddling tours based at warehouses and distribution centers
- If a peddling tour is chosen, the shipments will be allocated to warehouse and distribution centers from the regional database (commodity-specific)
- At each warehouse/distribution center, individual shipments may be combined and allocated to truck tours, making multiple stops
- EI/IE truckloads determined by payload factors

Truck Touring Models

- Both the freight truck and commercial vehicle touring models follow a similar general sequence:
  - Establish demand (freight model – shipment pick up and delivery, commercial vehicle model – service activity, home deliveries)
  - Estimate activity durations at stops
  - Allocate appropriate vehicles types to support the activity
  - Group and sequence stops into tours
  - Establish time of day
  - Add in intermediate stops for breaks, refueling etc.
  - Finalize the trip timing with both scheduled and intermediate stops

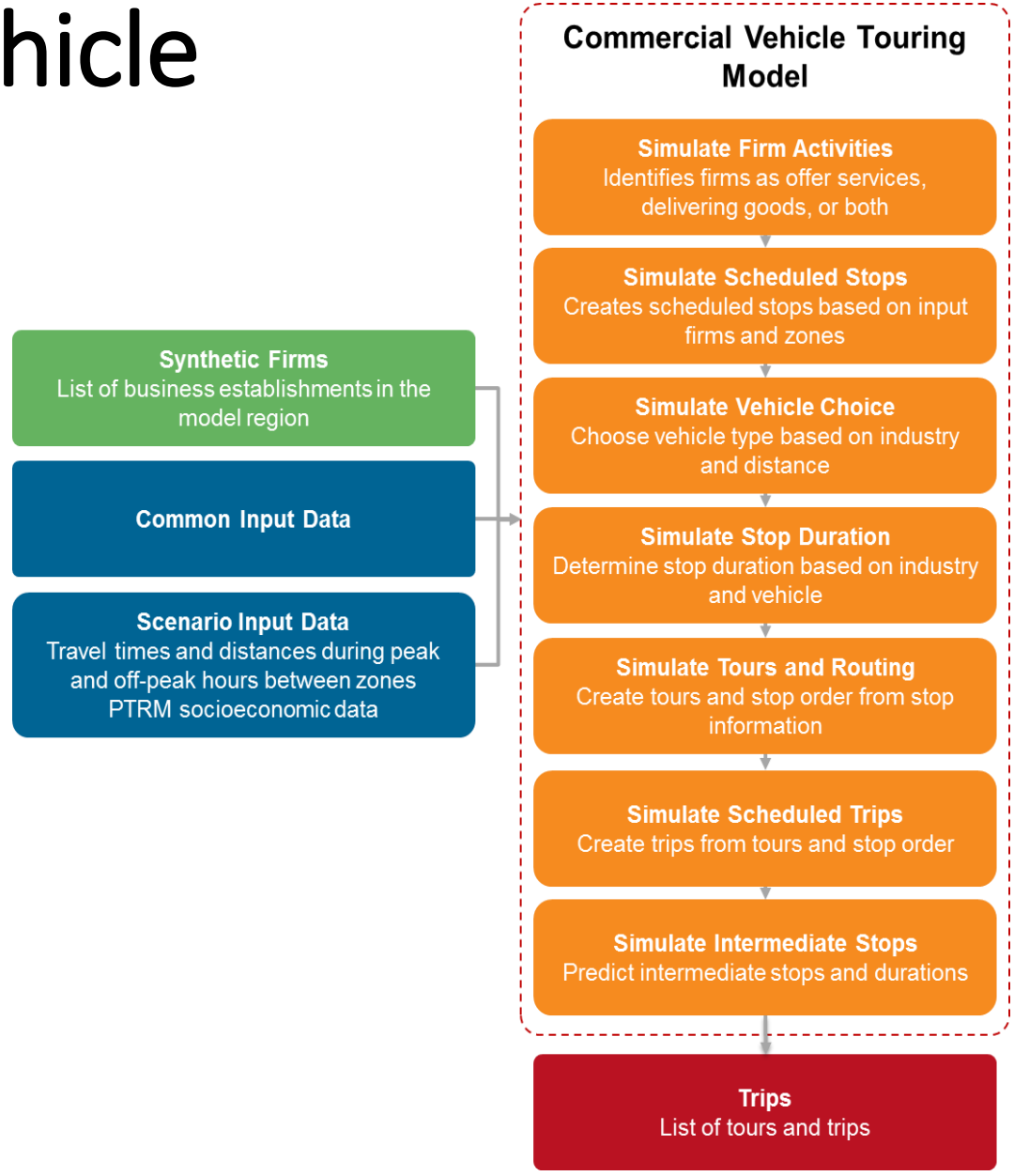
Freight Truck Touring Model

The Freight Truck Touring Model (FTTM) simulates truck movements within the PART region that deliver and pick up freight shipments at business establishments.



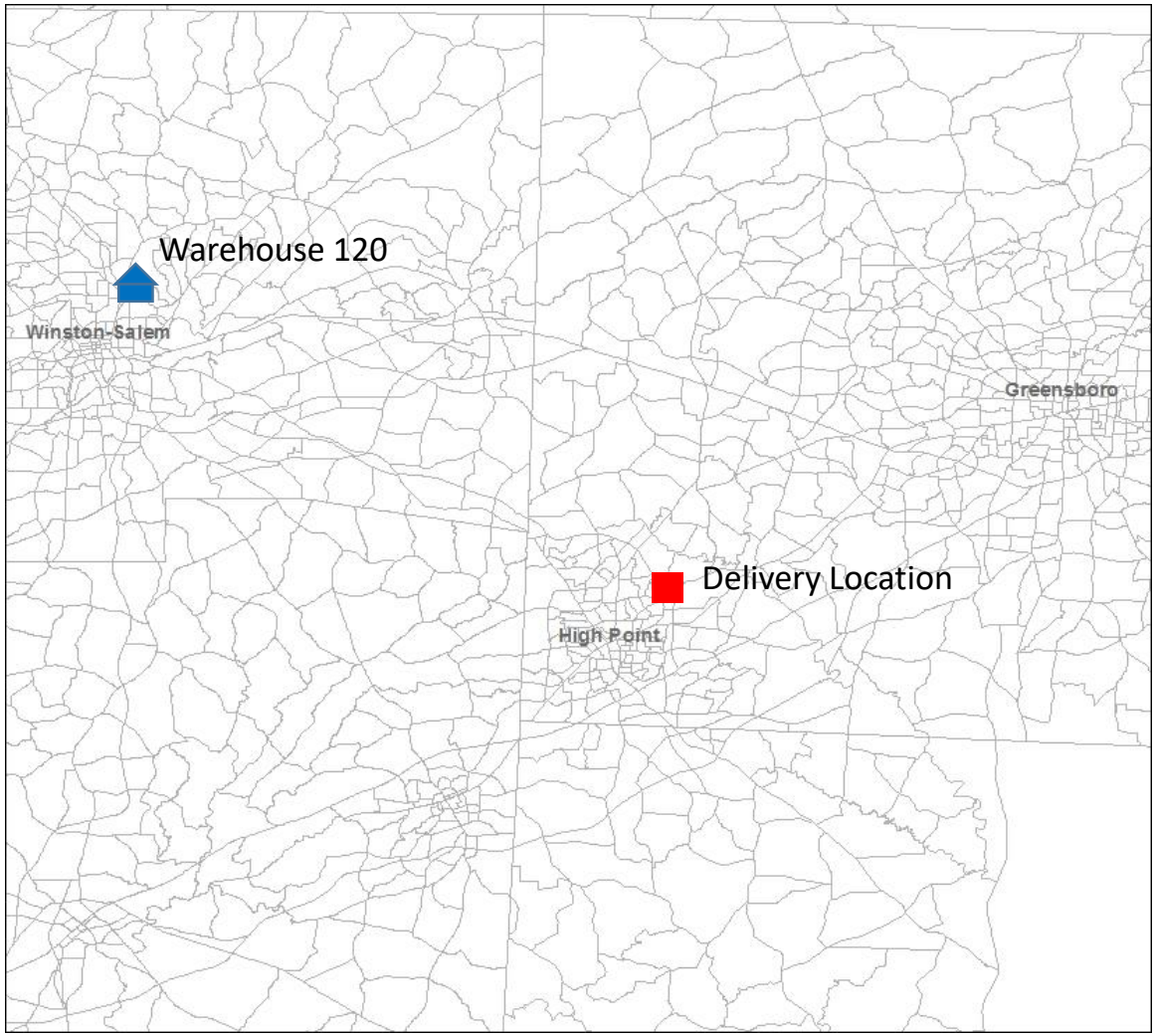
Commercial Vehicle Touring Model

The CVTM simulates the travel of light, medium, and heavy trucks for commercial purposes, i.e., providing services and goods delivery to households, and services to businesses.



