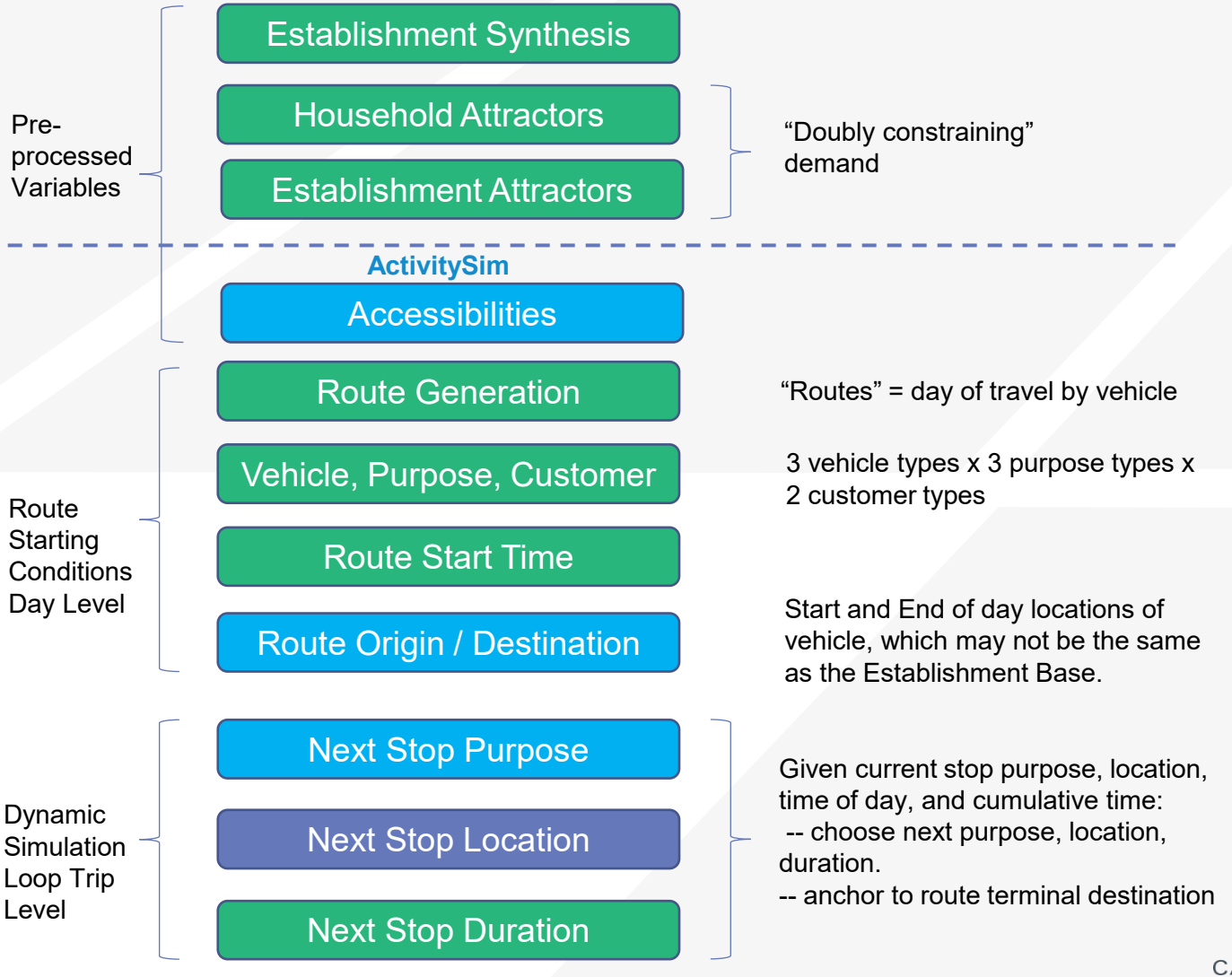
SANDAG Commercial Vehicle Model Update

Task 2: Detailed Design

Working Draft for Team Development and Discussion

Last Revised, November 21, 2023

Commercial Vehicle Model (CVM) Design Flow Diagram



CAMBRIDGE SYSTEMATICS

Establishment Synthesis

- Needed to model commercial vehicle route generation and trip attractions
  - Captures non-linear effects relative to number of employees per establishment. Decreasing marginal trip rate per employee.
- Inputs
  - MGRA total employment by industry
  - LUZ percent of establishments in 7 establishment size categories by industry
- Optimization Problem
  - For each LUZ and Industry, create individual establishment records that satisfy the targets for total employees in each MGRA, while matching the percentage distribution of establishments by the 7 size categories
- Outputs
  - Table of synthetic establishment records with attributes of industry, number of employees, and MGRA location

Establishment Size Categories

Size Class Definitions (number of employe			
1	"< 5"		
2	"5 to 9"		
3	"10 to 19"		
4	"20 to 49"		
5	"50 to 99"		
6	"100 to 249"		
7	">= 250"		

Household Attractors

- Attraction variables representing the *proportion* of households receiving:
  1. Package delivery
  2. Food delivery (grocery or meals)
  3. Service stops
- Binary choice logit model
- Apply to all the households in each TAZ to get total attractors
- Derive from questions in Household Survey
  - » Estimate based on household attributes, such as: income, size, vehicle sufficiency, presence of children, age of householder, urban form/density, etc.
- Application options:
  - » Apply to Synthetic Population of households and aggregate results by TAZ

Establishment Attractors

- Attraction variables representing the *number of trips to* establishments receiving:
  1. Goods deliveries/pickups and/or Service stops
- 2-Stage Model:
  1. Probability of at least one stop (binary logit)
  2. Given at least one stop, attractions per employee

  Both models segmented by establishment size (number of employees) and industry group
- Derive from questions in Establishment Survey
- Application
  - » Apply to Synthetic Establishments, defined by industry group and number of employees

Accessibilities

- Use in Route Generation and Stop Generation models.
- Use Household Attractors and Establishment Attractors in combination with a distance-decay function negative exponential like gravity model
- Impedances will be based on generalized travel time:
  - Congested travel time and toll skims converted to equivalent minutes using value of time
- Possible segmentation schemes:
  - Access to Households with Package Delivery Attractors
  - Access to Households with Food Delivery Attractors
  - Access to Households with Service Stop Attractors
  - Access to Establishments with Goods and/or Service Attractors
  - Access to general employment by type, likely retail and service, for use with Maintenance/Other tour/stop types.

