Piedmont Triad Freight Study

Phase 2

Piedmont Triad Freight and Commercial Vehicle Model

Presented to:
North Carolina Model User's Group
November 16, 2016

Presented by:

OUTLINE AND LEARNING OBJECTIVES

- Introduction to truck touring models: freight delivery and commercial vehicle simulation
- Model components and sequence: commercial vehicle example
- Piedmont Triad Model Case Study
- Using R and rFreight for simulation and visualization

Introduction to truck touring models

Introduction to Truck Touring Models

- Disaggregate modeling vs. aggregate modeling
- What is the decision framework we are modeling?
- What is a tour?
- What do tour structures look like visually and in data

Introduction to Truck Touring Models

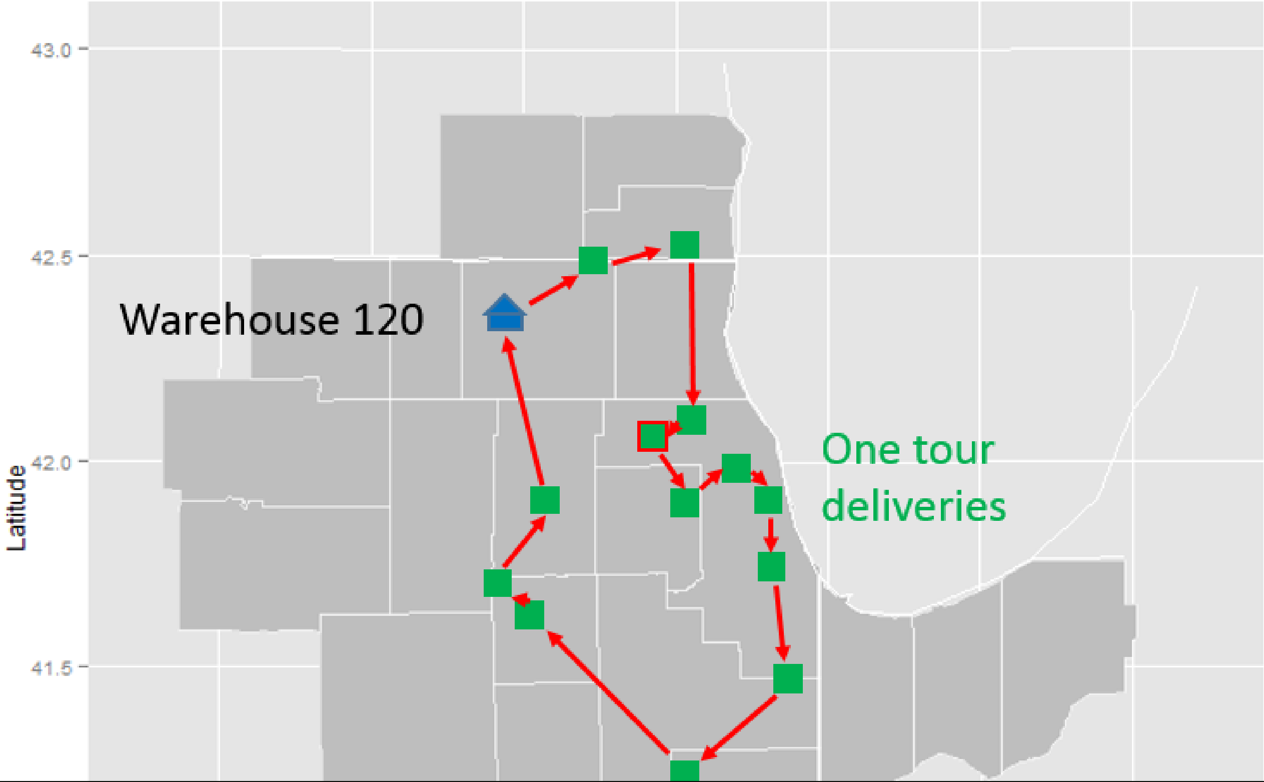
- Disaggregate modeling vs. aggregate modeling
  - Truck touring models are “disaggregate” in that they represent the travel behavior of individual trucks
  - This compares to aggregate truck models that model a quantity of truck travel between aggregate spatial units (e.g. TAZs)
  - The models are a 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 truck

Introduction to Truck Touring Models

- 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

Introduction to Truck Touring Models

- What is a tour?
  - A sequence of trips connecting activities that starts and ends at the same location
- What do tour structures look like visually and in data



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

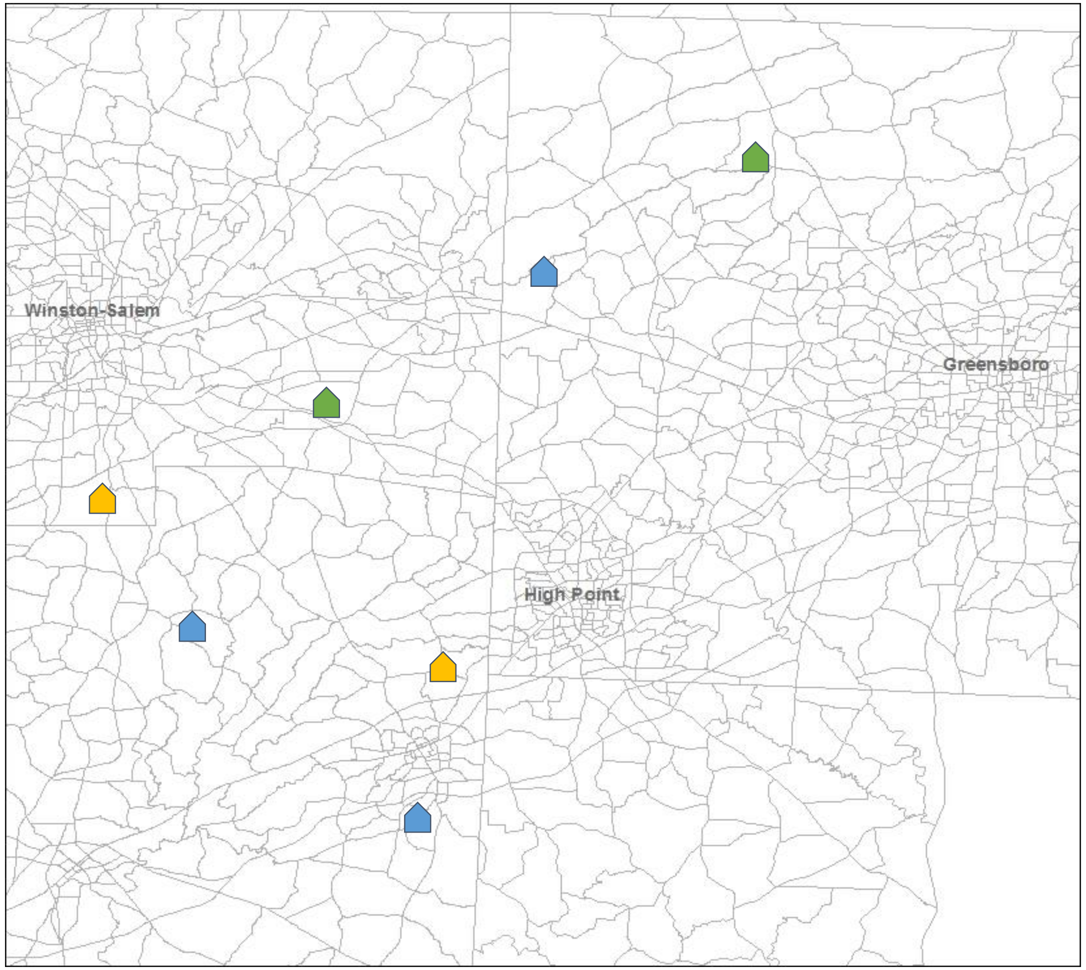
Model components, sequence, and sensitivity