Freight Truck Touring Model: Warehouse Selection

A portion of the model area



Note: not all firms depicted

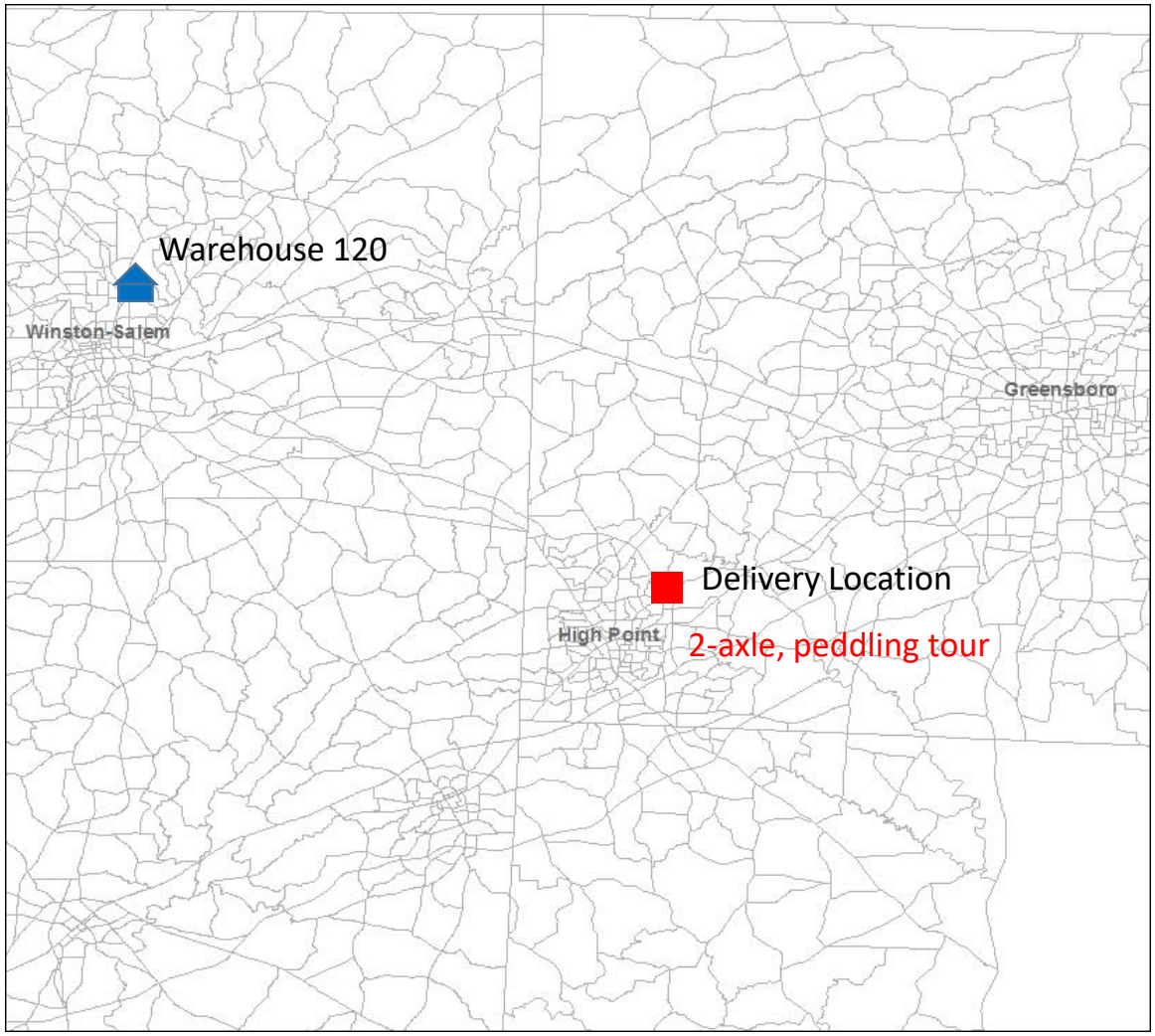
Warehouse Selection

All shipments that are not delivered directly are assigned randomly to a warehouse in the region in proportion to observed or estimated activity and commodities handled

Activity at each warehouse is forecast based on employment, size and other variables, based on the Phase 1 study

Freight Truck Touring Model: Vehicle Choice

A portion of the model area



Note: not all firms depicted

Vehicle Choice and Tour Pattern

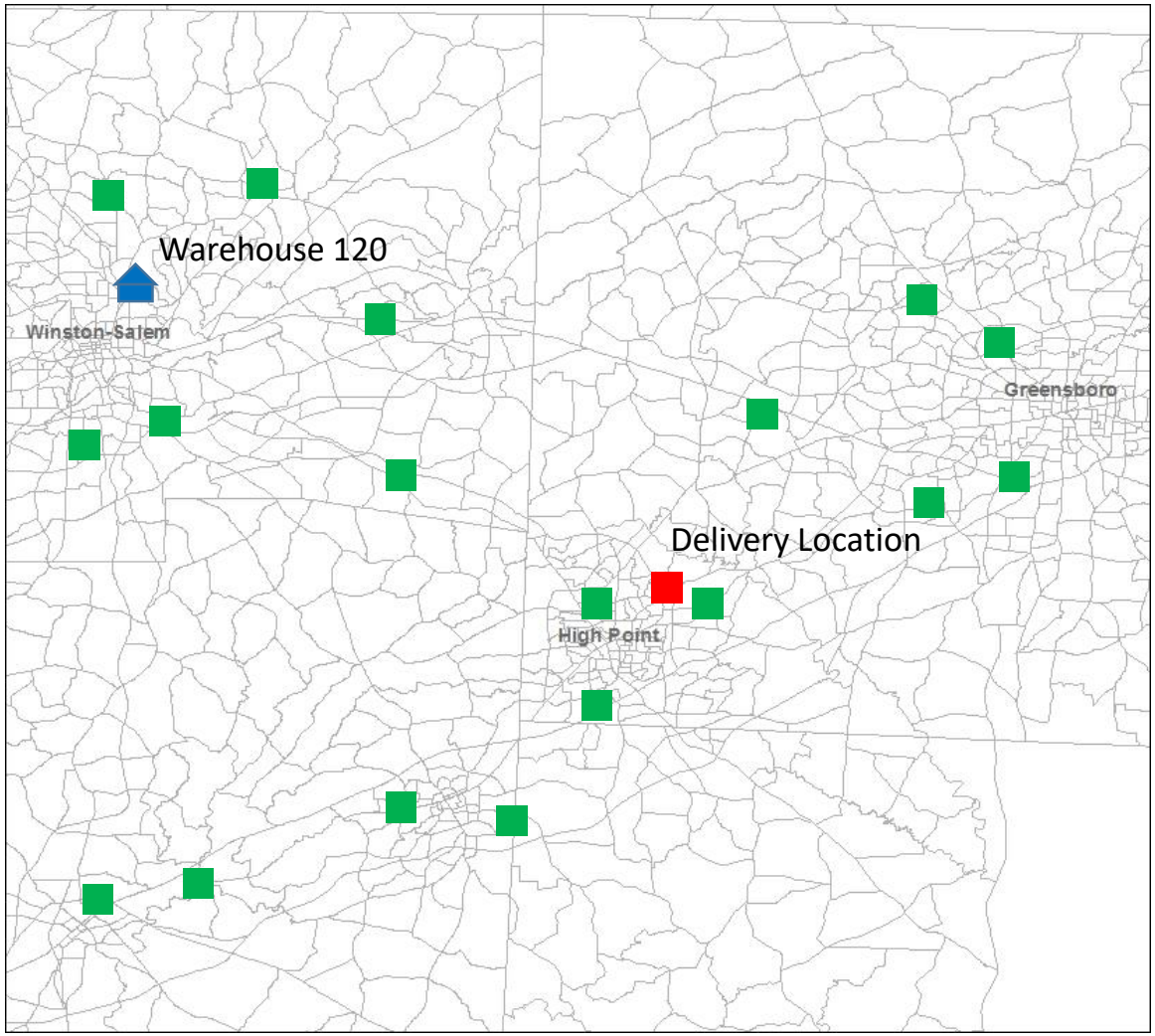
Joint choice model of vehicle type and tour pattern