Accessibilities Formula

$$Accessibility_i^k = \sum_{\forall j \in J} Attractors_j^k \times \exp\left(\theta_k * TravelTime_{ij}\right)$$

Where i and j are TAZs and k is an attractor type:

- Households with Package Delivery Attractors
- Households with Food Delivery Attractors
- Households with Service Stop Attractors
- Establishments with Goods and/or Service Attractors
- Maintenance/Other (use service and retail employment in TAZ)

θ_k are parameters (TBD) specific to attractor types. Use -0.025 as a default until we derive them.

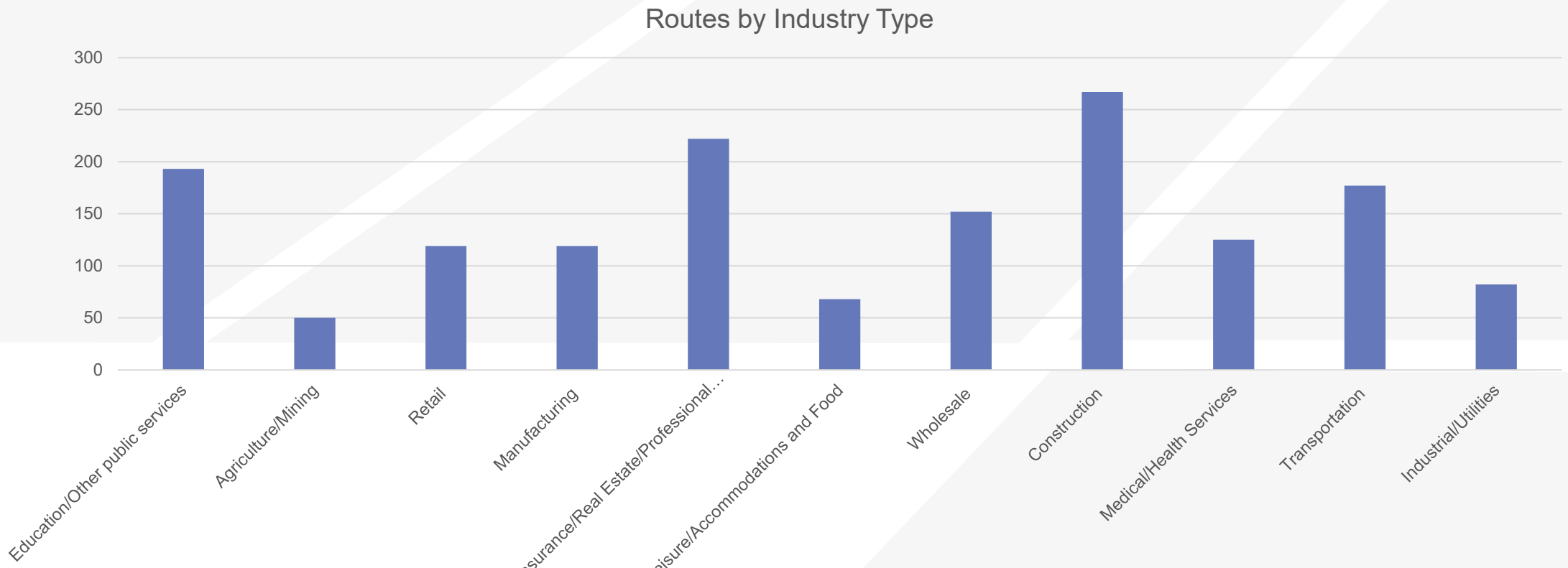
Accessibility Impedances

- Trips to customer sites (access to customers)
- Generalized cost travel times
  - Includes tolls converted to minutes by VOT
- MD period skims by Light, Medium, Heavy truck types
- Weighted by vehicle usage by industry group (proportional)
- Example:
  - $AccessTravelTime = TravelTime_L * Proportion_L$
  + $TravelTime_M * Proportion_M$
  + $TravelTime_H * Proportion_H$

Route Generation

- "Route" is a day-level record for a vehicle not driver
- 2-Stage Model:
  1. Probability of at least one route generated from establishment (binary logit)
  2. Given at least one route, number of routes per employee
  - » Variables:
    - Employment by Business Type in TAZ and Establishment Size Class
    - TAZ Household and Establishment Accessibilities
- Apply to synthetic establishments by industry group (business type) and number of employees

