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Impacts of Autonomous Trucks on Urban Network Performance

Soumya Sharma

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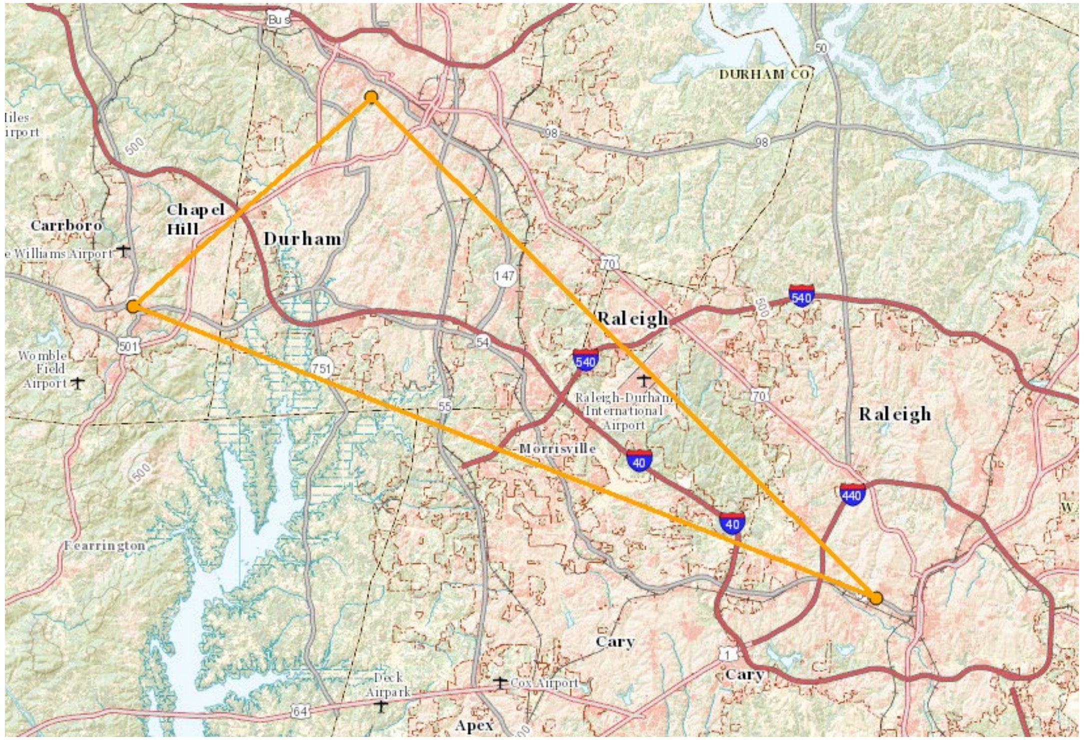
OUTLINE

- Purpose & Scope
  - Level 4 Automation Scenario
  - Level 5 Automation Scenario
- Methodology (Level 4):
  - ✓ Network
  - ✓ Analysis at a Glance
  - ✓ Which Trips are AV?
  - ✓ Trip Matrix Adjustments
  - ✓ Travel Demand Modeling of AV Trips
- Results
- Next Steps (Level 5)
- Acknowledgements



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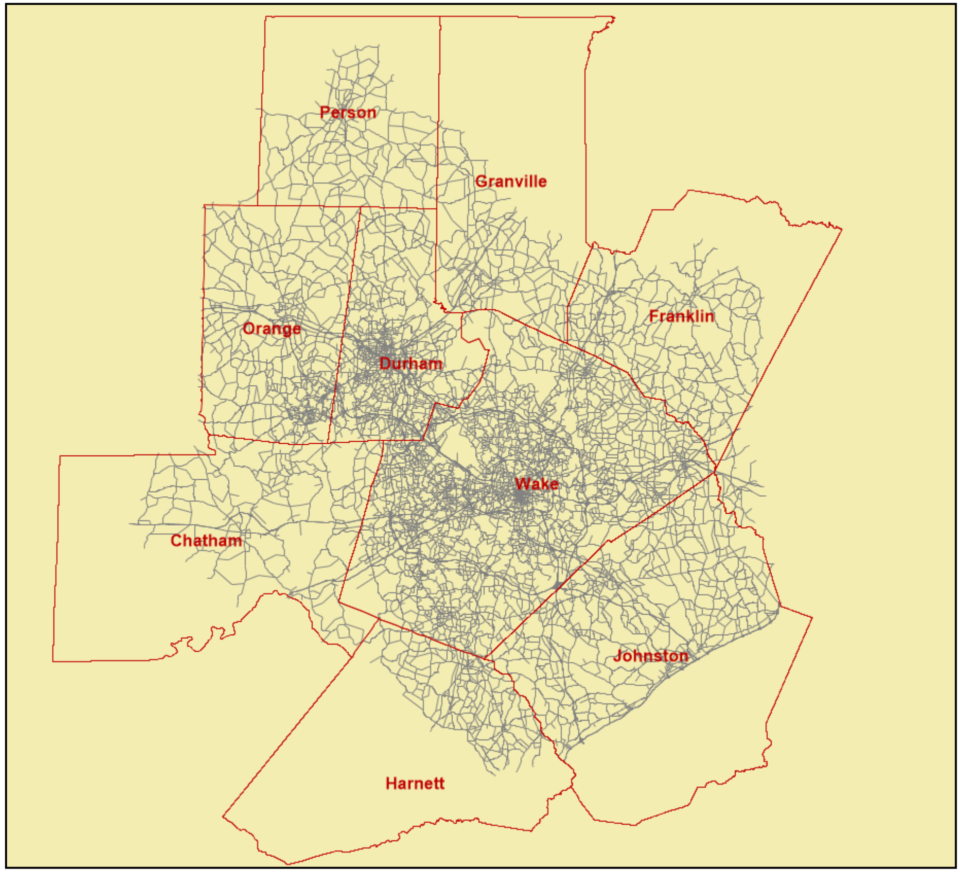
Purpose & Scope

- **Purpose**
  - Assess the impacts of AV trucks on urban networks
  - Identify a methodology for assessing the impacts
  - See if there are special network features needed by AV trucks
- **Scope**
  - **Tool: Triangle Regional Model (TRM)**
  - **Year: 2045**
  - **Network: Triangle Region, North Carolina (Based on SAE[1] Levels of Automation)**
    - Level 4 => AVs on allowable links (limited access facilities, i.e., freeways)
    - Level 5 => Avs allowed everywhere
    - Time period simulations are independent (8 equilibrium assignments)
    - No special assumptions about non-truck trips or vehicle operations
  - **Time periods**
    - All eight (8): AM Peak + shoulders (3), PM Peak + shoulders (3), Midday, Overnight
  - **Trip types**
    - Level 4 => Goods delivery
    - Level 5 => Goods delivery and service
  - **Truck types**
    - Level 4 => Single Unit Trucks (SUTs), Multi Unit Trucks (MUTs)
    - Level 5 => Light Commercial Vehicles (LCVs), SUTs, MUTs



