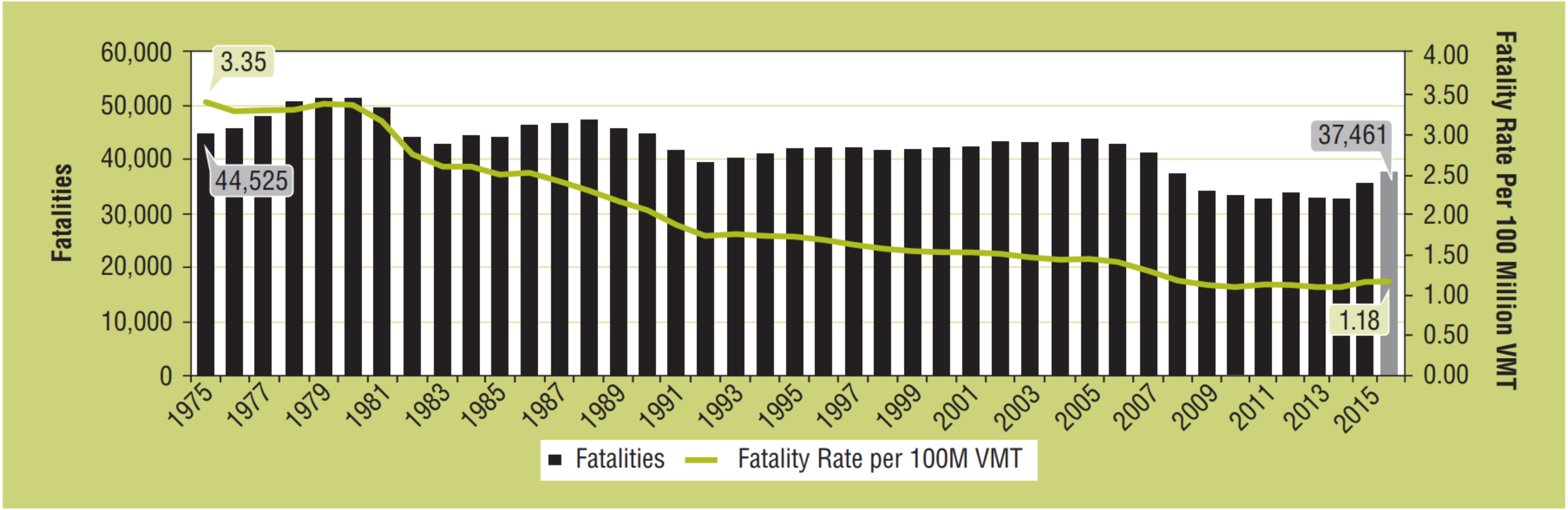
Connected Vehicles: Are We There Yet?

Angshuman Guin

March 2019

Fatalities and Fatality Rate per 100 Million VMT, by Year, 1975–2016



Sources: FARS 1975–2015 Final File, 2016 ARF; Vehicle Miles Traveled (VMT): FHWA.

10,874
DEATHS FROM DRUNK-DRIVING CRASHES IN 2017

29%
PERCENTAGE OF MOTOR VEHICLE TRAFFIC FATALITIES CAUSED BY DRUNK DRIVING IN THE UNITED STATES IN 2017

220
CHILDREN 14 AND UNDER KILLED IN DRUNK-DRIVING CRASHES IN 2017

20%
PERCENTAGE OF NIGHTTIME WEEKEND DRIVERS WHO TESTED POSITIVE FOR DRUGS IN THE 2013-2014 NATIONAL ROADSIDE SURVEY

48%
INCREASE IN WEEKEND NIGHTTIME DRIVERS TESTING POSITIVE FOR THC FROM 2007 TO 2013-2014

3,450
NUMBER OF PEOPLE KILLED BY DISTRACTED DRIVING IN 2016

481,000
PASSENGER VEHICLES DRIVEN BY PEOPLE USING HANDHELD CELL PHONES DURING THE DAY IN 2016

391,000
NUMBER OF PEOPLE INJURED BY DISTRACTED DRIVING IN 2015

90,000
MOTOR VEHICLE CRASHES INVOLVING DROWSY DRIVING IN 2015

VISION ZERO

NO MORE TRAFFIC DEATHS

Source of stats: NHTSA

Image source: https://www.denvergov.org/content/denvergov/en/vision-zero.html

ITS

VANET

MANET

VII

RFID

RDS

C-ITS

onnected

V2I

V2C

V2P

V2V

V2X

ehicles

Research News

no.203.078

Research shows the global market for connected cars could grow as much as 270% by 2022.

Source: https://www.electronicdesign.com/automotive/put-it-reverse-why-it-s-time-design-connected-cars-backward

Connected Vehicle Technology Battle

C-V2X (4G / 5G)

- Volkswagen
- Ford
- Audi
- BMW
- Daimler
- Ducati
- Baidu
- Qualcomm , Ericsson, Huawei, Intel, Nokia

DSRC

- Honda
- Toyota / Lexus
- Cadillac
- Nissan
- GM

Auto News

> While Ted Klaus, of Honda R&D Americas, told the 2018 AutoMobility LA show in November that the carmaker remains "agnostic" in the battle between 5G and DSRC, it's clear the on-board Safe Swarm technology looks more geared to the latter rather than the former.