Route Generation

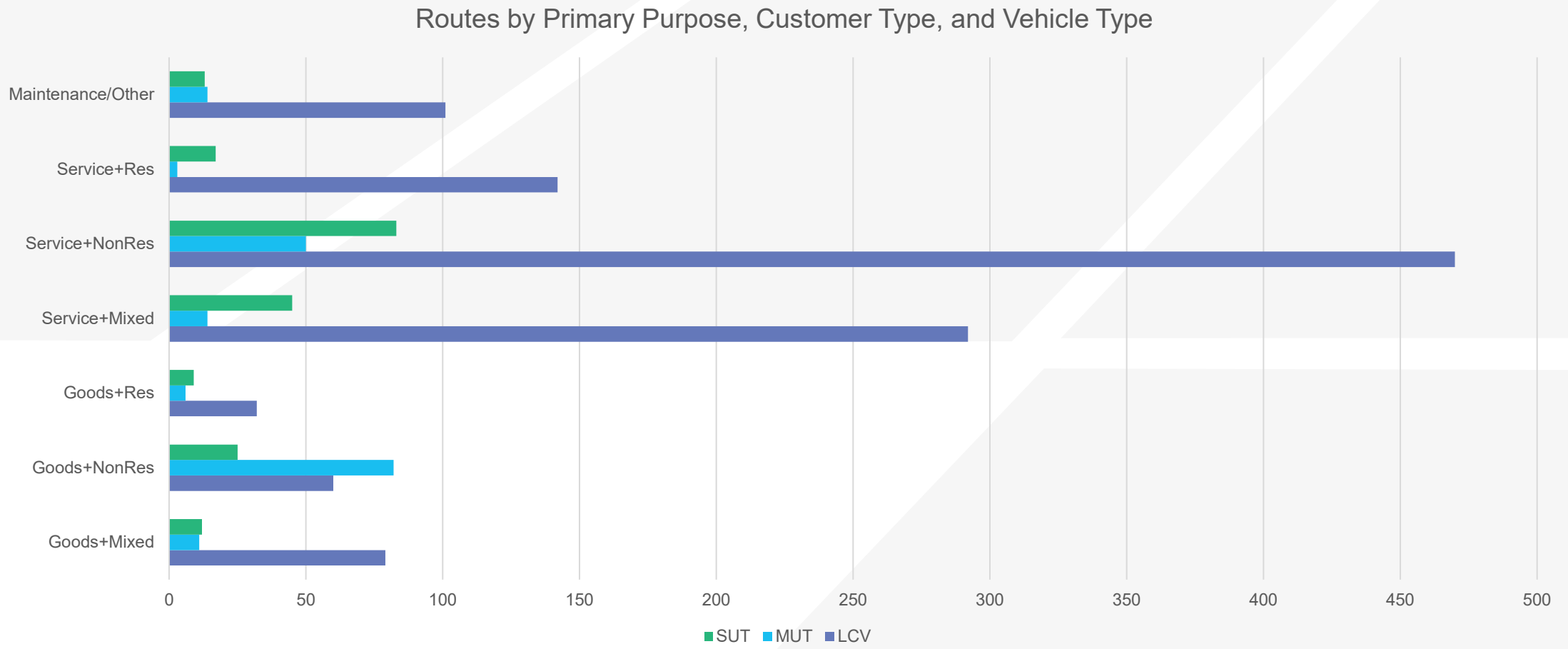


CAMBRIDGE SYSTEMATICS

Vehicle, Purpose, Customer Types

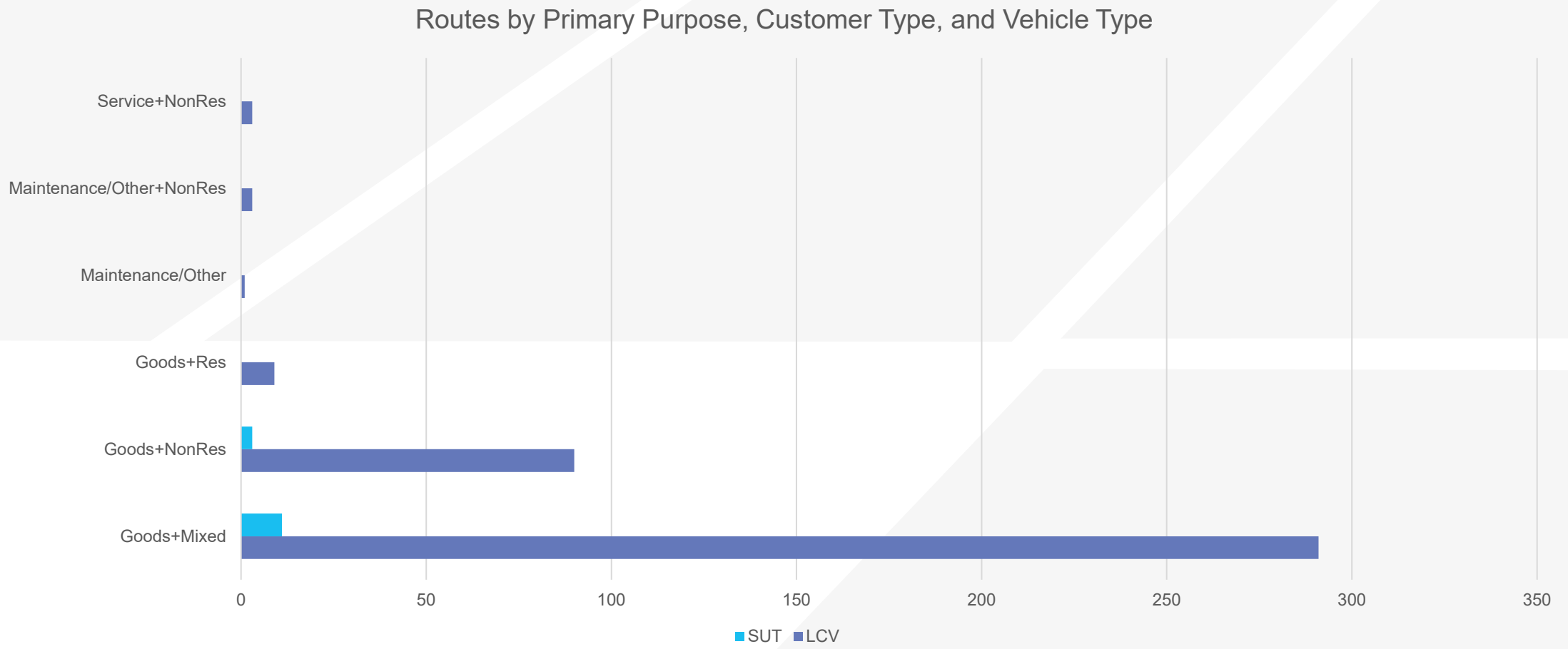
- Given: Business Type from Route Generation
- Dependent Variables:
  - Feasible combinations of Vehicle Types, Primary Purposes, and Customer Types joint choice
  - 21 Alternatives possible
- Vehicle Types
  1. Light
  2. Medium
  3. Heavy
- Primary route/tour purposes hierarchy:
  1. Goods customer-oriented; may include Services and other stop types
  2. Service customer-oriented; does not include Goods stops; may include other stop types
  3. Maintenance/Other refueling, driver breaks, vehicle/equipment repositioning, buying supplies, other; does not include Goods or Services stops; not customer oriented
- Customer Types at Stops only applies to routes with Goods and/or Service purposes
  1. Residential Only households, including multi-family buildings
  2. Non-residential Only commercial, public/government
  3. Mixed Residential and Non-residential