The Triangle Regional Network

1. https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles

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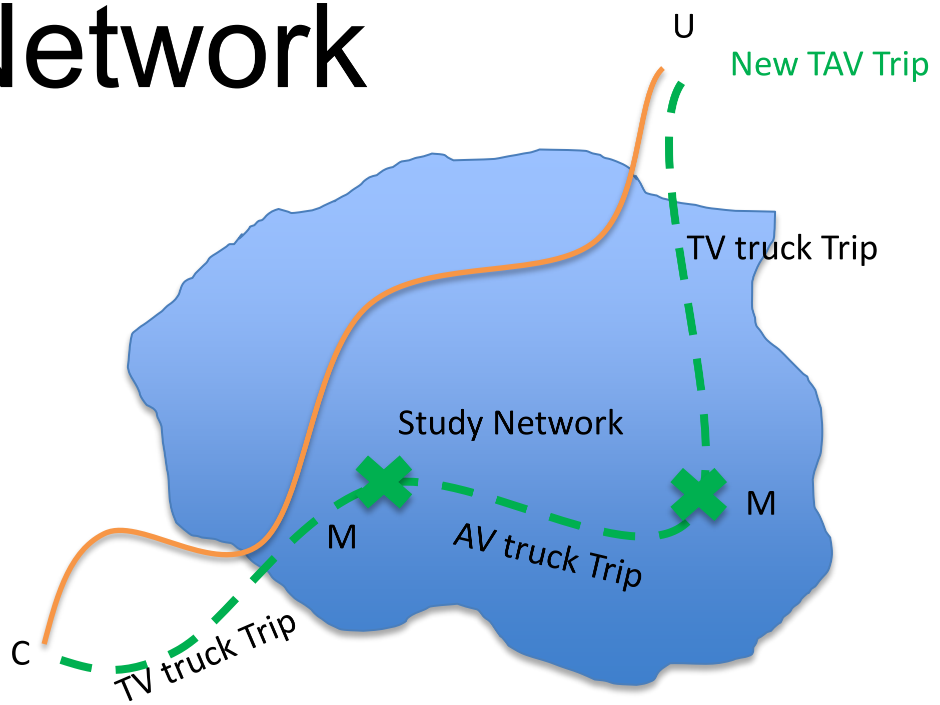
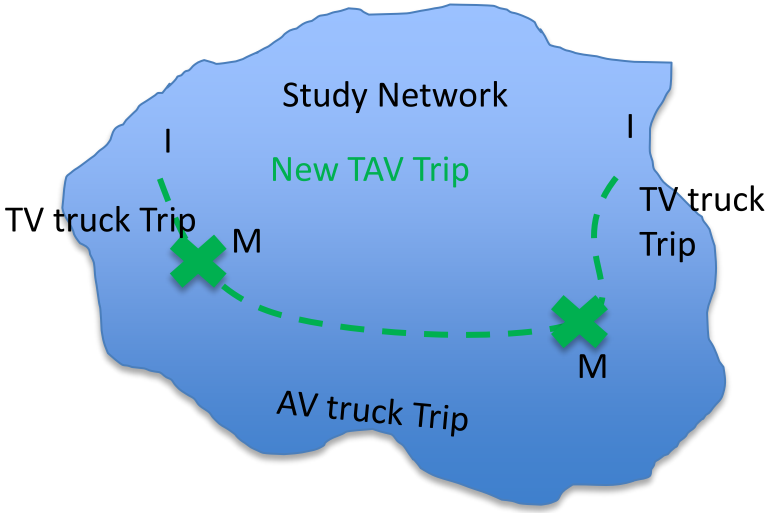
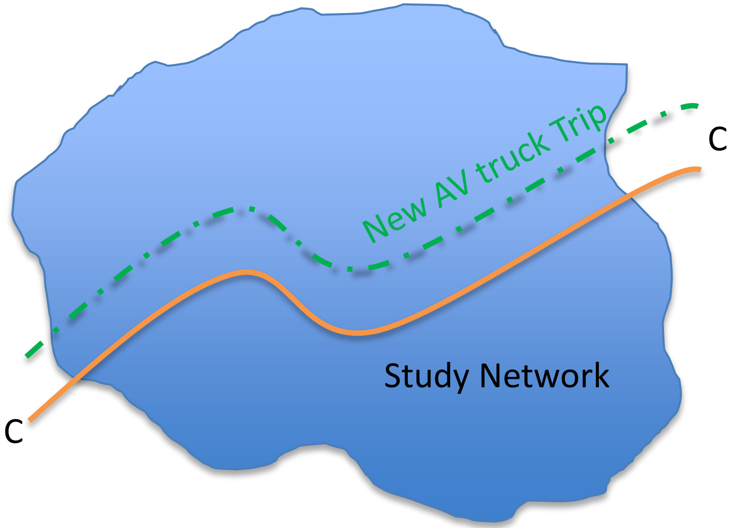
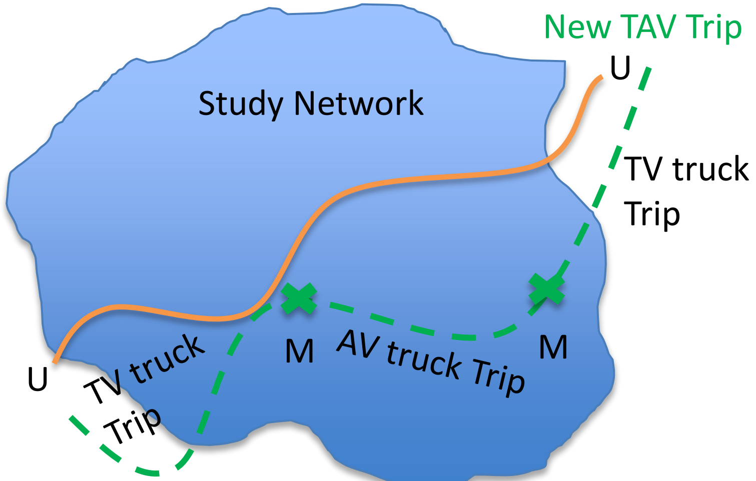
Methodology: The Level 4 Network

- Facility Types: Controlled (freeways), Uncontrolled (surface arterials)
- Traffic Analysis Zones (TAZ) Types: Internal (I), Controlled (C), Uncontrolled (U) and Mode Change Lots (M)
- Mode Change Lots: A TAZ close to high truck-activity areas where AV trucks can start or end an AV trip.
- TV Trips : Traditional Vehicles Trips
- TAV Trips : Traditional & Autonomous Vehicle Trips

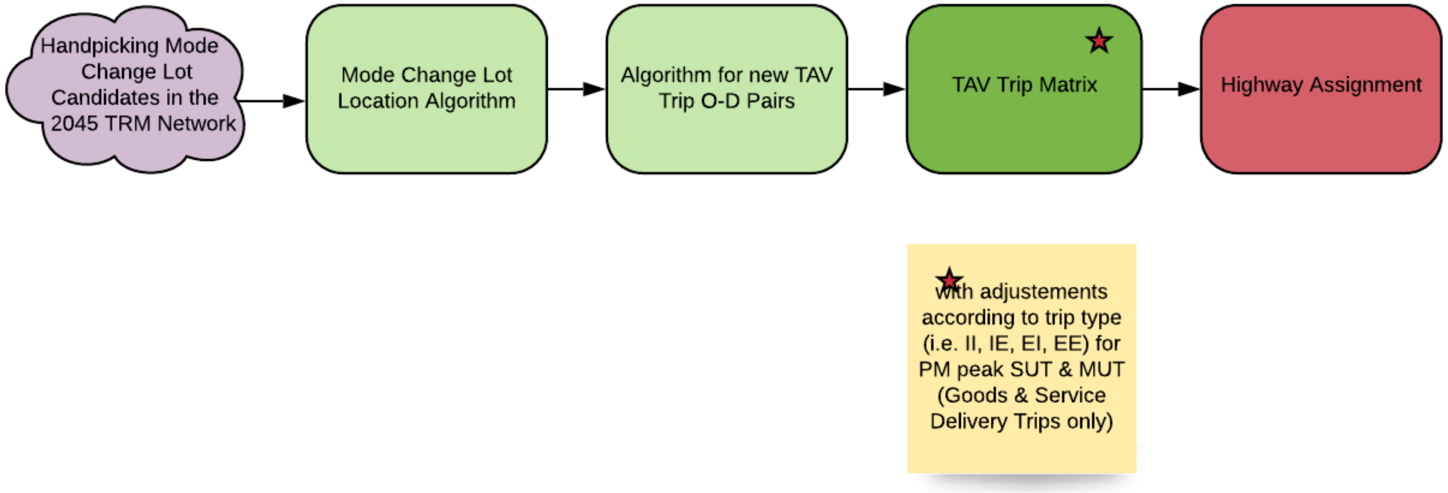








Methodology: The Level 4 Analysis



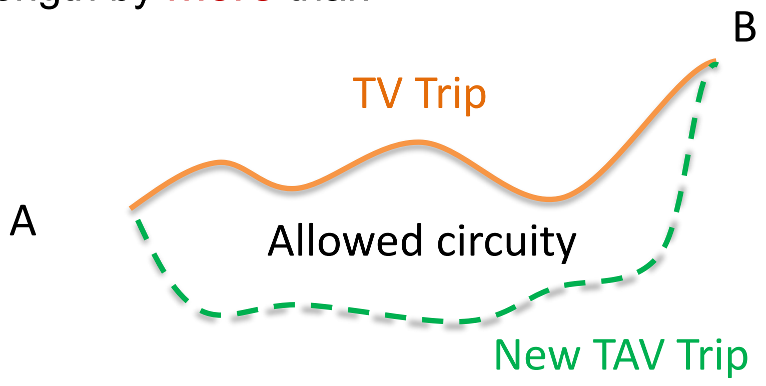
Goals:

1. Adding new AV Trips on controlled facilities
2. Temporal Shifting: Shifting some of the AV trips to off-peak
3. Add new TAV trips with the help of Mode Change Lots

Methodology: Which Trips are AV?