Introduction

- 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

Commercial Vehicle Model Example: Establishment Type Model

A portion of the model area



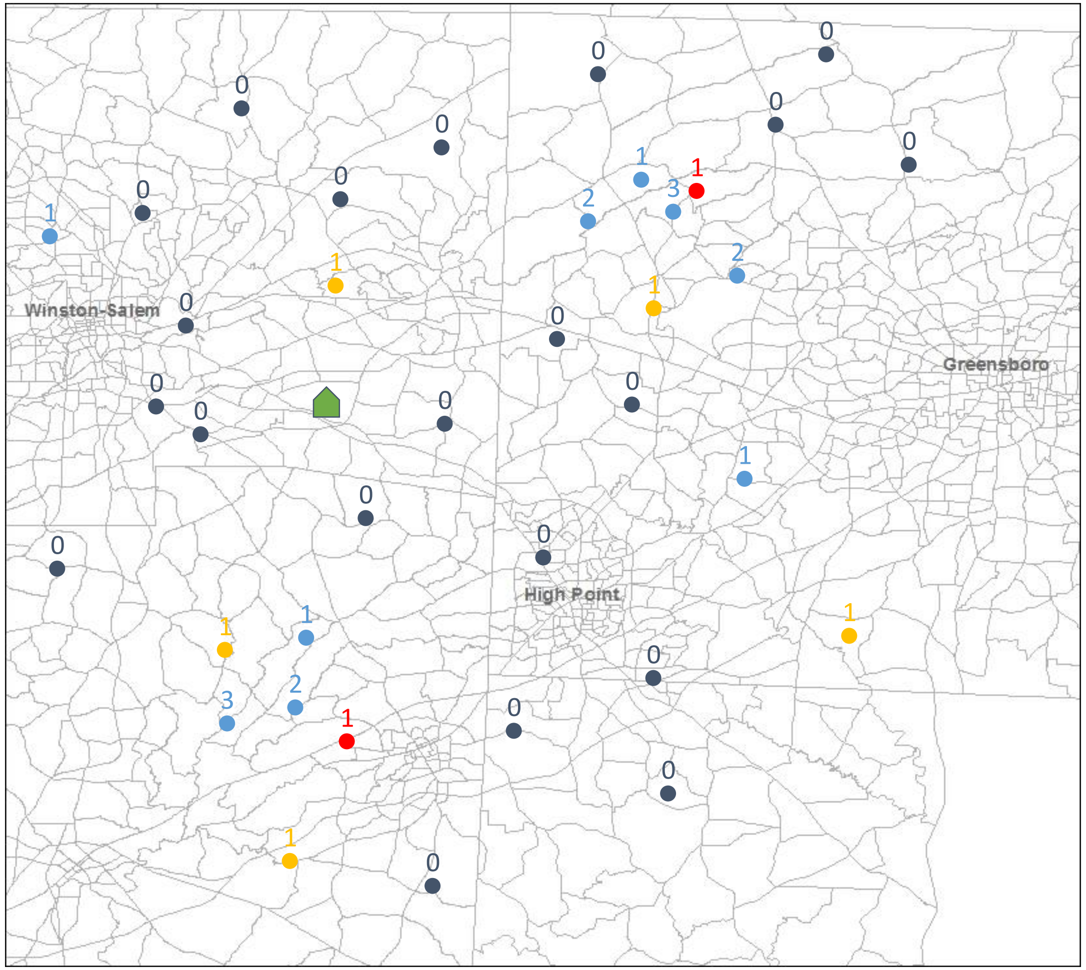
Note: not all firms depicted

For each synthesized firm…

- 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



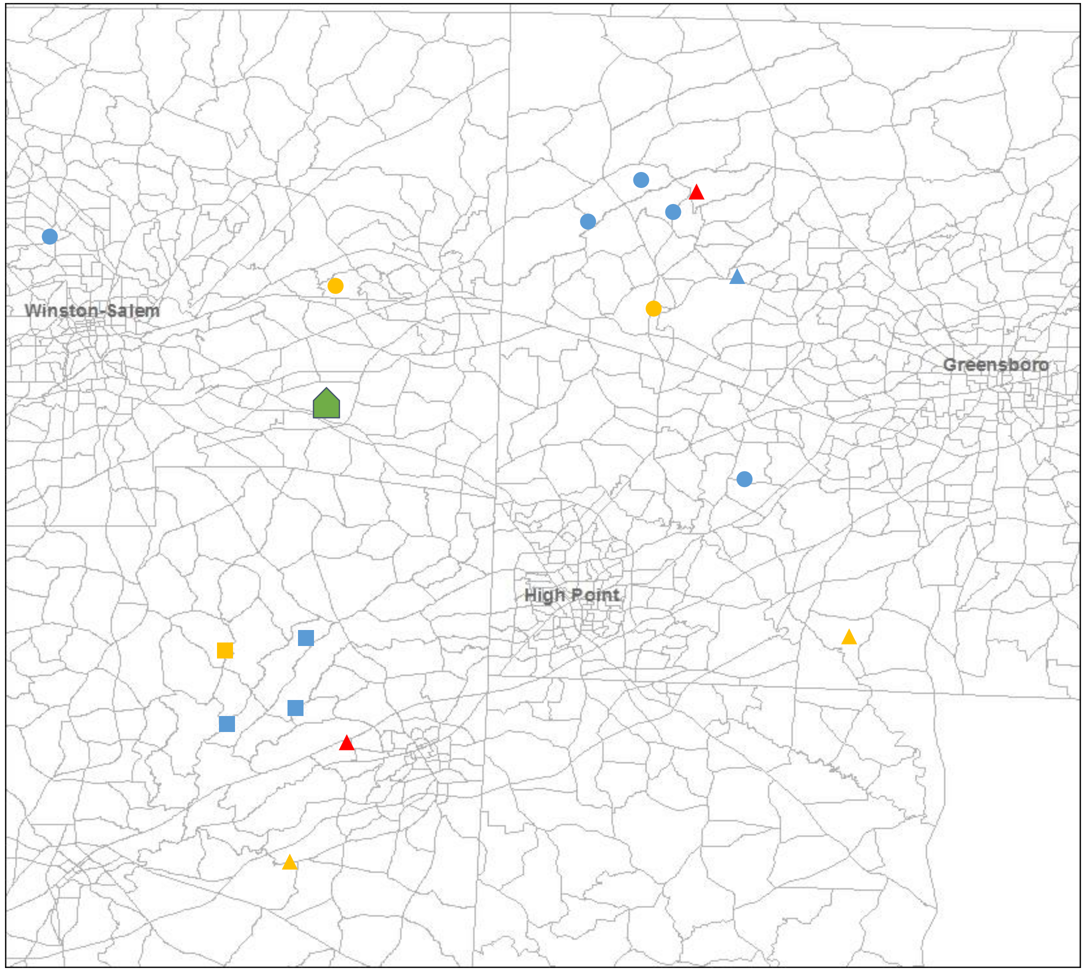
Note: not all TAZs depicted

For each <u>synthesized firm</u>…

- TAZs sampled as candidates for stops
- Hurdle model predicts number of goods 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

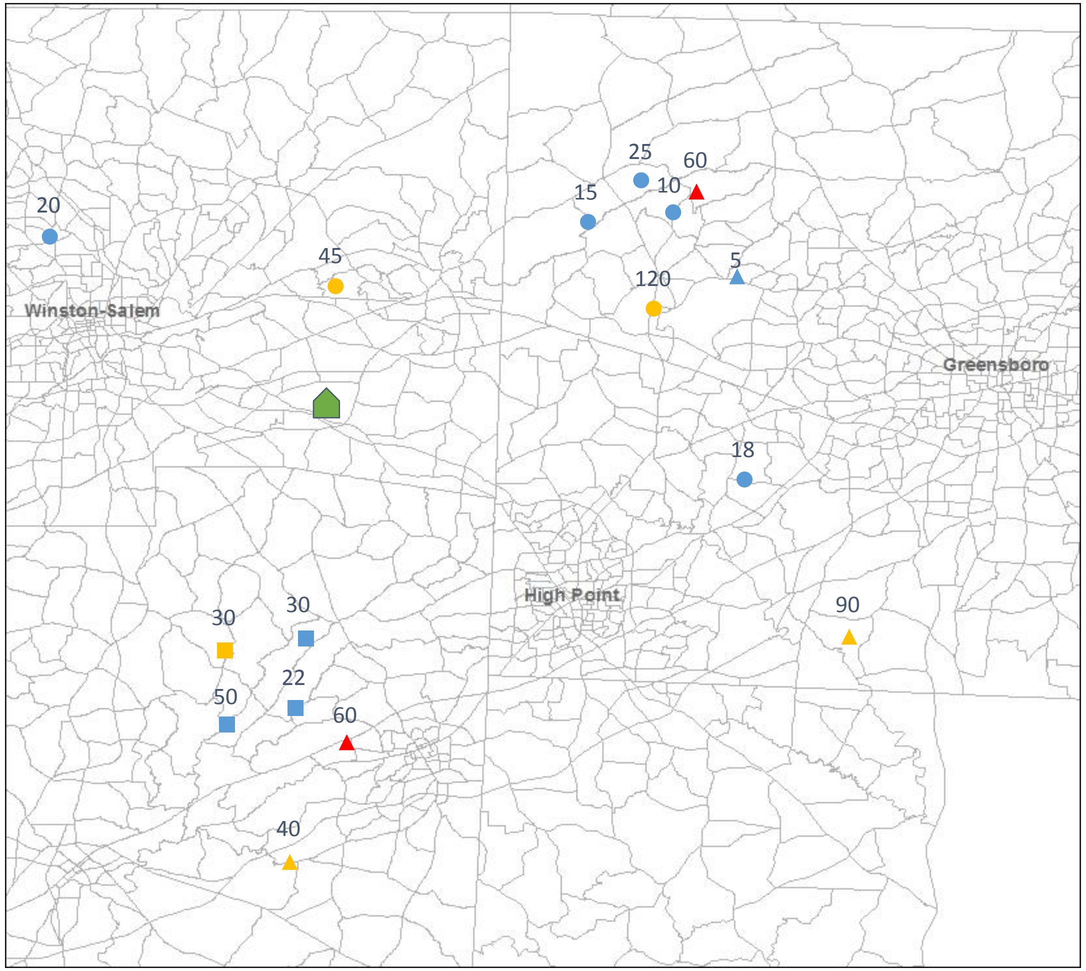


For each stop...

