Dynamic Transit Modeling

(User Equilibrium + System Optimal)

North Carolina A&T State University
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MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

CHART

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URBAN PLAN. & ENG.

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MULTIMODAL TRANSPORTATION INCENTIVIZING TRAVELERS WITH PREDICTION, OPTIMIZATION AND PERSONALIZATION

SEOUL MPO BUS INFORMATION SYSTEMS

I-95 CORRIDOR COALITION

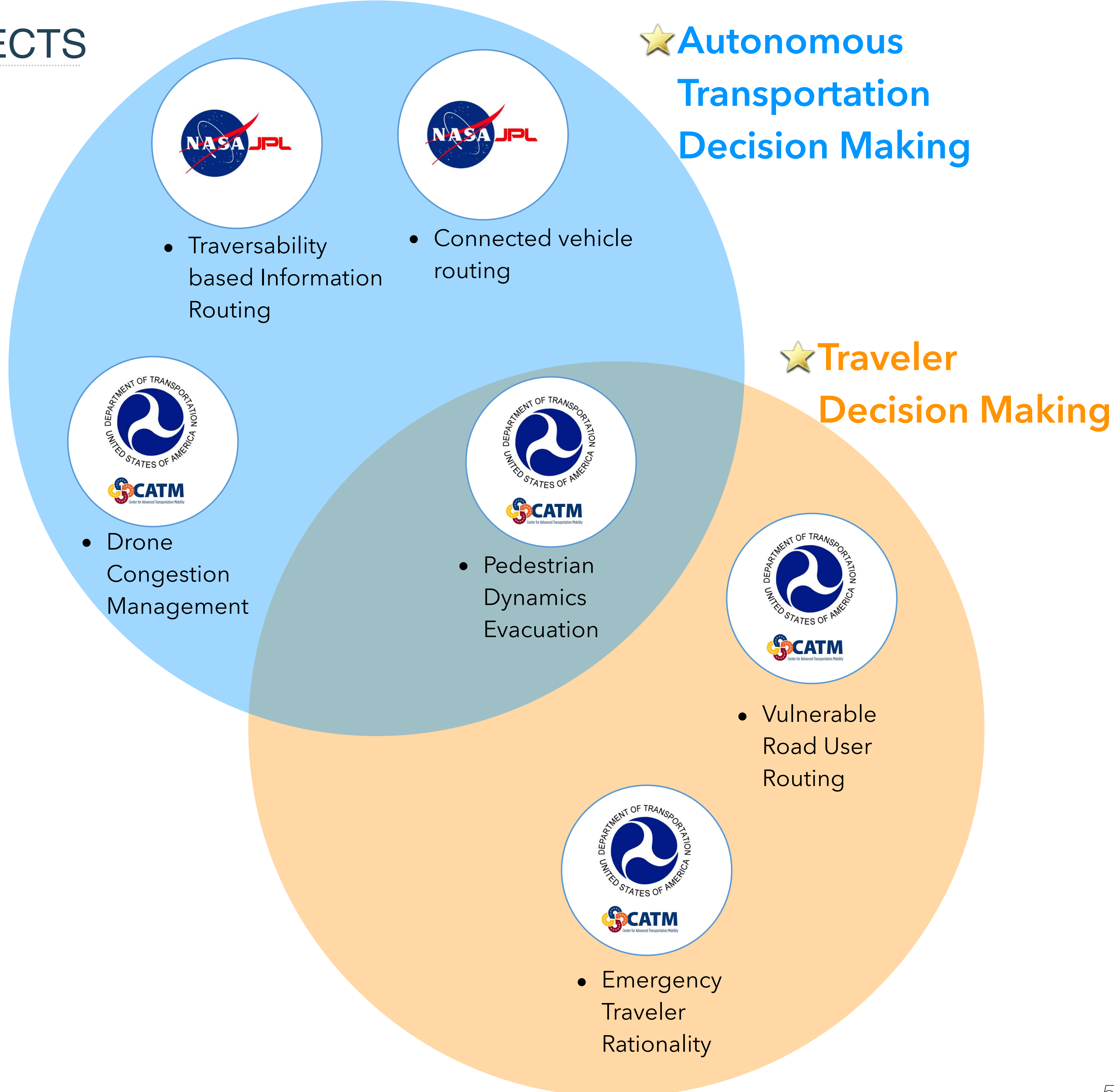
I-95 CORRIDOR VEHICLE PROBE PROJECT: INRIX VALIDATION

CURRENT PROJECTS

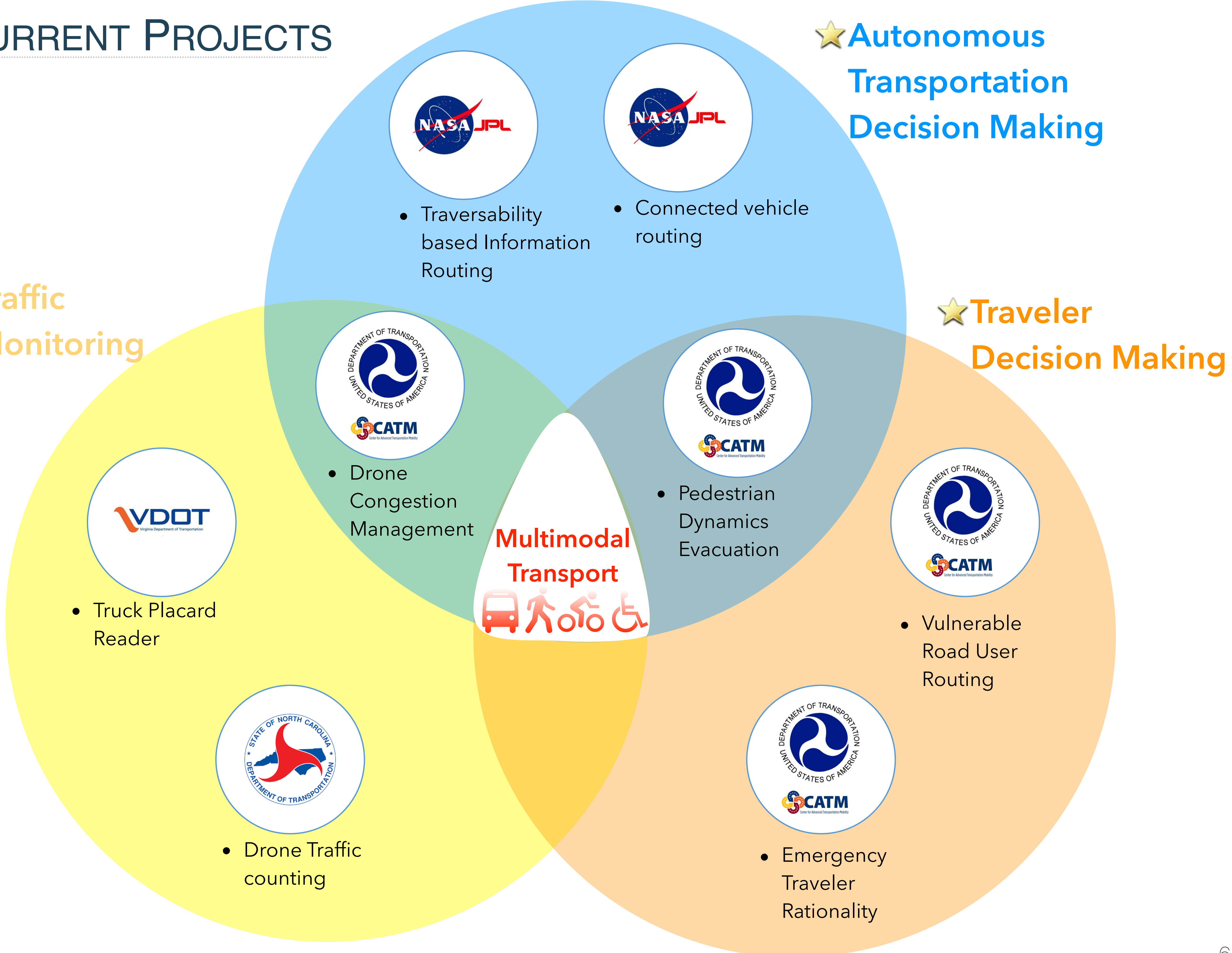
Traveler Decision Making

- Pedestrian Dynamics Evacuation
- Vulnerable Road User Routing
- Emergency Traveler Rationality

Current Projects

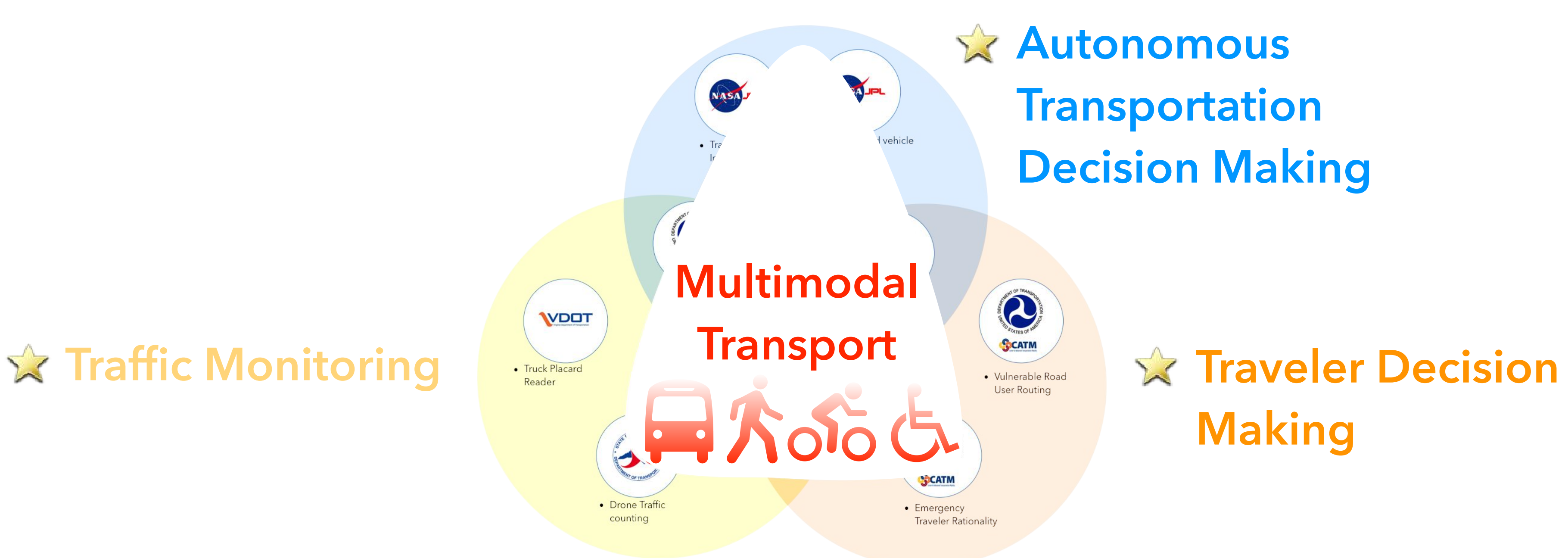


Current Projects



THREE CONTRIBUTIONS

1. Walk + Transit network fully integrated in a dynamic transit for various travelers.
2. Motivating travelers to switch to public transit with an app-based trip planner.
3. Cloud source managing missing information with uncertainty



Three Contributions

1. Walk + Transit network fully integrated in a dynamic transit for various travelers.

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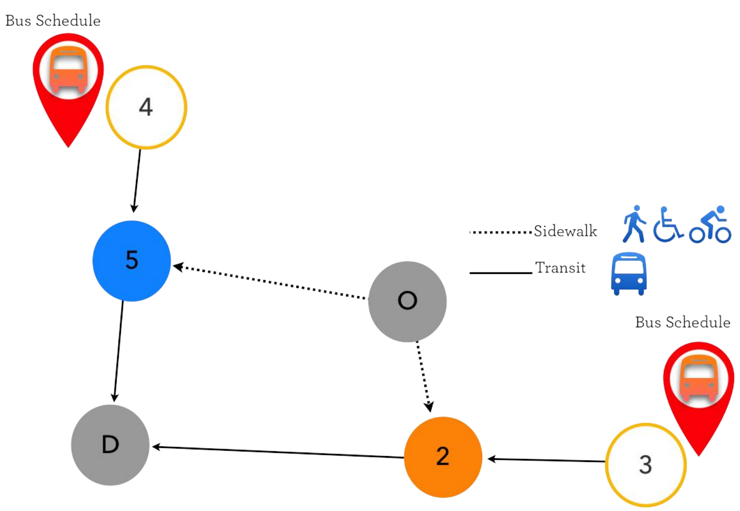
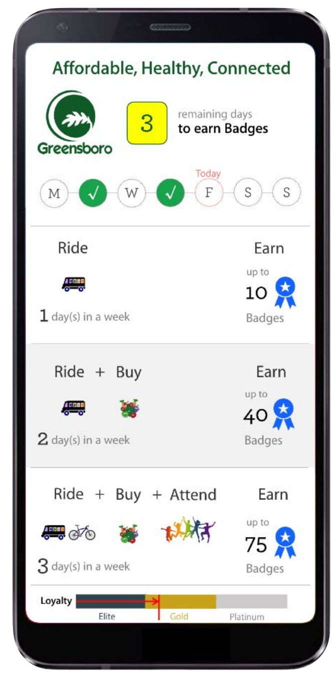
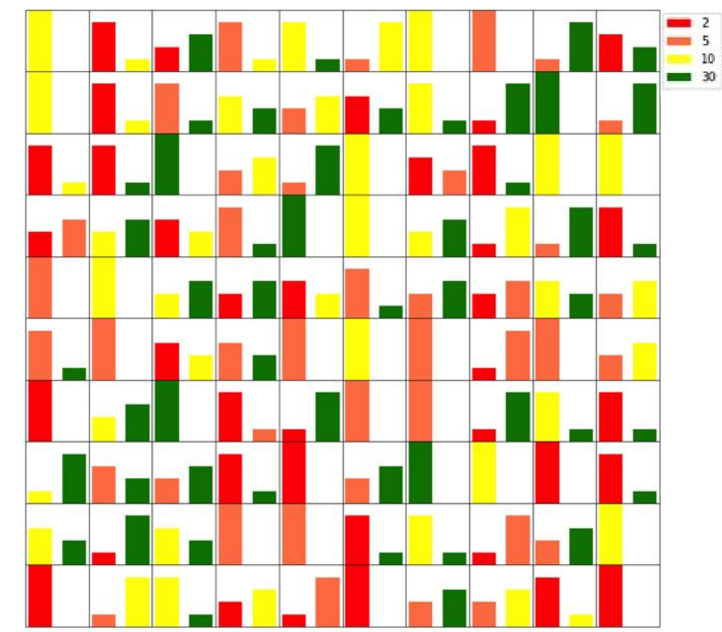
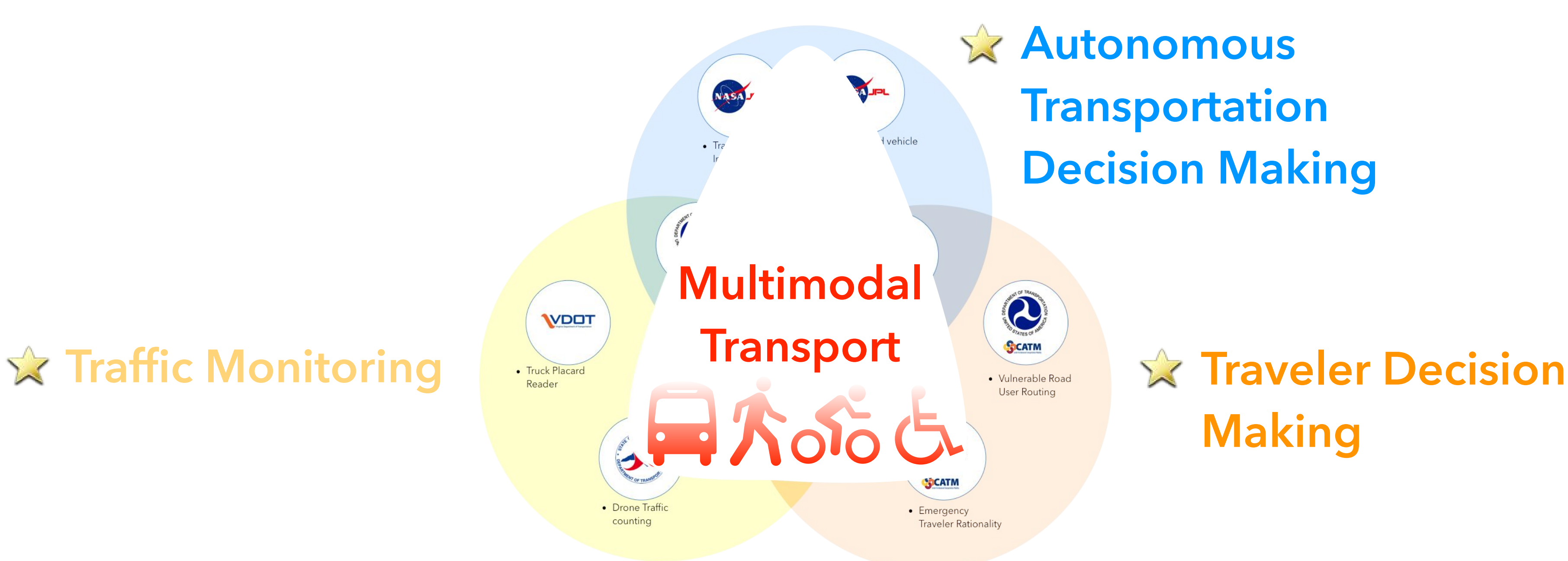
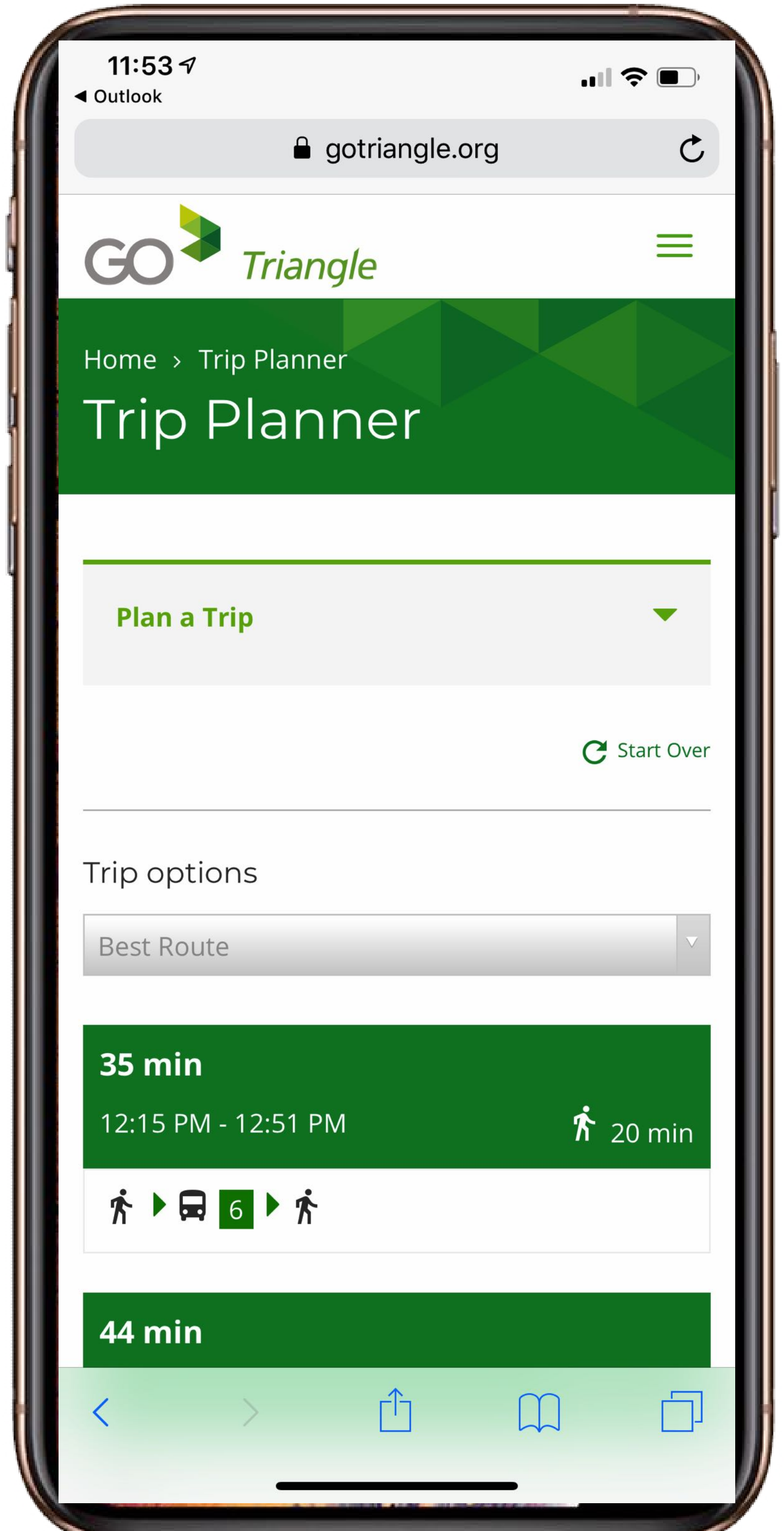