- Total Originating & Terminating (OT) Trips for each TAZ: Minimum OT value threshold to be chosen as a MCL
- Diversion percentage (*P*)
  - Indicates what percentage of the trips would become AV trips if the network conditions are favorable
  - 30% and 100% considered
- Only the controlled facility portions of the trips could become AV
  - C-M, M-C, M-M
- Decide based on circuity (*β*)
  - Distance penalty for an AV Trips increasing the trip length by more than 30% of the original trip length
  - Else, they stay TV Trips (100%)

Level 4 Scenarios	Scenario 1	Scenario 2
Diversion Percentages	30%	100%
Allowable circuity	15%	15%
Minimum OT for each TAZ	200	200
Minimum miles between MCLs	20	20



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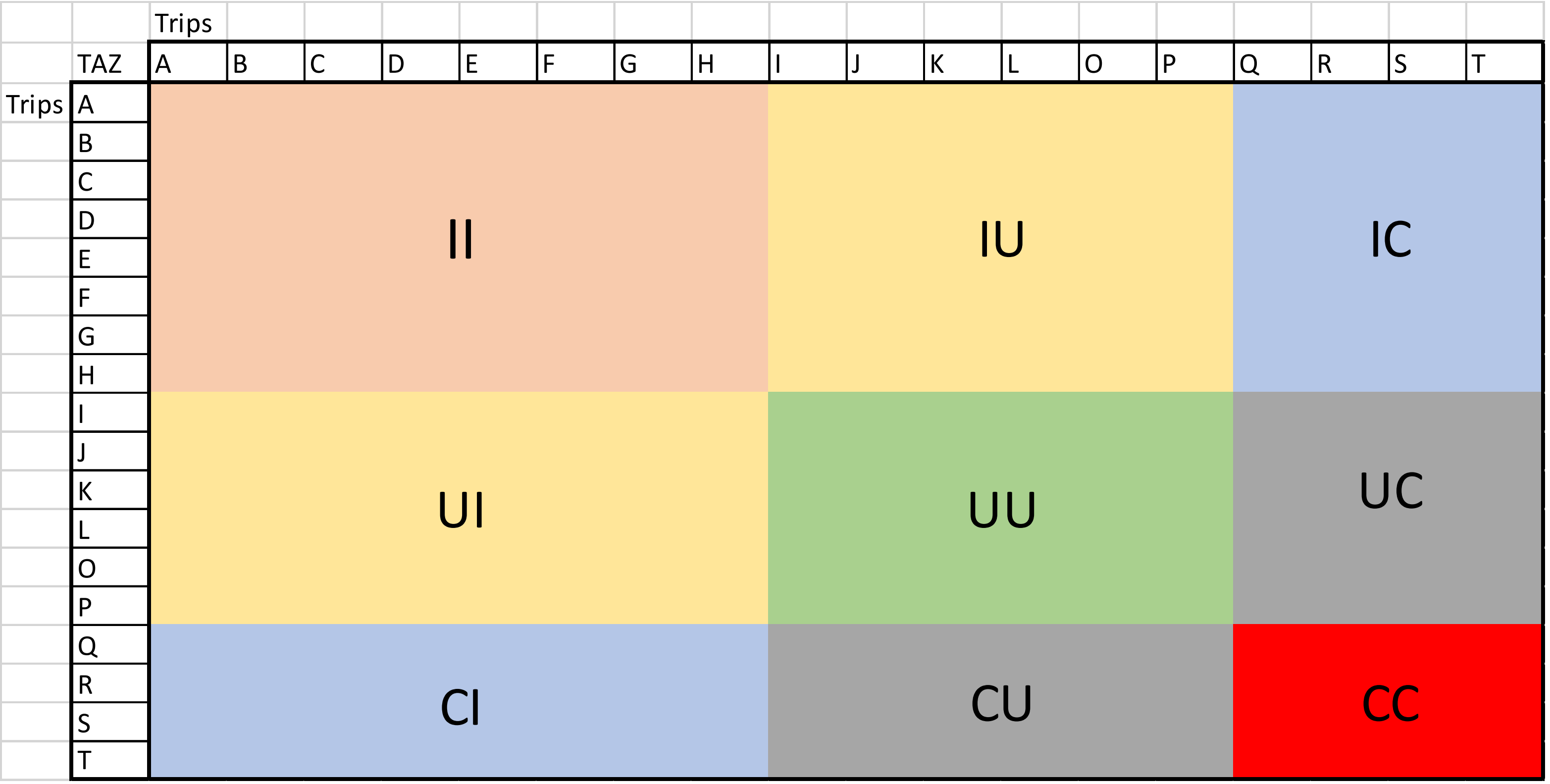
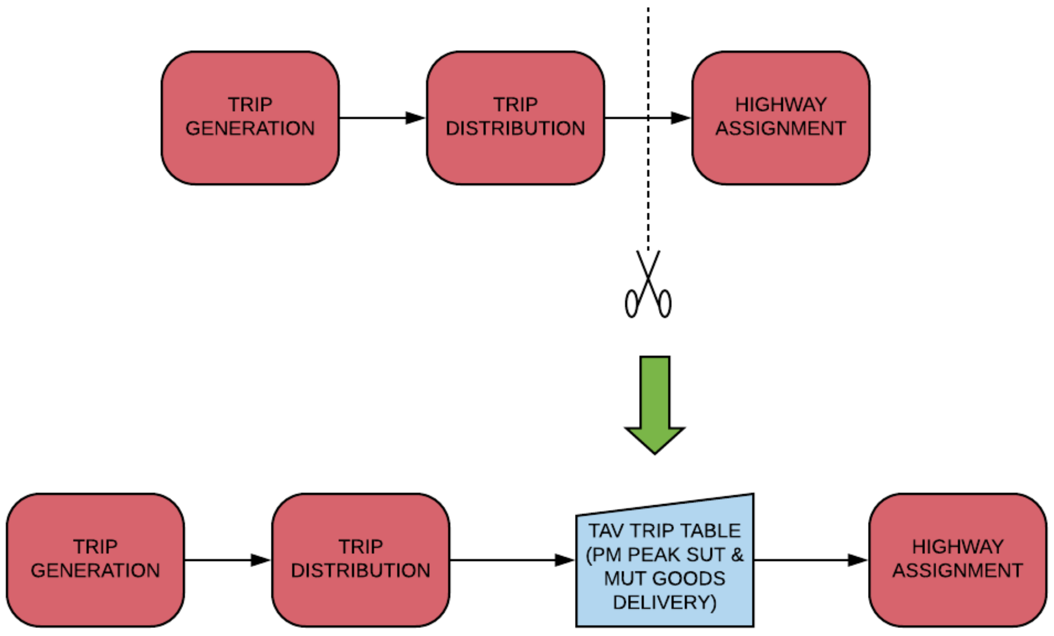
Methodology: Trip Matrix Adjustments

- **Visualization:**
  - Sample **T** shown below: PM MUT Goods delivery Trips.
  - **Partitions into 8 sub-matrices:** CC, CU, CI, UC, UU, UI, IC, IU, and II



Original Trip Table Sample

Methodology:
Travel Demand Modeling for TAV trips



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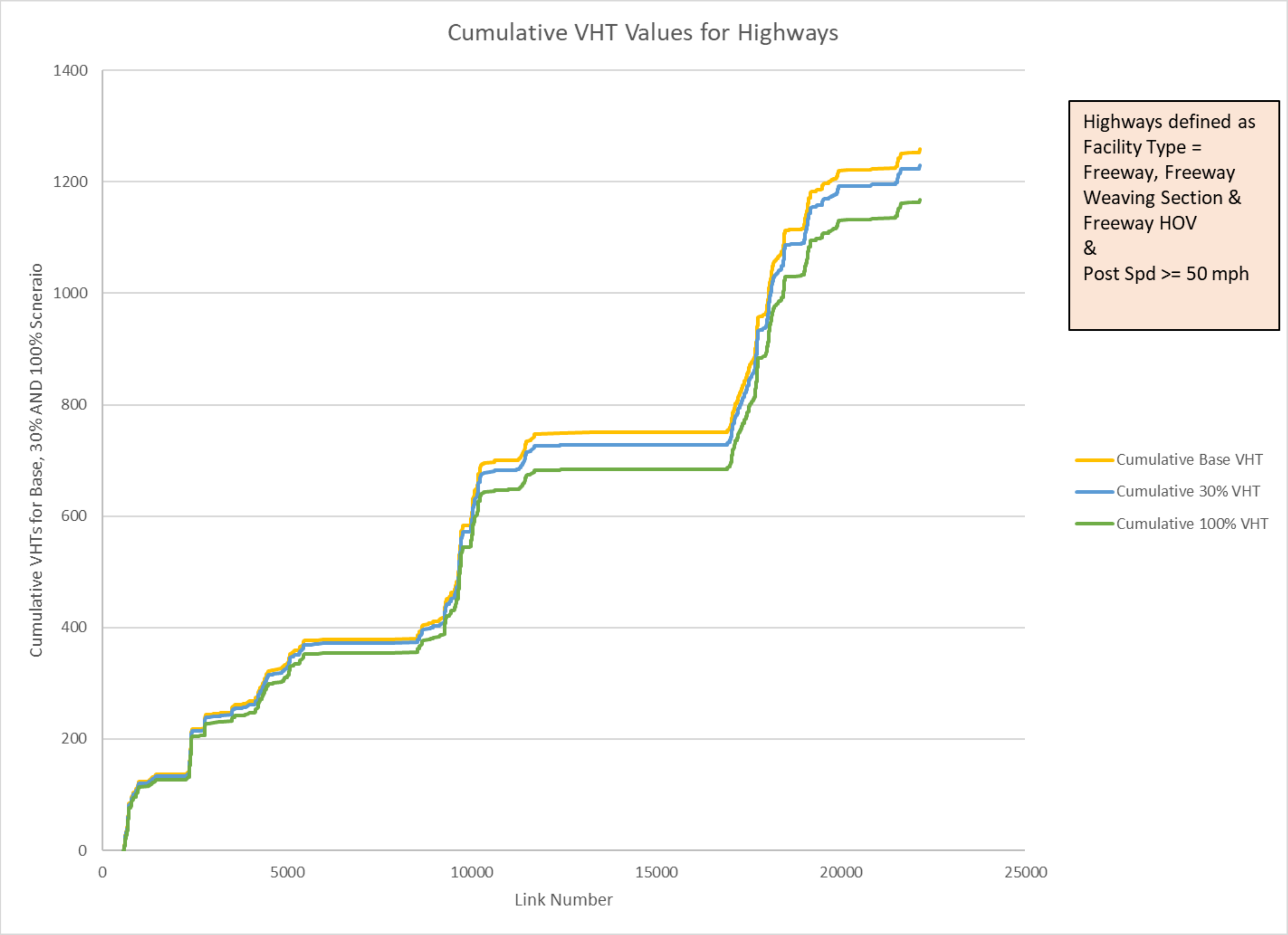
RESULTS