Each shipment is assigned to one of:

2-axles, direct tour
3-4 axles, direct tour
Semi, direct tour
2-axles, peddling tour
3-4 axles, peddling tour
Semi, peddling tour

Freight Truck Touring Model: Vehicle Choice

A portion of the model area



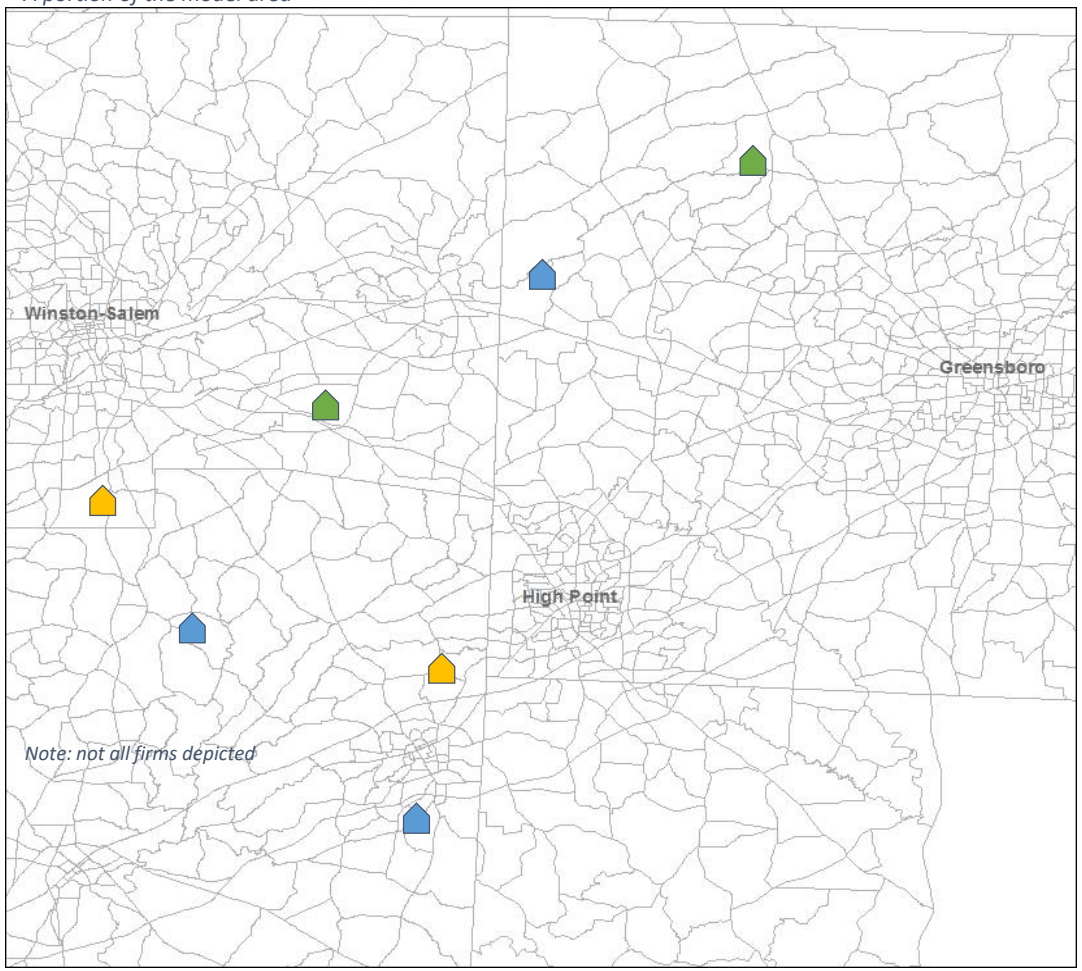
Note: not all firms depicted

All shipments from a warehouse with the same vehicle type and tour type

Our delivery is one of several from that warehouse that will be delivered by the same vehicle type – these must be grouped into tours and sequenced for delivery

Commercial Vehicle Model Example: Establishment Type Model

A portion of the model area

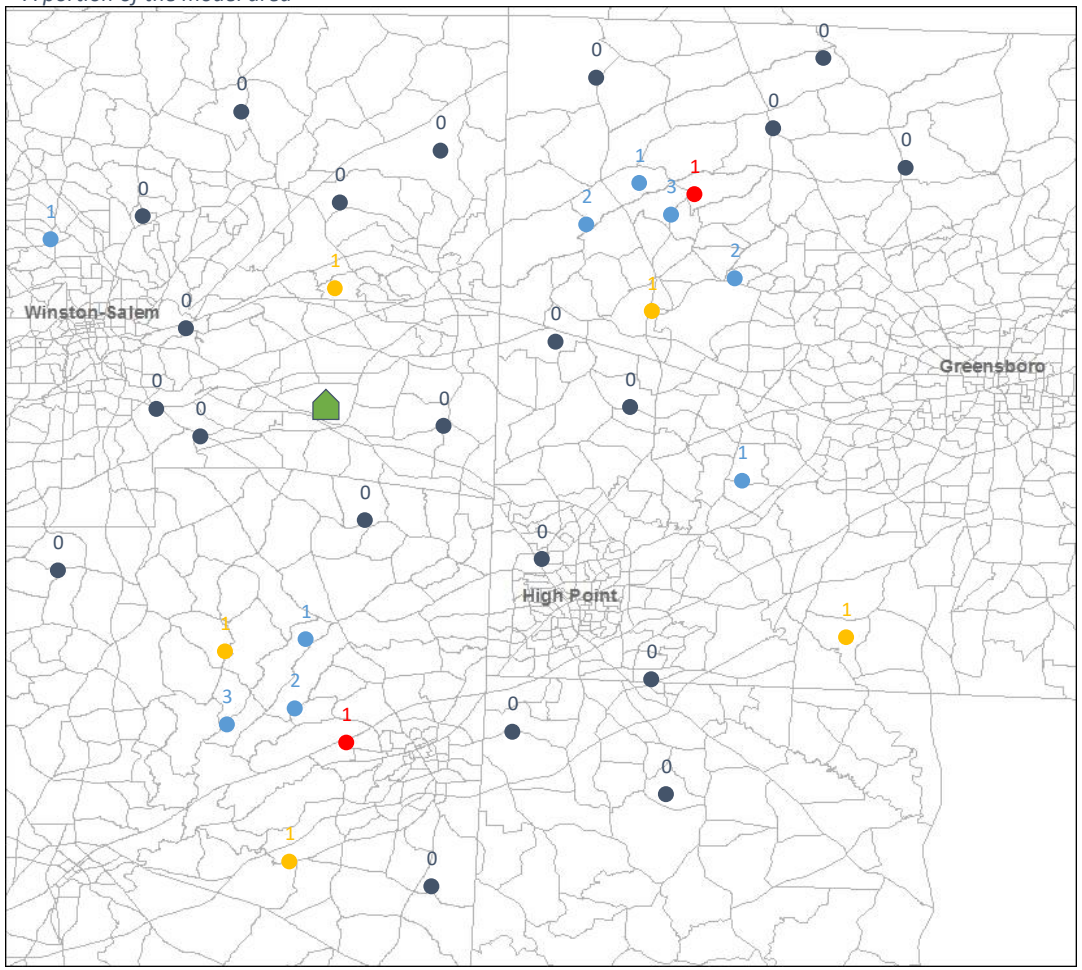


For each <u>synthesized firm</u>…

- Predicts type of establishment:
  - Goods delivery
  - Services
  - Both
- Monte Carlo simulation used to draw from observed distributions of establishment types by industry