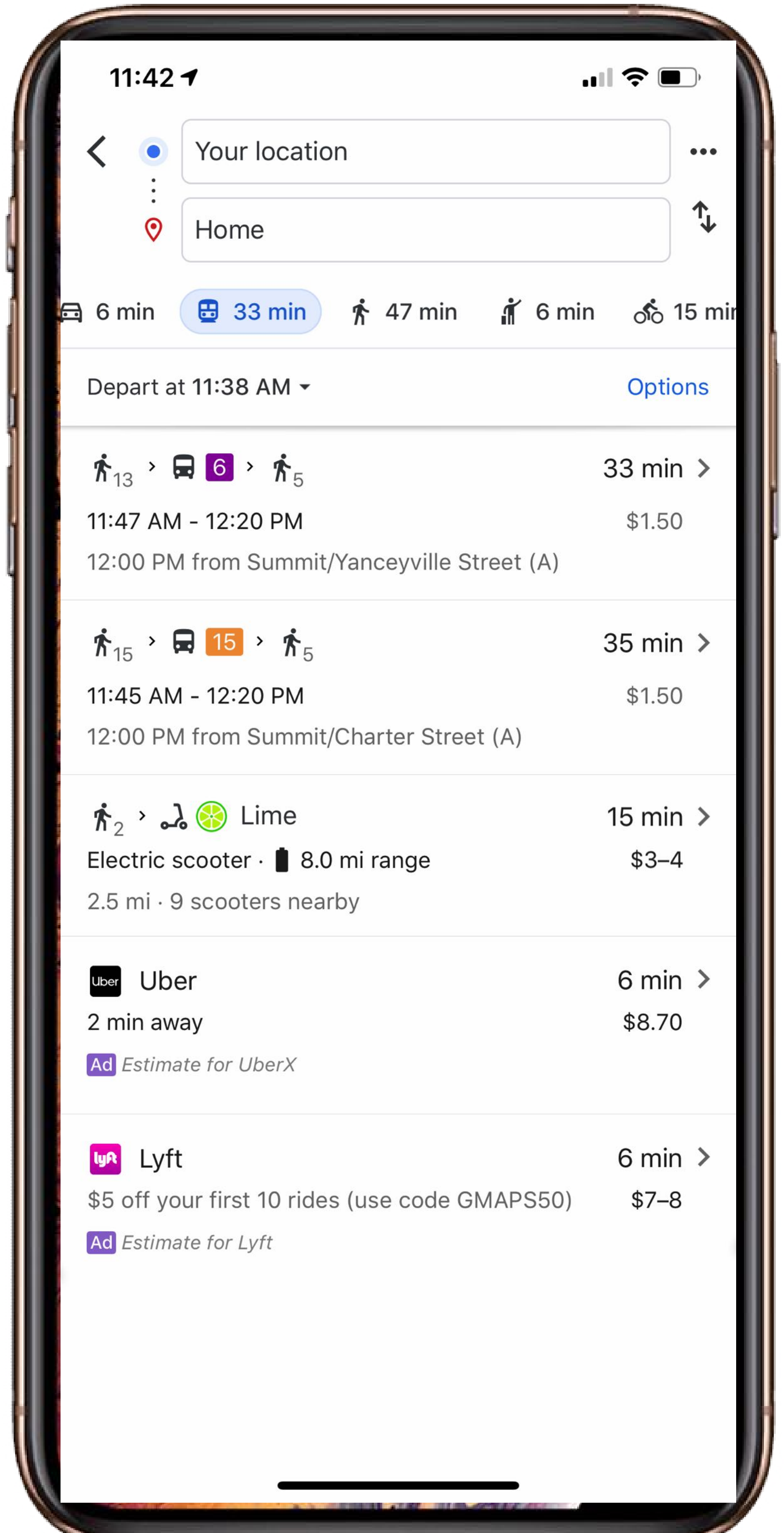


Existing Trip Planner



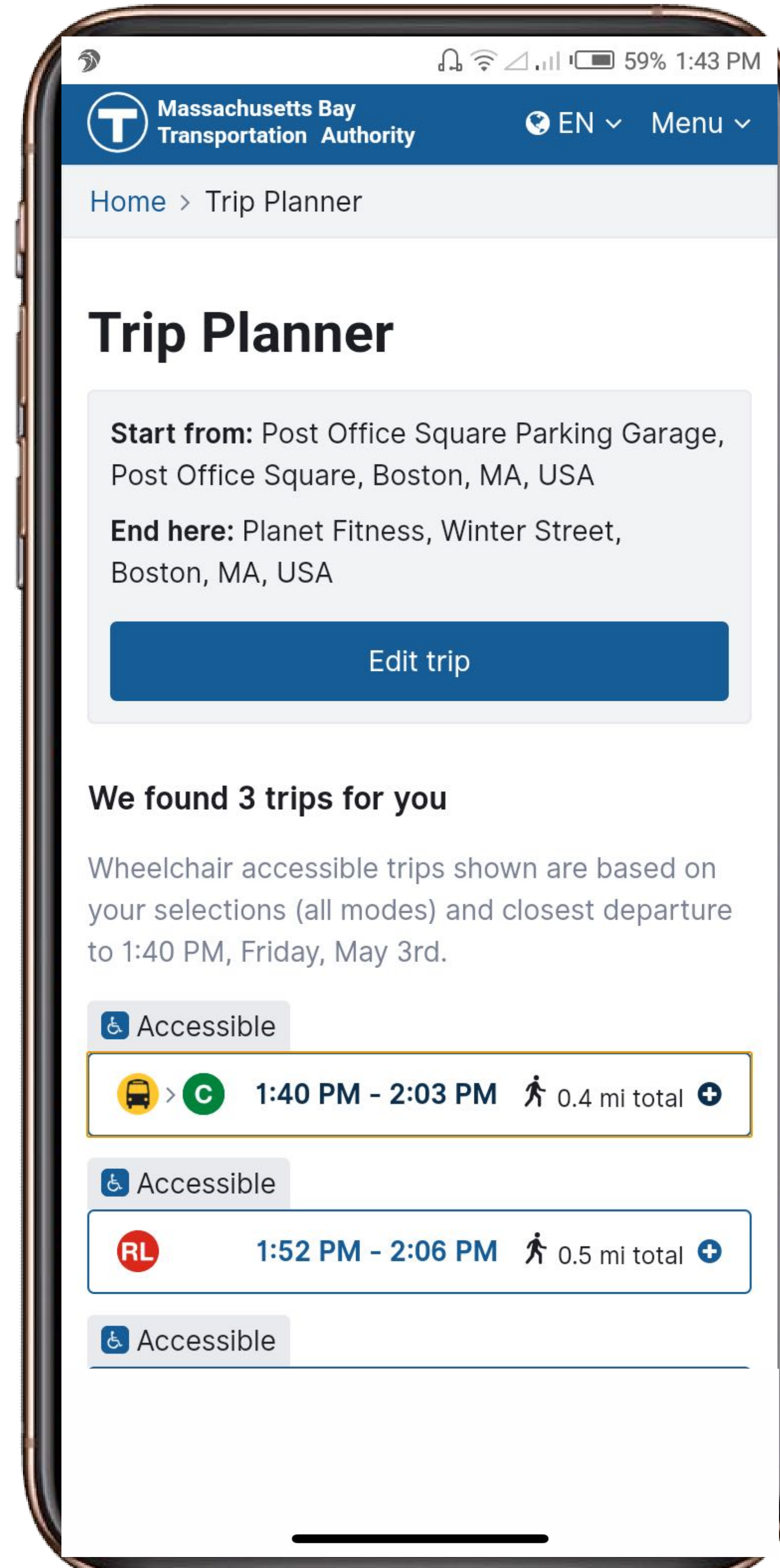
- Full & flexible Multimodal

☆ Lacks bikes, scooters options: may not provide best multimodal route option for an individual.



- Exclusive Wheelchair user

☆ Transit cannot be integrated with wheelchair users



- Dynamic adaptive trip planner

☆ Recalculation of static version, failing to capture dynamic network conditions

Case Study for People with Disabilities

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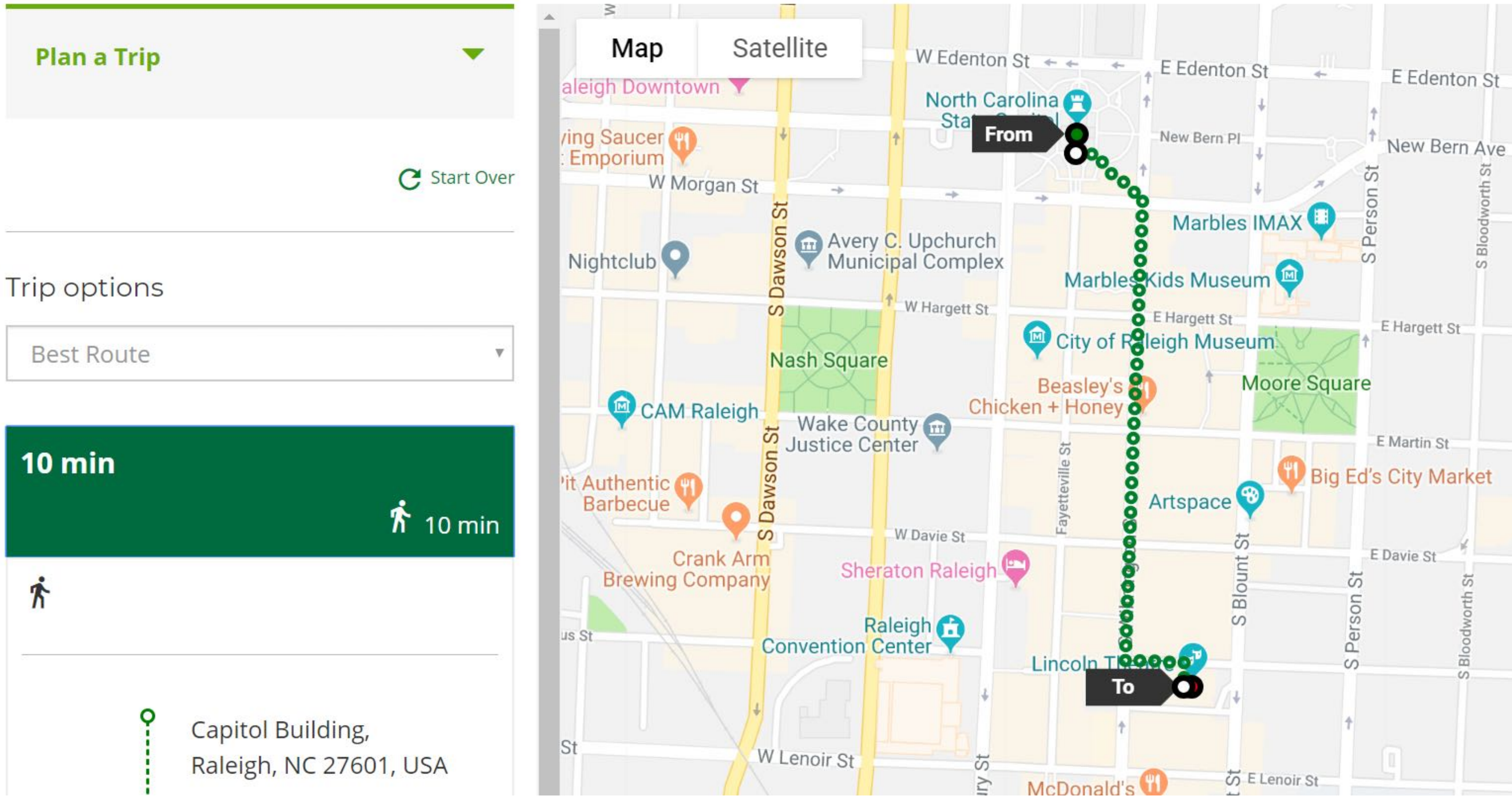
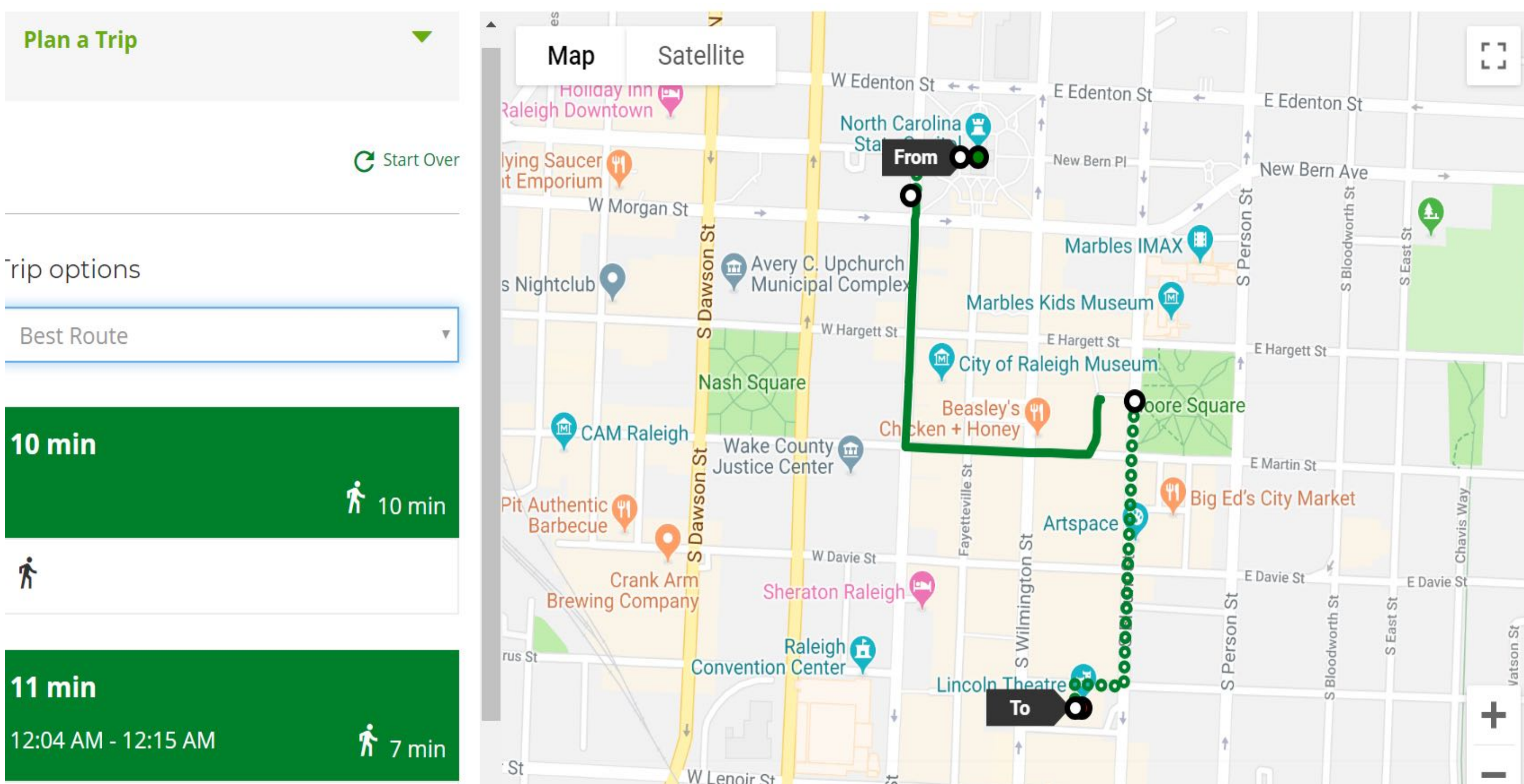


- Non wheelchair accessible walking route option from go triangle trip planner



- Non wheelchair accessible route incorporating transit from go triangle trip planner

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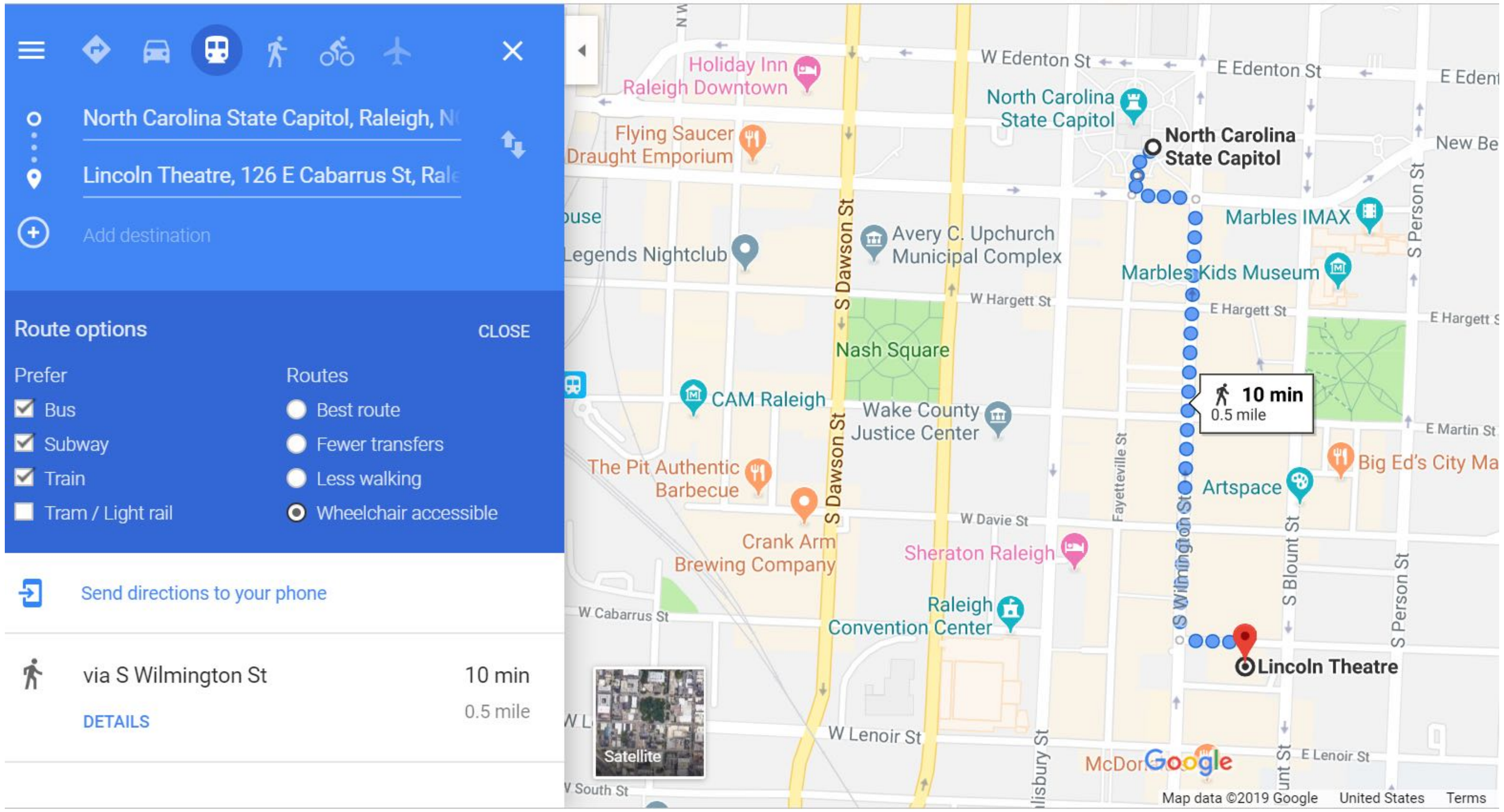

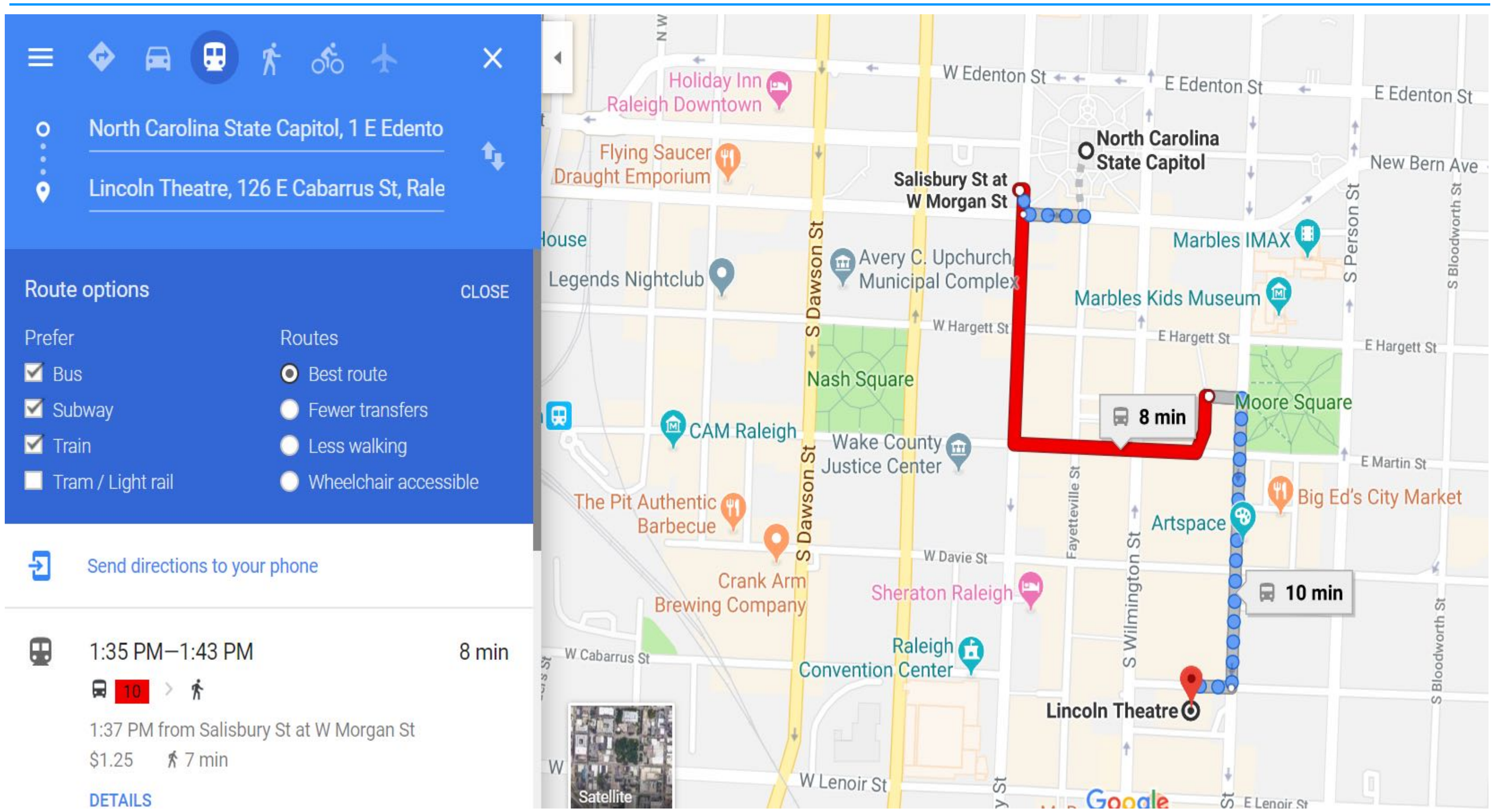

- You can choose wheelchair accessible options, but Google Map cannot be integrate wheelchair accessible transit and Americans with Disabilities Act (ADA)

- Best route option does not necessary good for wheelchair users.