Vehicle, Purpose, Customer Types -- CVS



CAMBRIDGE SYSTEMATICS

Vehicle, Purpose, Customer Types -- TNCs



CAMBRIDGE SYSTEMATICS

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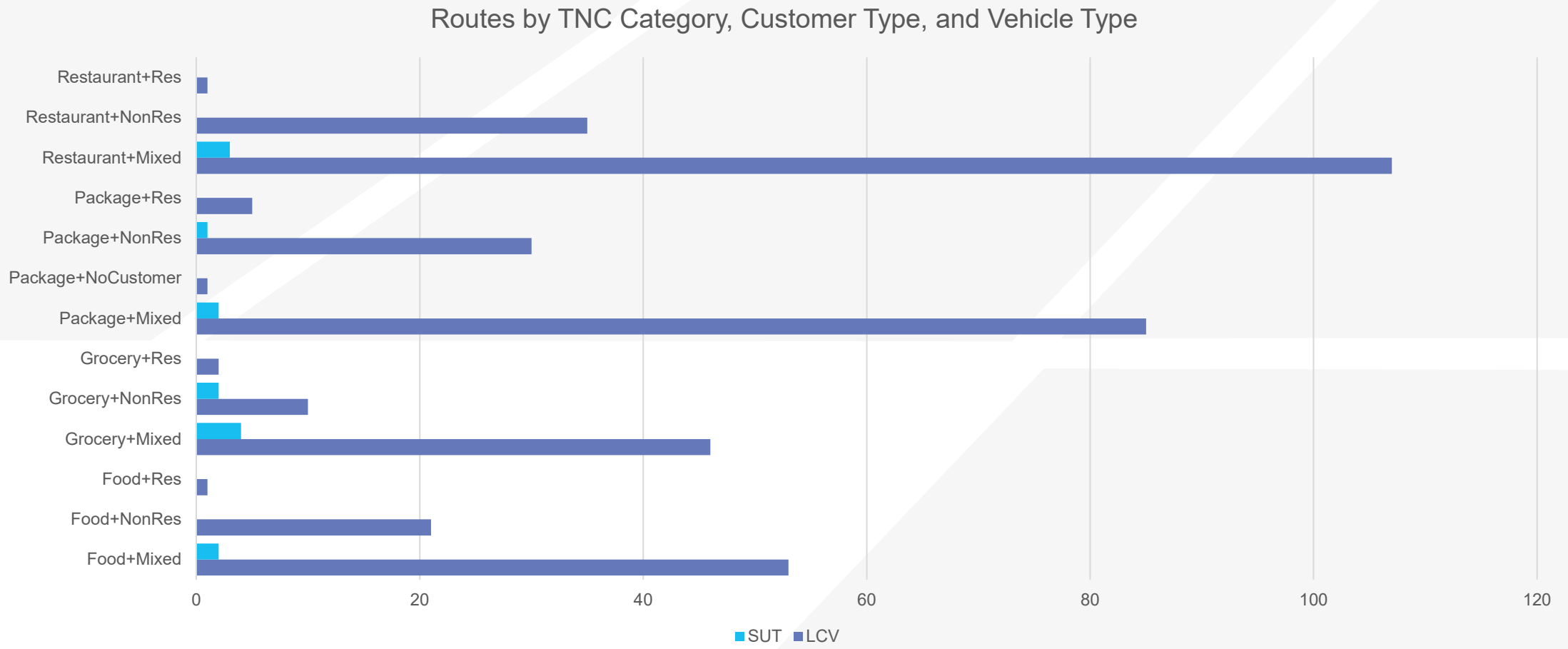
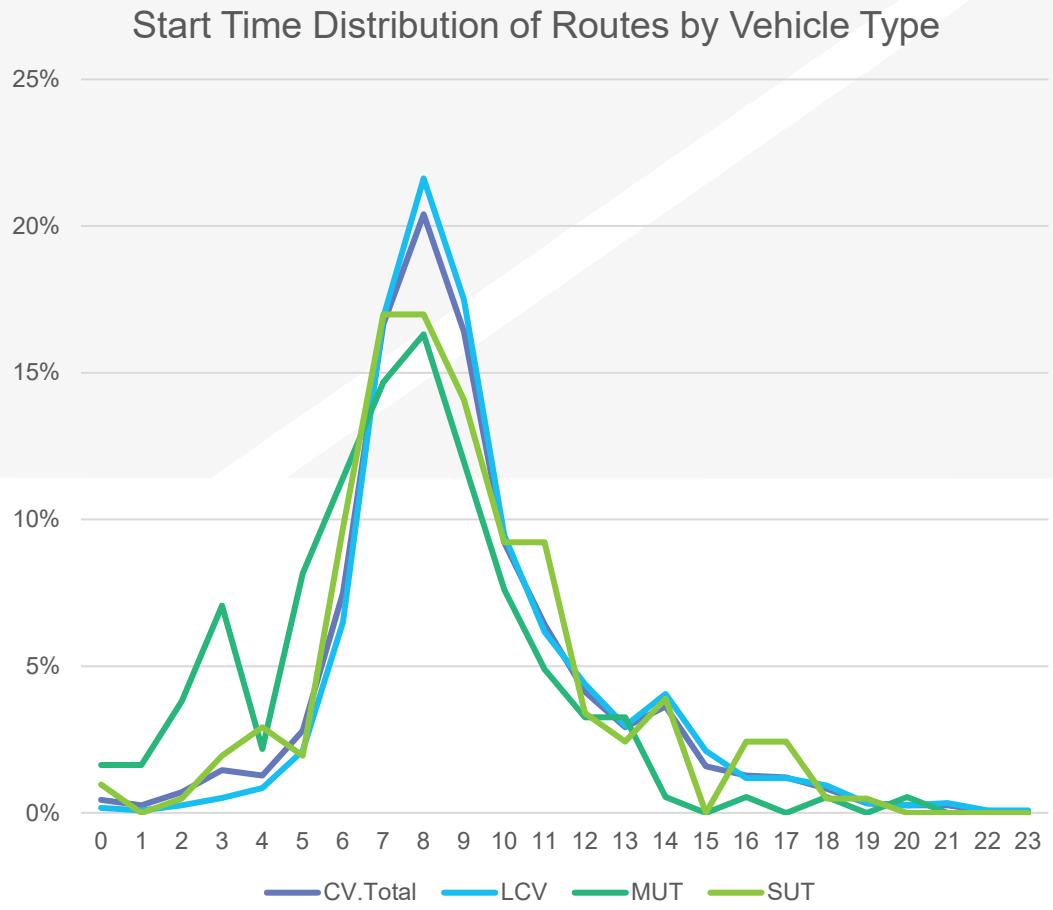