Next Steps

- Level 5 Analysis Coming Up ..
  - Autonomous trucks can use all parts of the network
  - Specific percentage of TV trips
  - Shift trips out of the peaks
  - Change PCE values
  - Change Impedances for trucks on links (e.g. high for surface arterials)

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ACKNOWLEDGEMENT

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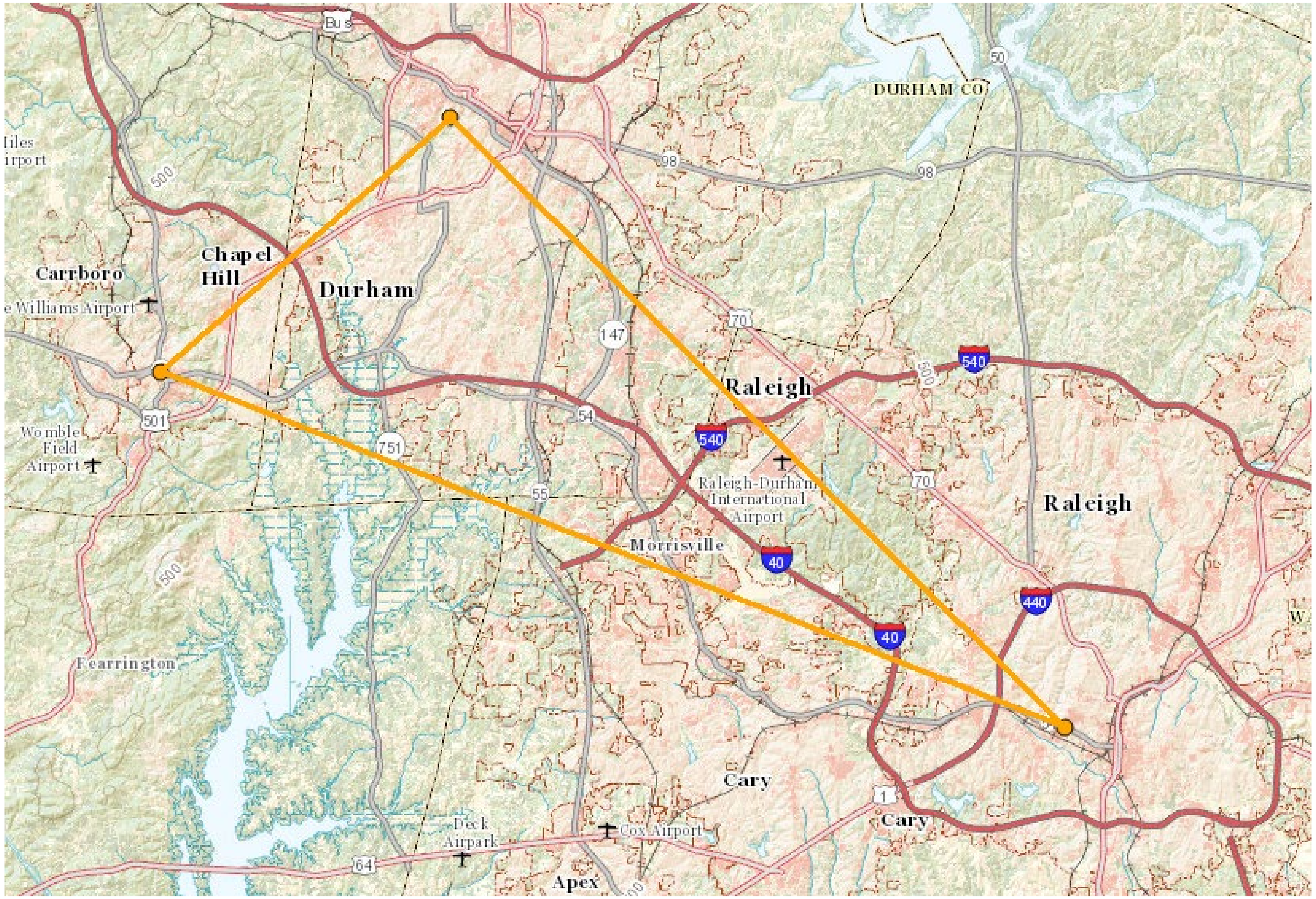
QUESTIONS ?



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Congestion-Aware Vehicle Routing Based on Wireless Networking Paradigms

Vishwa Alaparthy, Duke University

PI: Missy Cummings, Duke University

Motivation

What are we trying to accomplish?

- Design a route planning algorithm for vehicles operated from a dispatch center, which also alleviates congestion.

Why an analogy with wireless protocols?

- Distributed system decreases delay, overhead rather than centralized.
- Easy to implement for a dispatcher.
- Less overhead at the dispatcher location.
- No large computing clusters needed

AODV: Adhoc on demand distance vector routing

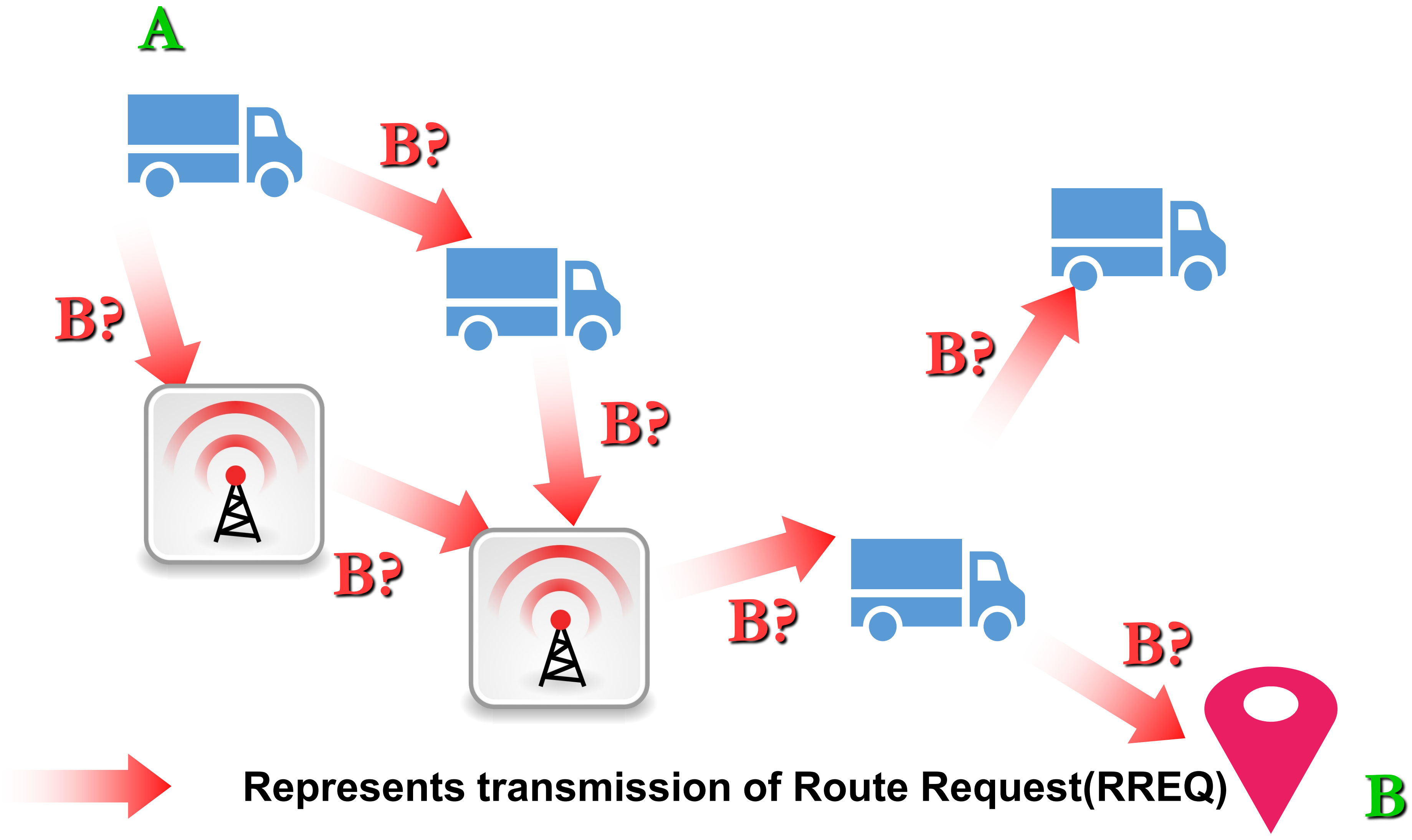
What is it?