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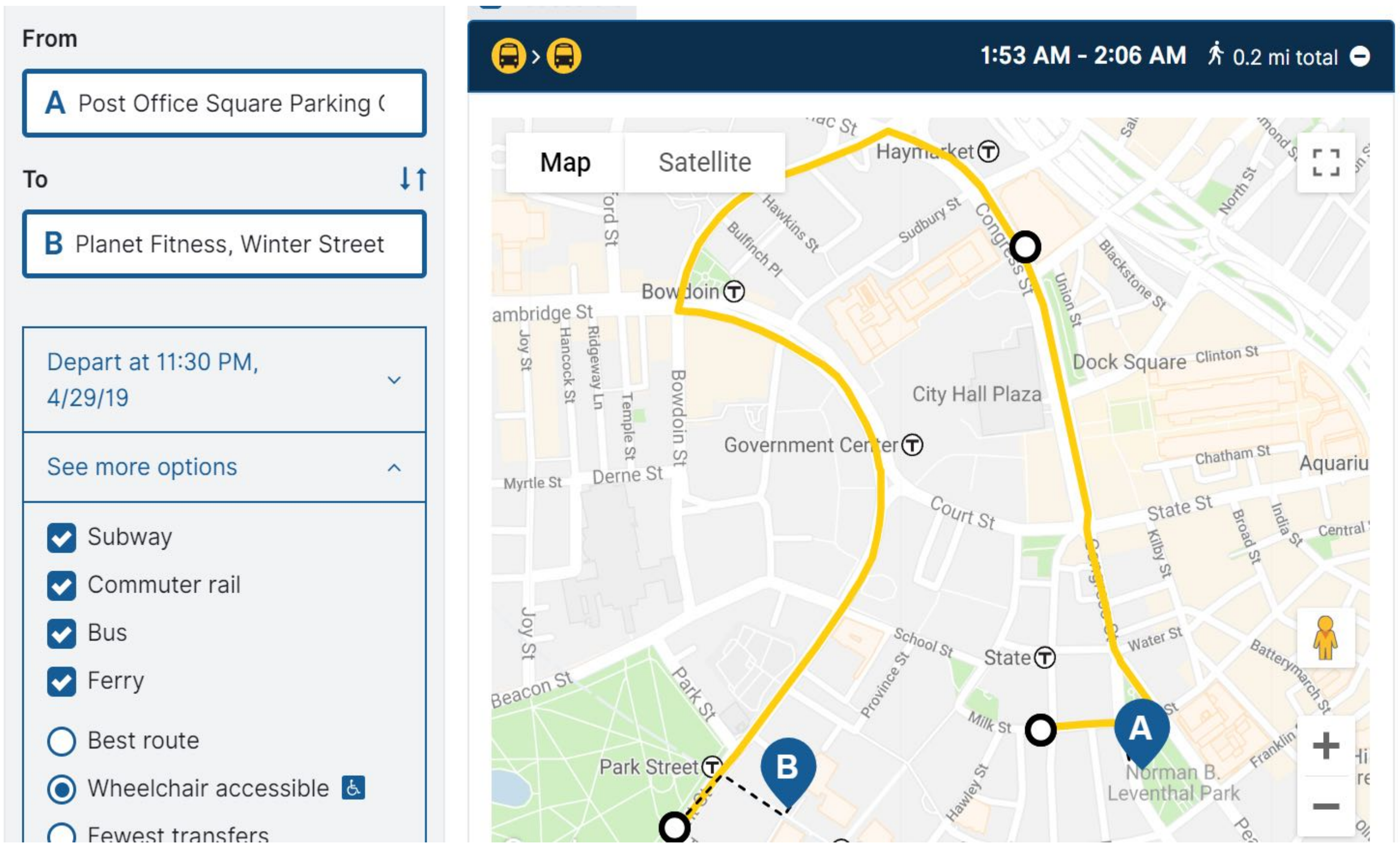
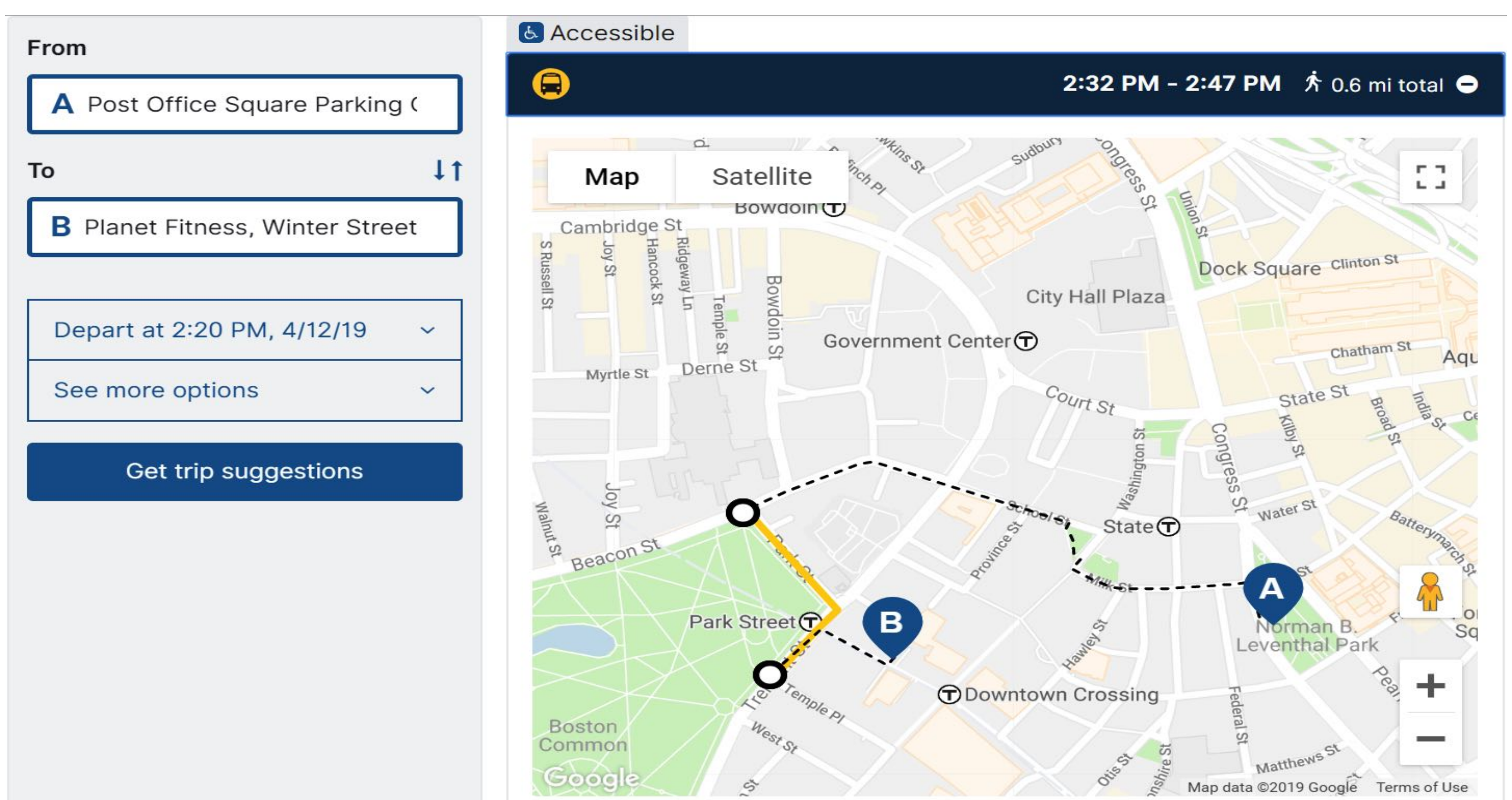


- Minimum wheel chair travel time but longer transit time



- Longer wheelchair travel time

State-of-the-Art App Limitations

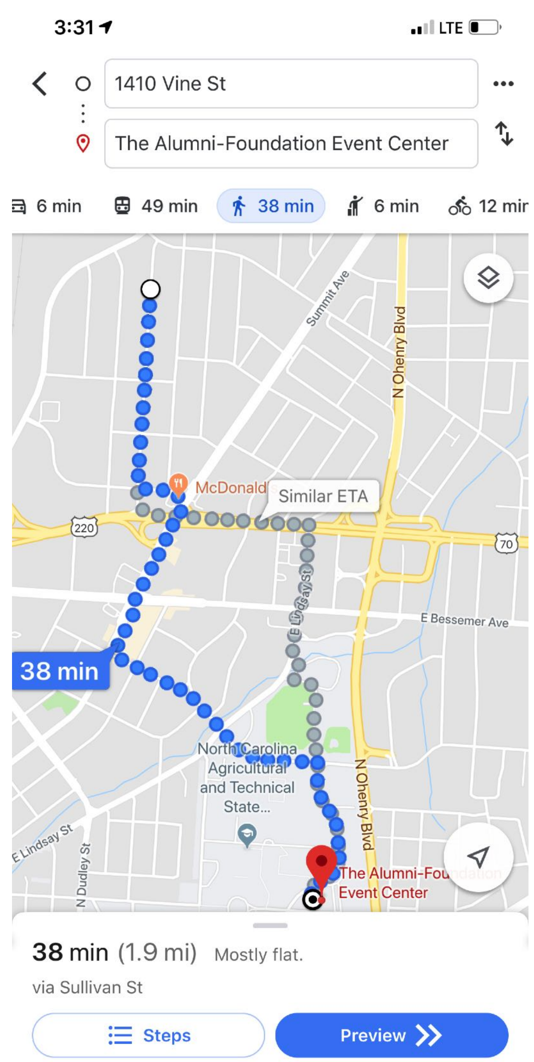
1. **Cost** function should change when **dynamic** events occurs (construction site).
2. Time-dependent network condition change (**transit on-time arrival**) makes the path cost time-dependent.
3. **Interactions** between factors contributing to the path choice also **changes by time**.

CASE STUDY FOR PEOPLE WITH DISABILITIES

1. Dynamic Cost
2. Transit on time-arrival
3. Time-dependent interaction

☆ Assist people who have physical or other disabilities with non-driving navigation of the built environment

☆ I'd walk to NCDOT Summit!



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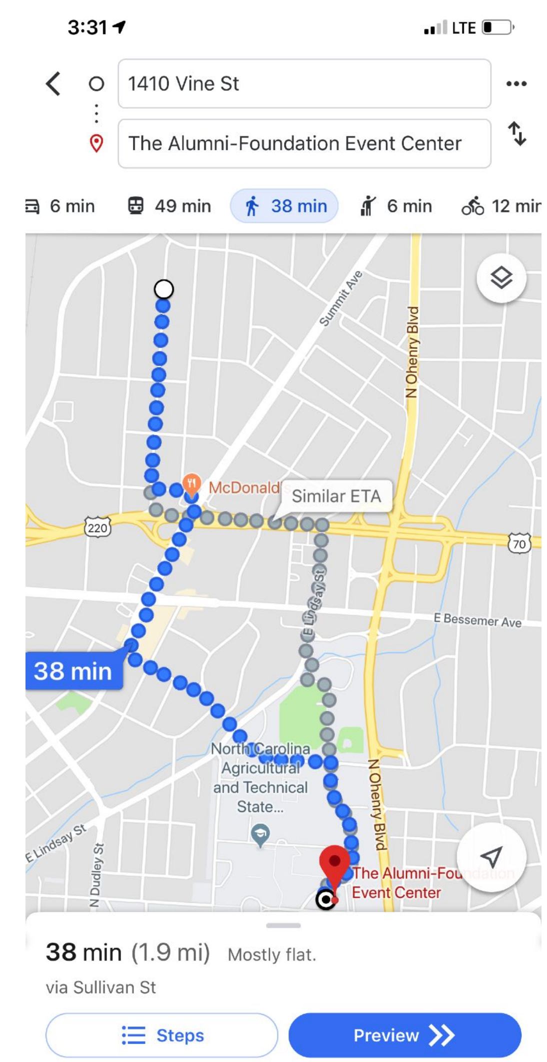

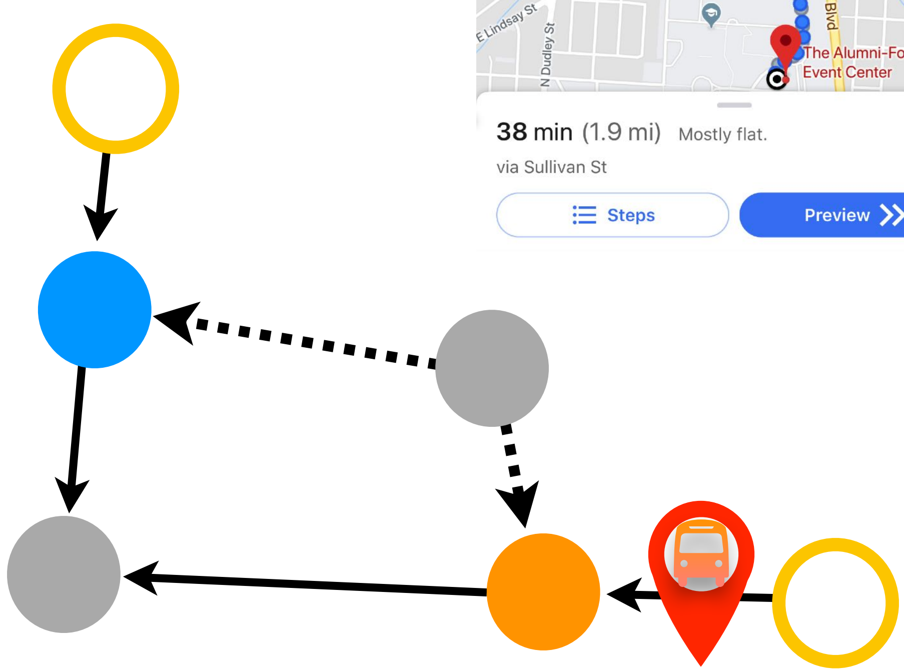

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Case Study for People with Disabilities

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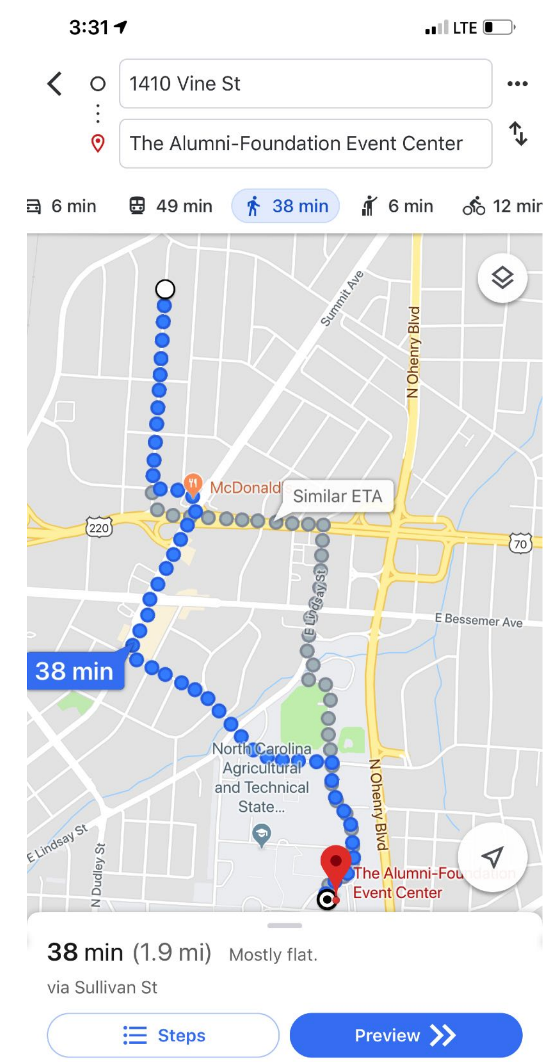

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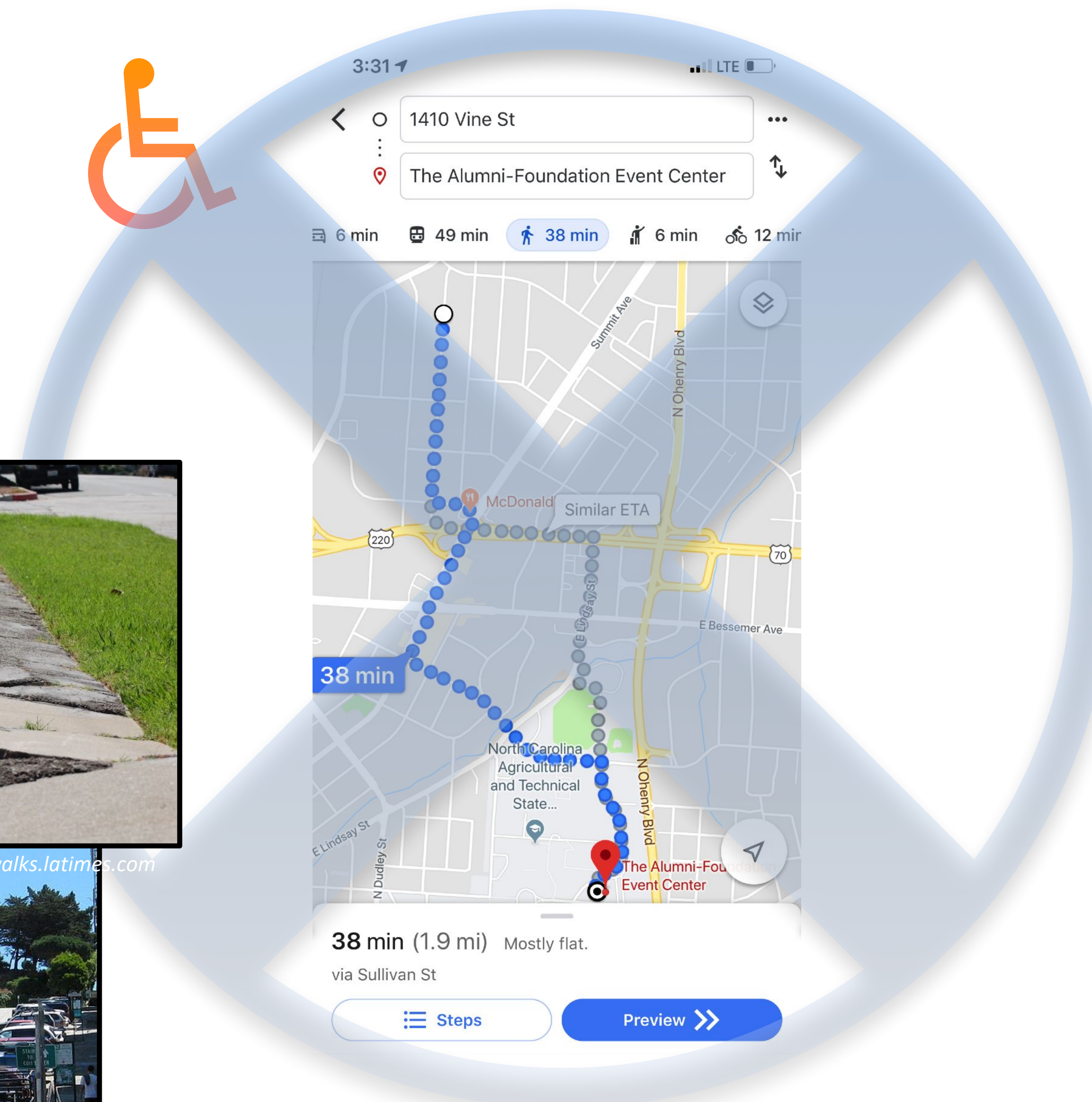

Case Study for People with Disabilities

- Assist people who have physical or other disabilities with non-driving navigation of the built environment
- Combine personal capabilities with external information to result in a flexible personalized assistance platform

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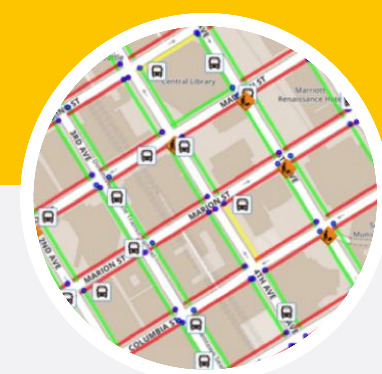
STATIC & DYNAMIC UTILITIES

Interactions between factors change by **time**

- Wheelchair user more limited with **steep** slope (elevation) in inclement **weather**.
- Transit on-time arrival change the importance of **travel time** over **elevation**.