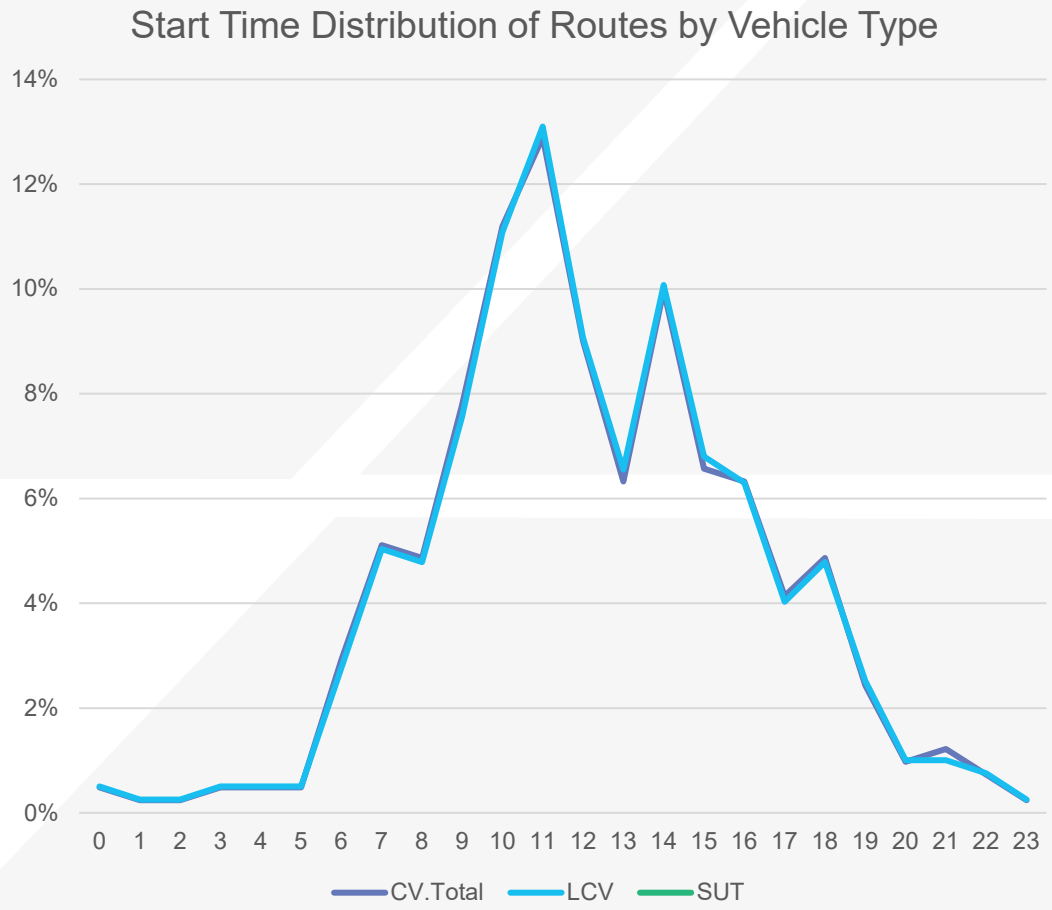
CAMBRIDGE SYSTEMATICS

Route Starting Times

- Given: business type, vehicle type, primary purpose, and customer type
- Choose a starting time for the Route minute of the day, could be 15-minute intervals
- Option 1: Drawing from a distribution of route starting times, segmented by business type, vehicle type, purpose, and customer type weighted observations from CVS
  - Pros: Simple, businesses tend to follow fixed hours, often related to customer hours, unlikely to be affected traffic congestion
  - Cons: Static distribution, insensitive to policy parameters
- Option 2: Estimate a parameterized model e.g., regression or choice model
  - Pros: Allows testing potential accessibility, policy, or congestion-related impacts
  - Cons: Congestion effects may be minimal or not statistically significant.

Route Starting Times: CVS, TNCs





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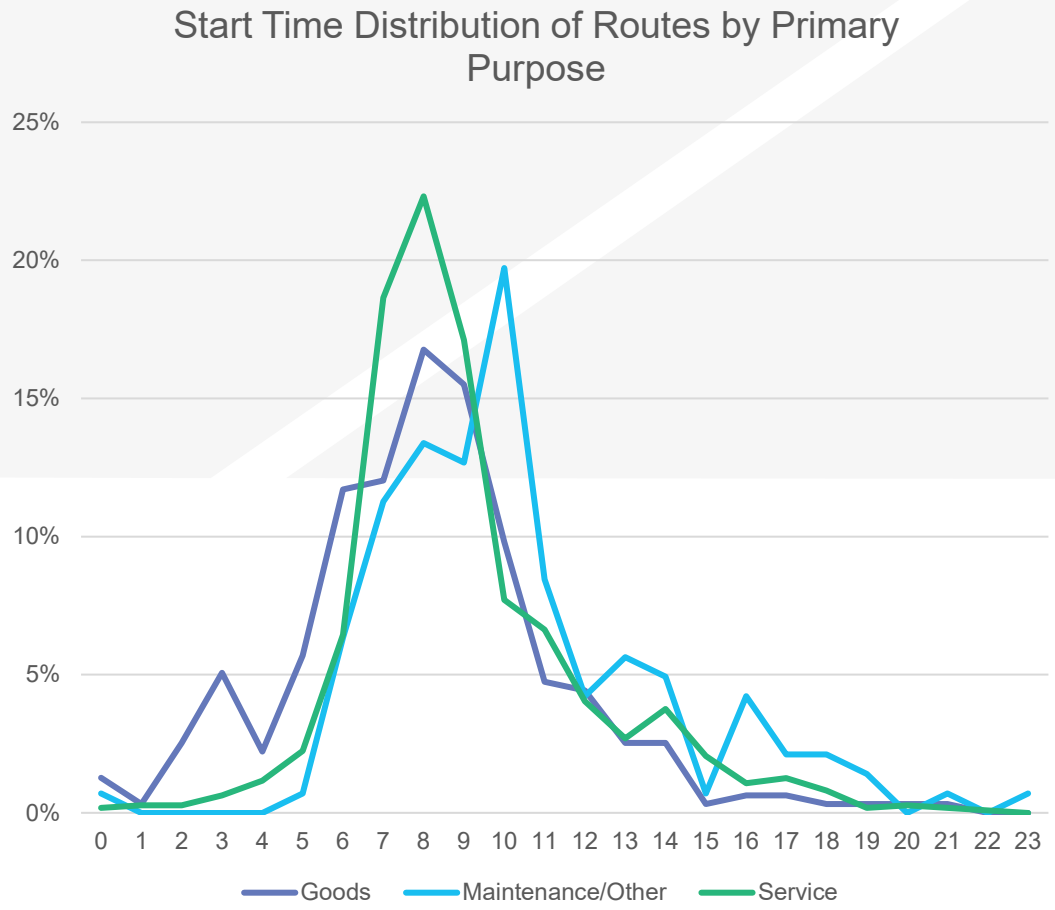