- 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

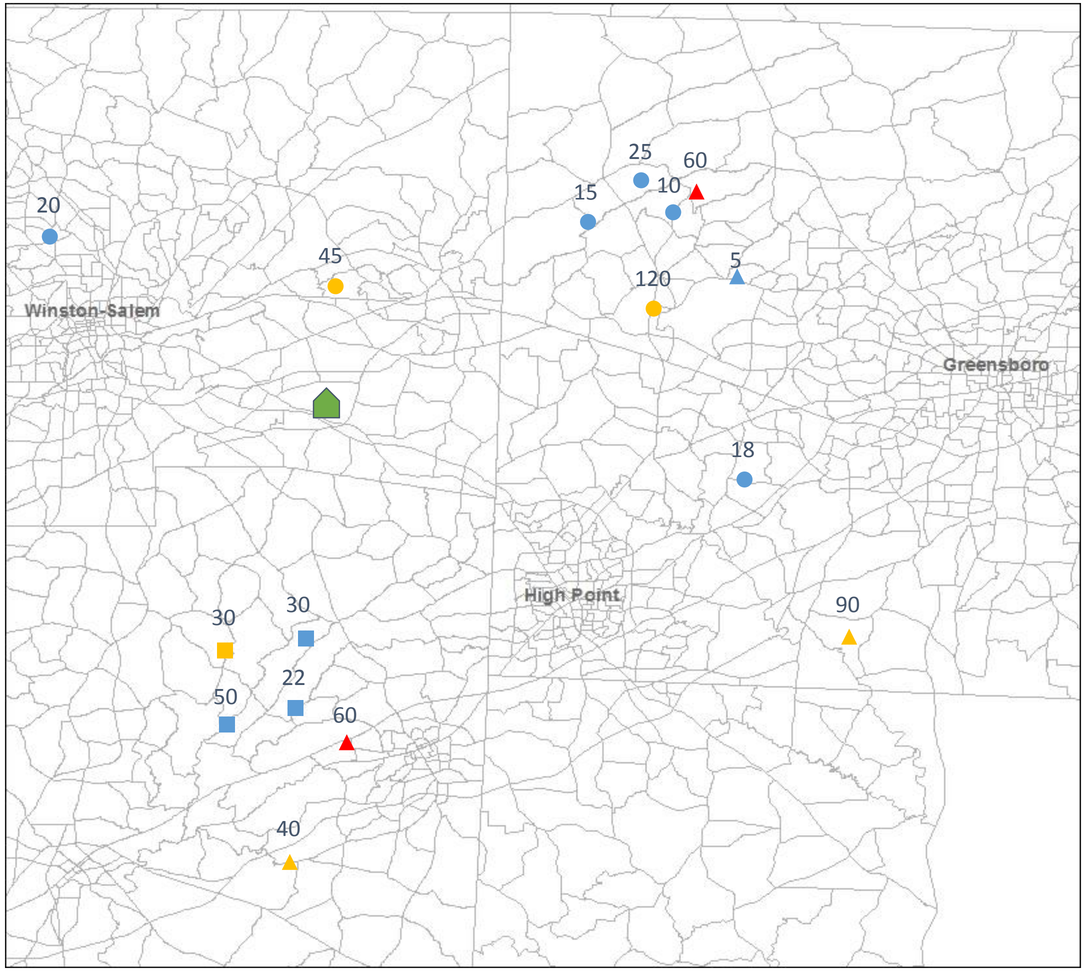


For each <u>stop</u>…

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

Stop Clustering Model

A portion of the model area

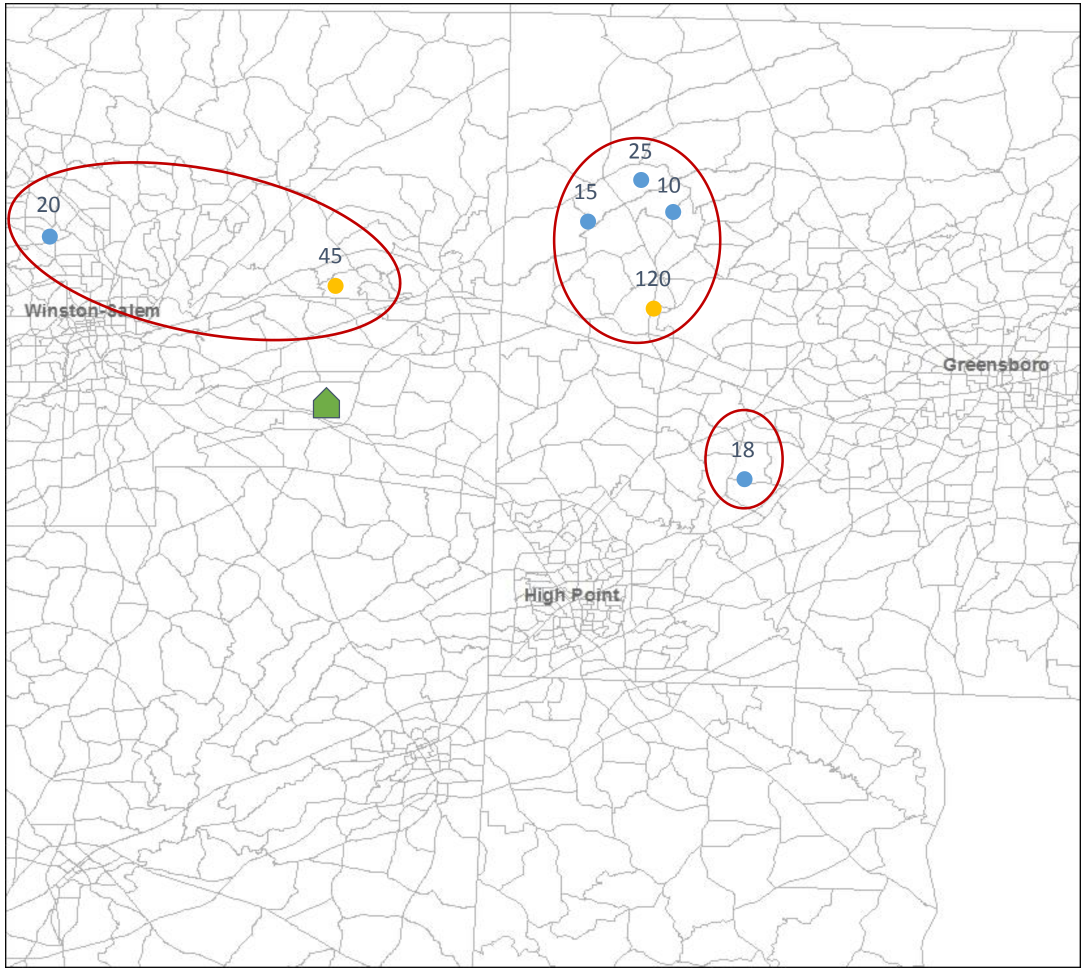


For each vehicle type…

- 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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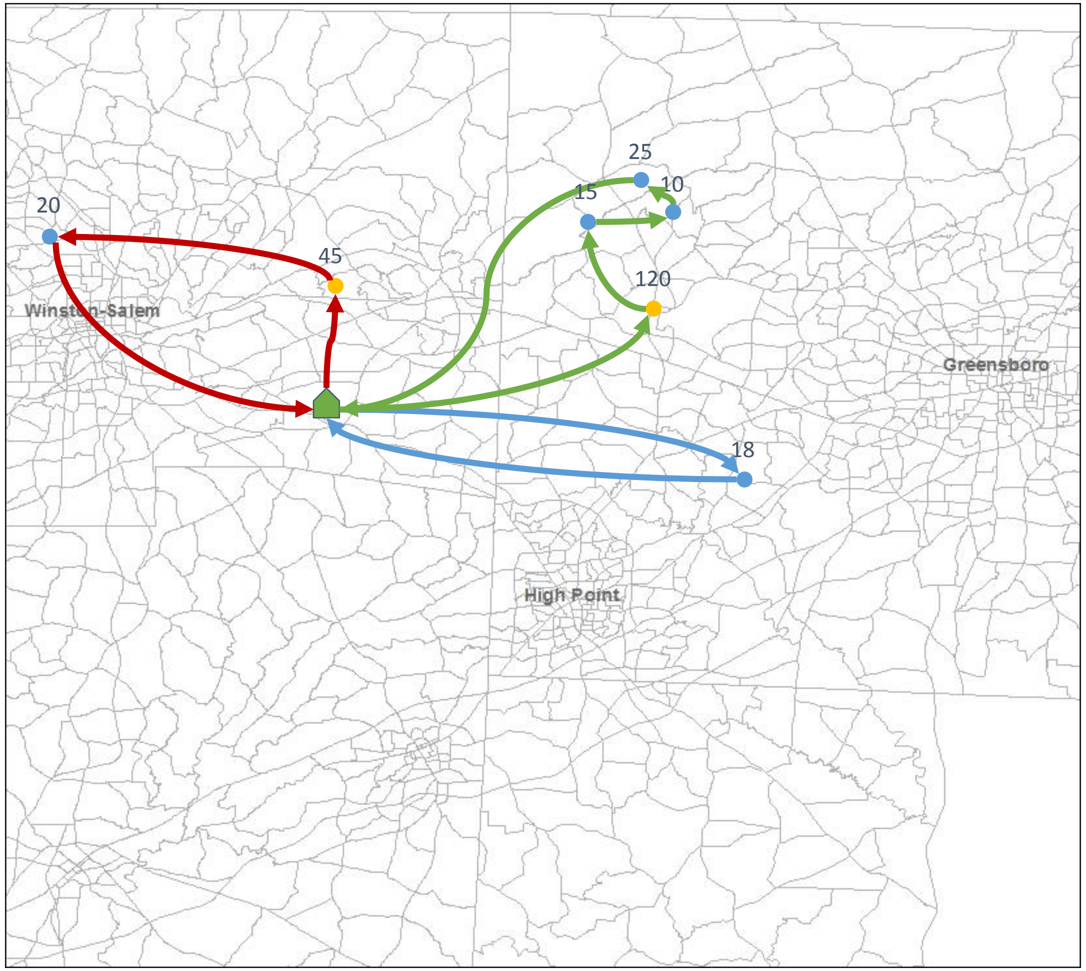
Stop Sequencing Model