NO CHANGE

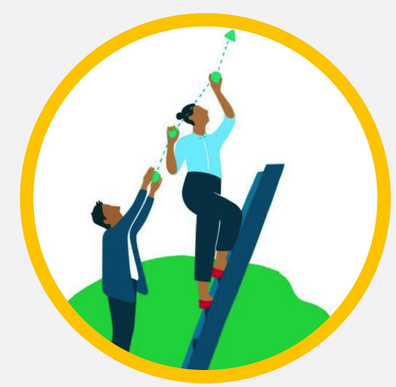
STATIC PARAMETERS

- Sidewalk width
- Sidewalk surface
- Sidewalk elevation

CHANGE OR PLAN

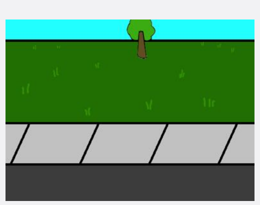
DYNAMIC UNEXPECTED PARAMETERS

- Construction
- Bus delay
- Weather condition



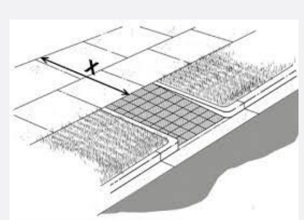
DYNAMIC PREDICTABLE PARAMETERS

- Bus delay
- Weather condition
- Congestion sidewalk



Surface

Elevation



Width

Weather conditions

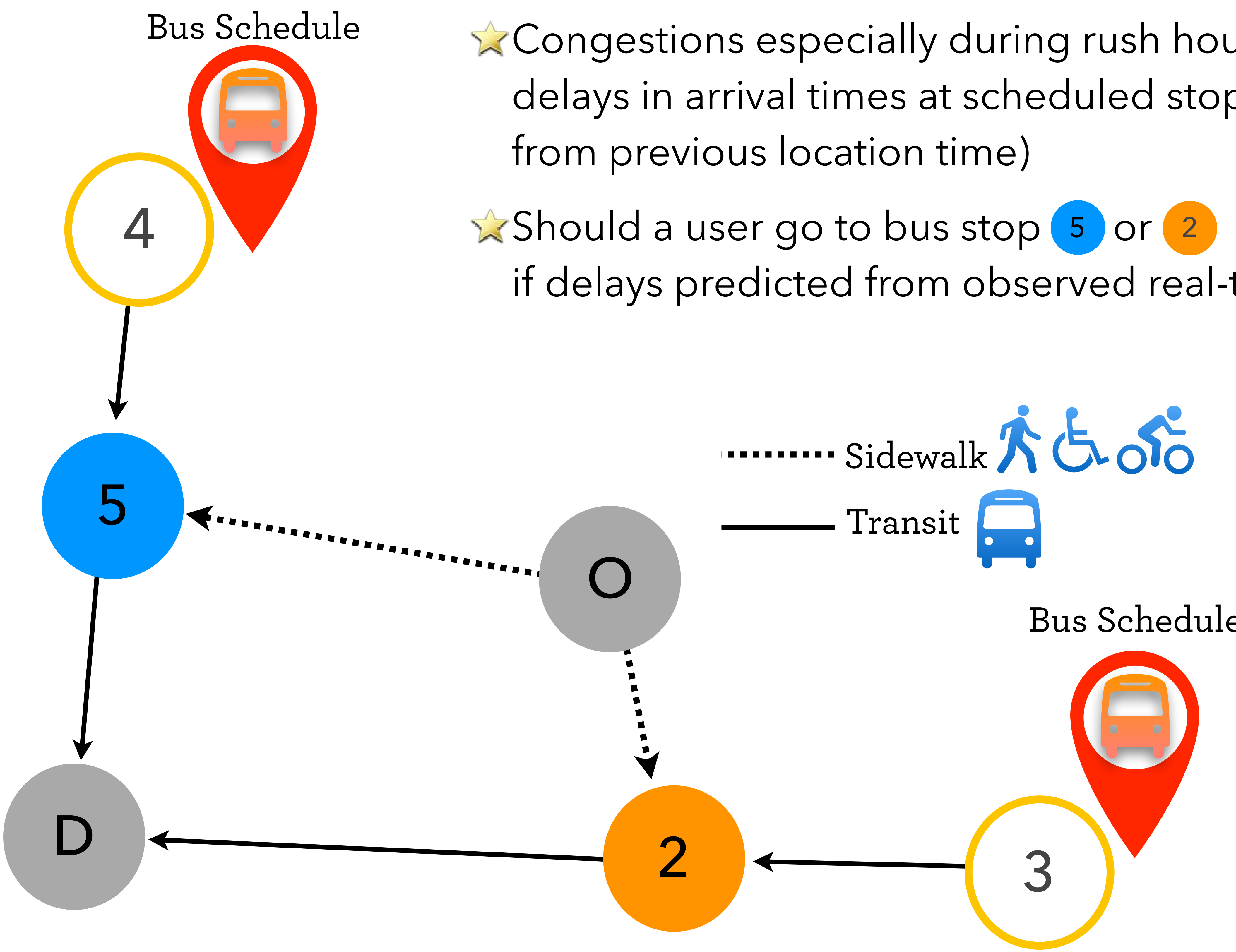
Construction

Bus delay

Congested sidewalk

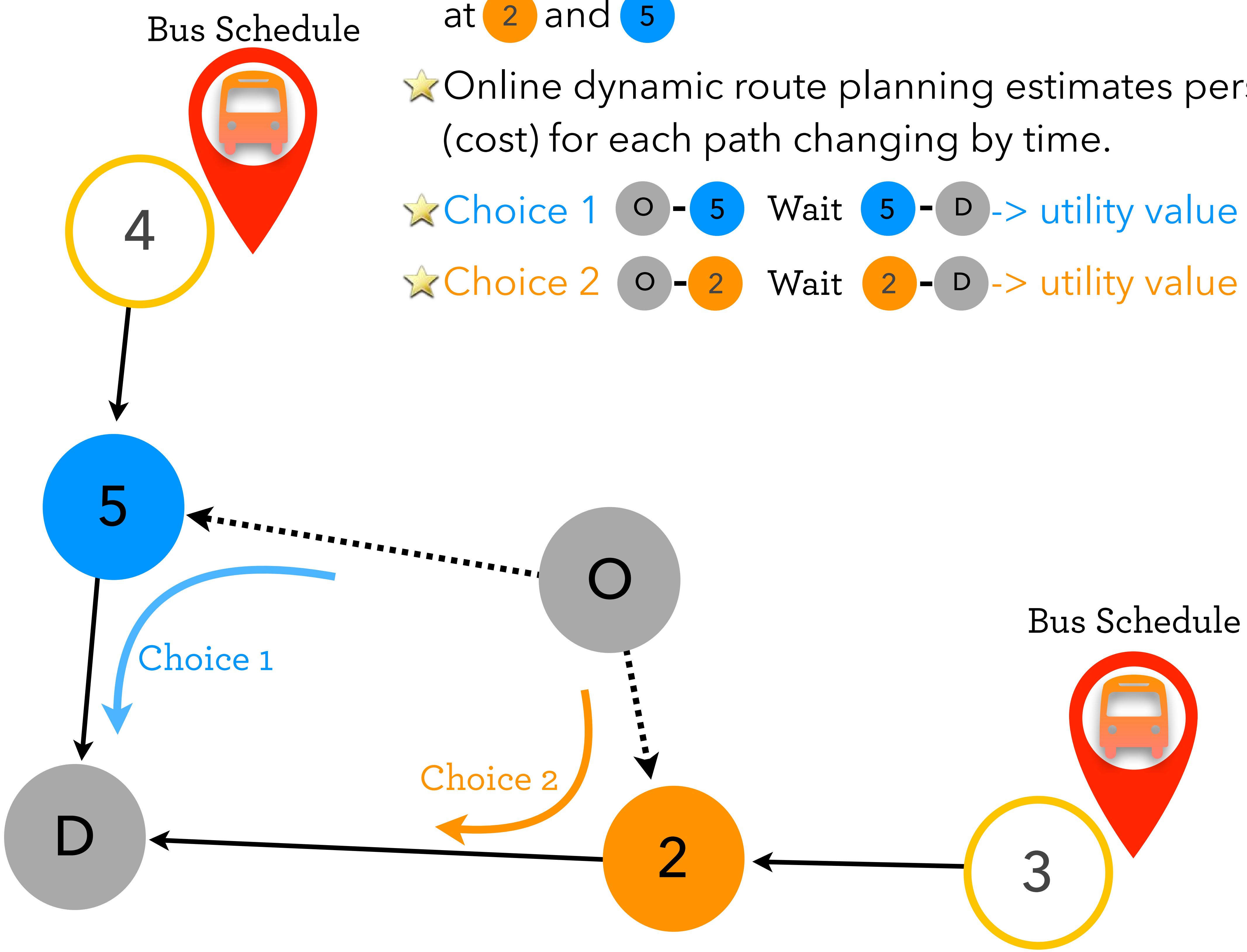
PREDICTIVE & REAL-TIME TRANSPORT

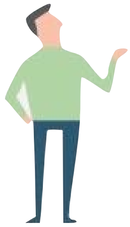
- Each O - D, traveler multimodal options sidewalk (bike, walk) or transit (bus) available.
- Congestions especially during rush hour introduces delays in arrival times at scheduled stops (predicted from previous location time)
- Should a user go to bus stop 5 or 2 if delays predicted from observed real-time data?



PREDICTIVE & REAL-TIME TRANSPORT

- Personalized cloud-source real-time data improve mobility with the best multimodal transport options with waiting time at 2 and 5
- Online dynamic route planning estimates personalized utility (cost) for each path changing by time.
- Choice 1 O - 5 Wait 5 - D -> utility value for user 10?
- Choice 2 O - 2 Wait 2 - D -> utility value for user 7?





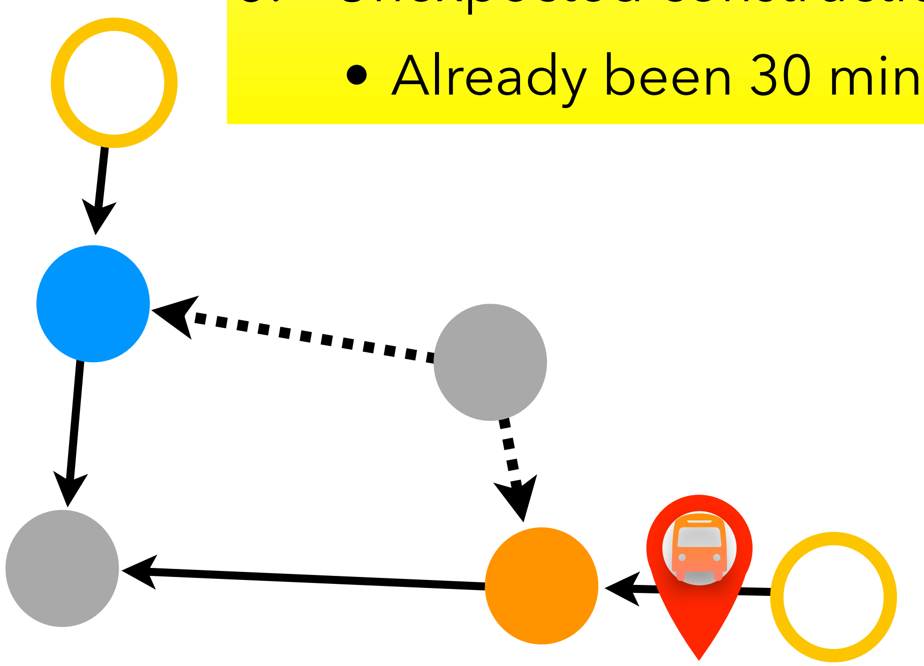
Case Study for People with Disabilities

- Okay I know your preferences, then why don't you just recalculate the utility every time something unexpected event happens?
- Interactions between factors contributing to the path choice also changes by time.

1. Adverse weather (e.g. snow) affect impedance and tiredness of road user with disability? Weather Elevation

3. Value of time when transit arrival delay cause potential delay for doctor's appointment Time Delay Weather Elevation
   - Relative importance of time is more important than tiredness

5. Unexpected construction make quick route non-traversable Time Delay Weather Elevation
   - Already been 30 mins, and another 30 min or 10 min with high slope? Construction



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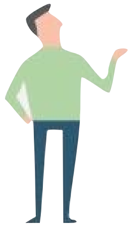
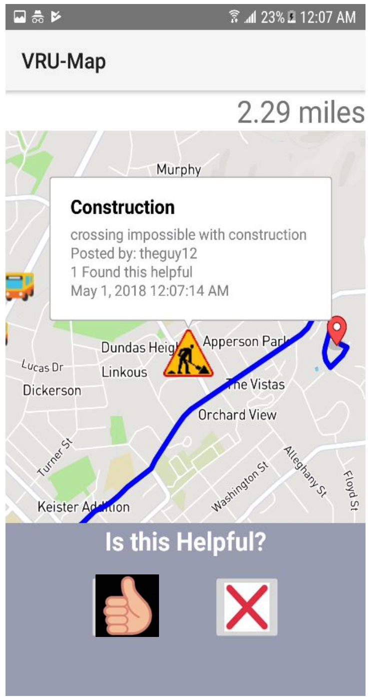
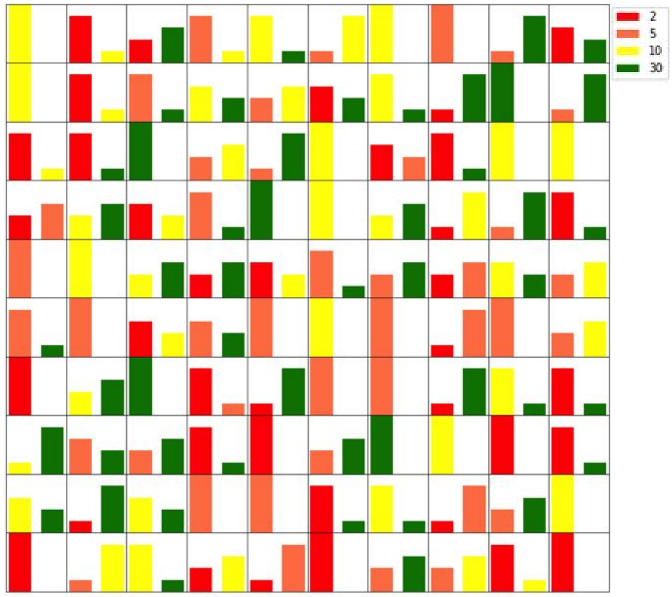


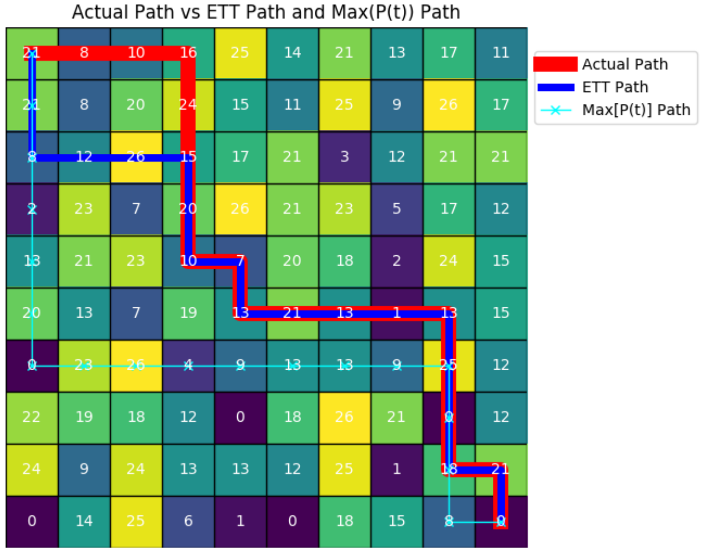
Case Study for People with Disabilities

- ⭐Current databases are not sufficient for all users' needs
  Crowdsourcing allows for additional information
- ⭐Probabilistic distribution of travel time for formulating the best options to travel with partial, sequential, and mixture of information gain





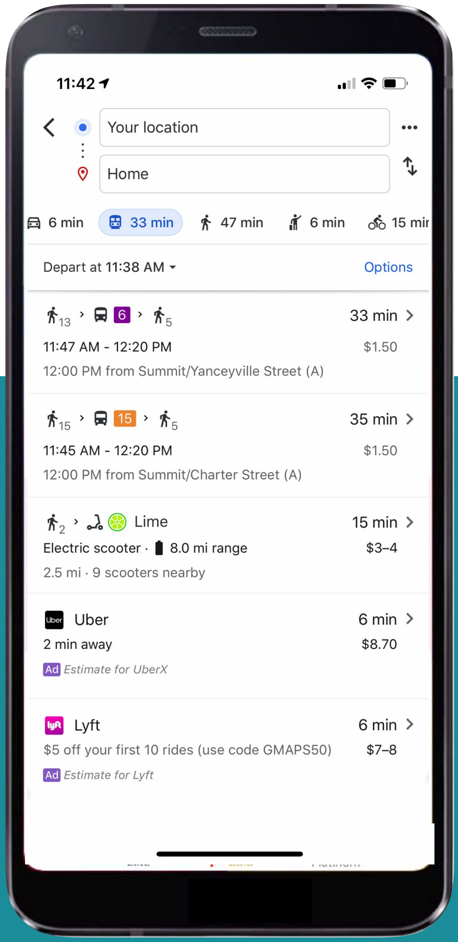
- ⭐Images of the sidewalk network from the satellite provides some sort of secondary data which has an associated uncertainty.
- ⭐Incorporated in estimating the parameter for the surface condition that a traveler may encounter with some certainty by using that path.



- ⭐Utility Function based path vs two theoretical paths: minimize initial Expected Travel Time (ETT) vs Max[P(T)] (highest probability classification)-based travel time.
- ⭐grid each cell type by number (white), filled color.
- ⭐The highest information gain is achieved by visiting the maximum number of different cell types.

DYNAMIC TRANSIT MODELING

- Inform transit drivers 'pick-up change' through cell phone cloud source



Transit System

Balance between transit time with/without riders efficiently pick-up and drop-off passengers while considering **dynamic** change.

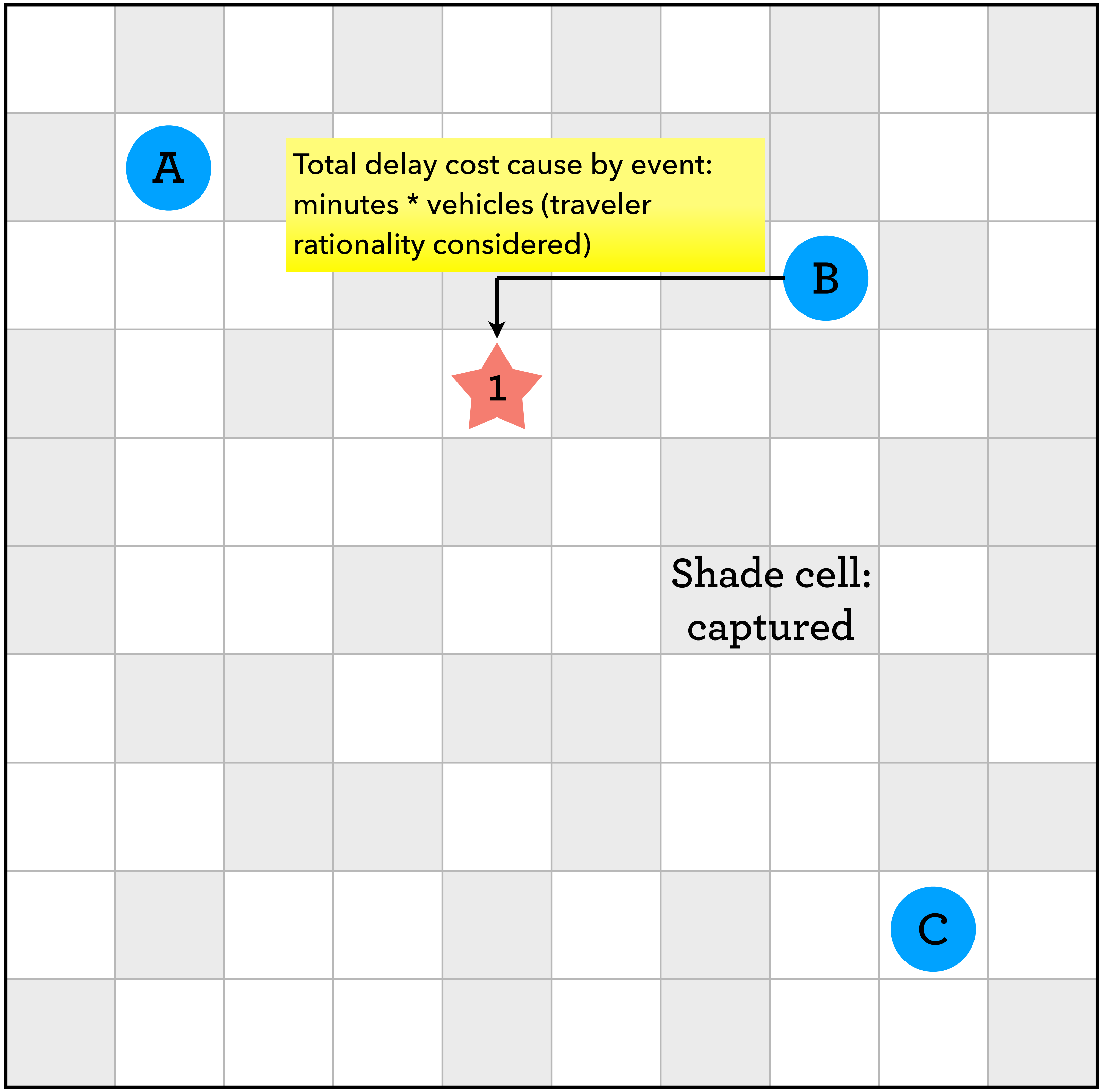
Road User

Maximize **individual** user social **surplus** considering the bounded rationality

Successful Service Operation

- To be applied to transit operation - Predictive operation based on traveler choice on TransModeler.

  - Published Transportation Research Part C & TRB 2019 Annual Meeting, # 19-05975



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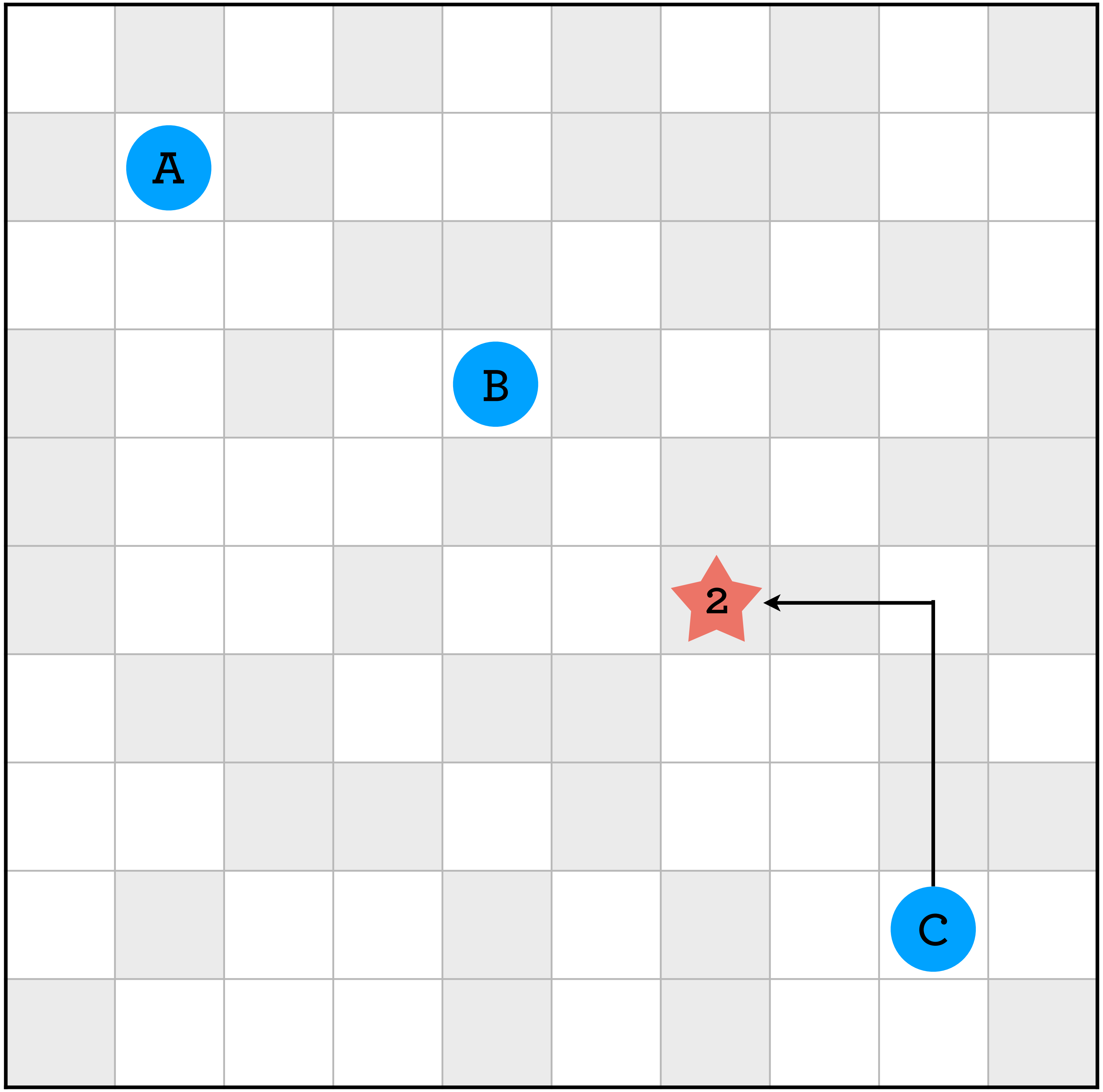

- Modeling a driver behavior in TransModeler using Driver Groups option

Driver Groups

Driver Group Parameters

Driver Group	Uninformed	Informed
Fraction of population	0.50	0.50
Informed	☐	☑
Relative travel time	-2.1500	-2.1500
Travel time (1/min)	-0.0500	-0.0500
Non-freeway length (/miles)	0.0000	0.0000
Freeway length (/miles)	0.0000	0.0000
Controlled intersections	0.0000	0.0000
Different from current path	-0.0100	-0.0100
Value of time distribution	High Income	High Income
Value of time ($/hr) *	25.00	25.00
Toll cost (1/$) **	-0.0020	-0.0020
Choice set threshold (%)	50.0	50.0
Update delay threshold (%)	5.0	5.0
Reroute bias horizon (min)	10	30
Reroute threshold (%)	-0.06	-5.00

* The mean value of time for distribution chosen for this group.