Stop Generation Model

A portion of the model area

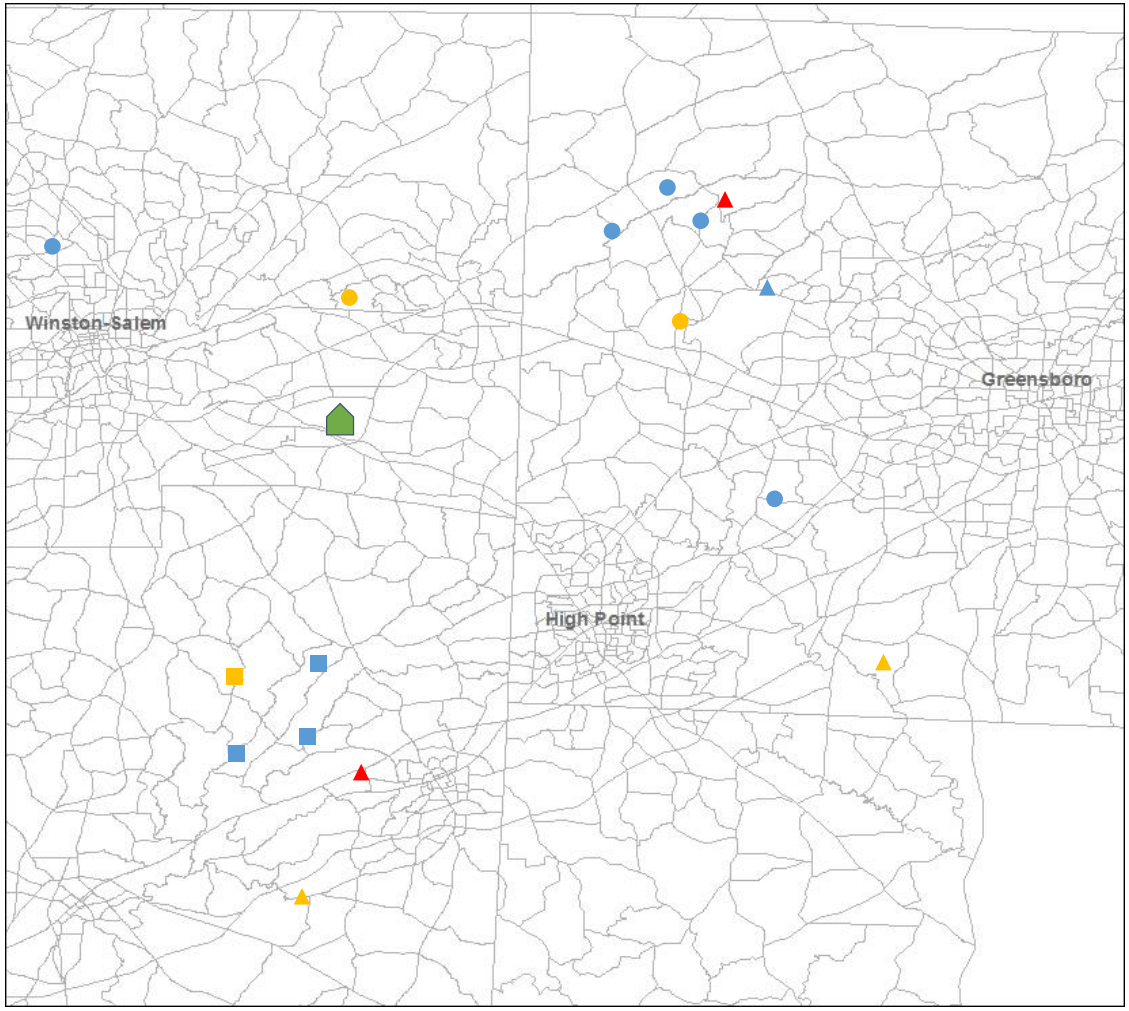


For each <u>synthesized firm</u>…

- TAZs sampled as candidates for stops
- Hurdle model predicts number of goods stops and service stops in each TAZ as applicable
- All firms may generate meeting stops as well
- Number of stops a function of firm size, industry, stop purpose, and TAZ socio-economic characteristics

Vehicle Assignment Model

A portion of the model area

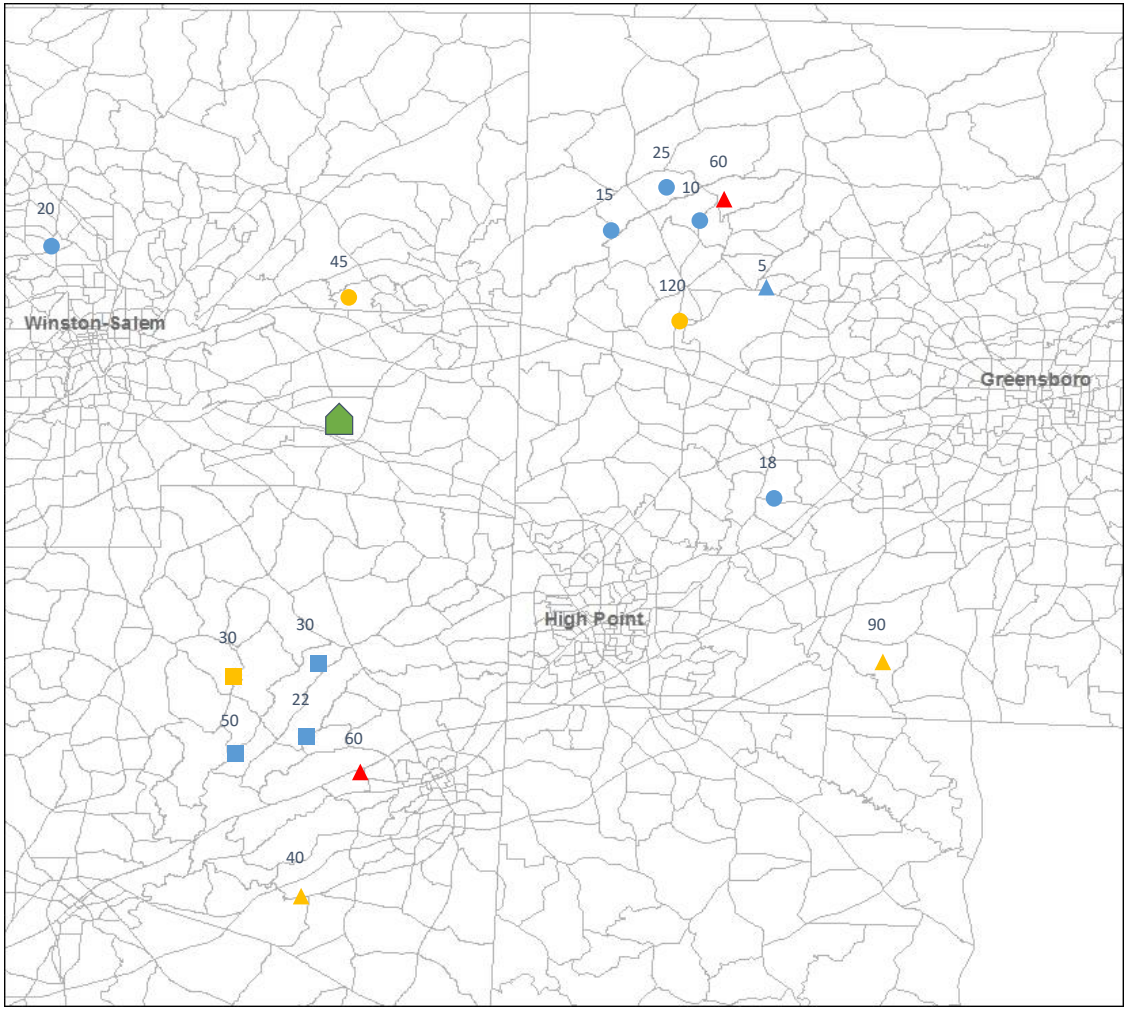


For each <u>stop</u>…

- MNL model predicts commercial vehicle type for each stop:
  - Light: car, van, pickup
  - Medium: single-unit truck
  - Heavy: multi-unit truck
- Vehicle type a function of:
  - Firm industry
  - Distance
  - Stop purpose