- Used in MANETS for on demand routing.

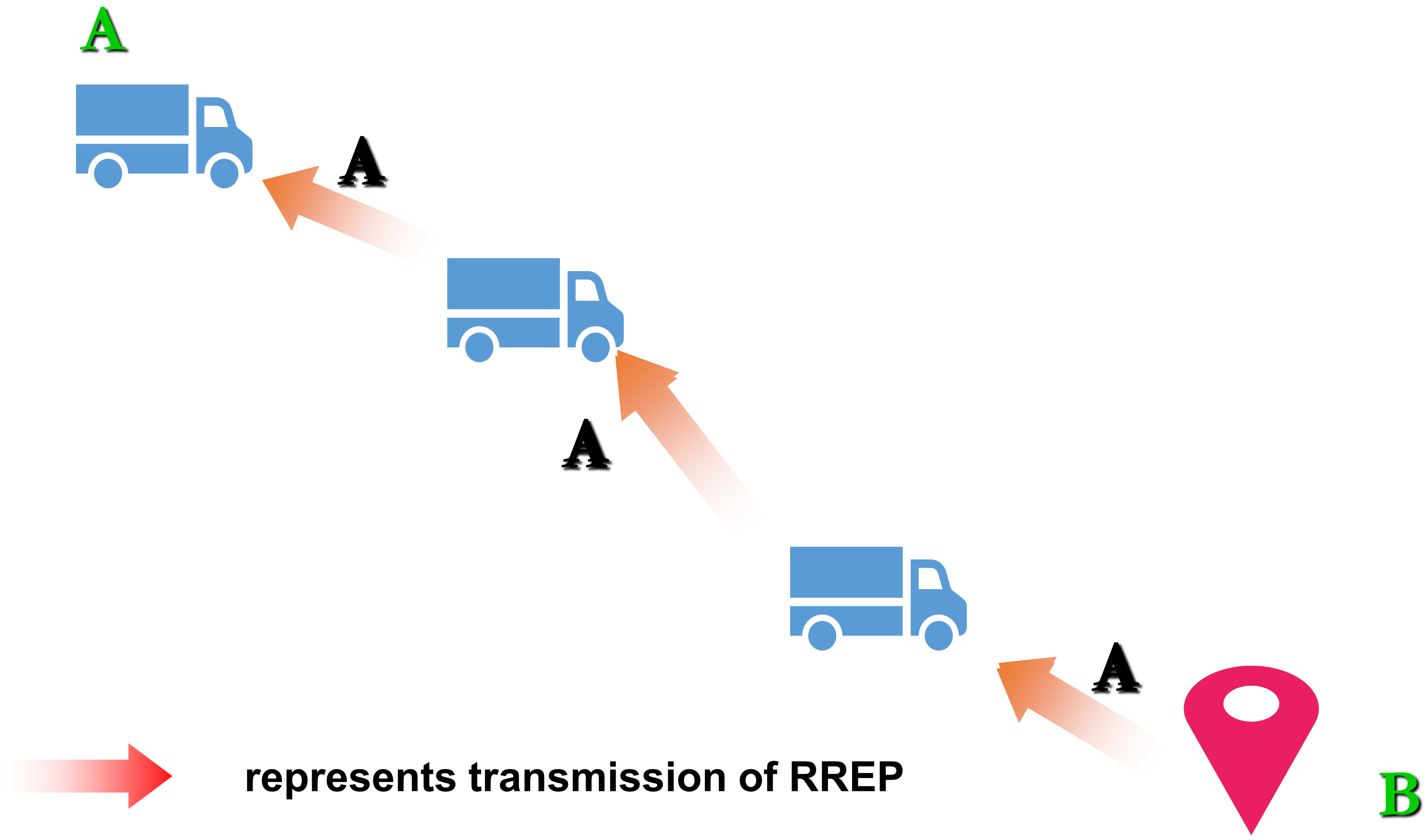
Why is it appropriate?

- Simple
- Establishes routes on demand
- Reacts and adapts to changes in the topology or environment quickly.
- Recency of routes can be preserved

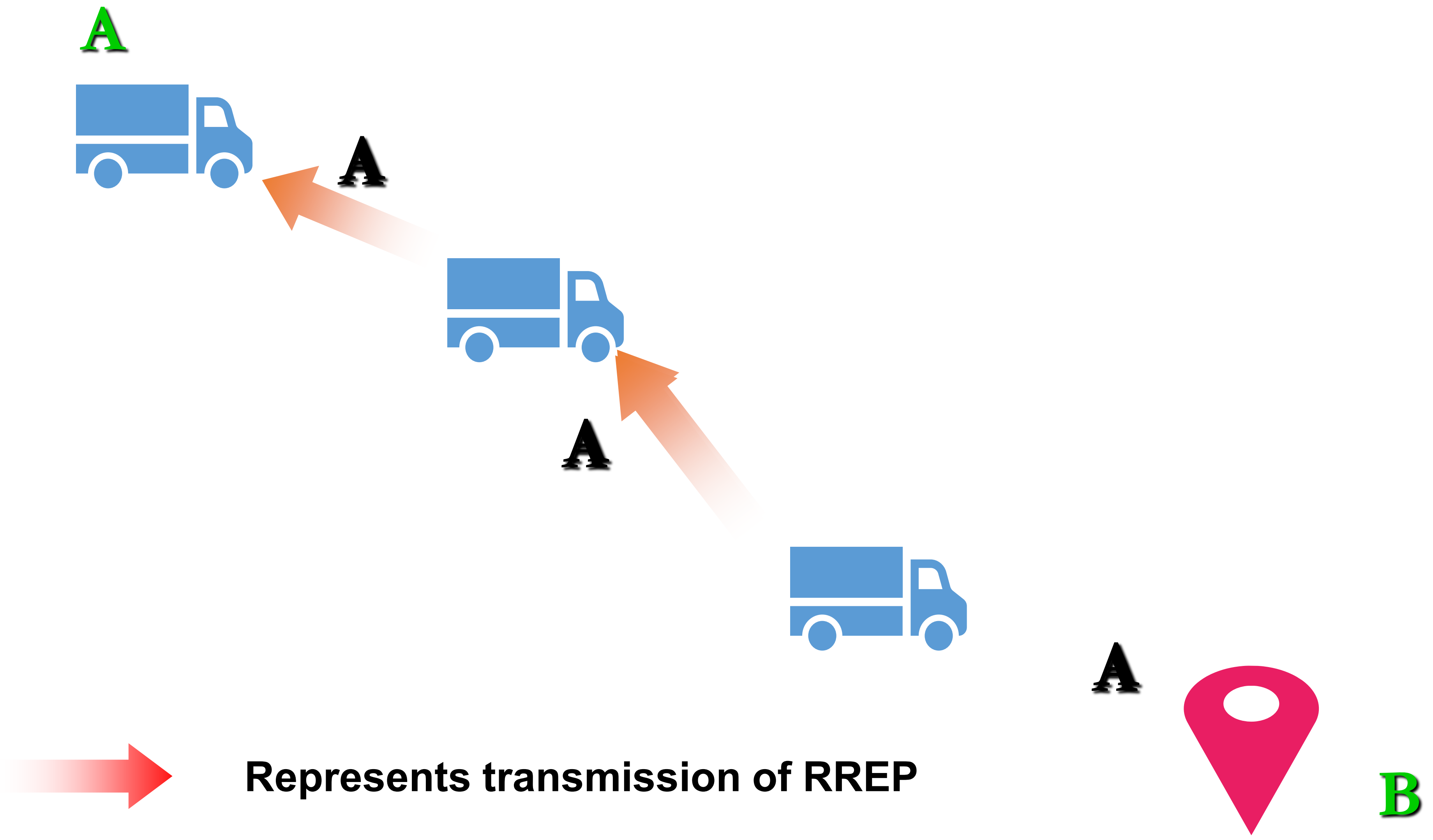
Deriving an Analogy



Route Reply (RREP) message



RREP Message, when an intermediate node has a route to the destination



Control Messages

Control Messages	AODV	Connected Vehicles
RREQ	broadcasted to neighbor nodes	used to establish a route between the vehicle and the destination.
RREP	reply from destination	used to establish a route and update all route tables in that route
RERR	route error message, for link breakage	used to determine if the road is under repair or closed permanently.
HELLO	periodic pings to know route or neighbor status.	used to monitor road status

Which path to choose?