** Ratio between Value of Time and coefficient for Travel Time.

Path-size Gamma: 1.00

Rerouting in Response to High Delay

Step size for evaluating reroute alternatives (sec): 60

Maximum bias against current path (%): 73.0

- Path-Size Logit model - calculate the probability of the travelers switching to alternative routes

$$P\left(i \middle| C_n(t)\right) = \frac{e^{V_{in}(t)+lnPS_{in}}}{\sum_{j\in C_n(t)} PS_{jn} e^{V_{jn}(t)}}$$

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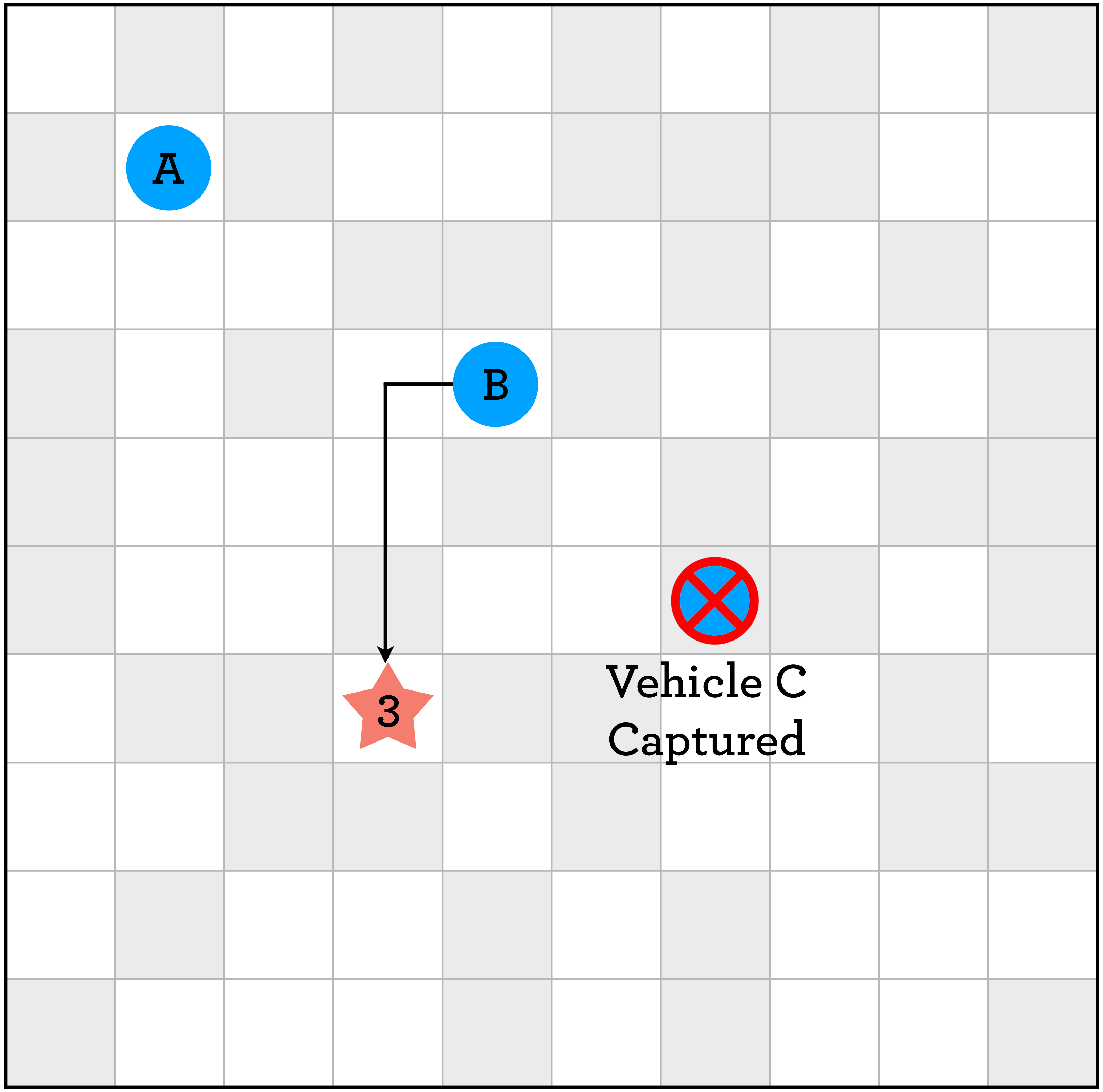

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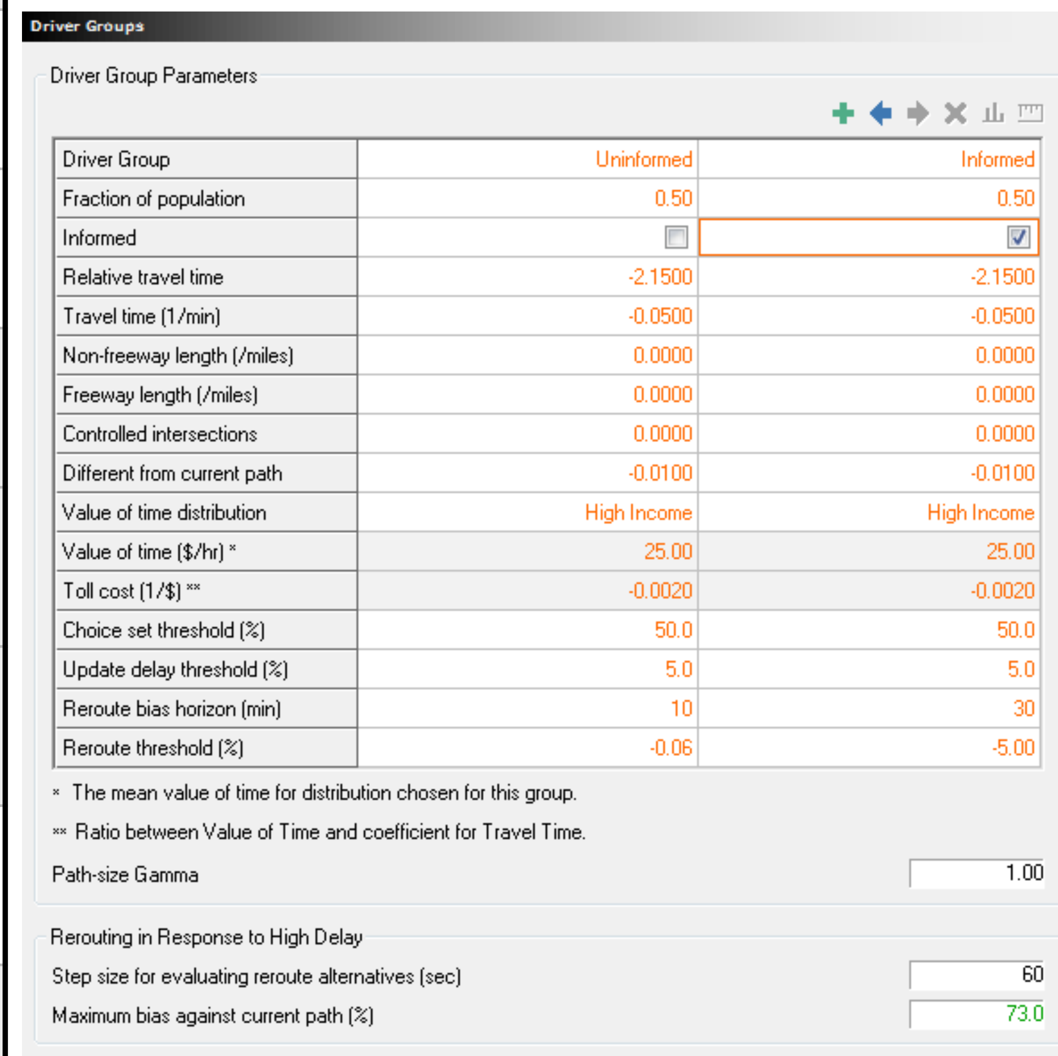

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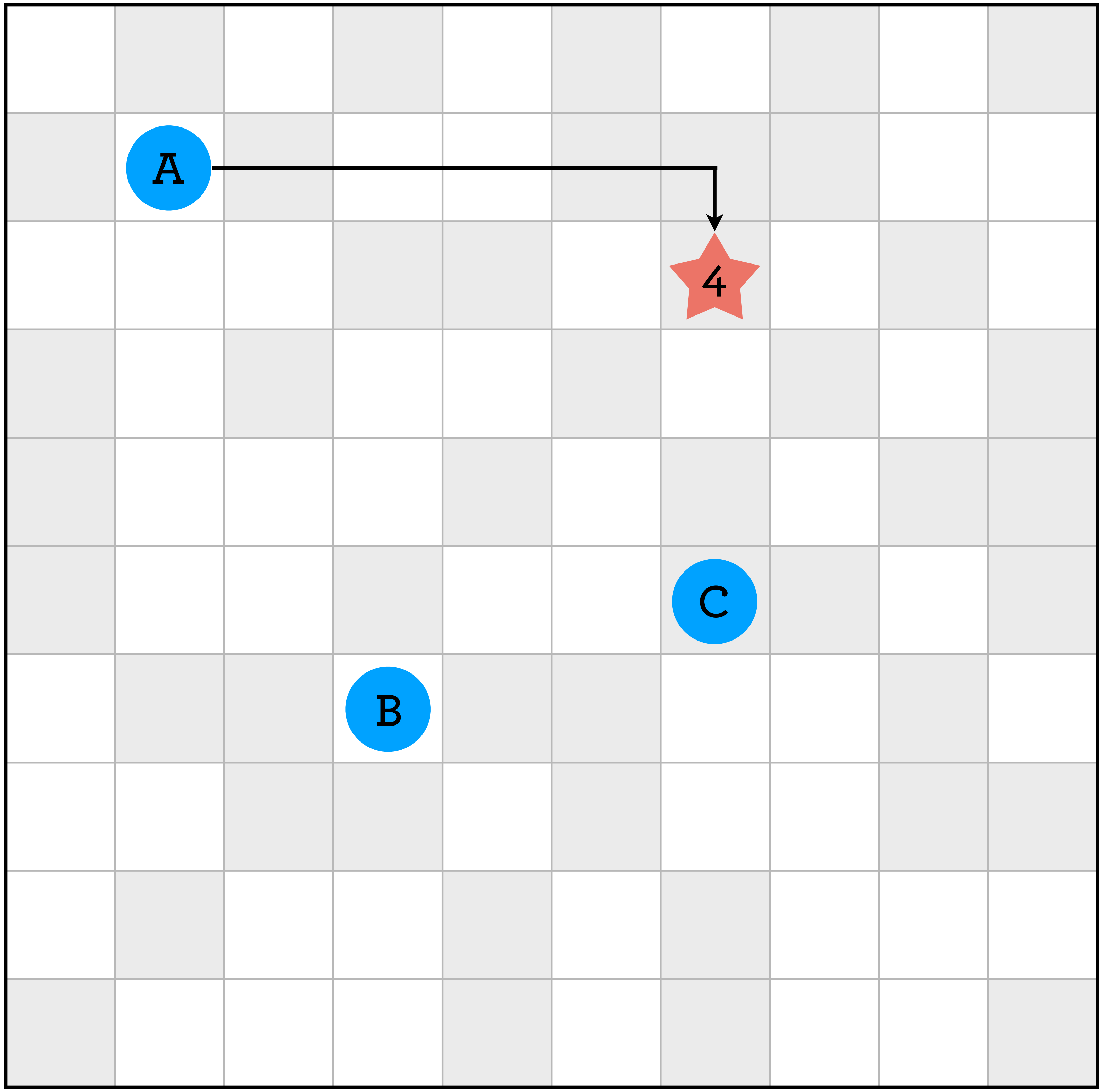

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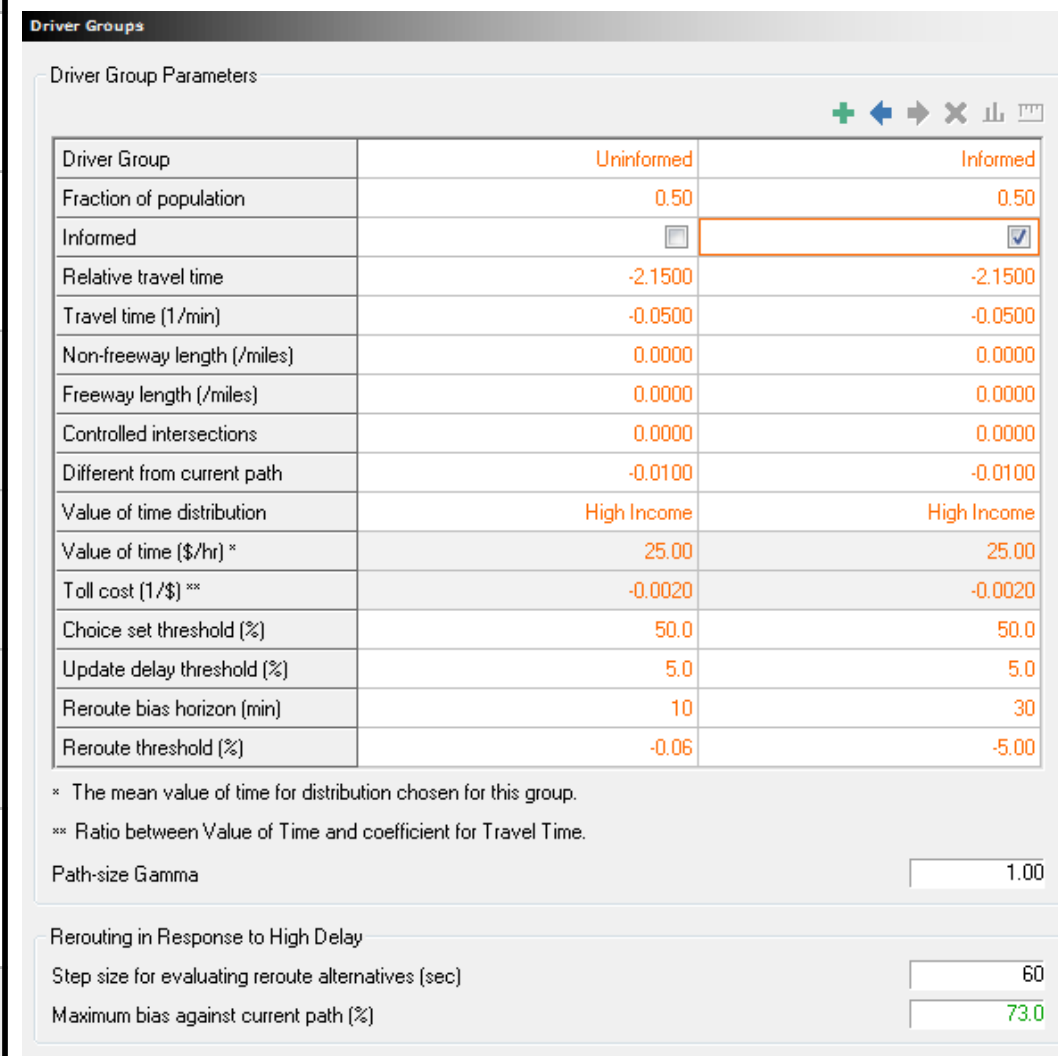

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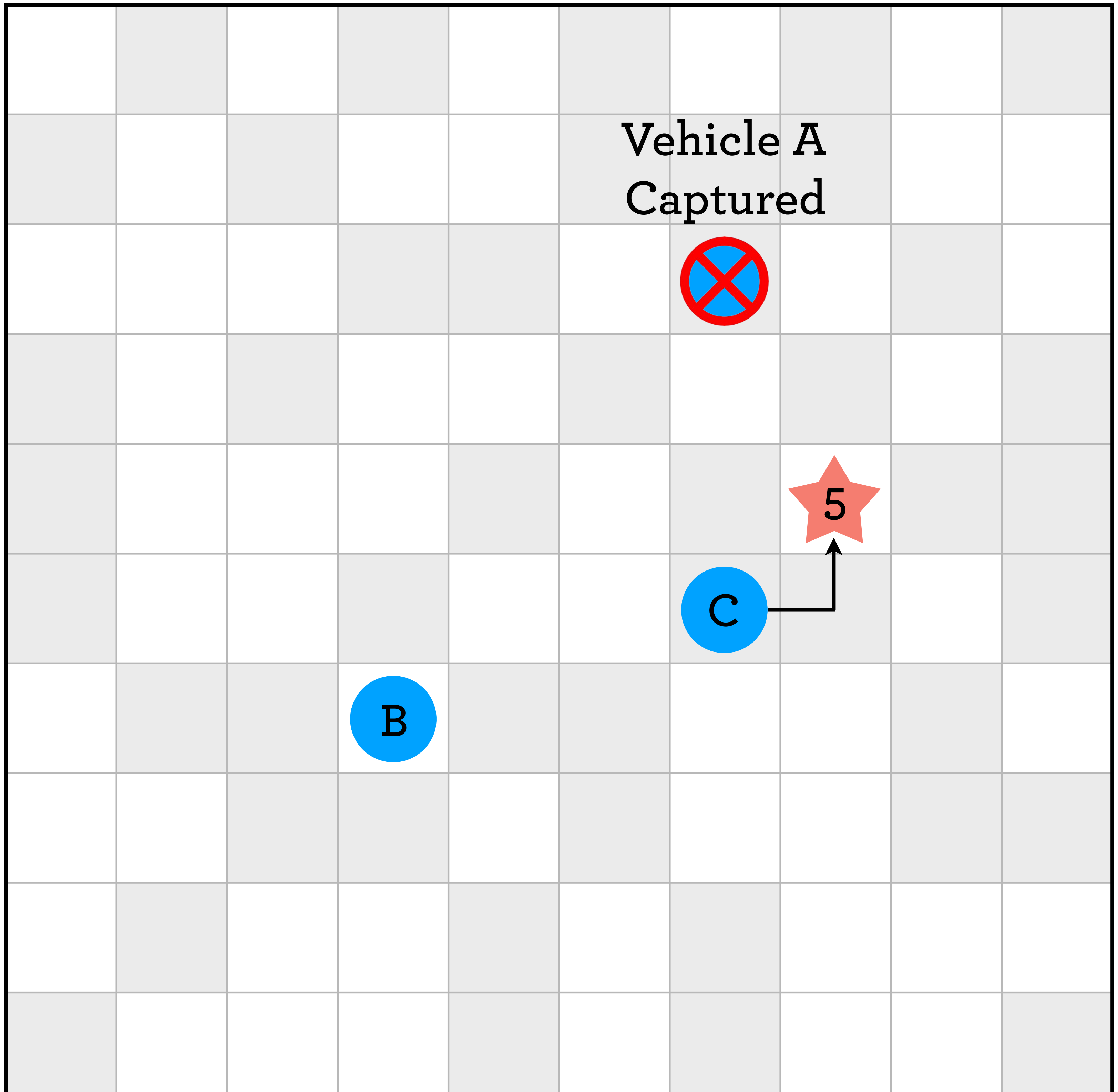

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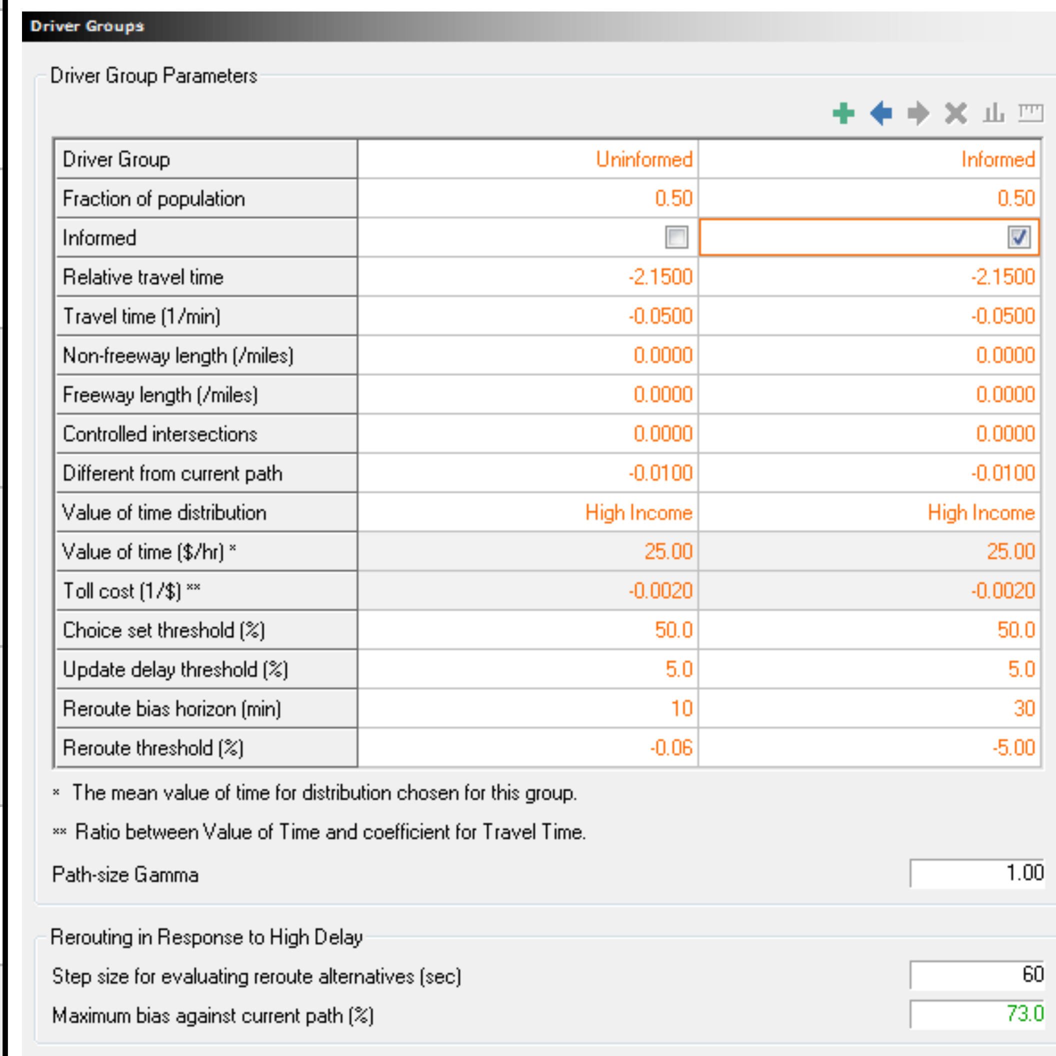


Driver Groups

Driver Group Parameters

Driver Group	Uninformed	Informed
Fraction of population	0.50	0.50
Informed	☐	☑
Relative travel time	-2.1500	-2.1500
Travel time (1/min)	-0.0500	-0.0500
Non-freeway length (/miles)	0.0000	0.0000
Freeway length (/miles)	0.0000	0.0000
Controlled intersections	0.0000	0.0000
Different from current path	-0.0100	-0.0100
Value of time distribution	High Income	High Income
Value of time ($/hr) *	25.00	25.00
Toll cost (1/$) **	-0.0020	-0.0020
Choice set threshold (%)	50.0	50.0
Update delay threshold (%)	5.0	5.0
Reroute bias horizon (min)	10	30
Reroute threshold (%)	-0.06	-5.00

* The mean value of time for distribution chosen for this group.