A portion of the model area

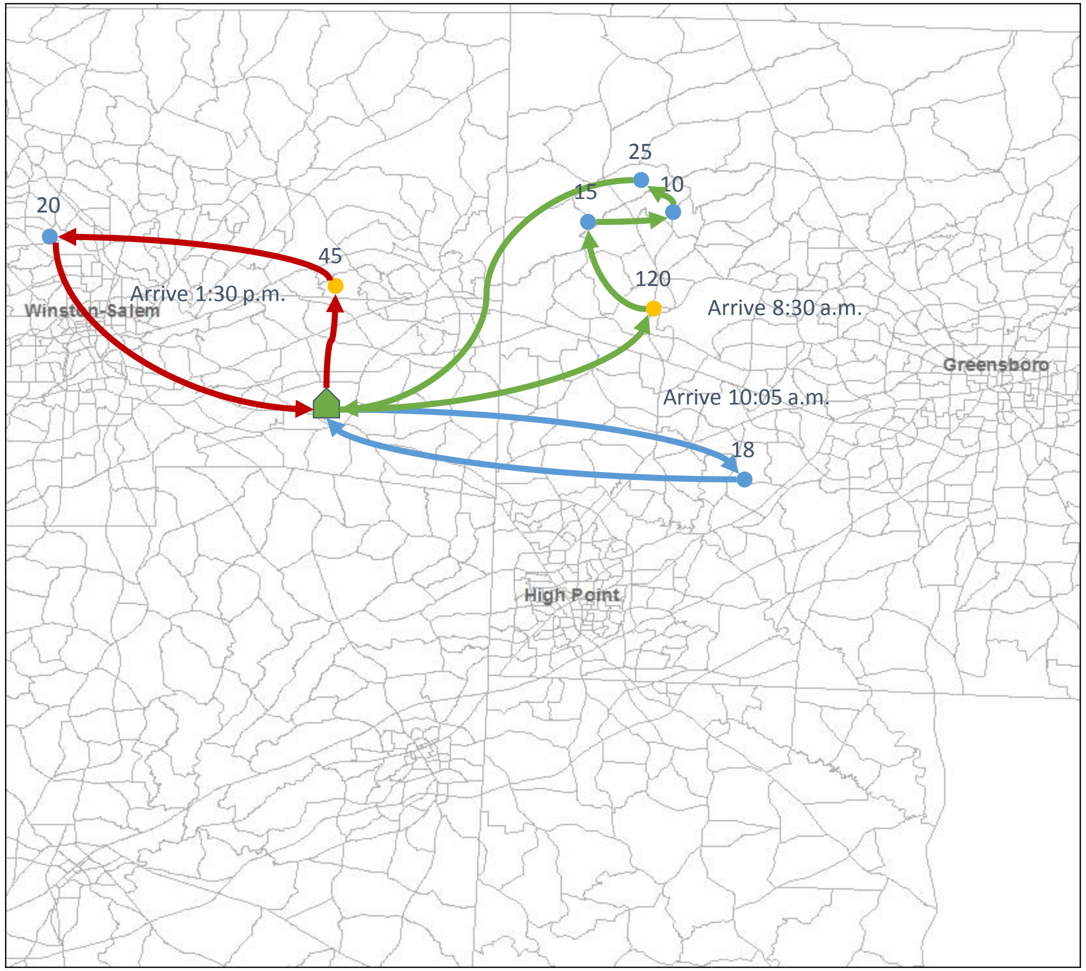


For each tour...

- 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

Stop Sequencing Arrival

A portion of the model area



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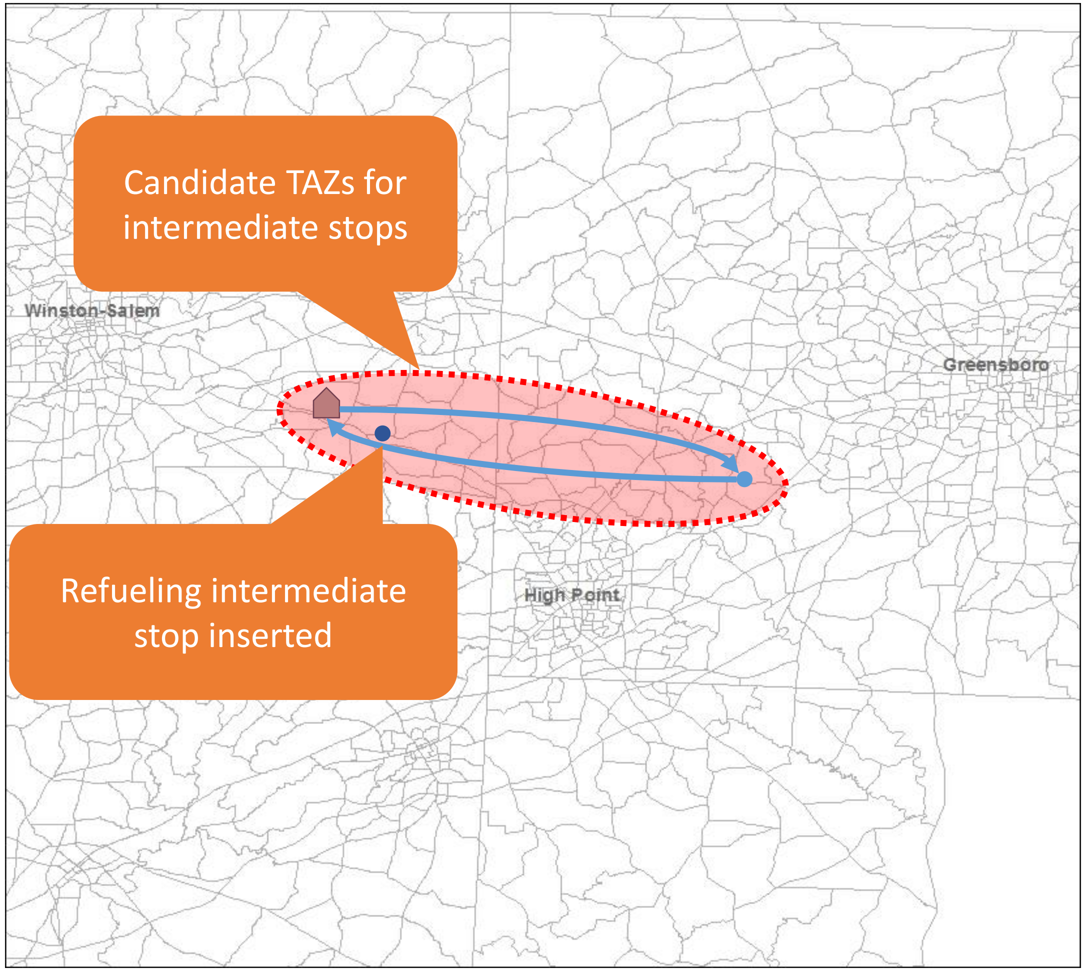
Intermediate Stop Model

A portion of the model area

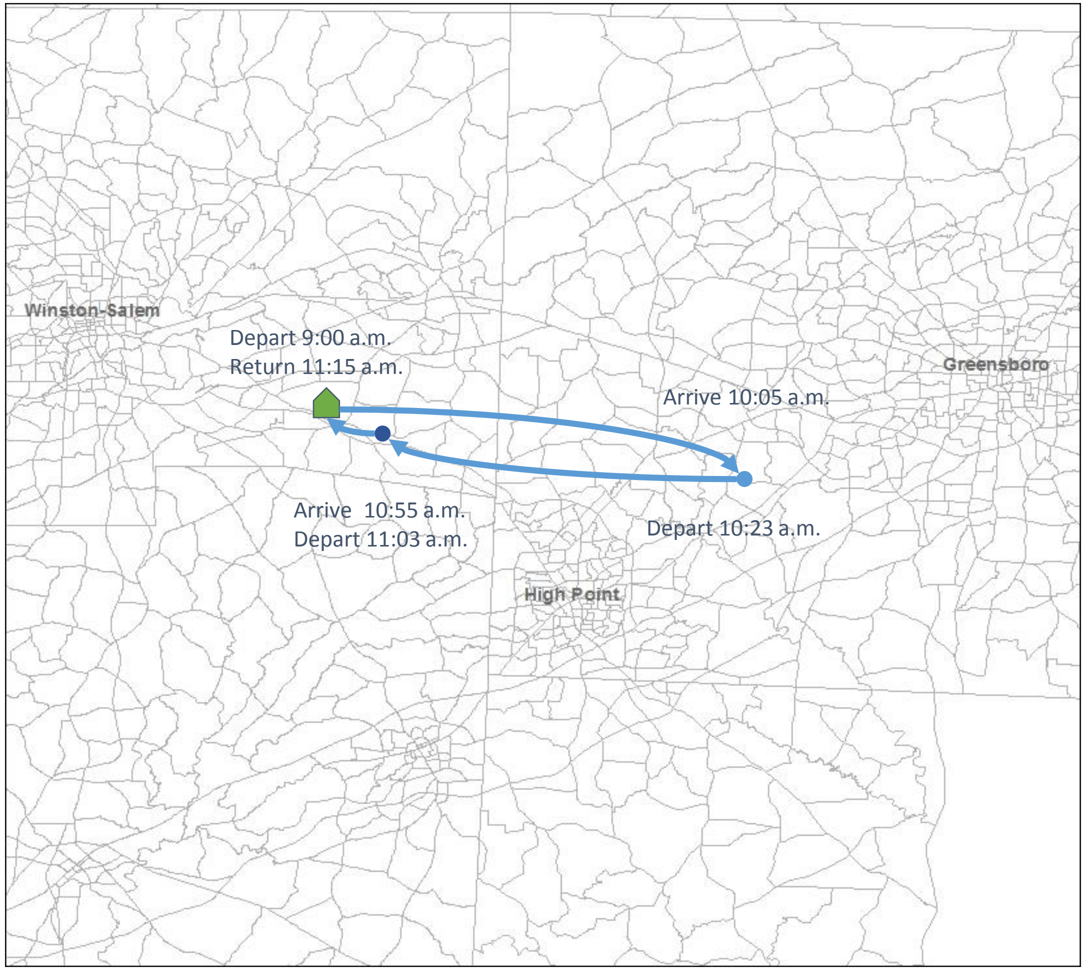


For each trip...