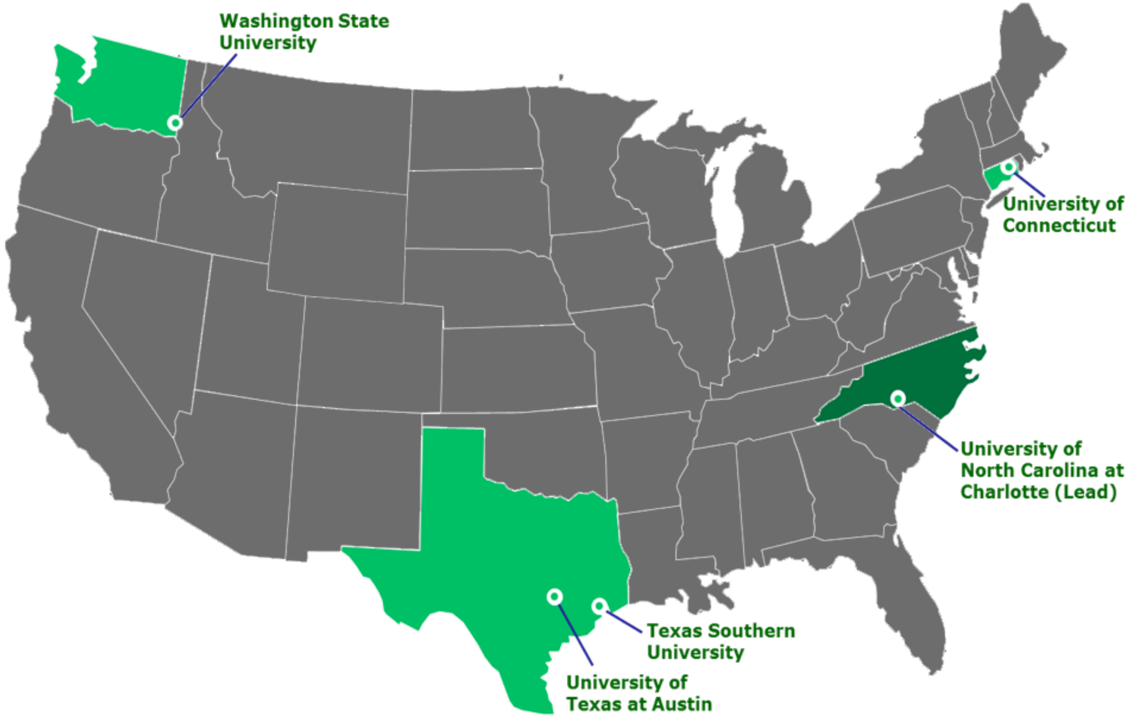
use weighted shortest path

Few factors influencing weights:

- Speed limit
- Congestion
- Number of lanes
- Direction
- Traffic lights
- School Zones

Thank you!

CAMMSE



Optimizing Transit Equity and Accessibility by Integrating Relevant GTFS Data Performance Metrics (TGI)

Wednesday, October 14, 2020 | Yang Li, Ph.D.

UNC CHARLOTTE

The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

Acknowledgements

The authors want to express their deepest gratitude to the financial support by the United States Department of Transportation, University Transportation Center through the Center for Advanced Multimodal Mobility Solutions and Education (CAMMSE) at The University of North Carolina at Charlotte (Grant Number: 69A3551747133)

Transit Gap Analysis (TGI)

$$TSS_j = TSC_j \times D_j$$

$$TSC_j = \frac{RUC_j}{RUT_j}$$

$$D_j = \frac{\sum_i \frac{\sum_l F_l \times C_l \times RUC_{lij}}{RUC_i}}{P_j}$$

- TSC_j - Transit stop/station coverage ratio of blockgroup j
- RUC_{ij} - Number of residential units covered by stop i within 0.5-mile walking catchment area in blockgroup j
- RUT_j - Total number of residential units in blockgroup j
- D_j - Per capita maximum daily available seats of blockgroup j
- F_l, C_l - Frequency and per bus capacity of route l, respectively
- RUC_{lij} - number of residential units covered by stop i along route l within 0.5-mile walking catchment area in blockgroup j
- RUC_i - number of residential units covered by stop i within 0.5-mile walking catchment area
- P_j - Total population in blockgroup j

+

$$TDS_j = TD_j$$

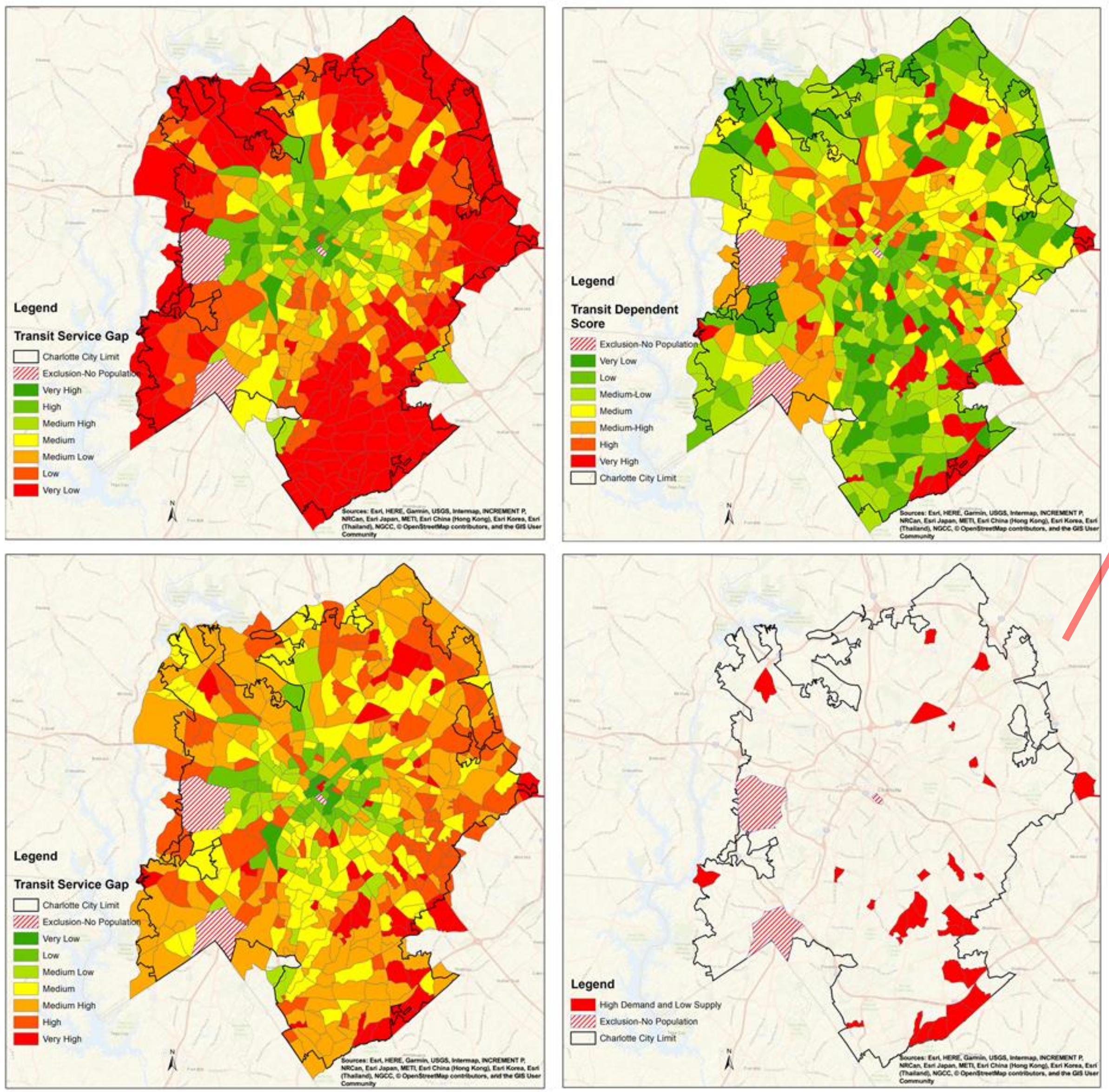
- **Household drivers** = (population age 16 and over) – (persons living in group quarters)
- **Transit-dependent household population** = (household drivers) – (vehicles available)
- TD_j **= Transit-dependent population** = (transit-dependent household population) + (population ages 10-15) + (non-institutionalized population living in group quarters)