** Ratio between Value of Time and coefficient for Travel Time.

Path-size Gamma 1.00

Rerouting in Response to High Delay

Step size for evaluating reroute alternatives (sec) 60

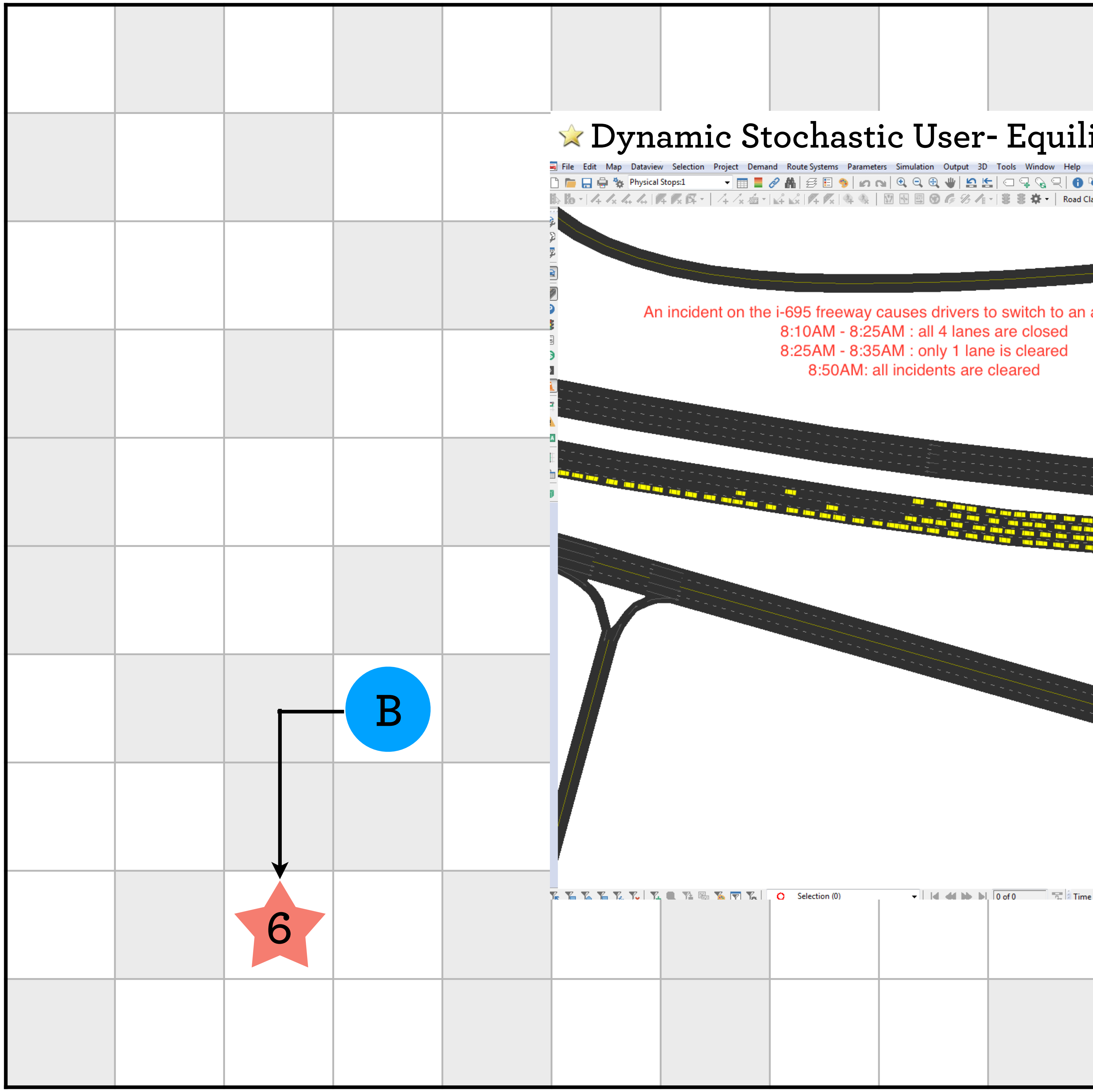
Maximum bias against current path (%) 73.0

⭐ Path-Size Logit model - calculate the probability of the travelers switching to alternative routes

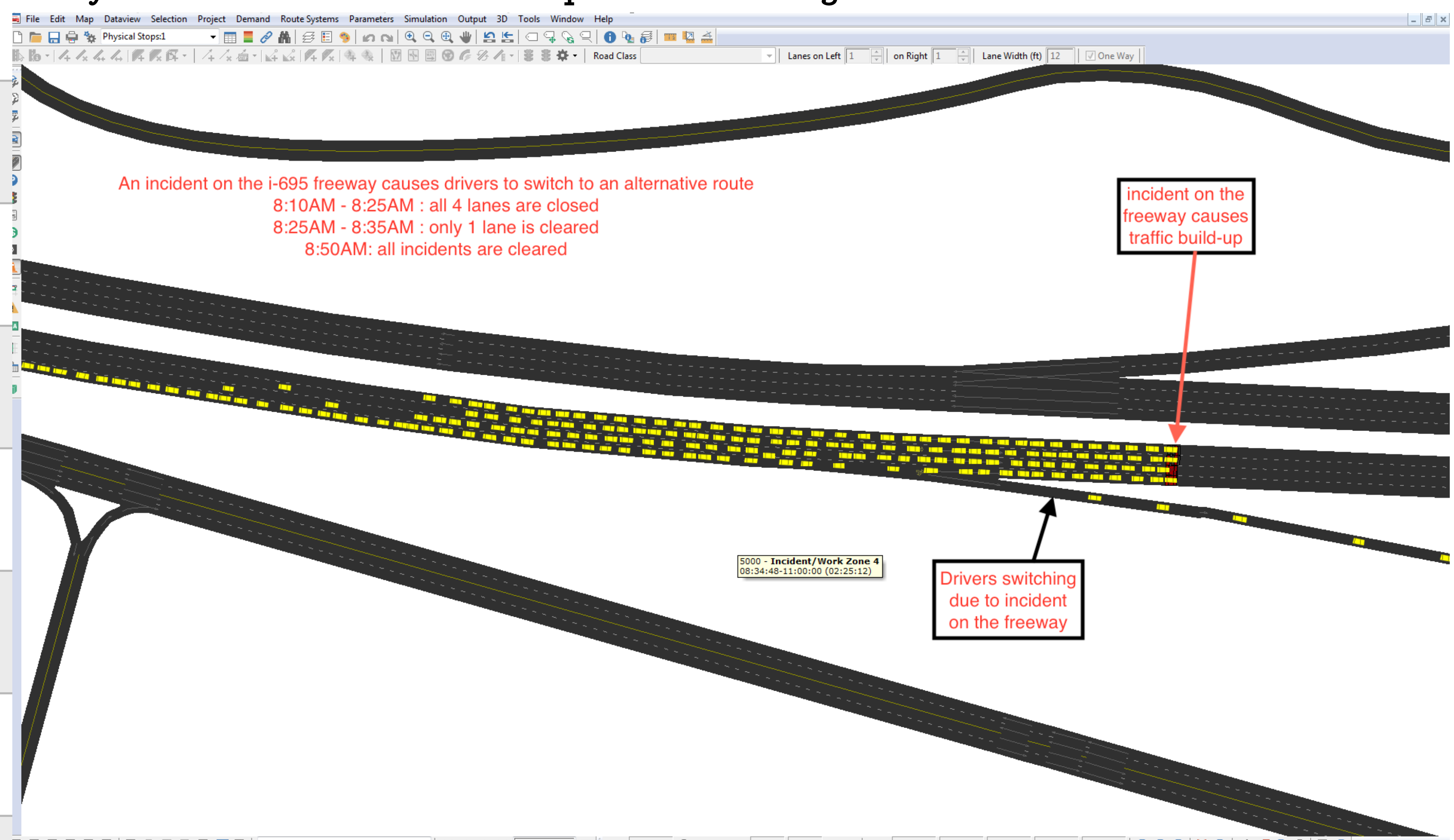
$$P\left(i\middle|C_n(t)\right) = \frac{e^{V_{in}(t)+lnPS_{in}}}{\sum_{j\in C_n(t)} PS_{jn}e^{V_{jn}(t)}}$$

Successful Service Operation

⭐ To be applied to transit operation - Predictive operation based on traveler choice on TransModeler.



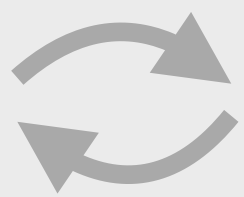
⭐ Dynamic Stochastic User- Equilibrium assignment considered - TransModeler



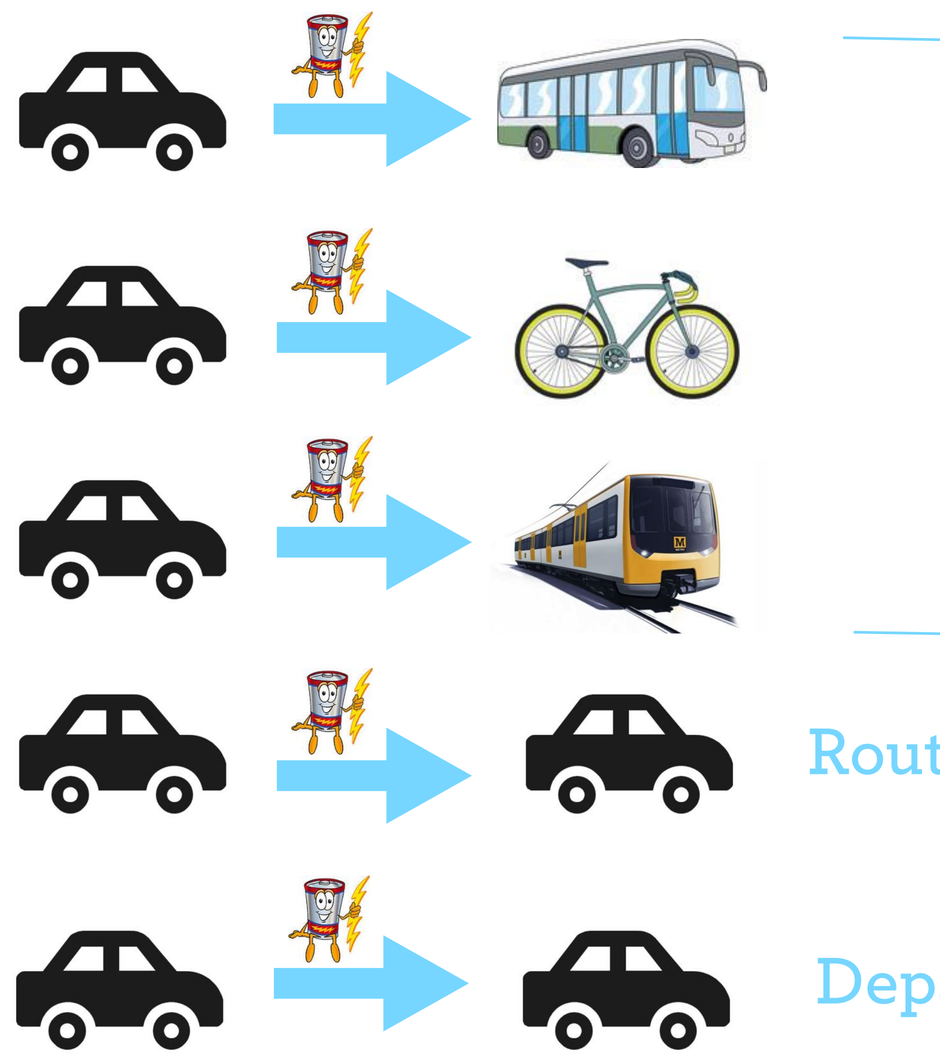
Task 3: Incentive Optimization

System Optimization

Optimal



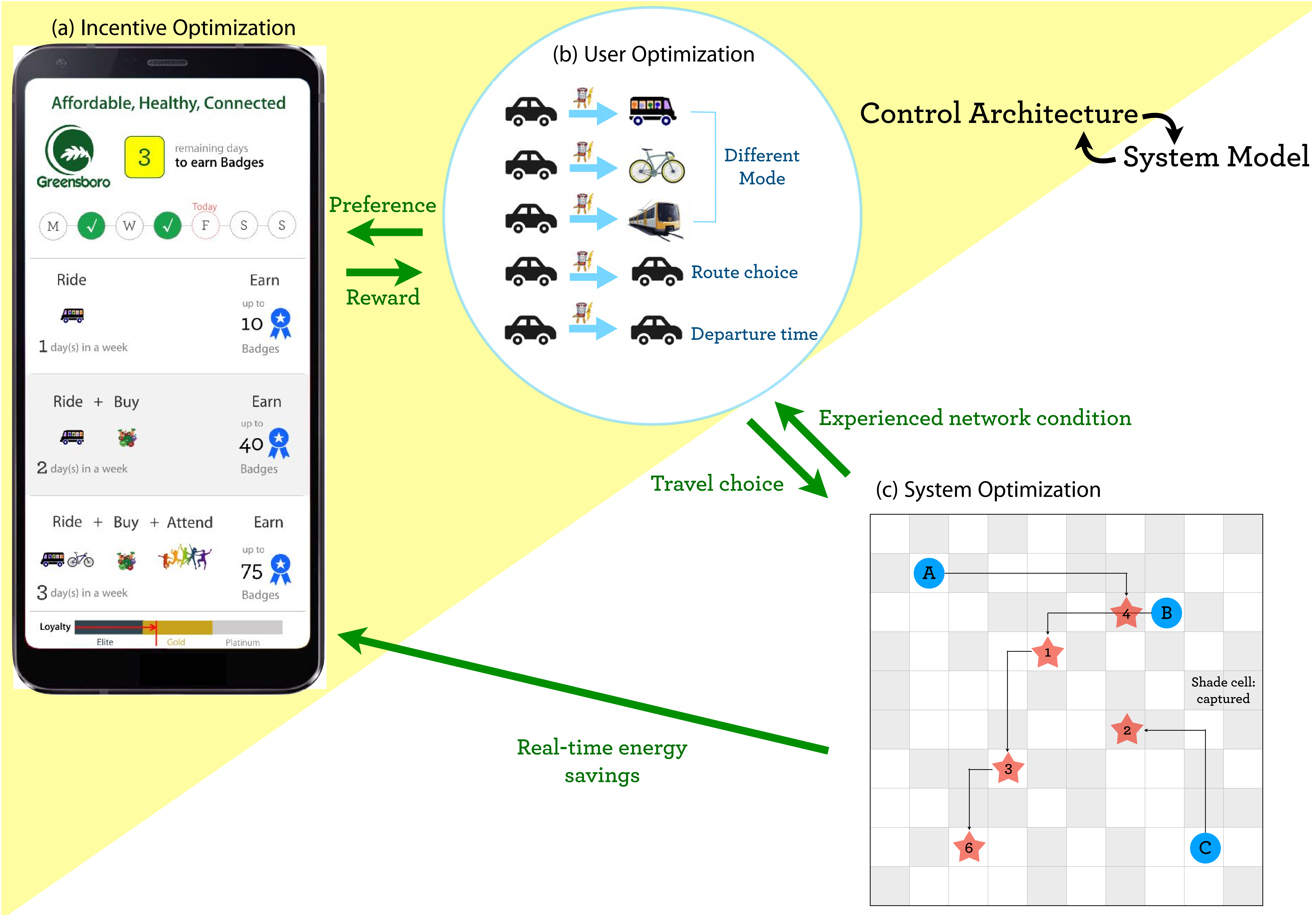
User Optimization



Different Mode

Route choice

Departure time



(a) Incentive Optimization
Affordable, Healthy, Connected
Greensboro
3
remaining days
to earn Badges
Today
M
W
F
S
S
Ride
Earn
up to
10
Badges
1 day(s) in a week
Ride + Buy
Earn
up to
40
Badges
2 day(s) in a week
Ride + Buy + Attend
Earn
up to
75
Badges
3 day(s) in a week
Loyalty
Elite
Gold
Platinum
Preference
Reward
(b) User Optimization
Different Mode
Route choice
Departure time
Control Architecture
System Model
Experienced network condition
Travel choice
(c) System Optimization
A
B
C
1
2
3
4
6
Shade cell: captured
Real-time energy savings

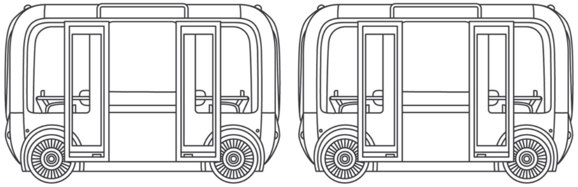
Thank you for your attention

Q & A

hpark1@ncat.edu

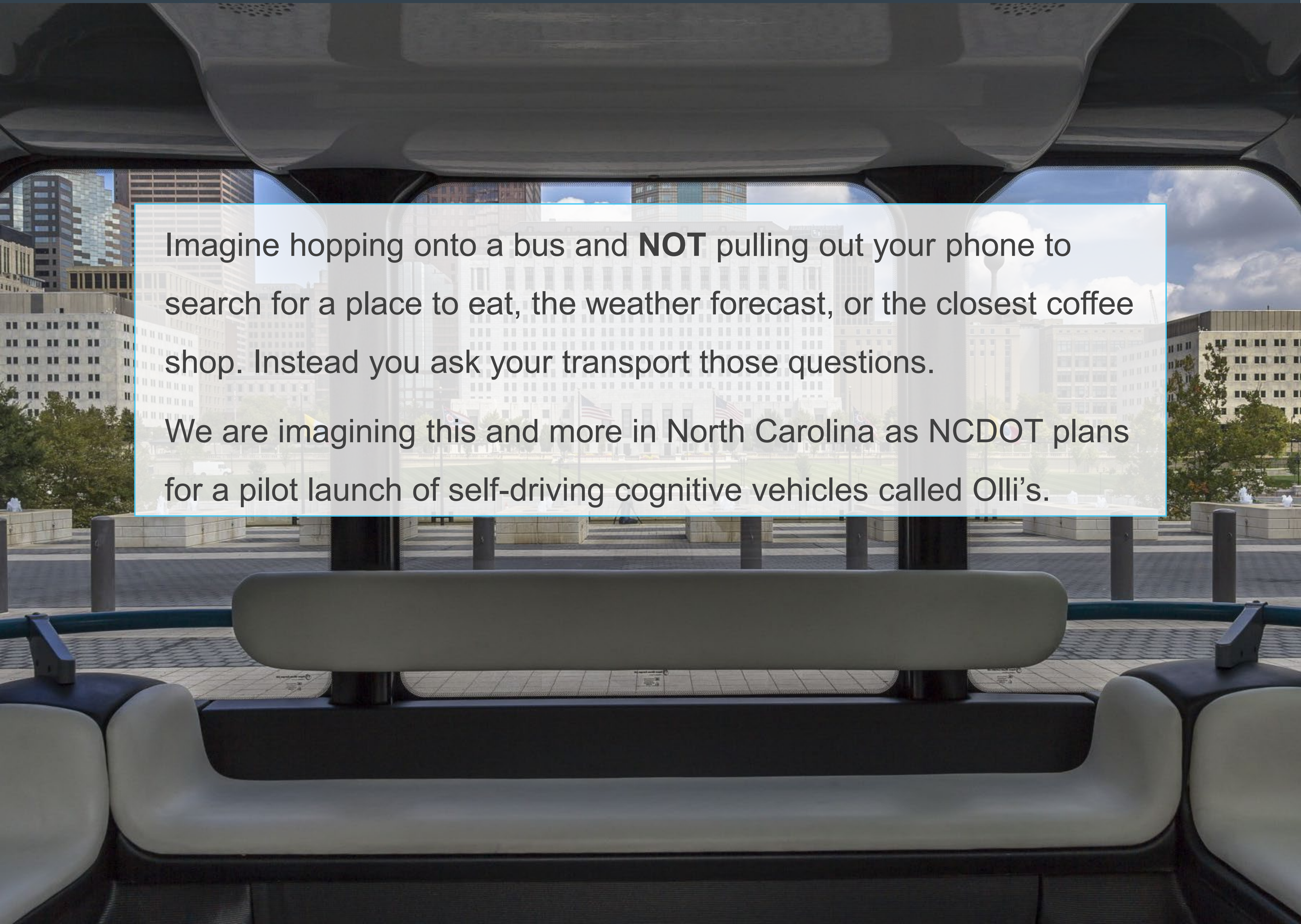
NORTH CAROLINA
Department of Transportation

The Olli's are Coming!



Stephanie L. Sudano, P.E.
NCDOT Multimodal Special Projects Engineer

May 3, 2019



Imagine hopping onto a bus and **NOT** pulling out your phone to search for a place to eat, the weather forecast, or the closest coffee shop. Instead you ask your transport those questions.

We are imagining this and more in North Carolina as NCDOT plans for a pilot launch of self-driving cognitive vehicles called Olli's.

Meet olli

by *local motors*

Self-driving, electric, cognitive (IBM Watson) shuttle, 3-D printed, Level 4/5 AV
25 mph maximum speed, seats 8-12 people

Coming this Fall

NCDOT has negotiated with Local Motors to bring two Ollis to NC.

NCDOT's pilot program will partner with local communities across North Carolina for a period of 24 month to deploy the Olli as a fixed-route transit circulator.

NC's Ollis will be 3-D printed in October and delivered in November

More about the Olli

Human Steward

15-18 MPH

Operating Speed

Electric

Level 4/5

IBM Watson

Interaction with Passengers

8-12 Passengers

Feedback Loop

Pre-set Route

Cloud-based Cognitive Computing

Lidar, Cameras and GPS

Max Speed 25 MPH

Customer Surveys

3D Printed

Ramping up for the Olli NC Campaign

Rural to Urban

Innovation

Outreach and Engagement

Technical Expertise

Diverse Environments

Customer Surveys

Communities

Data Collection

Statewide

Private then Public Streets

Collaboration

Why this project?

- Explore new transportation technology & innovative solutions
- Allow communities to experience new transportation technology
- Learn about the way this technology will change:
  - State and local transportation planning
  - Community planning
  - Perception of public transportation
  - Accessibility to transportation

Long-range Planning considerations:

- Impacts to public transportation
- Parking & urban street design
- Traffic signal timing
- Pedestrian interactions
- Impacts to industry
- Parking deck design
- More…..