- 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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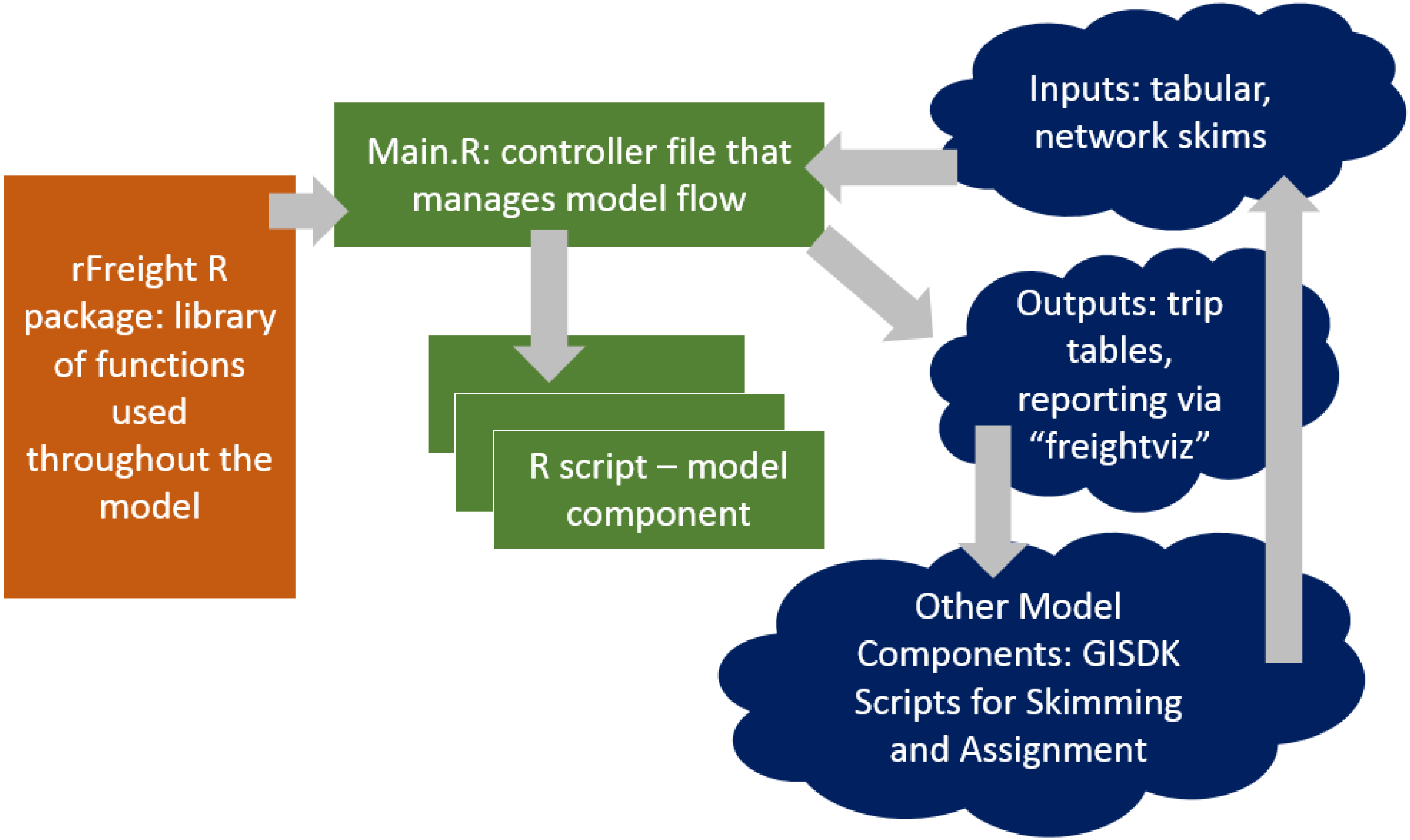
Using R and rFreight for simulation and visualization

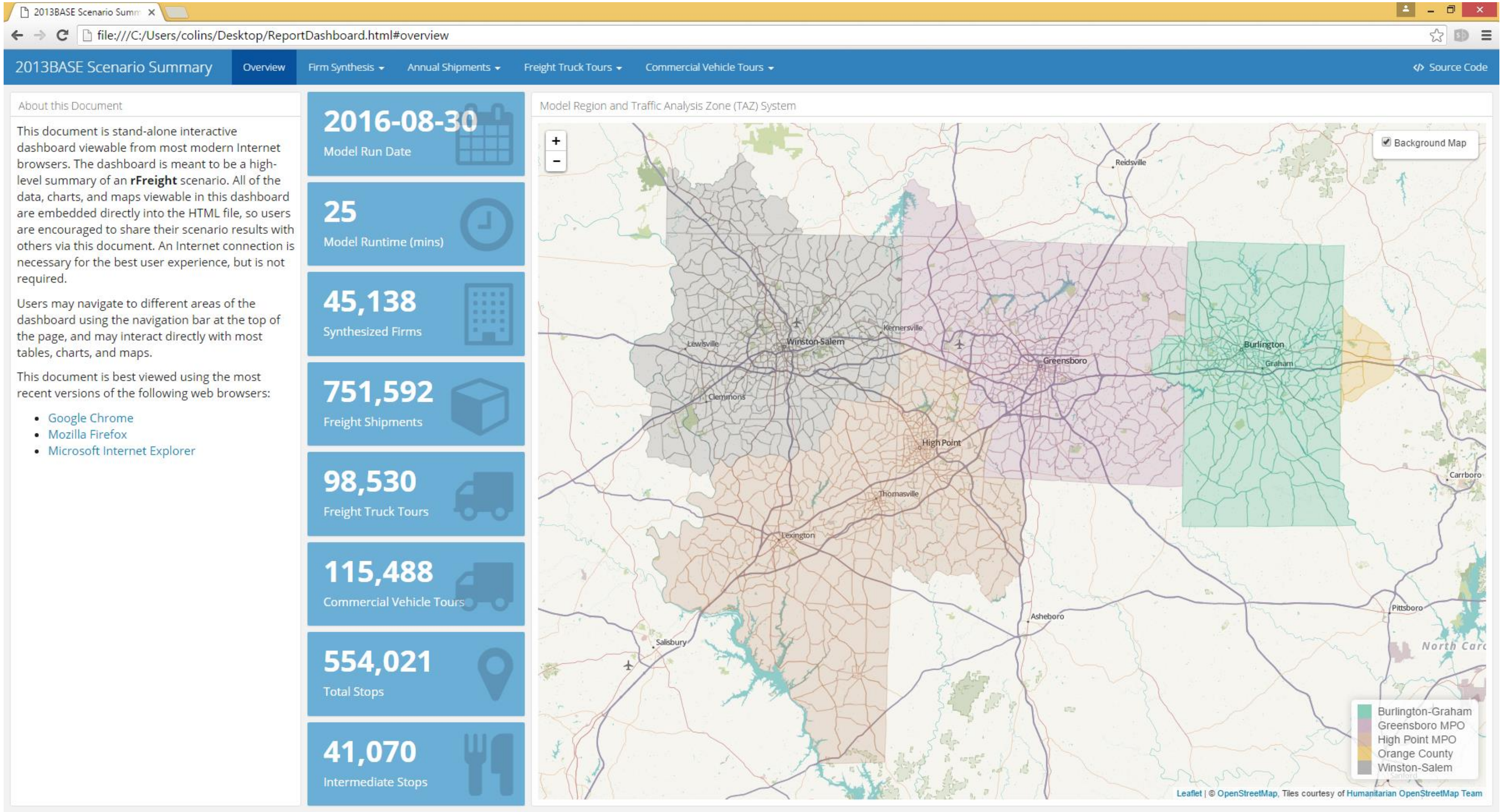
About R

- R is an open source statistics and programming platform
- The base application is open source and is available for Windows, OS X and Linux
- R is extended with R packages – add in libraries of functions
- The Comprehensive R Archive Network is a distribution network of submitted packages that meet certain minimum requirements; most are also fully open source
- R packages can be developed separate from those on CRAN
- Base R and packages provide code to estimate and apply many types of statistical model including simulation tools like MCMC
- Graphics is also a strong feature of R, and that has now extended to easy integration with web based visualization libraries such as java script based tools like D3

rFreight Application Structure



Model Outputs Dashboard



Dashboard Technology

- HTML file format dashboard comprising a single HTML file.
- Populated with many tables, charts, graphs, and maps
- Created using R Markdown and an R package called flexdashboard
- All of the interactivity is in the browser, no need for server (e.g., shiny server)
- The flexdashboard package changes the format of an R Markdown file from a "document" style into a "data visualization" style
- flexdashboard support objects from many **R** graphics packages, as well as support for the htmlwidgets package
- The dashboard mainly leverages two of these libraries: plotly and leaflet