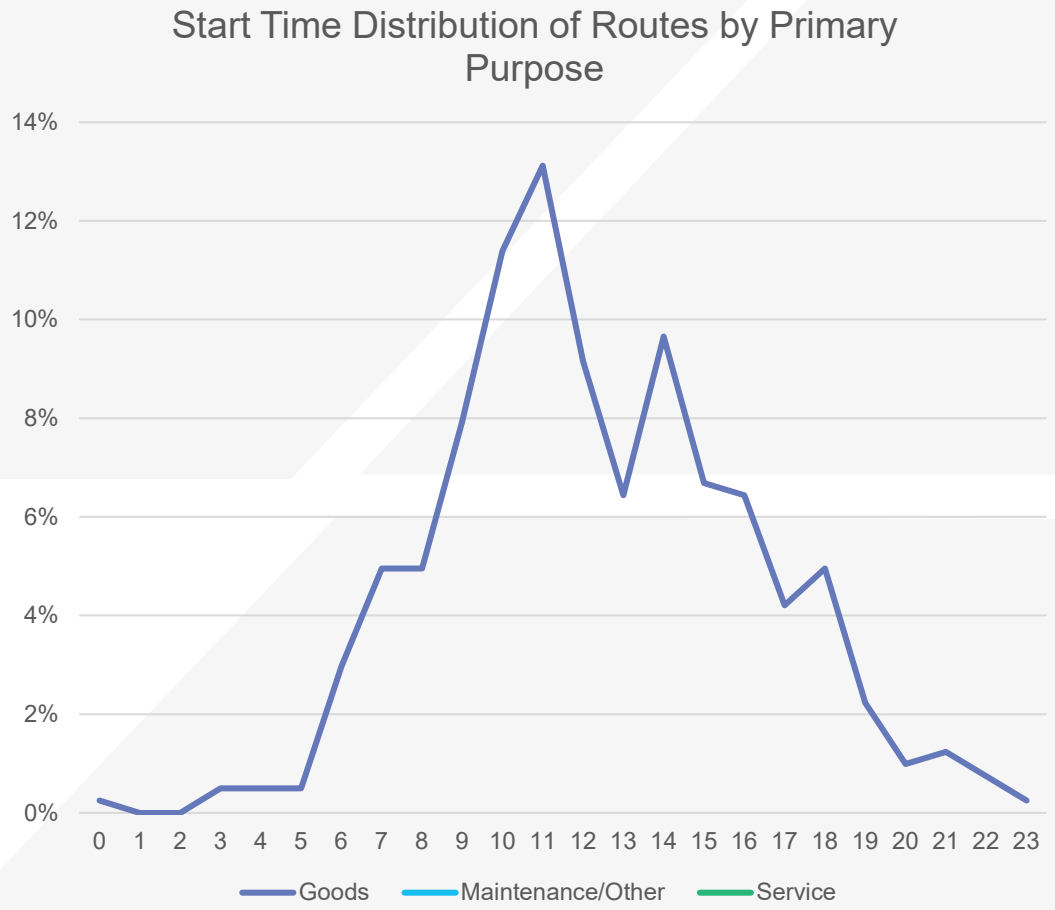

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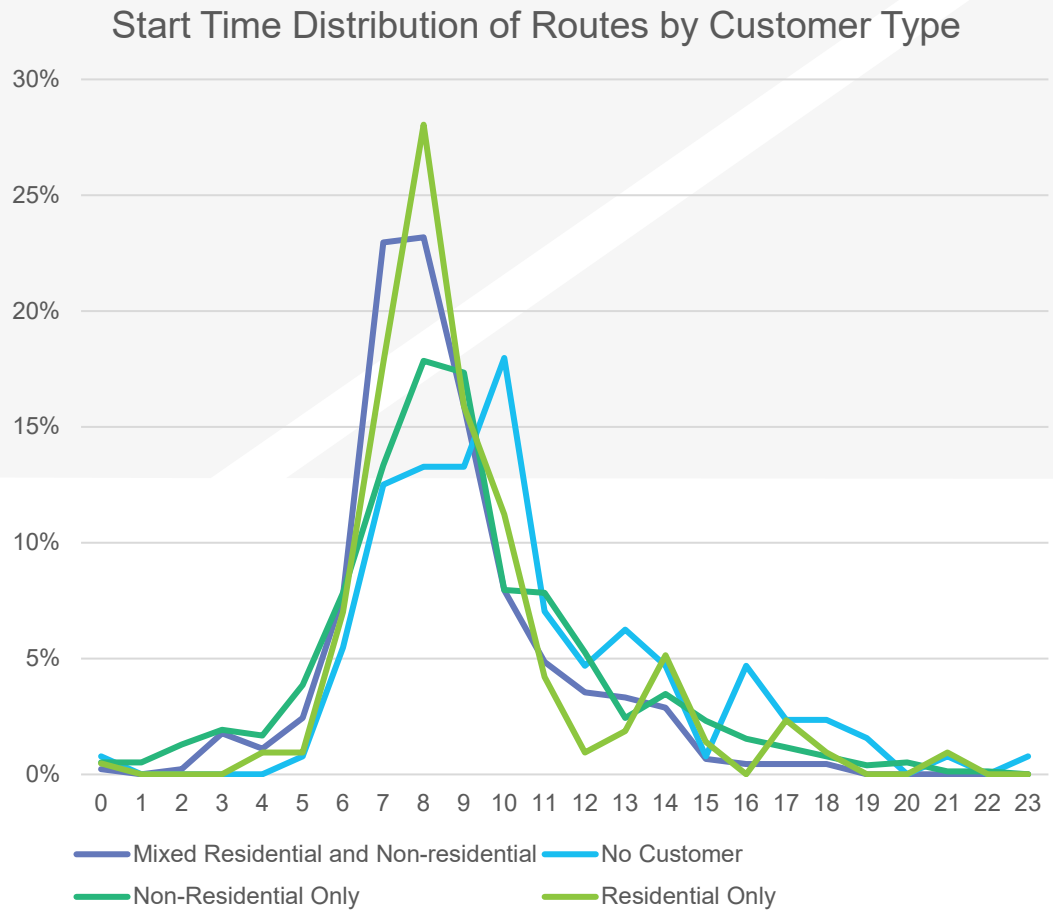