Stop Duration Model

A portion of the model area



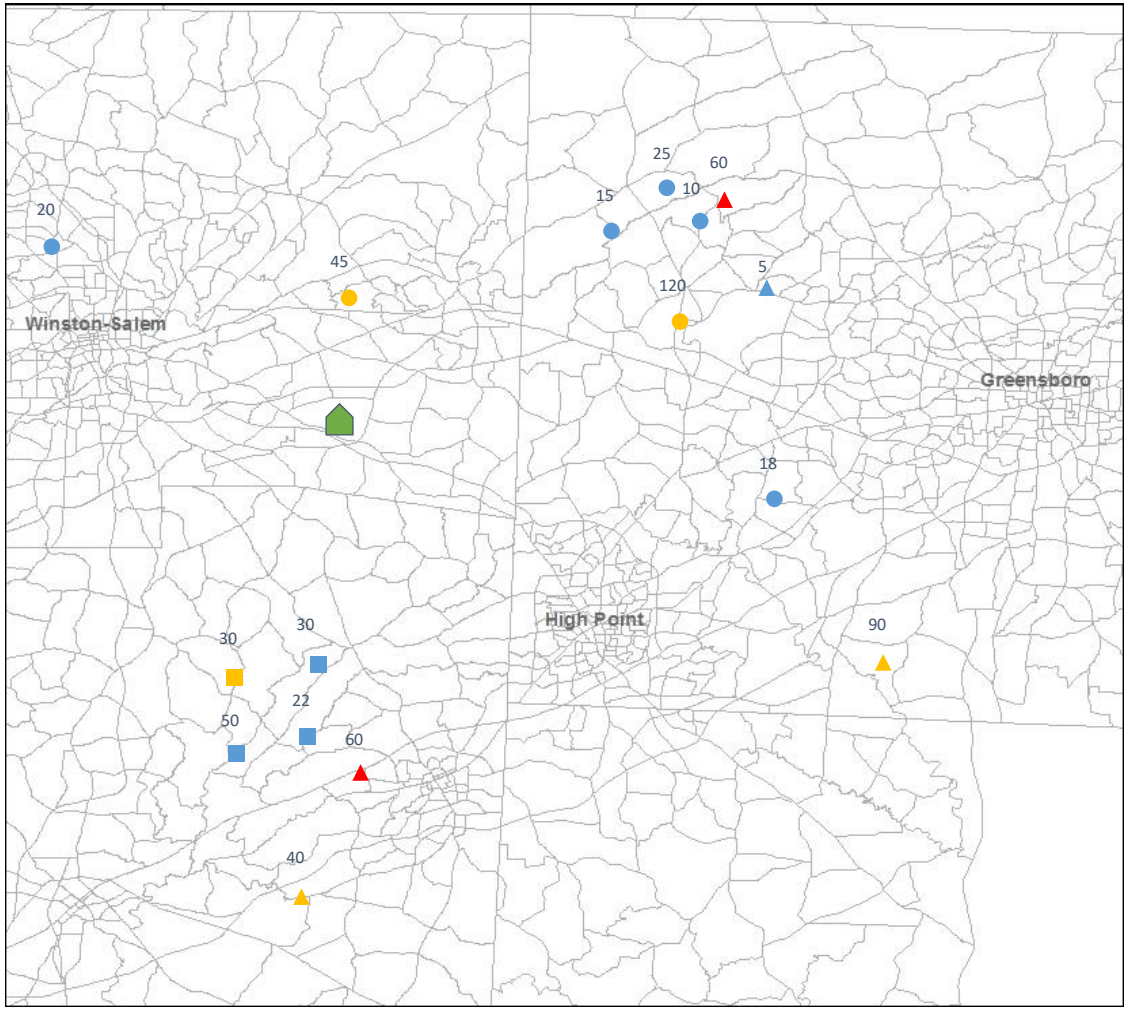
For each <u>stop</u>…

- Stop duration (minutes) drawn via Monte Carlo simulation from empirical distributions by:
  - Industry
  - Stop purpose

Stop Durations

Stop Clustering Model

A portion of the model area

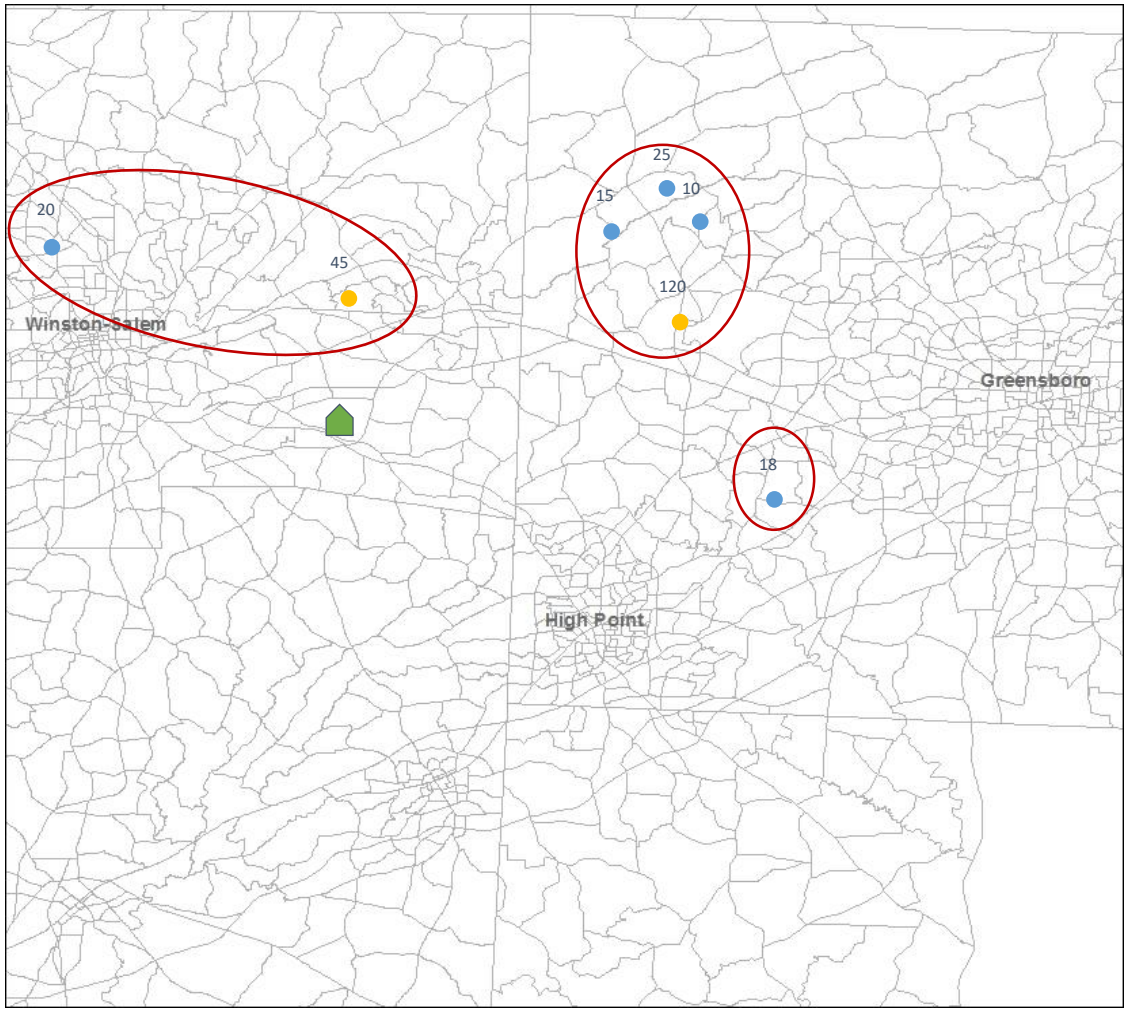


For each <u>vehicle type</u>…

- Hierarchical clustering groups spatially similar (travel time) stops into tours
- Weighted branch trimming prevents overly long tours without creating too many short tours
    - Based on stop duration as travel not known (stops not yet sequenced)

Stop Clustering Model (Medium Vehicles)