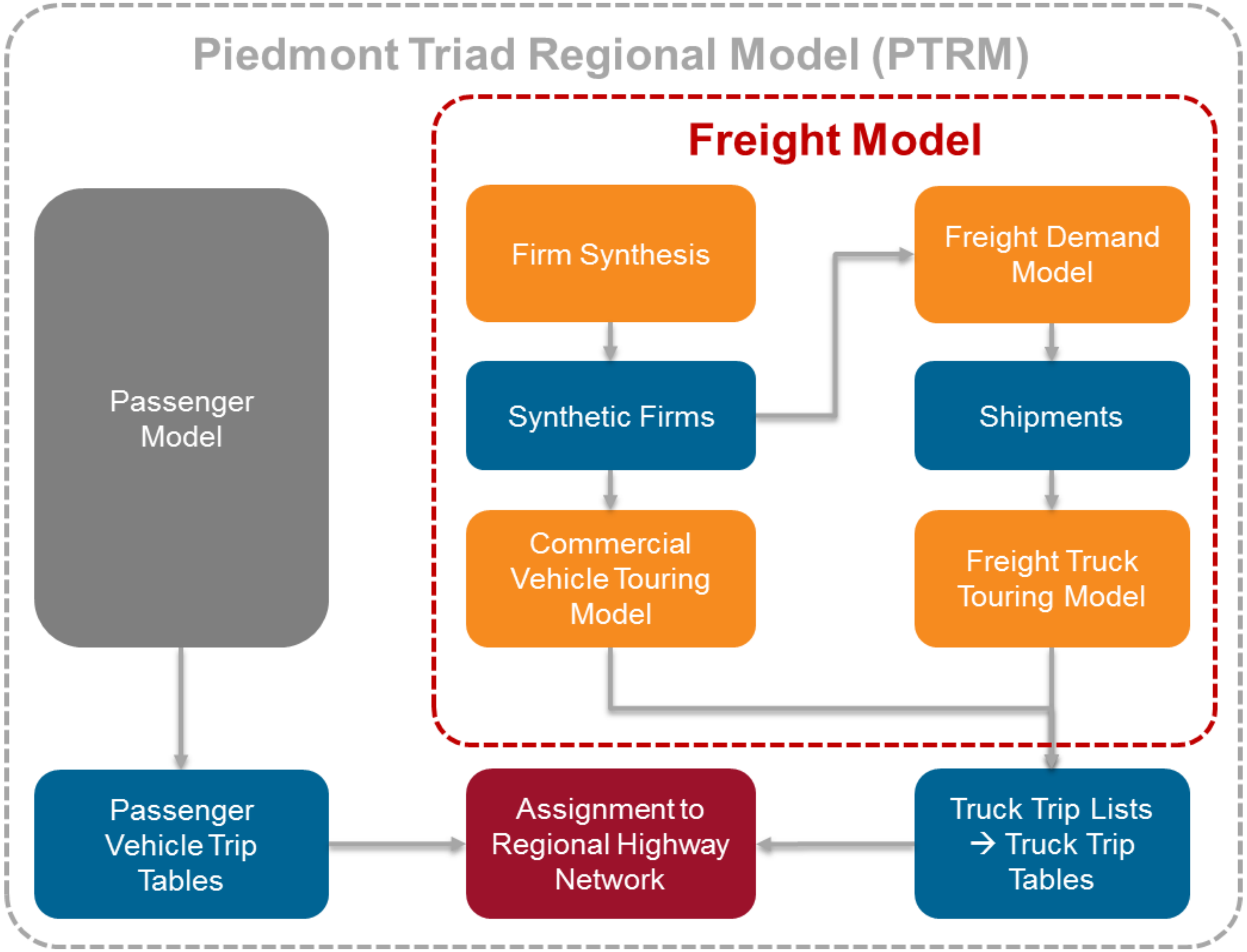
Piedmont Triad Case Study

Piedmont Triad Freight Study

- Objectives of phase 2:
  - To develop an enhanced freight component for the Piedmont Triad Regional Model (PTRM)
  - The Piedmont Triad region is an important transportation and logistics clusters -> this led to the requirement for an advanced freight truck sub-model that provided realism and policy sensitivity
  - Provide a roadmap for future improvements – both data and model improvements
- Key features of phase 2 model:
  - Capture the effects of long distance truck movements to and from the region
  - Interaction between long distance freight flows and local freight distribution
  - Represent local trucks movement complexity for both goods delivery and service activity

Model System

- Freight model integrated in the PTRM
- Four components simulate:
  - Businesses and households (locations, types, production, consumption, service needs)
  - Freight shipments (type, quantity, unit size, channel, mode)
  - Freight trucks (pick up and delivery tours)
  - Commercial vehicles (service and residential delivery tours)

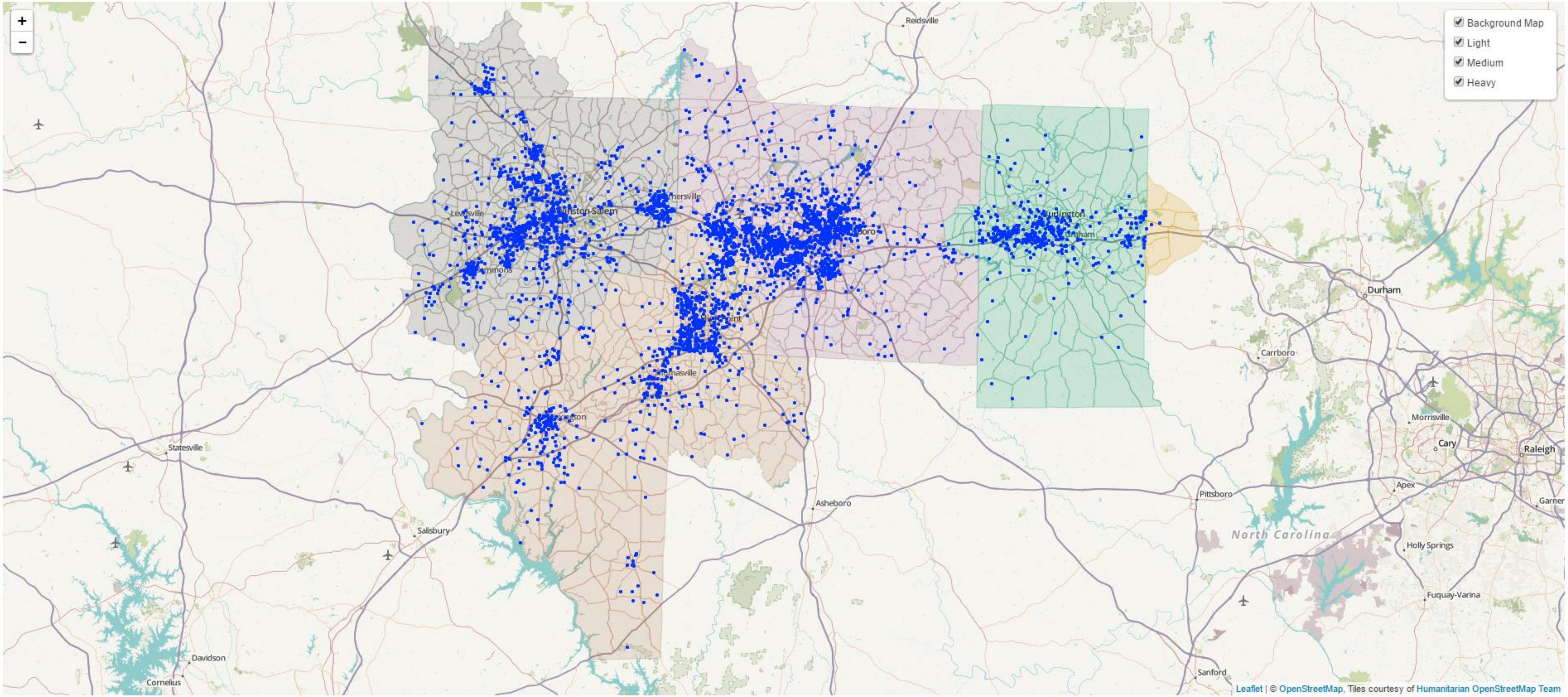


Freight Trucks: Outputs and Calibration

- Maps of stops by vehicle type, activity, and over time
- Plots of first stop arrival time by vehicle and activity
- Plots of tour length, trip length, tour duration, trip duration, stop duration by vehicle and activity
- Plots comparing model with calibration targets for first stop activity time, vehicle type, stops per tour, intermediate stops

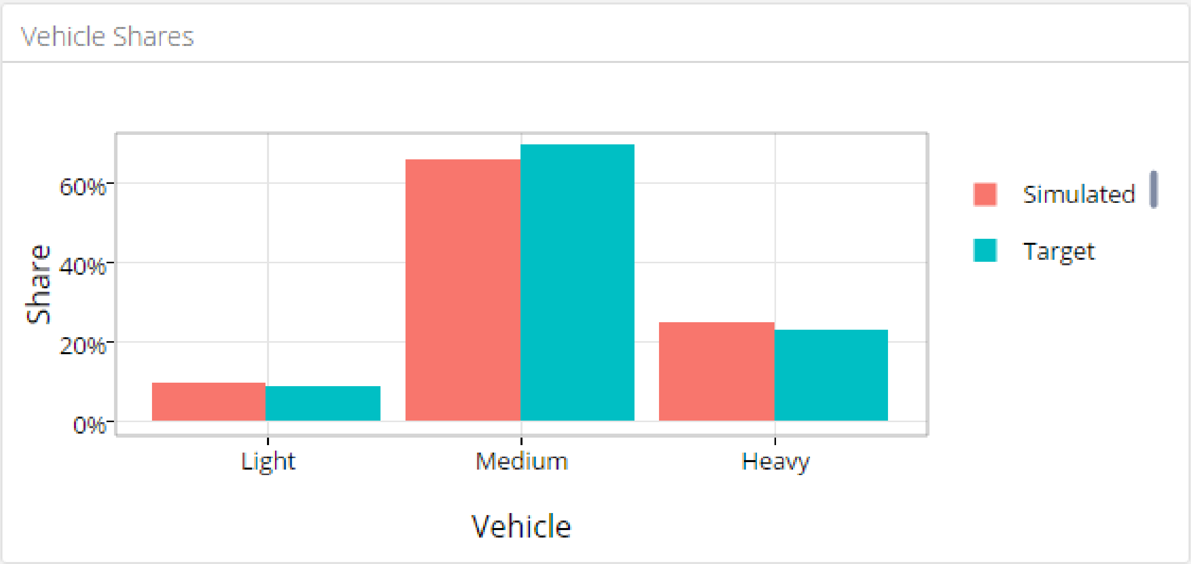
2013BASE Scenario Summary | Overview | Firm Synthesis | Annual Shipments | Freight Truck Tours | Commercial Vehicle Tours | Source Code

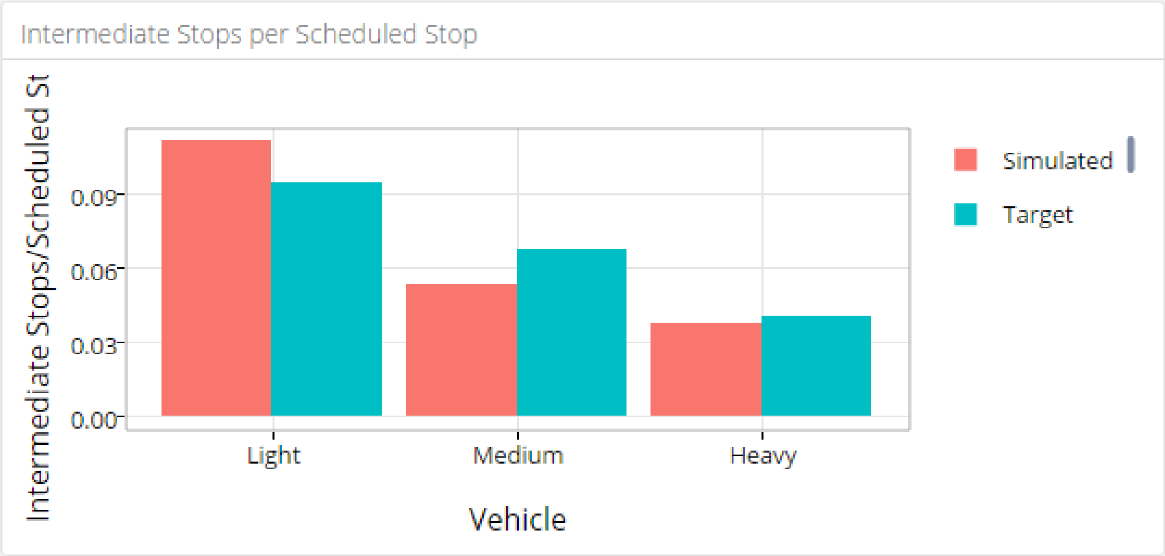
Stops Over Time | Sampled Tours | Stops by Vehicle Type | Stops by Activity