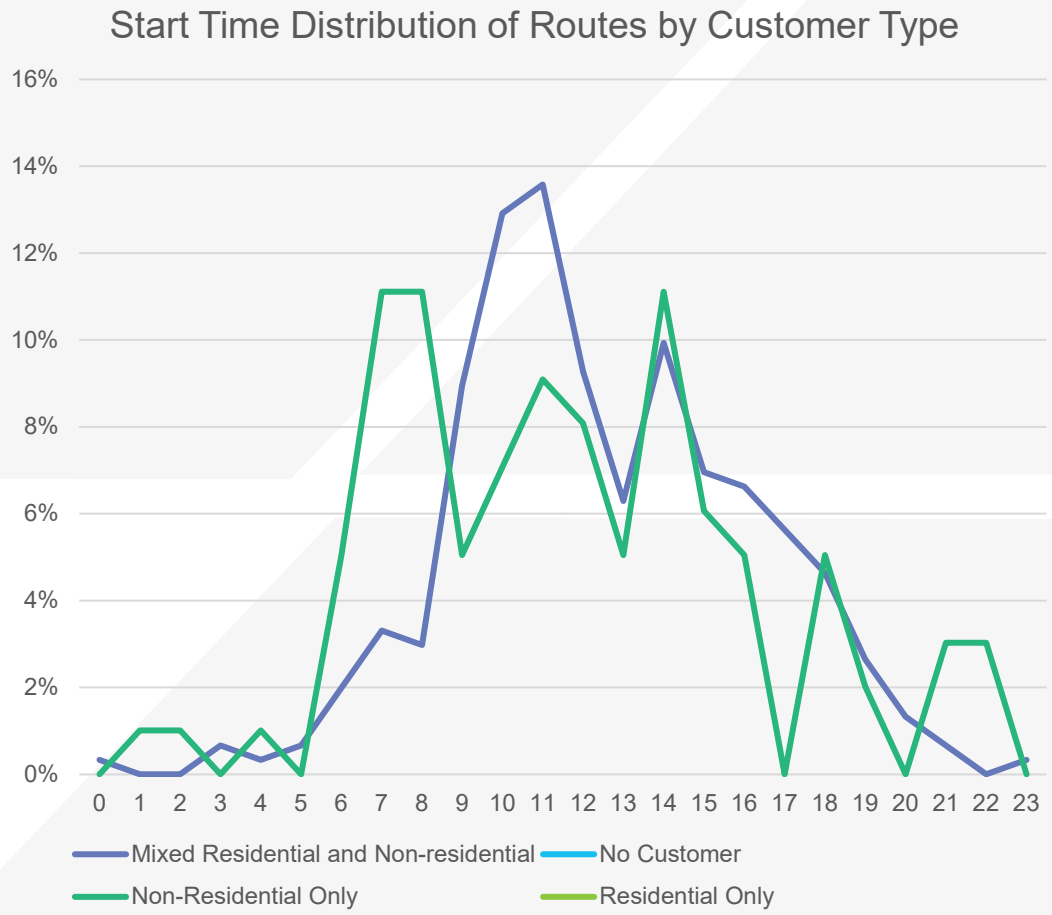

CAMBRIDGE SYSTEMATICS

Route Origin/Destination

- Given: business type, vehicle type, primary purpose, and customer type
- Provides anchor point for end of route
  - » Affects stop location choices “rubber banding”
- Two-level choice
  1. Choose the type of origin/destination
     - Base = TAZ of establishment
     - Warehouse/Distribution Center (join locations to survey)
     - Transport Node Airport, Seaport, Rail yard (join locations to survey)
     - Residential Use (Driver’s home)
     - Other Commercial Use
  2. If upper choice is not Base or Home if known, choose TAZ for type
     - May need to make simplifying assumptions about ‘home’ as an alternative base

Data Processing: Routes Table

- One day record for each vehicle in the CVS and TNC trip surveys
  - Aggregate over all trips
- Key Attributes:
  - Business type industry type
  - Vehicle type L, M, H
  - Primary purpose Goods, Services, Maintenance/Other
  - Customer type Residential, Non-residential, Mixed
  - Starting time of day first departure
  - Ending time of day last arrival
  - Starting Origin Base, Home, Warehouse/DC/Transport Node, Other
  - Ending Destination Base, Home, Warehouse/DC/Transport Node, Other
  - Number of stops by type: goods, services, maintenance/other, base, home
  - Total distance traveled

Dynamic Simulation Loop

- Given Starting Conditions:
  - Business type, vehicle type, primary purpose, and customer type
  - Starting time of day
  - Origin and destination type and TAZ
- For each Route:
  - Choose the Next Stop Purpose
  - Choose the Next Stop Location
  - Choose the Next Stop Duration
  - Continue adding stops until Next Stop Purpose = “Terminal”
    - This ends route/day with a final trip to the Terminal TAZ
- Track:
  - Current Location
  - Distance /Travel Time from Terminal TAZ
  - Current Time of Day
  - Elapsed Time on Tour

Next Stop Purpose

- Given:
  - Route Starting Conditions: business, vehicle, purpose, customer types
  - Terminal Type
  - Current Location
  - Distance/Travel Time from Terminal TAZ
  - Current Time of Day
  - Elapsed Time on Tour
  - Stop Purpose at Current Location
- MNL Choice model -- Choose the Next Stop Purpose from:
  - New Goods Pickup Stop
  - New Goods Delivery Stop
  - New Service Stop
  - New Maintenance/Other Stop
  - Return to Base
  - Go to Terminal Location
- Use Accessibility variables appropriate to Route Purpose goods, services, maintenance/other and Customer Type residential, non-residential, mixed
- Expect that as time of day and elapsed time on the tour increase, the likelihood of choosing Terminal will increase

Next Stop Location

- Given:
  - Route Starting Conditions: business, vehicle, purpose, customer types
  - Terminal Type
  - Current Location
  - Distance/Travel Time from Terminal TAZ
  - Current Time of Day
  - Elapsed Time on Tour
  - Stop Purpose
- Two-level choice
  1. Choose the type of destination
     - Residence
     - Warehouse/Distribution Center
     - Transport Node Airport, Seaport, Rail yard
     - Other Non-Residential commercial, public
  2. Choose TAZ for type
- Destination Choice Model with Rubber Banding
  - Size Function: Household and/or Establishment Attractors and/or Employment/Households depending on Stop Purpose and Customer Type
  - Travel time and cost skims: Current Location to Altj + Altj to Terminal Location
  - Test interaction terms: Travel times X Elapsed Time on Tour
- As time of day and elapsed time on the tour increase, the likelihood of choosing stop locations closer to the Terminal will increase

Next Stop Duration

- Given:
  - Route Starting Conditions: business, vehicle, purpose, customer types
  - Terminal Type
  - Current Location
  - Distance/Travel Time from Terminal TAZ
  - Current Time of Day
  - Elapsed Time on Tour
  - Stop Purpose and Location
- Choose an activity time duration for the stop minutes, could be 15-minute intervals
- Option 1: Drawing from a distribution of stop durations by stop purpose, potentially segmented by business type and customer type weighted observations from CVS and TNC
  - Pros: Simple, the amount of time required at a stop probably does not vary much for a particular purpose
  - Cons: Static distribution, insensitive to policy parameters if any
- Option 2: Estimate a parameterized model e.g., regression or ordered choice model from CVS and TNC surveys
  - Pros: Durations are likely to be shorter at the end of the day, can parameterize by elapsed time or clock time
  - Cons: Not clear what policy sensitivity to expect