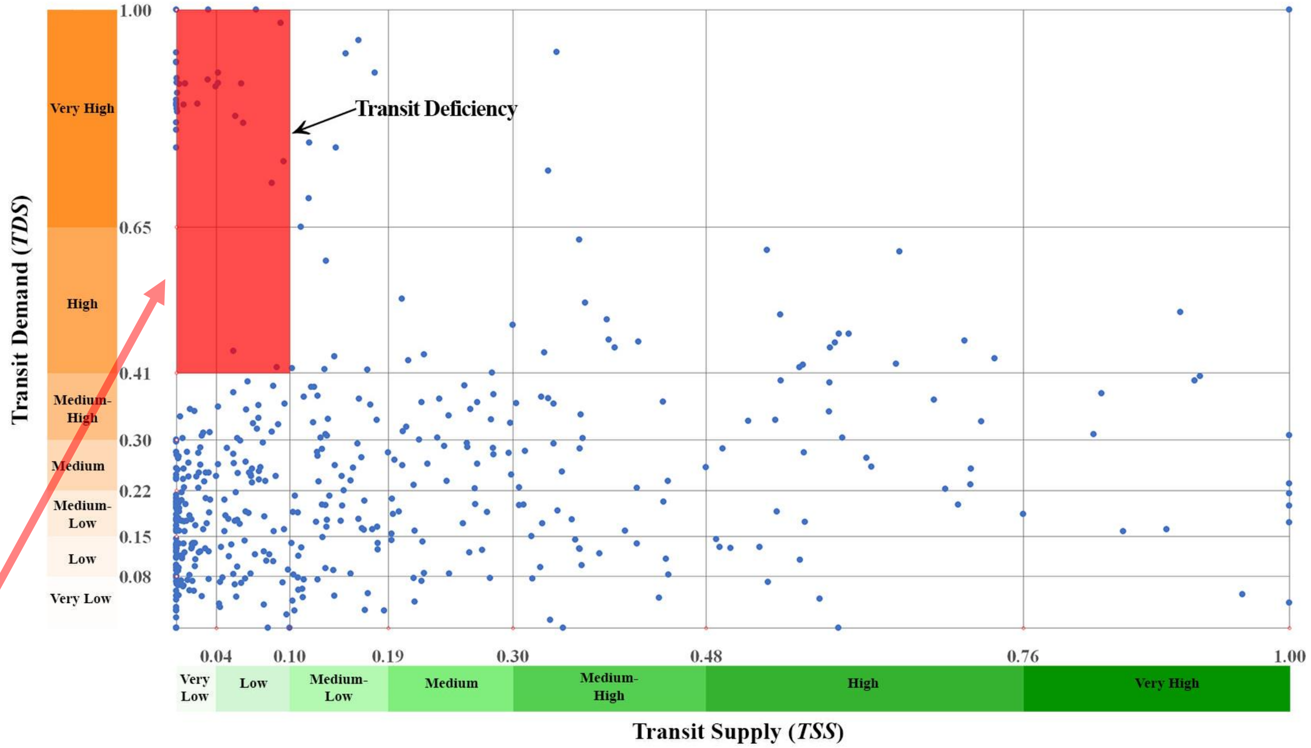
=

$$TGI_j = TSS'_j - TDS'_j$$

Normalization (Feature Scaling): $X' = \frac{X - X_{\min}}{X_{\max} - X_{\min}}$

Result of Transit Gap Analysis (TGI)





❑ The objective is to optimize the transit equity by mitigating the transit deficiency based on the results of *TGI*.

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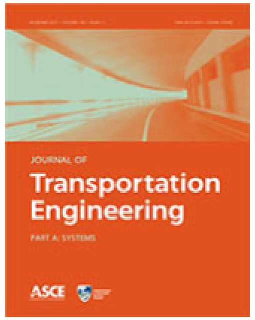

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CAMMSE

Center for Advanced Multimodal Mobility Solutions and Education

Project ID: 2018 Project 02

USING GENERAL TRANSIT FEED SPECIFICATION (GTFS) DATA AS A BASIS FOR EVALUATING AND IMPROVING PUBLIC TRANSIT EQUITY

Final Report

by

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September 2018

Optimization Models for Improving Transit Equity

- Model with Limited Budget

$$\text{Minimize} \sum_{i\in I} TGI_i'^2 = \sum_{i\in I} (TSS_i'' - TDS_i')^2 = \sum_{i\in I} \{(D_i + \frac{a_i x_i}{P_i \times TSS'_{\max}}) \times [1 - z_i + z_i \times TSC_i] - TDS_i'\}^2 \quad (1)$$

Subject to:

$$\sum_{i\in I} c_i x_i \le B, \forall i \in I \quad (2)$$

$$TSS_i'' \le TDS_i', \forall i \in I \quad (3)$$

$$0 \le x_i \le s_{\max}, \forall i \in I \quad (4)$$

$$z_i \in \{0,1\}, \forall i \in I \quad (5)$$

B – total budget

$I = \{1, 2, ..., 28\}$

P_i – population of blockgroup i;

$TSS'_{\max} = 100$;

$s_{\max}$ – the maximal no. of stops that can be added to one blockgroup;

c_i – cost for constructing new stop in blockgroup i;

a_i – average capacity of stop for blockgroup i;

x_i – decision variable, the no. of stops constructed in blockgroup i;

z_i – indicator, if $x_i = 0$, then $z_i = 1$, otherwise $z_i = 0$.

Numerical Results of Optimization Models

- Budget Information

Charlotte Area Transit System

Department Services (Focus Area)	FY 2015 Actual/ FTEs	FY 2016 Actual/ FTEs	FY 2017 Revised/ FTEs	FY 2018 Budget/ FTEs
	84,102,957 12.00	82,385,555 12.00	84,233,552 13.00	84,912,399 13.00
	12,294,077 111.00	13,394,899 146.00	18,751,711 225.00	24,373,103 225.00
	8,283,488 45.00	8,460,746 45.00	10,587,851 51.00	10,876,895 51.00
	8,957,998 109.75	9,520,710 109.75	9,508,131 115.75	10,280,528 115.75
	6,056,000 12.00	6,203,750 12.00	6,890,656 17.00	8,711,645 17.00
	4,173,765 42.00	5,245,646 42.00	5,530,573 44.00	6,882,247 44.00
Transit Facilities (Transportation and Planning) Manages and maintains light rail facilities, Park and Ride Lot, parking decks, bus garages, transit centers, and bus stops	5,411,637 12.00	5,925,558 12.00	5,737,159 14.00	8,337,458 14.00

- Other Parameters Information

➢ Potential stops' capacities (a_i) (each blockgroup)

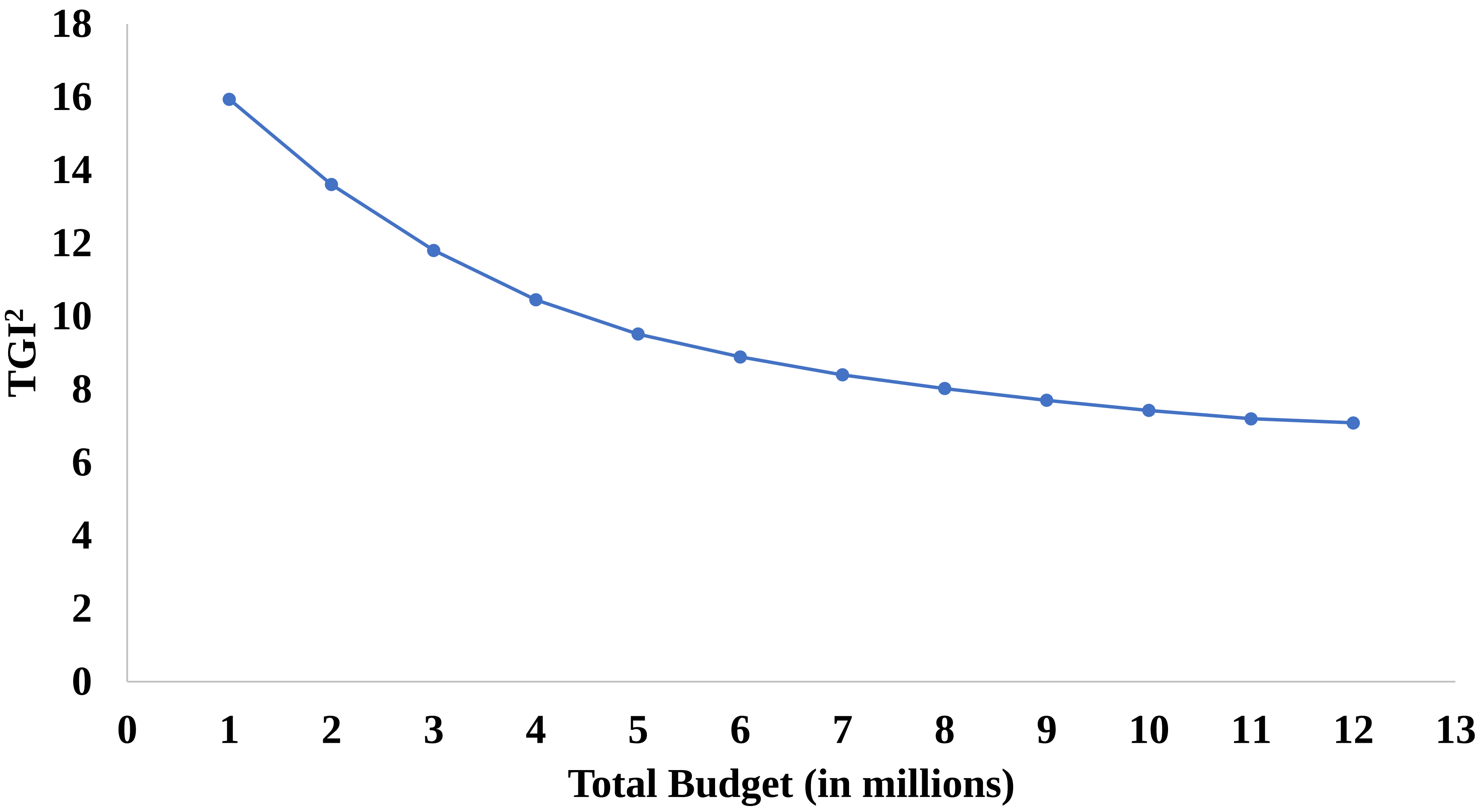
Blogkgroup ID	Potential Stops' Capacities
371190015071	2960
371190015083	3000
371190019153	3600
371190020024	3240
371190020031	4360
371190029041	320
371190030072	320
371190030073	320
371190030112	2120
371190030152	2080
371190030153	2080
371190030162	2080
371190031023	2920
371190053082	3480