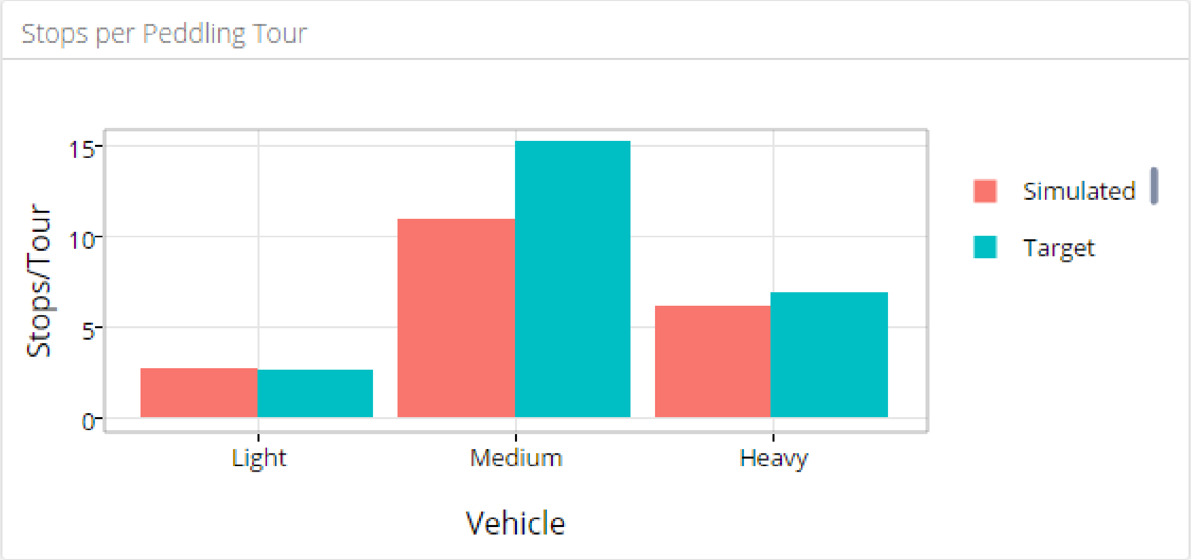


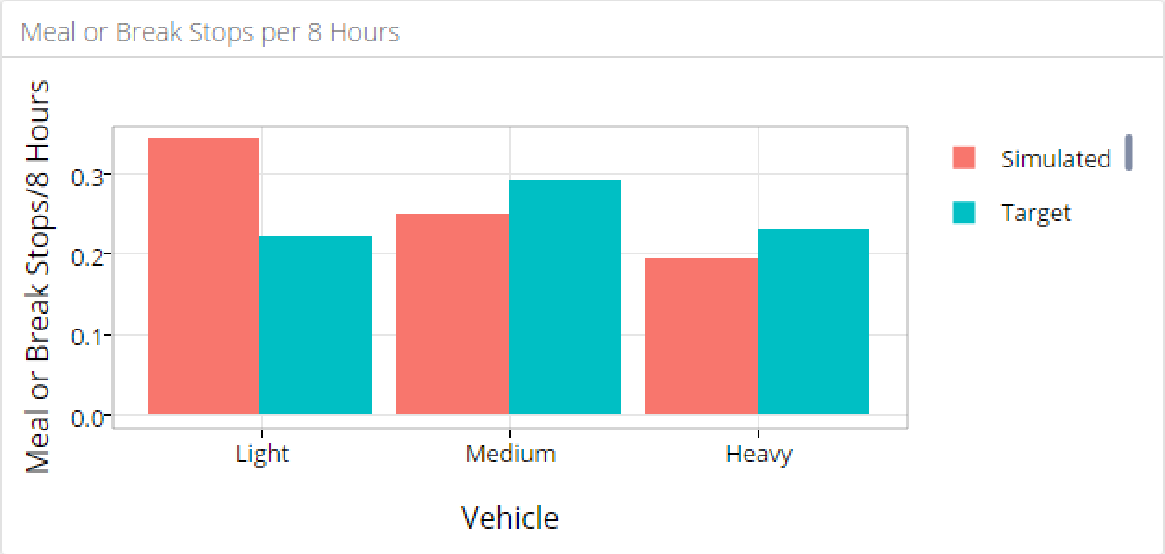
Note: Each data point represents 25 stops and precise locations are illustrative as firms are only identified geographically at the TAZ-level.