A portion of the model area



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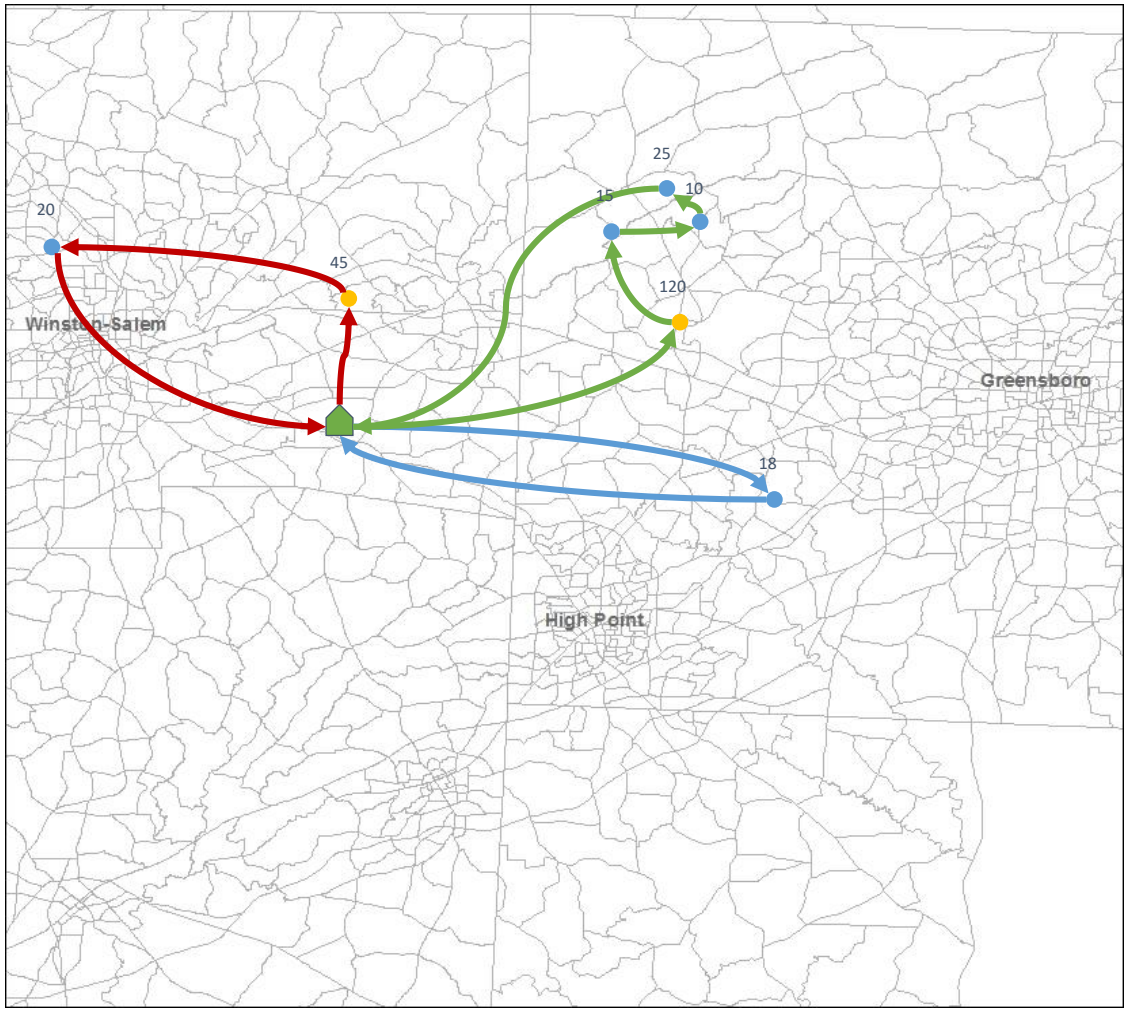
Stop Sequencing Model

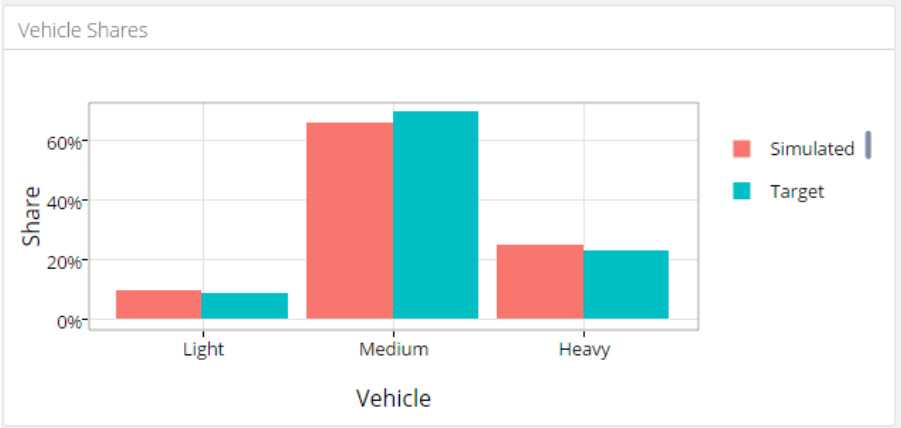
A portion of the model area

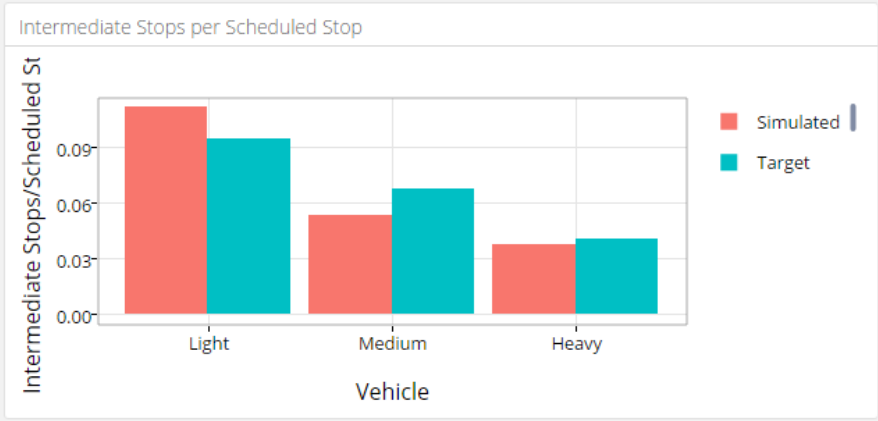


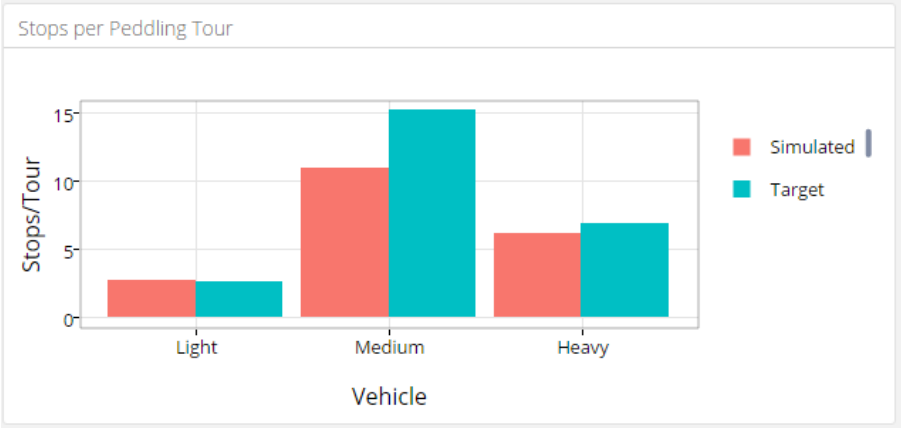
For each <u>tour</u>…

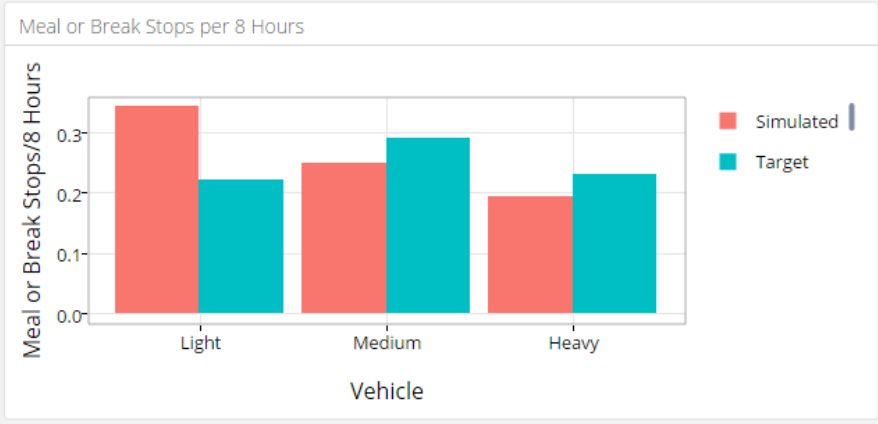
- Stops sequenced using Traveling Salesman algorithm on travel time combinations
- Provides reasonably short Hamiltonian circuits
- Avoids unrealistic tour patterns but not a true optimization
- Computationally feasible and generates realistic touring patterns