Blogkgroup ID	Potential Stops' Capacities
371190055133	3160
371190055233	3680
371190055246	3160
371190056212	400
371190058231	400
371190058232	400
371190058373	1920
371190058451	480
371190058461	480
371190058462	400
371190058471	400
371190058482	400
371190059072	2160
371190060101	240

➢ The maximal number of stops (s_{max}) is set to 40.

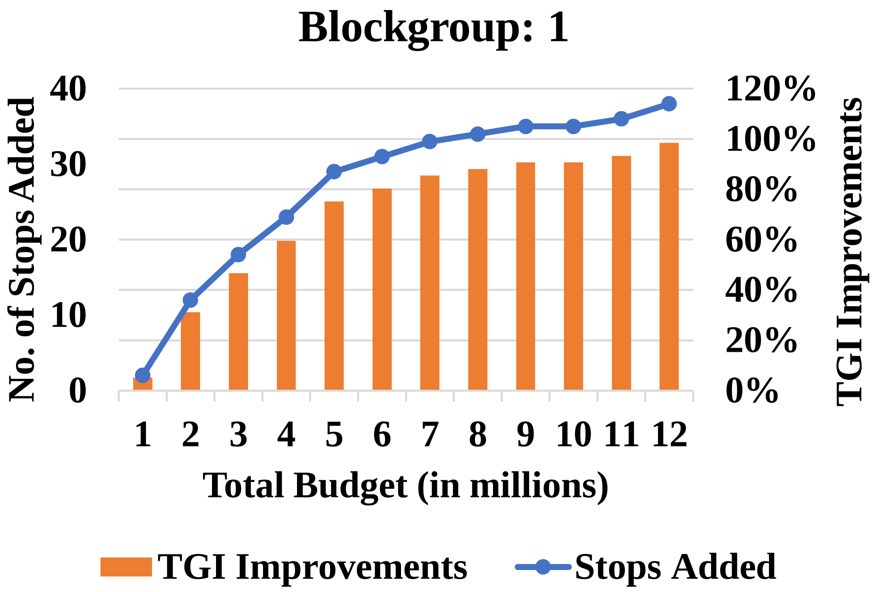
➢ The construction cost (c_i) for one stop is about $12,000, according to some reports and online sources.

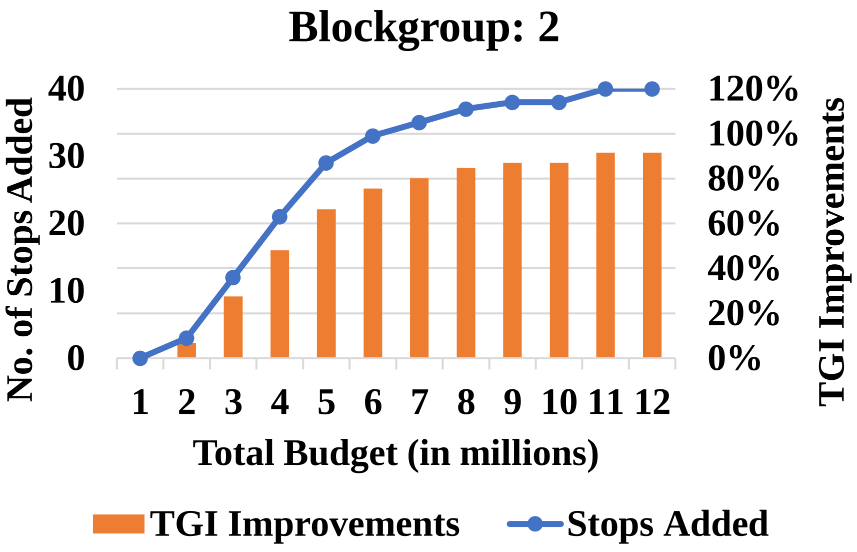
Numerical Results of Optimization Models

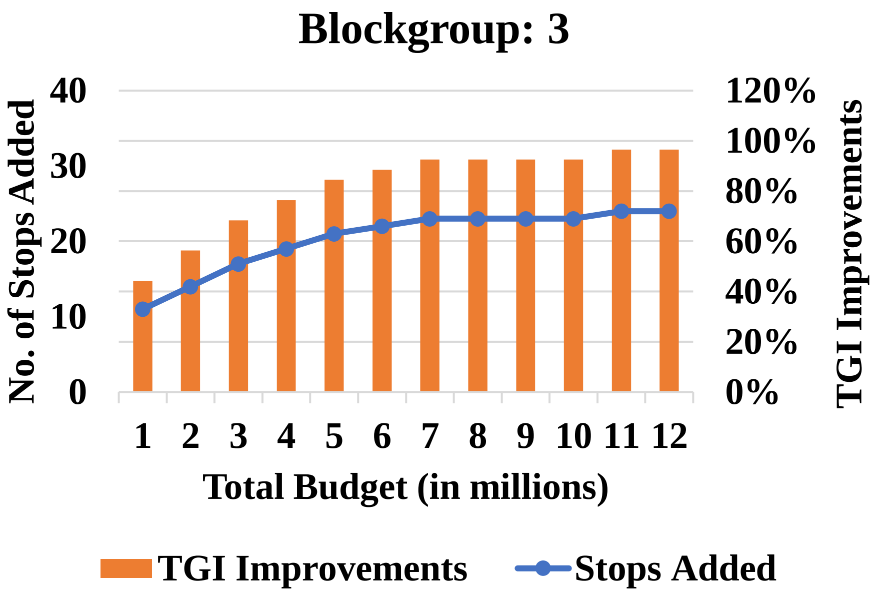


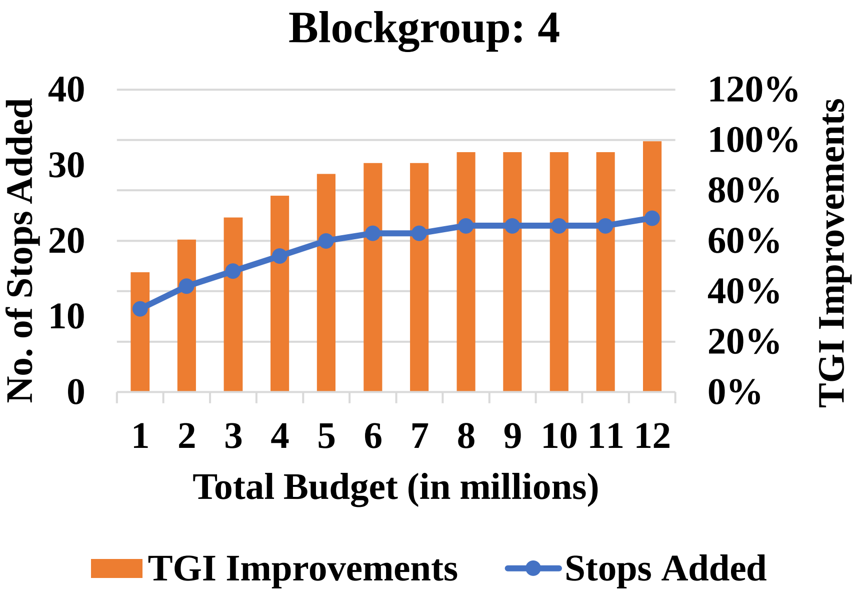
Changes of Objectives (TGI^2) with Changes of the Limited Budget Constraints

Numerical Results of Optimization Models









Conclusions

- A comprehensive review of the state-of-the-art and state-of-the-practice on public transit equity optimization, especially those with optimizing the use of performance metrics utilizing GTFS data, has been conducted;
- Model with limited budget constraint that is aiming at improving transit equity and accessibility for people by integrating performance metrics with using GTFS data was developed;
- A case study with was designed to show the capability of model and results were also presented.

THANKS