Vehicle Shares and Tour Patterns

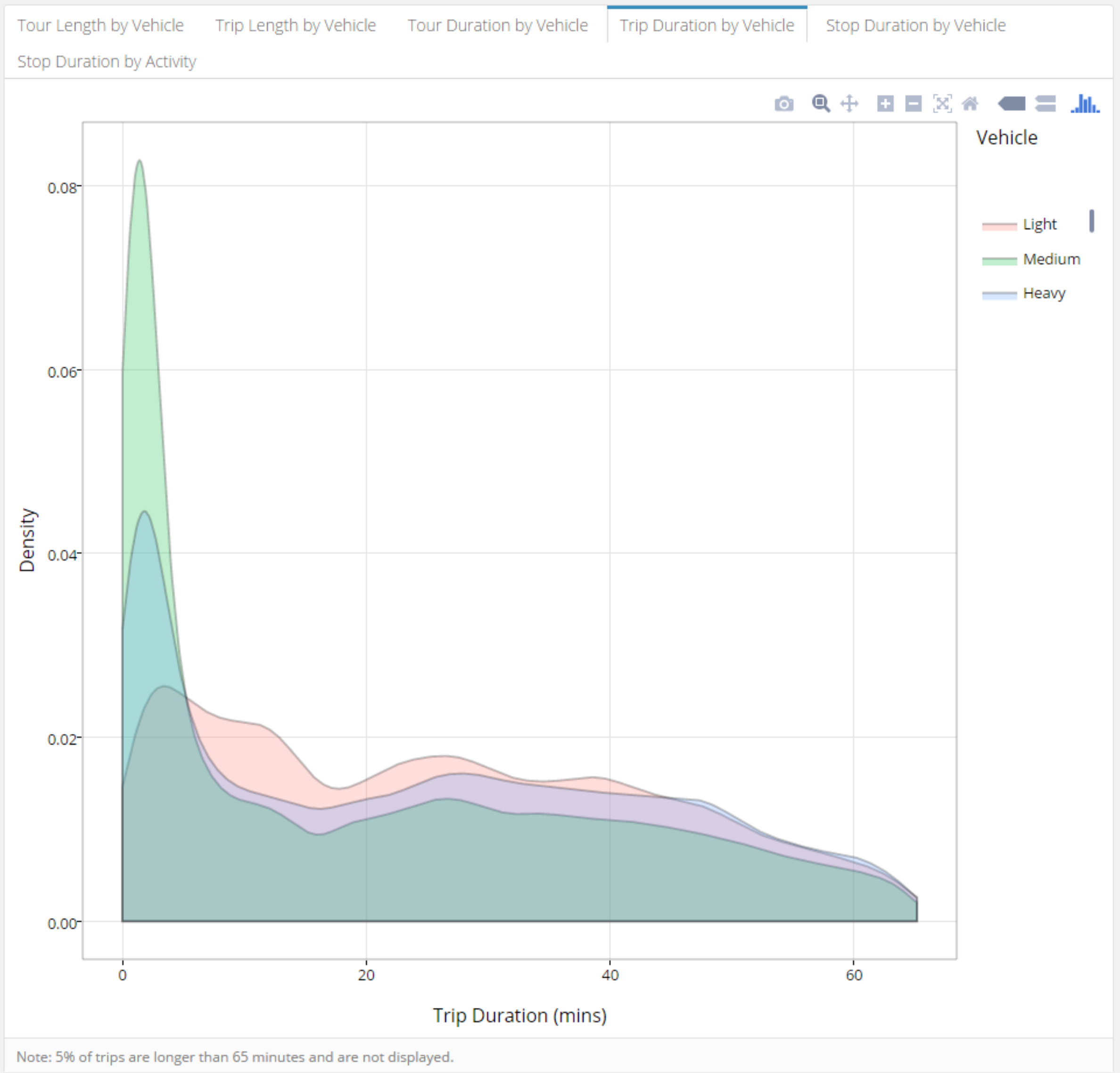


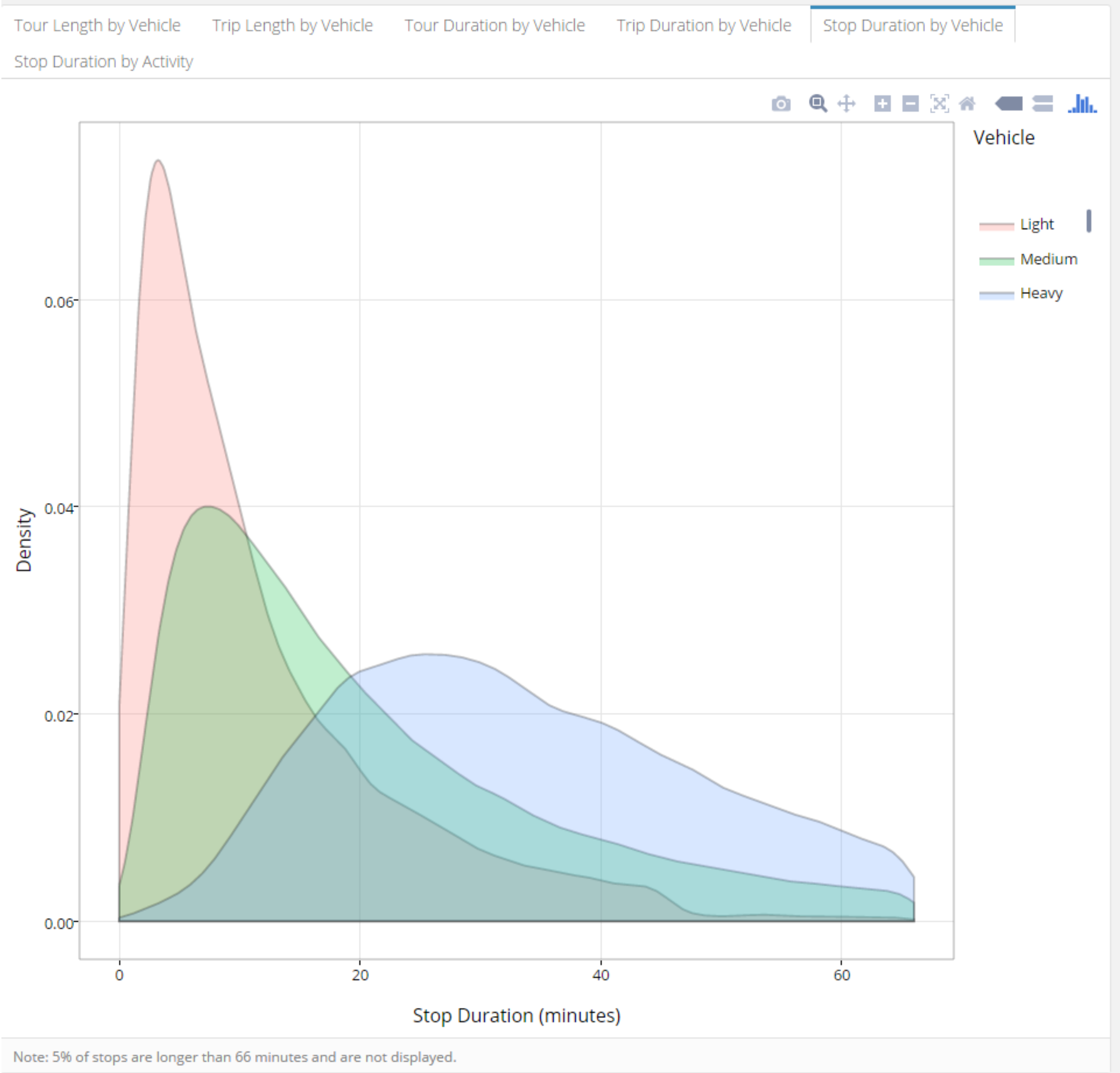




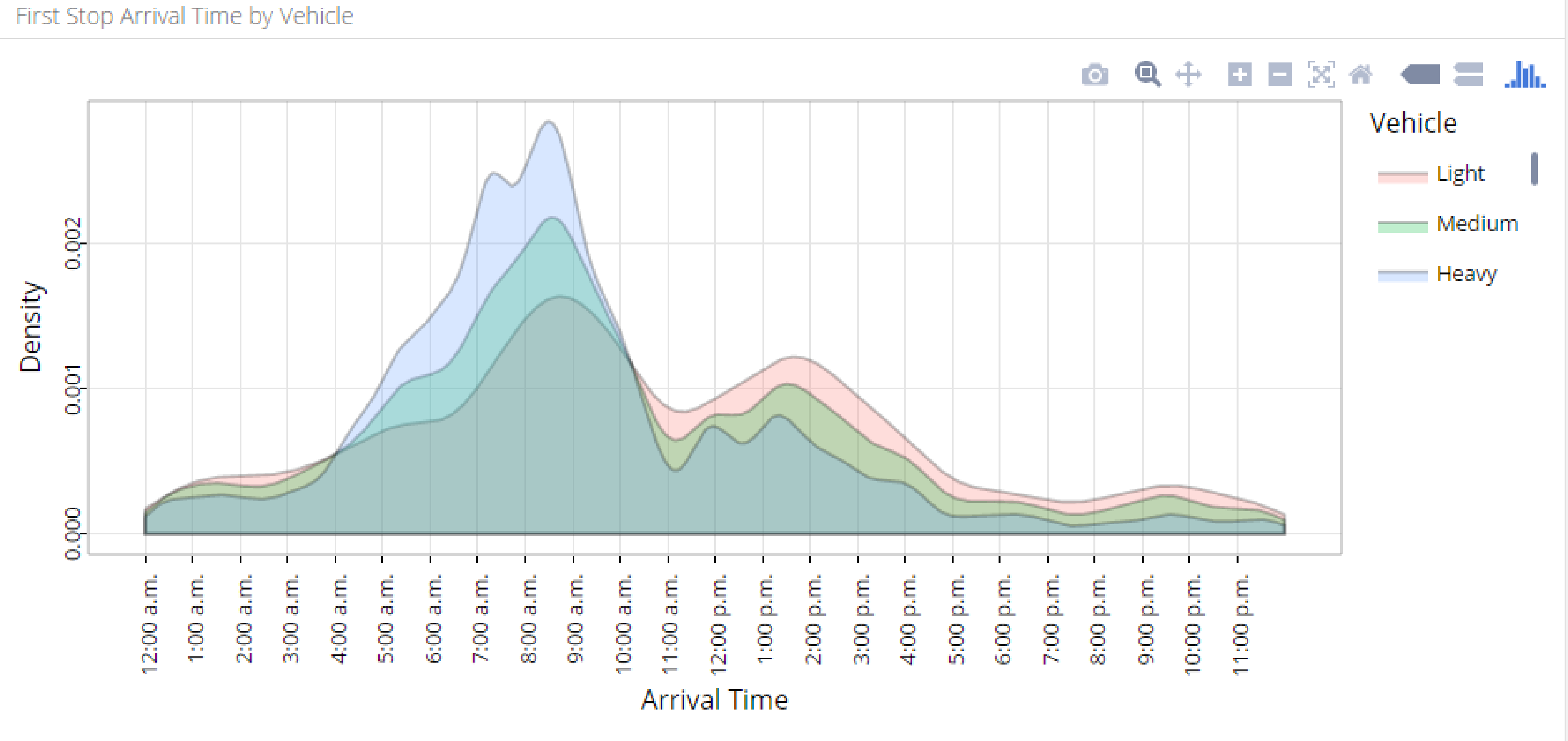


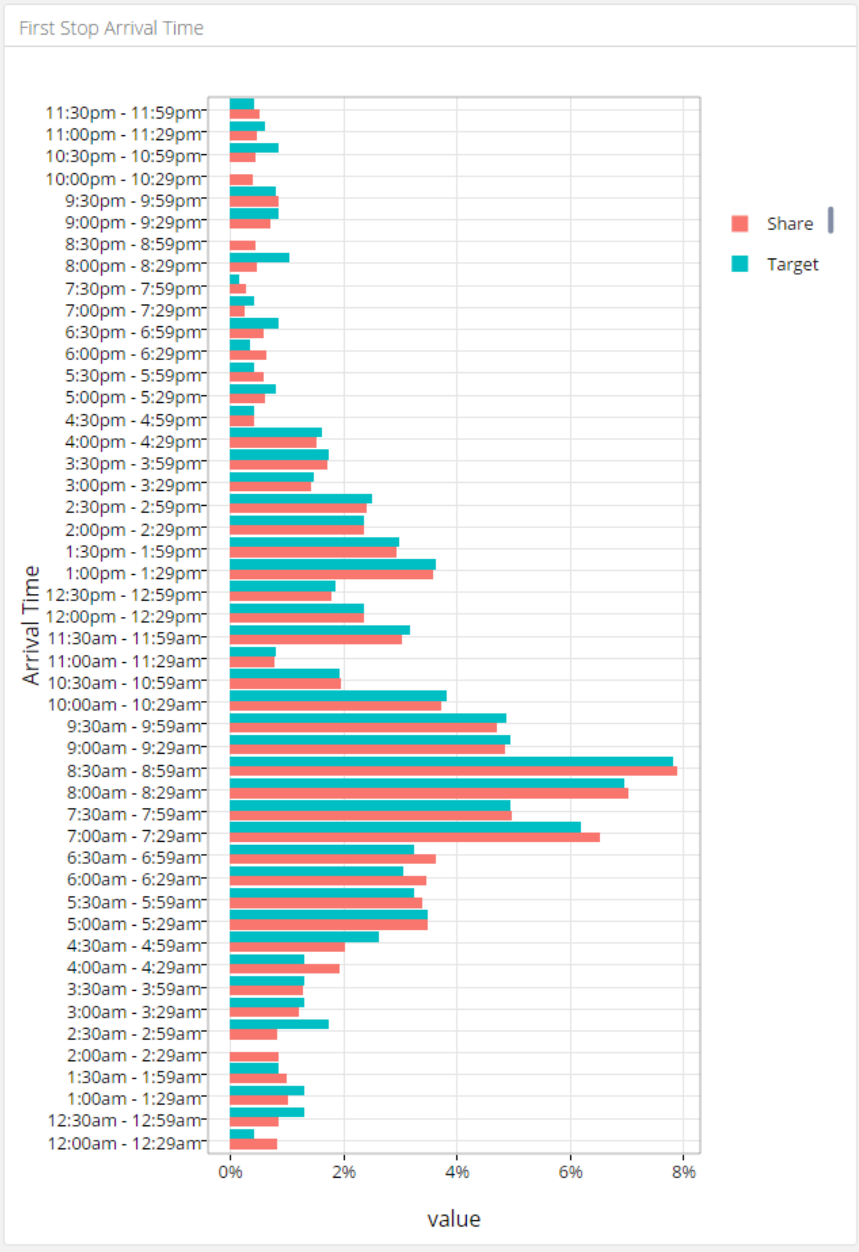
Trip and Stop Durations





First Stop Arrival Time





Summary

- Completing model development, validation, and sensitivity testing for the phase 2 model
- Carrying out training and model handover in early December
- Developing a plan for additional data collection, model enhancements, and calibration/validation with new data that will form the basis of phase 3

Questions and Discussion