The Olli Game Plan

(still under development)

Teams:

Olli NC Transit Deployment Team (ONC-TDT)

- NCDOT Division Leaders
- Crosscutting disciplines involved

Olli NC Technical Oversight Team (ONC-TOT)

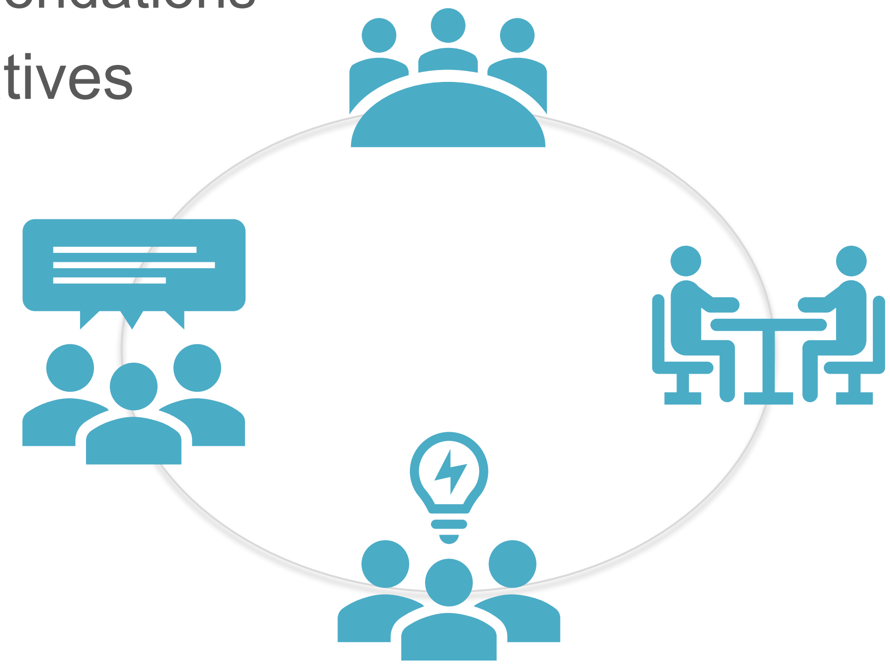
- Small Internal Team
- Day to Day Oversight

Olli NC Community Deployment Teams (ONC-CDT)

- Local leaders, city, town, and university leaders and staff members

Collaboration

- NC Fully Automated Vehicle Committee (FAV)
  - NCDOT CAV Roadmap
  - FAV Committee Recommendations
- Other AV and Transit Initiatives in NC
- Communities
- Universities
- Public Agencies
- And More…



Project Delivery

- Phase 1: Selecting first two communities from existing list of use cases
- Phase 2: Invitation for submittal of more use cases

Timeline:

- October 2019 NC's Olli 3-D Printed
- November 2019 Olli NC Transit Deployment Phase 1 begins
- December 2019 Phase 2 begins
- November 2021 Olli NC Transit Deployment ends

Challenges

- Reaching and engaging Communities
- Funding
- Logistics of Multiple Pilot Locations
- Short-term Deployments (4-6 months)
- Diverse Demographics
- Public Perception/Reception

- Who knows what else?
  This is NEW!

Contact:

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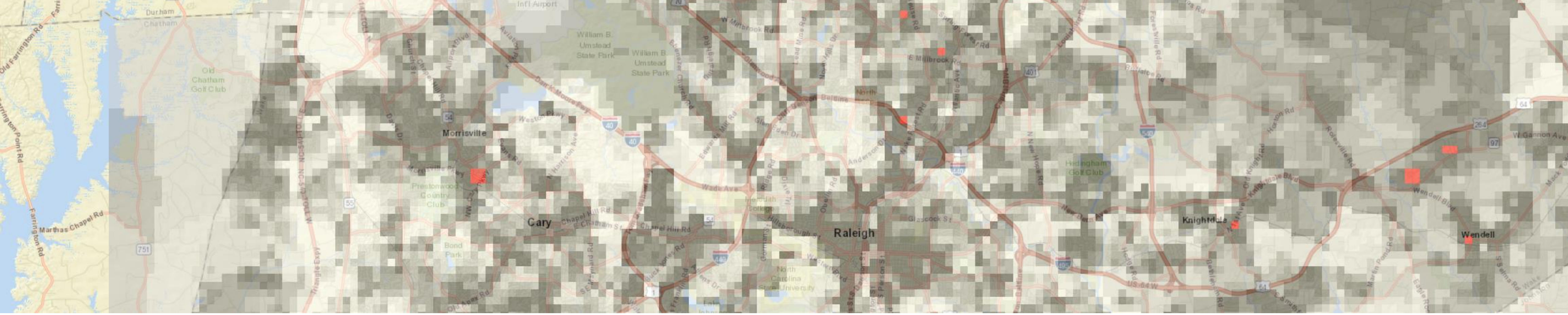
919-707-2611

Interested in learning more?
Add your name to the sign up sheet to be notified
when the Olli NC Transit website is launched.

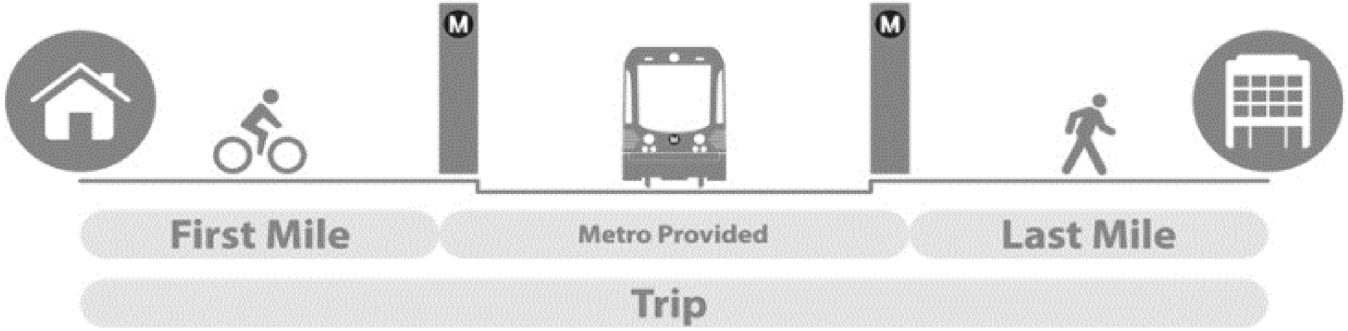


MAXIMIZING FIRST/LAST MILE TRANSIT ACCESS WITH A RASTER SUITABILITY ANALYSIS

PRESENTATION BY ***WESTON HEAD***

ITRE

THE FIRST/LAST MILE TRANSIT ACCESS PROBLEM



In order to use public transportation, the user needs to reach the station from his/her home and then reach his/her destination from the station

First and Last Mile access can be an issue in areas of low population density and with limited pedestrian and bicycle infrastructure

Many of the proposed solutions of this problem have shifted in recent years towards Mobility as a Service (MaaS) technologies

ITRE

Image Source: Los Angeles County Metropolitan Transportation Authority

Image Source: Clark Nexsen, Prototype Bus Shelter

PROPOSED SOLUTION: OPTIMAL PLACEMENT OF TRANSIT STATIONS

Focus on the placement of the transportation stations, not the resulting first and last miles

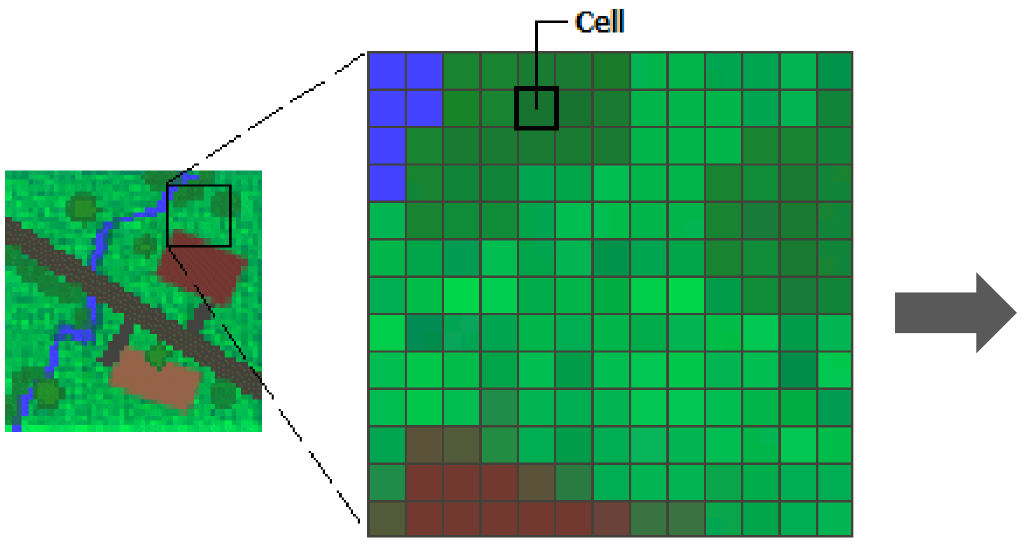
To maximize first and last mile transit access, a raster suitability analysis should be completed for the study area.

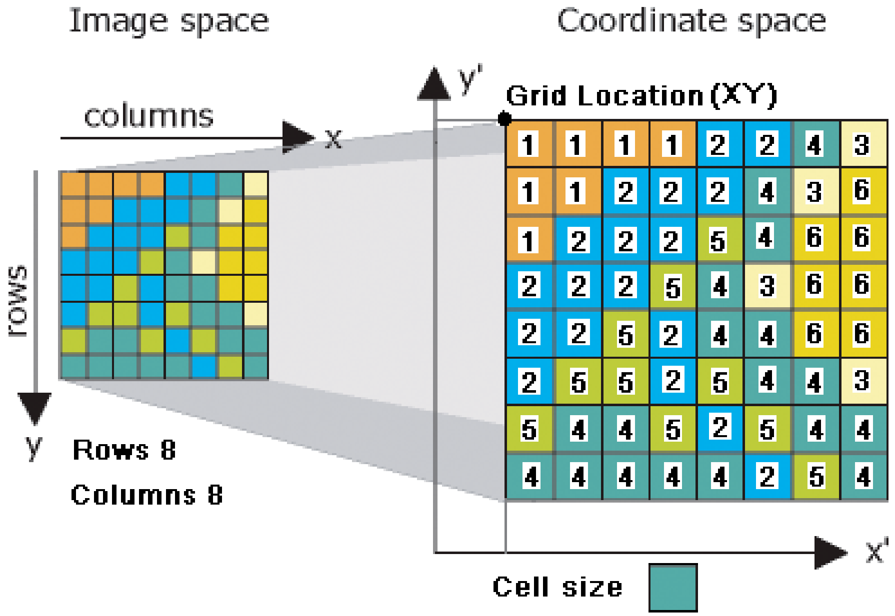
A raster suitability analysis will use quantitative data as inputs and output optimal locations for transit stations

The raster suitability analysis is consistent, repeatable, customizable, and based off of data.

ITRE

RASTERS: BACKGROUND





"In its simplest form, a ***raster*** consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature."

–ArcGIS Desktop Guide

Image Source: ArcGIS for Desktop: Raster and Images – Introduction (L), ArcGIS for Desktop: Geodatabases – An overview of the geodatabase (R)

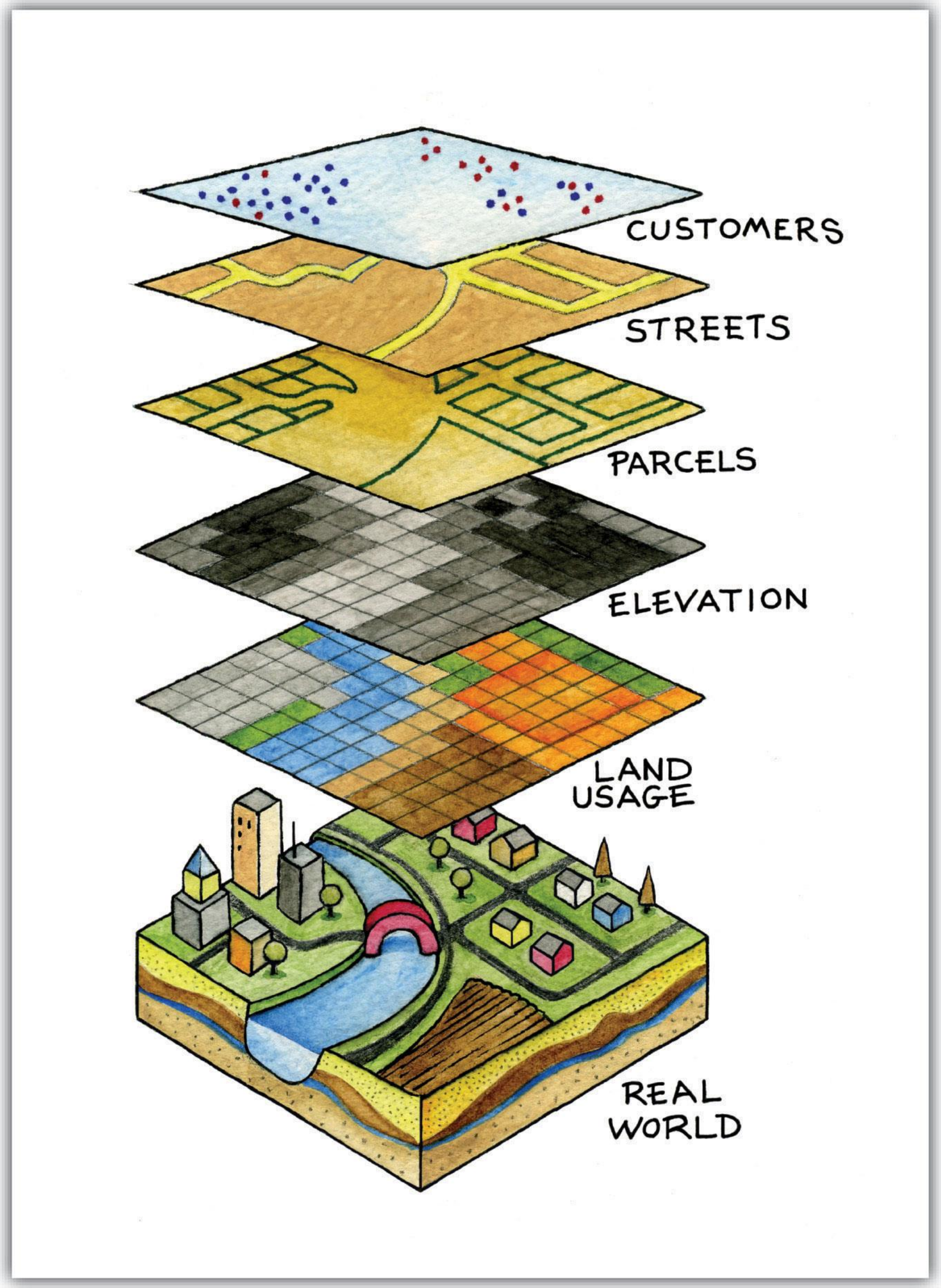


Image Source: Essentials of Geographic Information Systems, v1

RASTER SUITABILITY ANALYSIS: BACKGROUND

Suitability Analysis combines multiple layers of quantitative data, standardizes it into a scoring system, sums them, and results in a raster layer containing values representing each rasters suitability.

PROCESS STEPS AND AN EXAMPLE

Define Your Problem and Area of Interest

- **Problem:** Placing bus stops in locations that will maximize first and last mile transit access while avoiding existing bus stop locations.
- **Area:** Wake County

DEFINE FACTORS OF IMPORTANCE

A Bus stop that maximizes last and first mile transit access should:

- Have close proximity to high densities of residents
- Have close proximity to high densities of commercial parcels
- Be far away from existing bus stop
- Have close proximity to areas with a low average household income
- Have close proximity to areas with a low average vehicle access per household

Others: (Not included in this example)

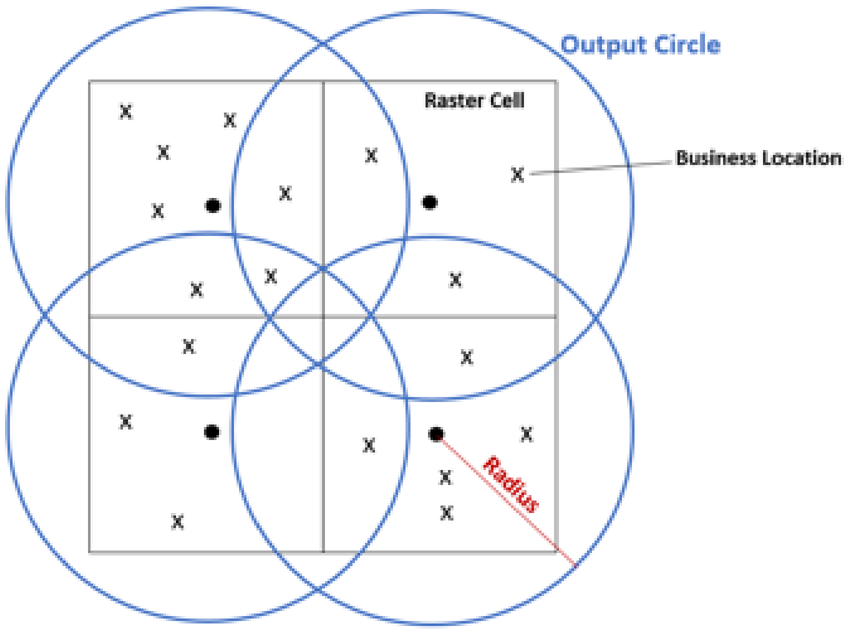
- Be located near schools, hospitals, libraries, etc.
- Be located near local bikeshare stations, train stations, other multimodal facilities
- ***Have anything else your research team or community thinks is important!***

ITRE

GATHER DATA AND GEOCODE IT

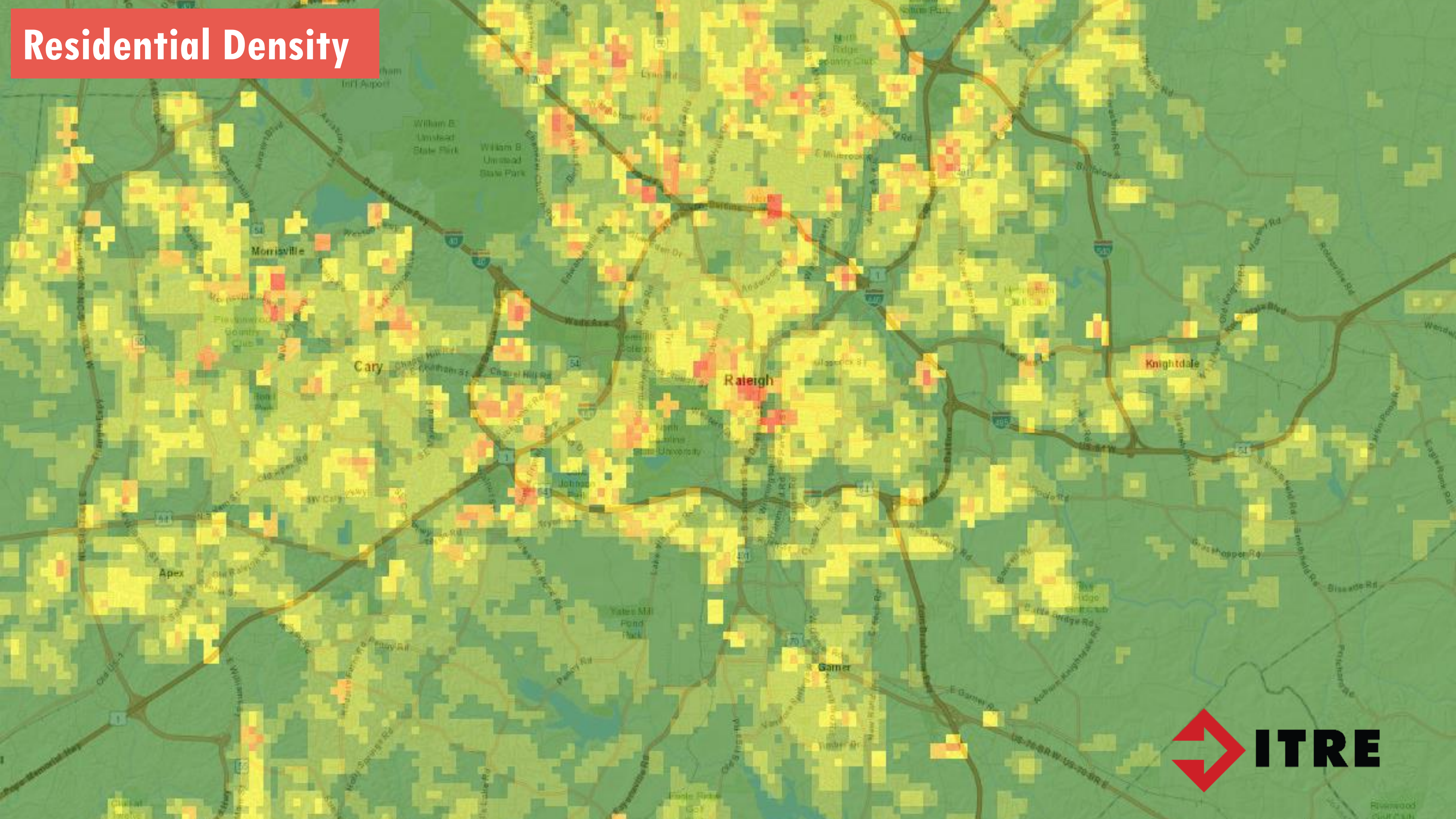
- For each factor, collect geo-located data that can be imported into GIS.
- Ideally, the data collected will already be a shapefile containing points or polygons
- Determine which quantitative method is appropriate for each field
    - Distance from each raster to a feature
    - Density of a feature within a distance of each raster
    - Average value of a feature around each raster