Vehicle Shares and Tour Patterns



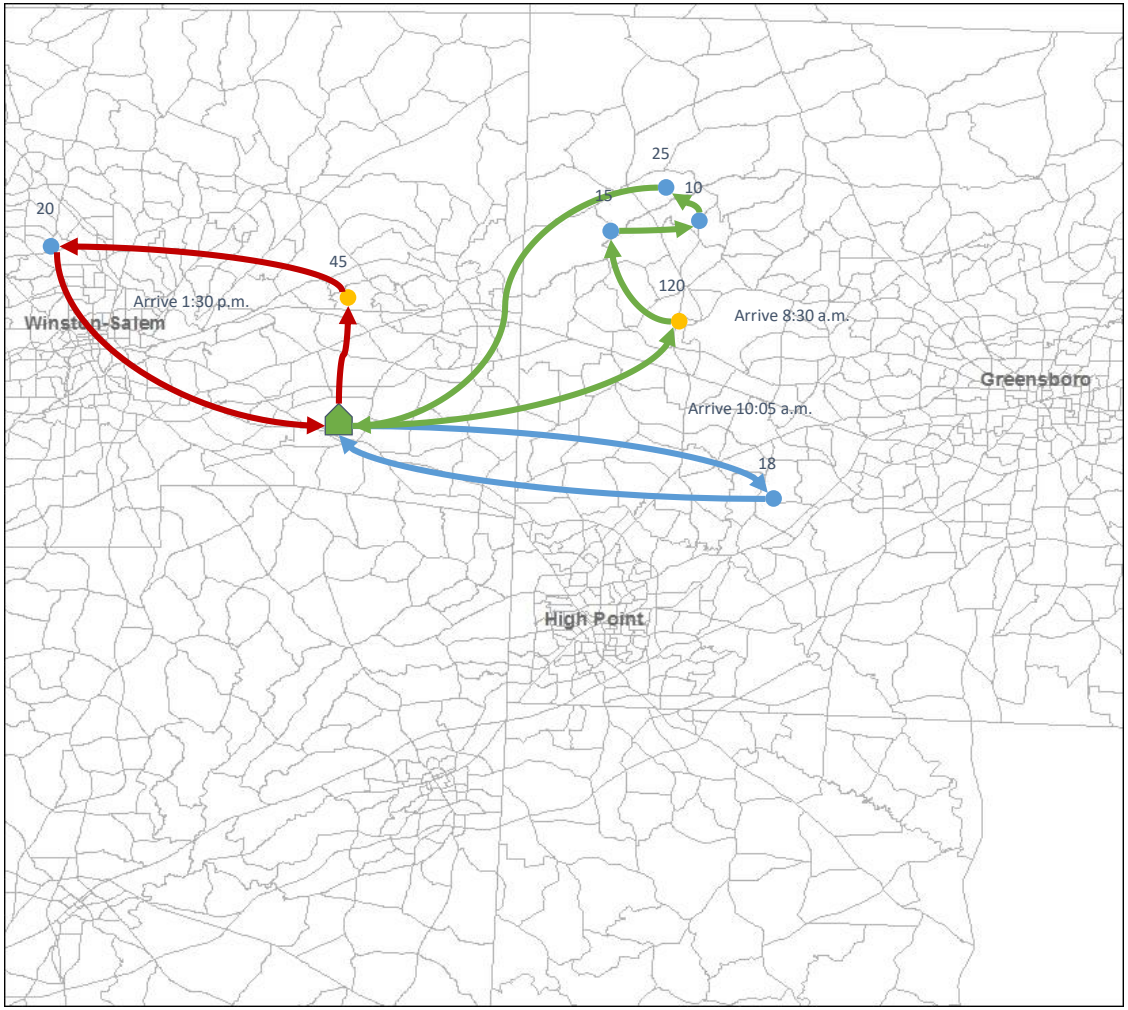






Stop Sequencing: Arrival

A portion of the model area



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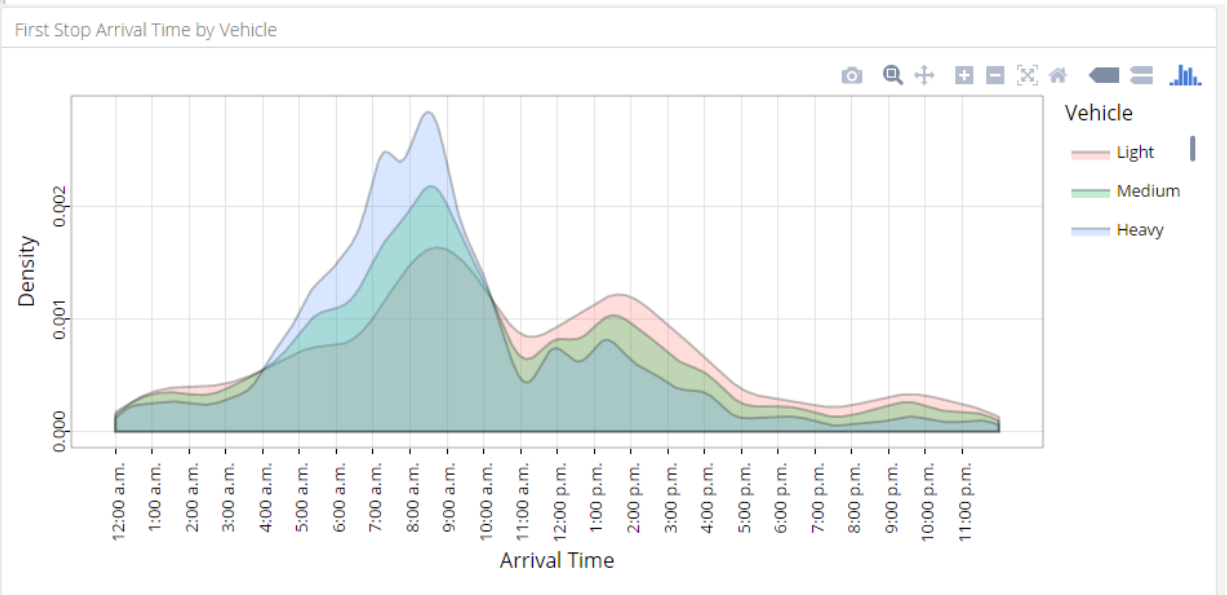
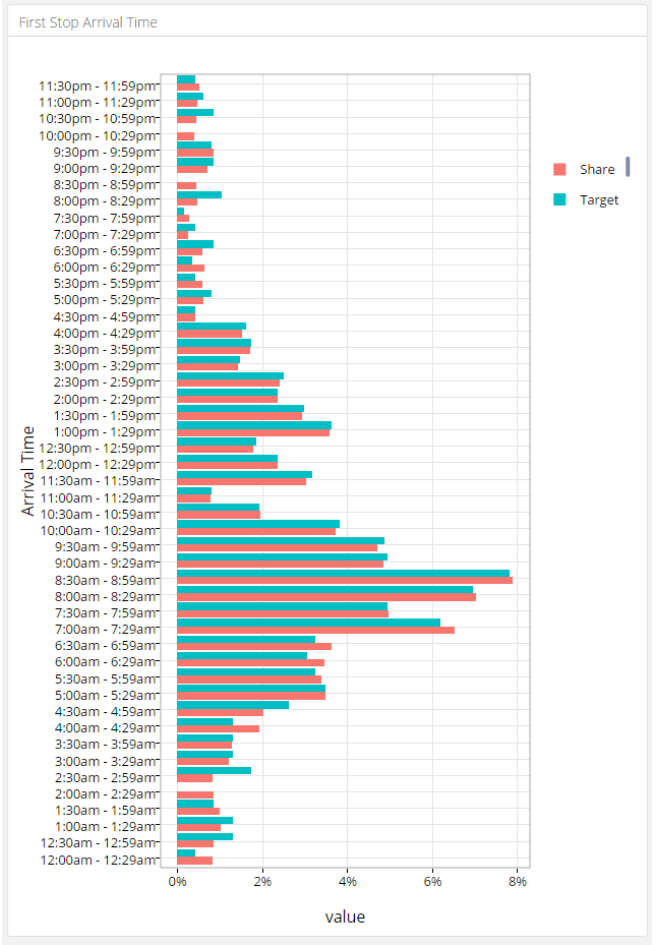
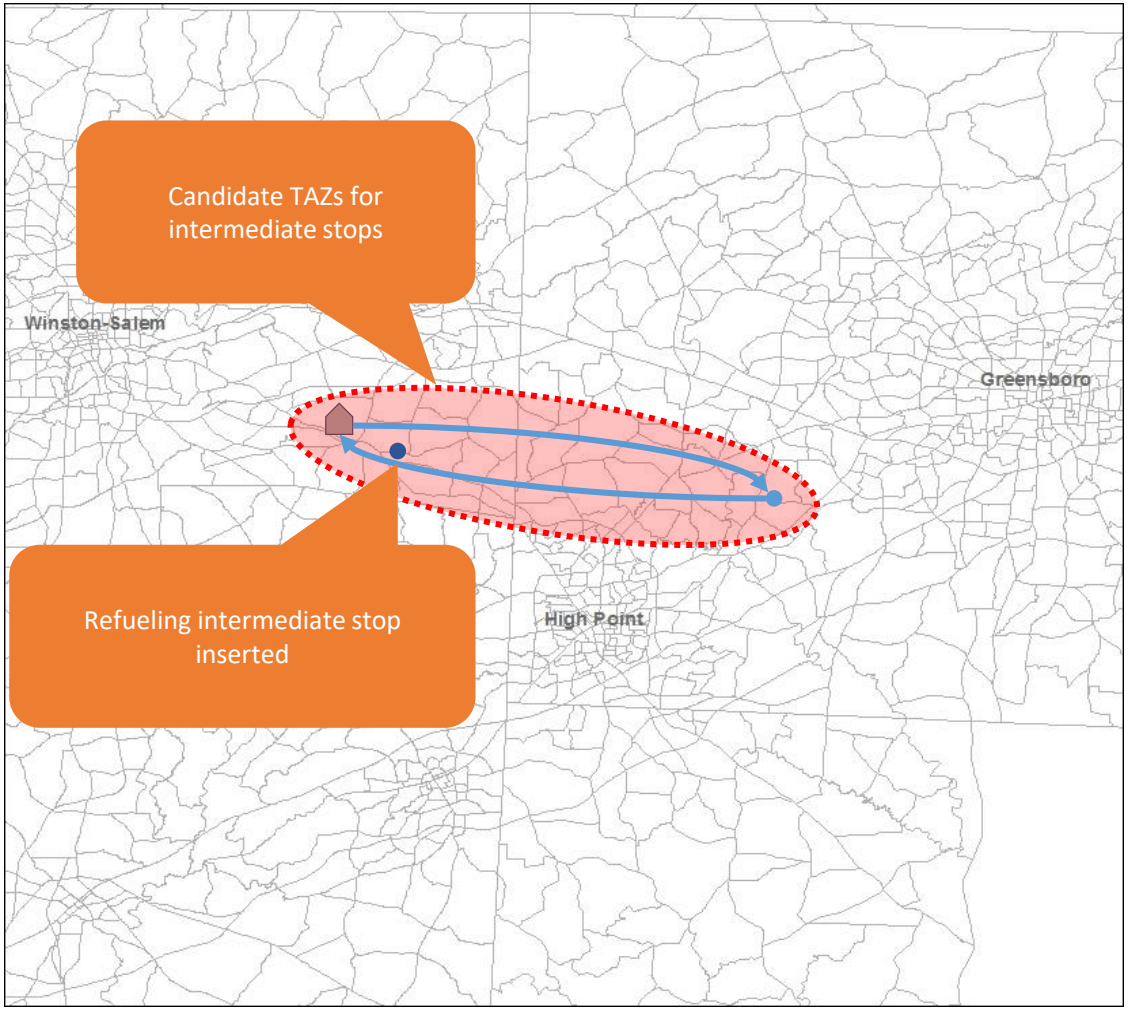
First Stop Arrival Time





Intermediate Stop Model

A portion of the model area

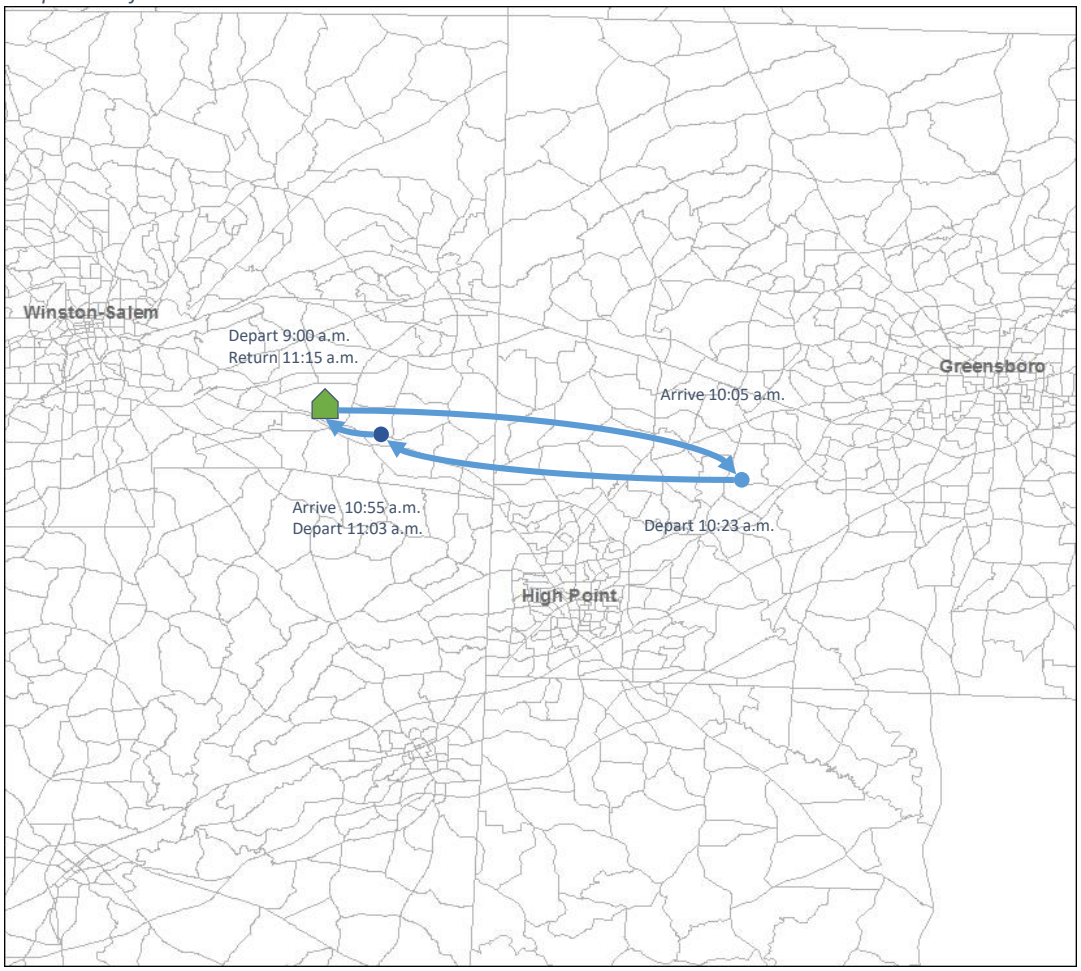


For each <u>trip</u>…

- Intermediate stop MNL model predicts whether an intermediate stop is inserted
  - Meal/break
  - Refueling/vehicle service
  - Other
- TAZs considered do not extend length of trip by some threshold (e.g., 3 miles)
- Stop duration model applied to any inserted stops
- Once all stops and order are known, trip is re-timed to determine arrival/departure times

Intermediate Stop Model (cont.)

A portion of the model area



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