Policy Sensitivity and Special Features

Representation of TNC Workers

- Freelance Transportation Services TNC workers are their own Business Type
  - Single-employee establishments, home-based
- Develop method to expand TNC worker usage rates to reflect the rates that establishments use them and the expanded number of establishments.
  - Establishment survey and TNC surveys should have enough data to support this
- Predict home/base locations based on household attributes and non-wage employment (land use input) – Route Generation, Origins/Destinations

Home Delivery/E-Commerce Linkages to Households in ABM

- Household Attractor model will be developed from the HH survey should help set the right locations and amounts of demand for goods and services from the customer side
  - Include both household and person attributes (income, ages, workers, children, cars)
  - Include accessibility to retail and land use density variables
- This could be applied to the Synthetic Households in the ABM directly, or an aggregate representation (e.g., TAZ household control totals)
- Consider an additional link/lever to ABM3 household maintenance/shopping trips as substituted by home deliveries fulfillment.
  - Test using the ABM's predicted home-based shopping and home-based eat-out tours as explanatory variables in the Household Attractor model

Linkages to Freight/Logistics Nodes HTM

- Establishment Attractors model should help to get the right number of trips in the right TAZs on the customer side
- Terminal Destination and Stop Location Choice models have upper-level choice that will include:
  - Warehouse/Distribution Center
  - Transport Node Airport, Seaport, Rail yard
- Currently, there is no proposal to make an explicit linkage to FAF flows, which would be aggregated at the County level, or possibly allocated Caltrans zoning districts
  - These would be too aggregate to calibrate CVM flows but could be used as an overall check on total intra-County goods movements.

EV Policy Sensitivity

- Notes from SANDAG EV Policy Planners
  - Electric trucks will have shorter range relative to diesel or gas-powered trucks. This will have an effect on routes that can be taken to address commercial vehicle demand and the frequency and duration of recharging stops. We can provide assumptions for range and fuel type turnover that we are using in planning studies.
  - Hydrogen trucks are expected to have range similar to those of diesel trucks, although their penetration is expected to occur on a more delayed schedule compared to electric. We can also provide assumptions on hydrogen truck performance.
- Model Requirements
  - The model will need to incorporate scenario configurable tables that specify:
    - EV fleet adoption percentages for light, medium, and heavy vehicles
    - Range assumptions for light, medium, and heavy vehicles
    - Charging time turnover assumptions for light, medium, and heavy vehicles
  - Initial proposal is to post-process the simulated routes resulting from the model and to identify those most likely to be EV compatible, based on scenario input, as above.

EV Policy Sensitivity (1 of 4)

- Oversize/overweight corridor
  - Would increasing truck size and weight limits along a freeway corridor change the distribution of commercial vehicle travel throughout the region? Would it reduce the number of commercial vehicle trips and VMT, assuming a fleet fuel type turnover schedule?
  - Assume that payload is decreased for electric trucks, and electric trucks are expected to become increasingly common according to forecasts that we can provide based on state regulation.
- Model Requirements
  - The objective is to promote EV usage, and the assumption is that battery weights add to vehicle weight, affecting total payload capacity.
    - This is mostly an issue with Heavy Vehicles.
    - There is an expectation that, without such a policy, there would need to be more EV truck trips to haul the same aggregate load or ICE trucks would be preferred.
  - Currently, there are no weight limits coded in the highway network, just truck prohibitions
  - The model would need to add a 4th vehicle class (e.g., “very heavy”) and then code network links where very heavy is prohibited / permitted.
  - To do this well, the model would need to predict and track payload variation and empty backhauls, which is not currently done.

EV Policy Sensitivity (2 of 4)

- Last mile delivery fees
  - Would adding a flat delivery fee to each transaction involving shipping of goods via vehicle with any fuel type other than zero-emission to the customer, especially for residential customers, reduce the number of commercial vehicle last-mile deliveries and reduce commercial VMT? Would it incentivize the use of zero-emission vehicles (electric trucks of any size, or bikes)?
  - Assume that high fees decrease likelihood that customers order goods for delivery, or that they order more products per transaction.
  - Measure substitution of personal shopping trips with purchases to have goods delivered.
- Model Requirements
  - The extra delivery fees would be passed on to the consumer. The decision would be that of the consumer.
  - We do not have data on how much consumers spend on delivered food and other goods or current delivery fees. This would be required to model price elasticity of demand.

EV Policy Sensitivity (3 of 4)

- Delivery speed: same day/next day
  - Would adding a fee on same-day deliveries reduce the number of commercial vehicle last-mile deliveries and reduce commercial VMT?
  - Assume that high fees decrease likelihood that customers order goods for same-day delivery, resulting in more efficient use of delivery vehicles.
- Model Requirements
  - The extra delivery fees would be passed on to the consumer. The decision would be that of the consumer.
  - We do not have data on how much consumers spend on delivered food and other goods or current fees. This would be required to model price elasticity of demand.
  - We do not have information on when consumers placed their orders and whether they were same-day or next-day. We may be able to derive something from Nielsen IQ panelists.

EV Policy Sensitivity (4 of 4)

- Low/zero-emissions zones
  - Would establishing a zone where only zero-emission vehicles could make deliveries increase commercial VMT? Would it increase congestion on roads surrounding the zone?
  - Assuming that the geography is granular enough to be meaningful.
- Model Requirements
  - We would need to code an attribute for those zones in the model and use it to restrict destination choice models
  - To add the desired sensitivity, we would need to bring the vehicle technology (fuel) choice inside the model decision framework.
    - Route level choice of vehicle, purpose, customer types would need to include “EV” as a vehicle alternative.
    - Ideally, there would also be an EV fleet adoption model component, although it could be a simplified table based on scenario inputs.
    - This would not work as well with the proposal to post-process resulting simulated routes and identify those most likely to be EV compatible.

Linkages to Other Special Market Models

- Determine whether existing models represent total coverage of both goods and service trips
  - Not a major concern – to be explored in calibration/validation
  - EI/IE/EE
    - FAF disaggregation process should cover goods movements
    - Evaluate whether service movements from Riverside County are significant
  - Cross Border Model
    - Only residents of Mexico who are in San Diego for some part of the day.
    - Appears not to impact CVM or HTM. If they work for a San Diego establishment, then they would be covered at the establishment.