Point Density Functional Diagram

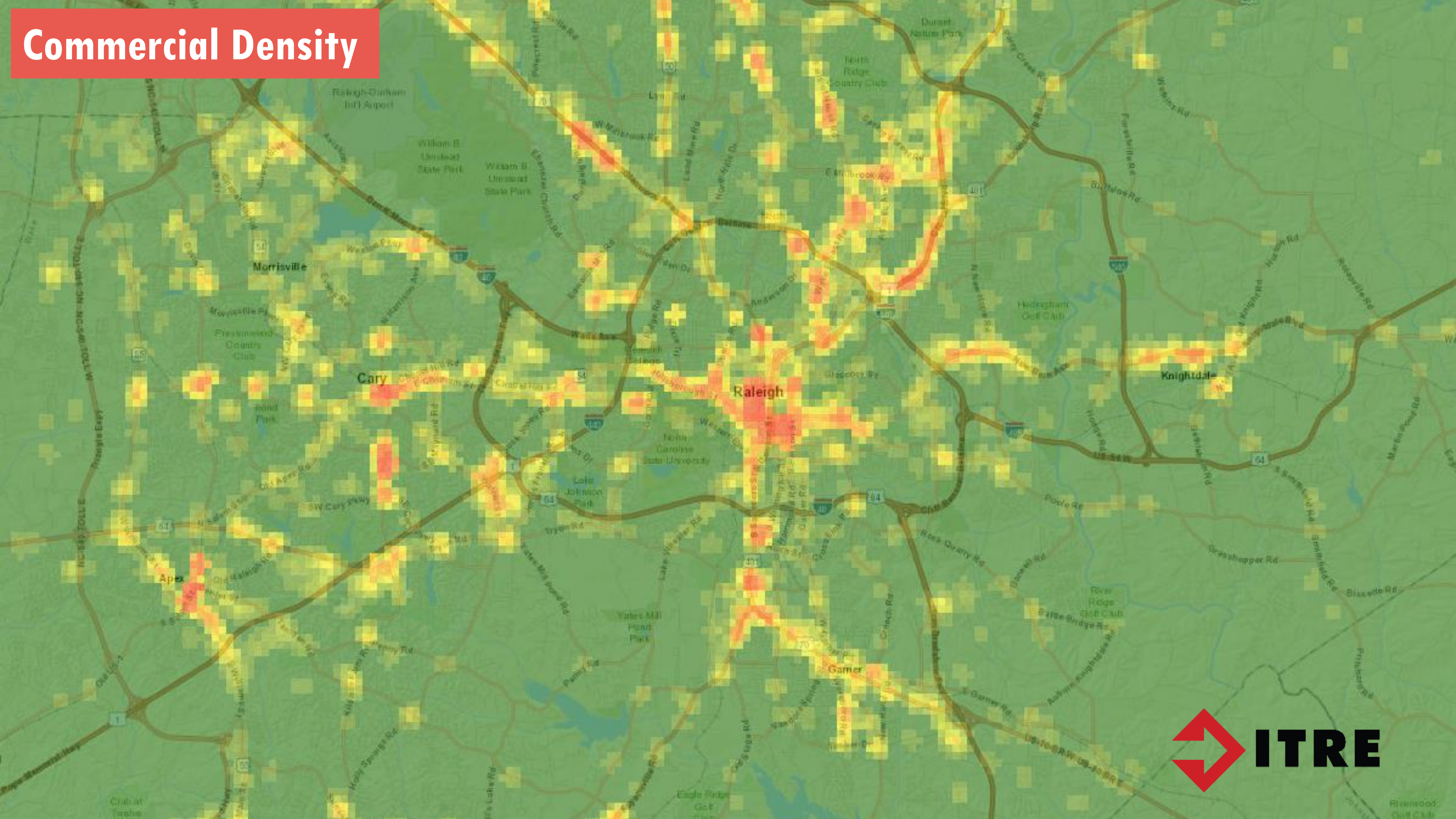


Information Source: ArcGIS Tool Reference,
How Point Density Works

Residential Density

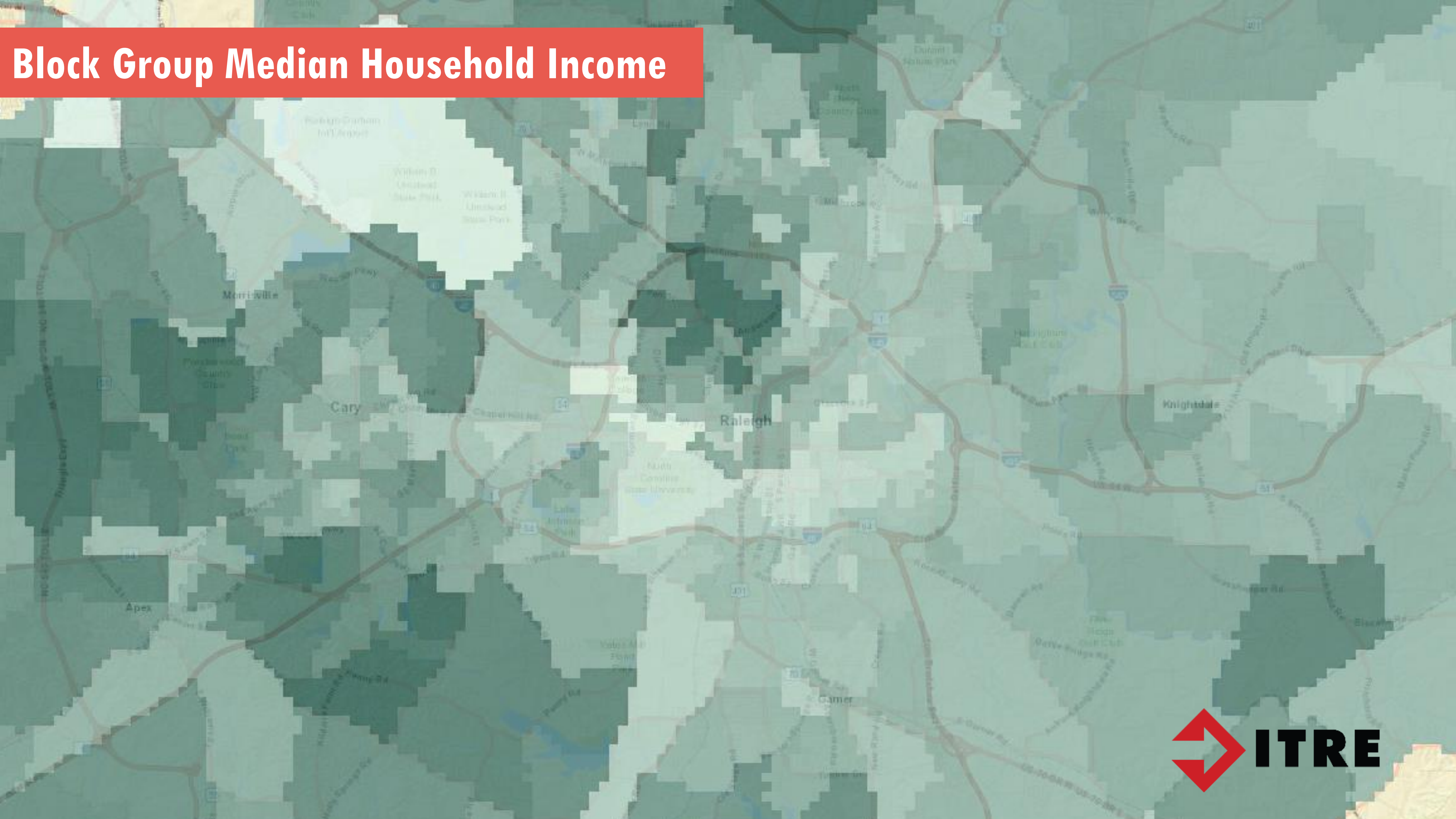


Commercial Density



ITRE

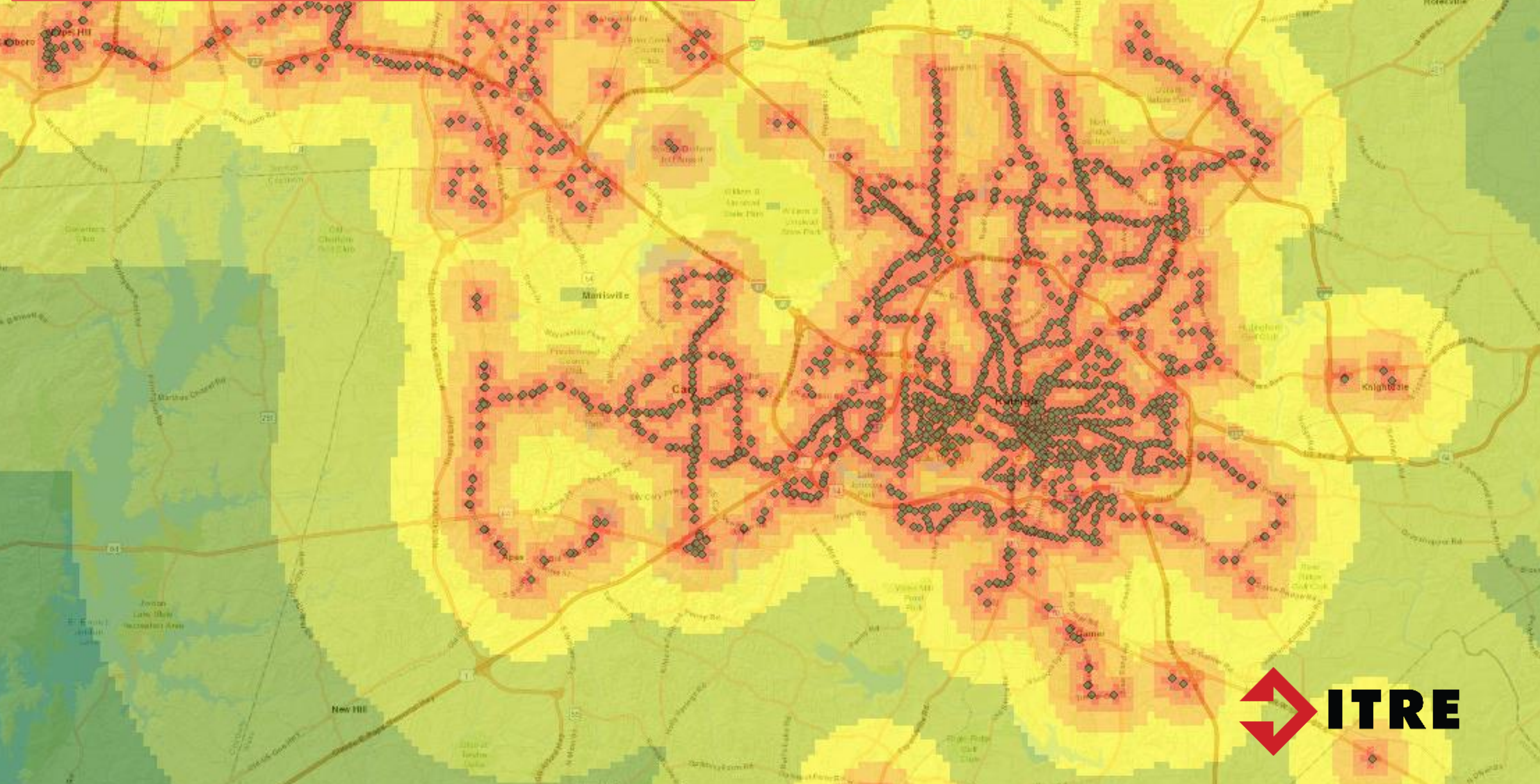
Block Group Median Household Income



ITRE

Average Vehicles per Household

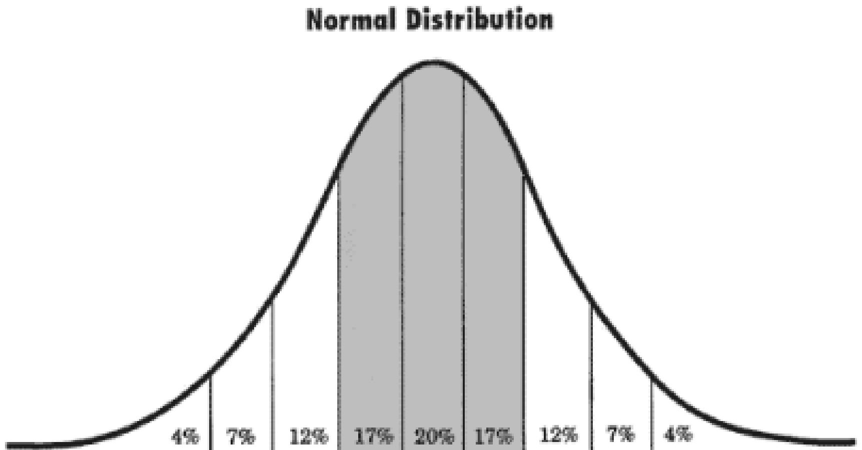
Distance from Current Bus Stops



ITRE

STANDARDIZE AND WEIGHT EACH FACTOR

- In order to add the raster layers together, a common scale needs to be determined
- The scale can be based on quantiles, even interval, or by design
- Once each layers distributions have been converted into a scale, the factors should be weighted by importance
- The more important a factor is, the larger weight it should get



Stanine	1	2	3	4	5	6	7	8	9
Percentile Rank	Below 4	4-10	11-22	23-39	40-59	60-76	77-88	89-95	Above 95
NCE	1.0-10.4	13.1-23.0	24.2-33.7	34.4-44.1	44.7-54.8	55.3-64.9	65.6-74.7	75.8-84.6	86.9-99.0
	Below Average			Average			Above Average		

A Normal Distribution of Stanines, Percentile Ranks, Normal Curve Equivalents, and Performance Classifications

Image Source: Study.com, Stanine: Definition & Explanations

SUM THE RASTER LAYERS TOGETHER

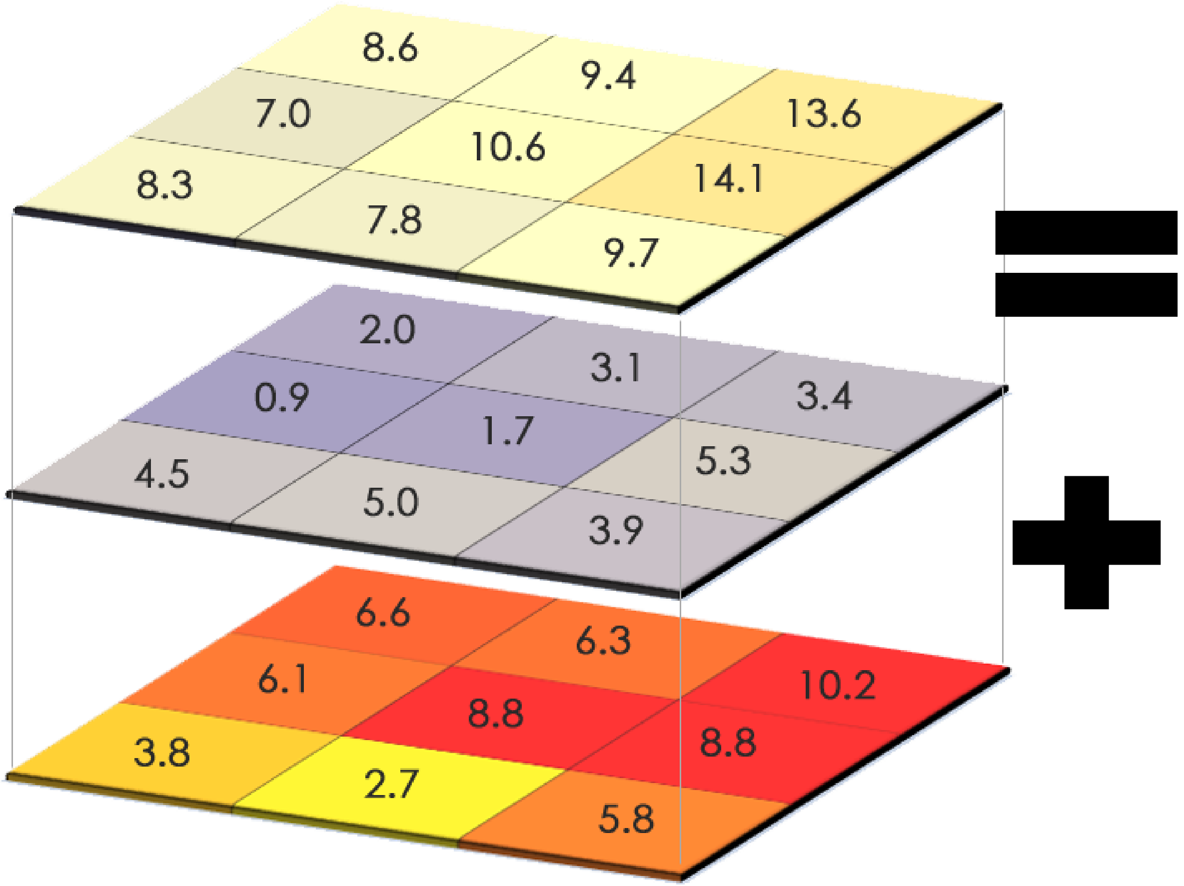


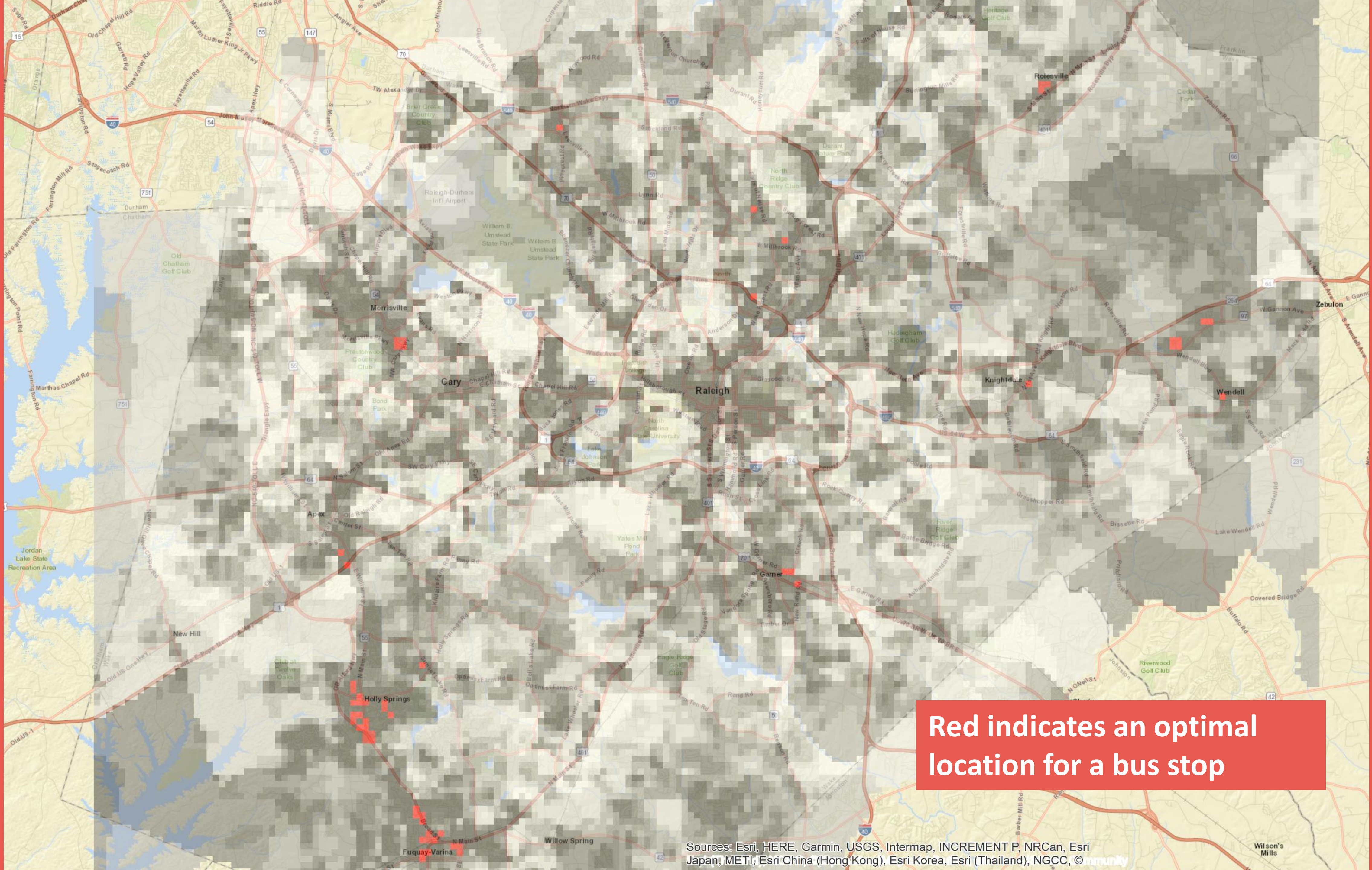
Image Source: GISGeography

RASTER SUITABILITY ANALYSIS: STEPS

- Define your problem and area of interest
- Define Factors of importance
- Gather geo-spatial data for each factor
- Perform raster analysis for each factor
- Standardize the raster analysis layer scales to a common scoring scale (i.e. 1 to 7)
- Determine weights for each variable raster layer based on importance
- Add together each weighted raster output layer to form one aggregate score per raster
- Choose the rasters with the highest scores as the optimal solutions

ITRE

RESULTS



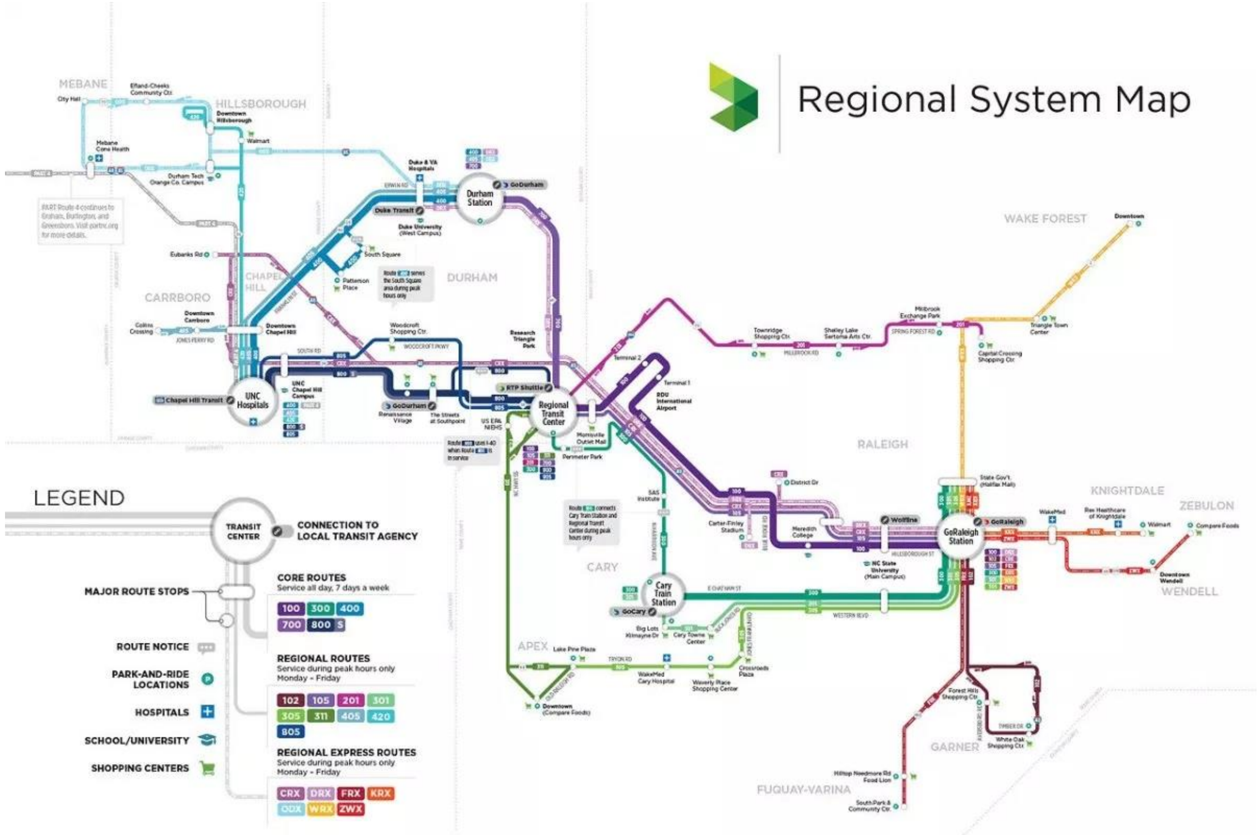
Red indicates an optimal location for a bus stop

BENEFITS OF THIS METHOD

- Can be implemented today, for any location
- Repeatable
- Data Driven
- Consistent
- Adaptable
- Creates the opportunity for community input

OPPORTUNITIES FOR IMPROVEMENT

This suitability analysis currently only places stations, but does not provide any guidance on routes. It could be paired with origin and destination data to decide routes.



QUESTIONS?

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