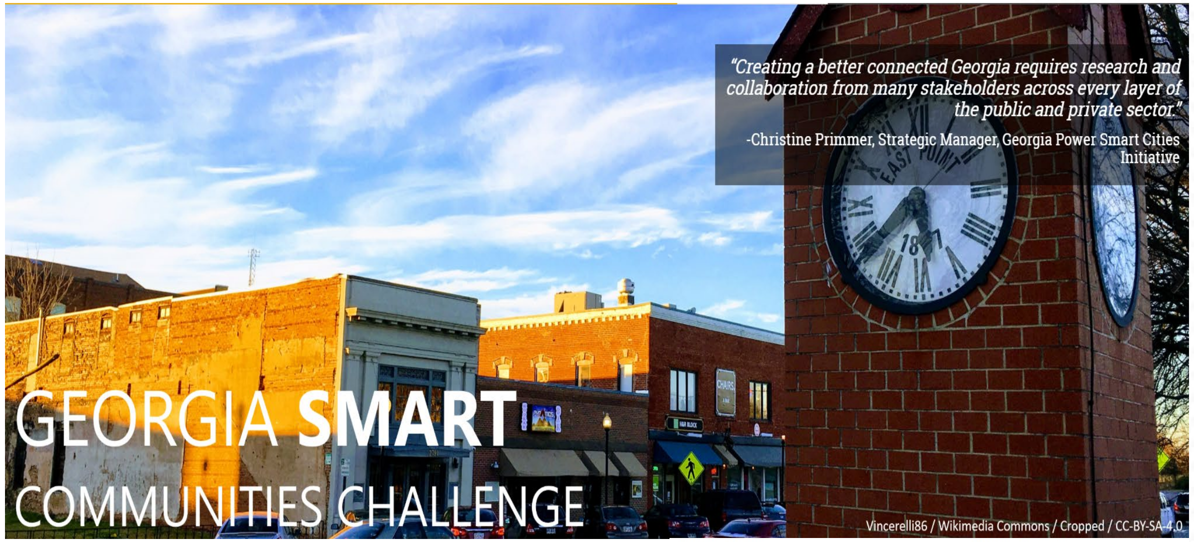
Source: https://www.tu-auto.com/honda-safe-swarm-v2x-tech-looks-dsrc-facing

Georgia Tech Partnership Projects

City of Atlanta / Renew Atlanta

Photo Credit: https://smartatl.atlantaga.gov/index.php/blog-post/georgia-tech-city-of-atlanta-launch-north-avenue-smart-corridor-project/

Gwinnett County



Georgia Power
ARC Atlanta Regional Commission
ACCG Advancing Georgia's Counties
Georgia USA
GEORGIA CHAMBER
Georgia Department of Community Affairs
Georgia Municipal Association
TAG Technology Association of Georgia
Metro Atlanta Chamber
Global City Teams Challenge

City of Albany

Chatham County

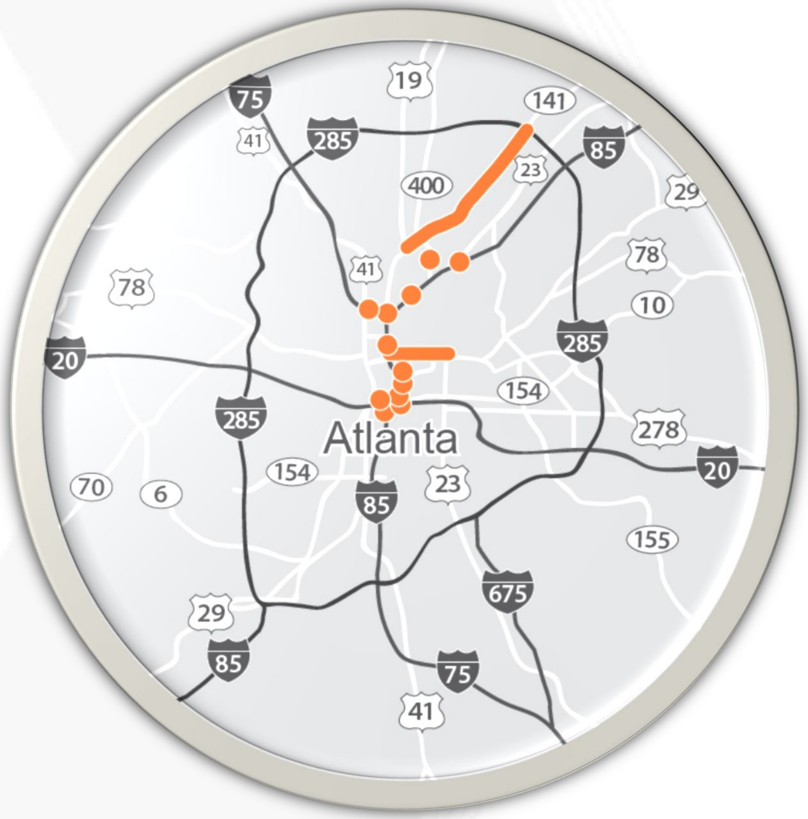
City of Chamblee

Gwinnett County

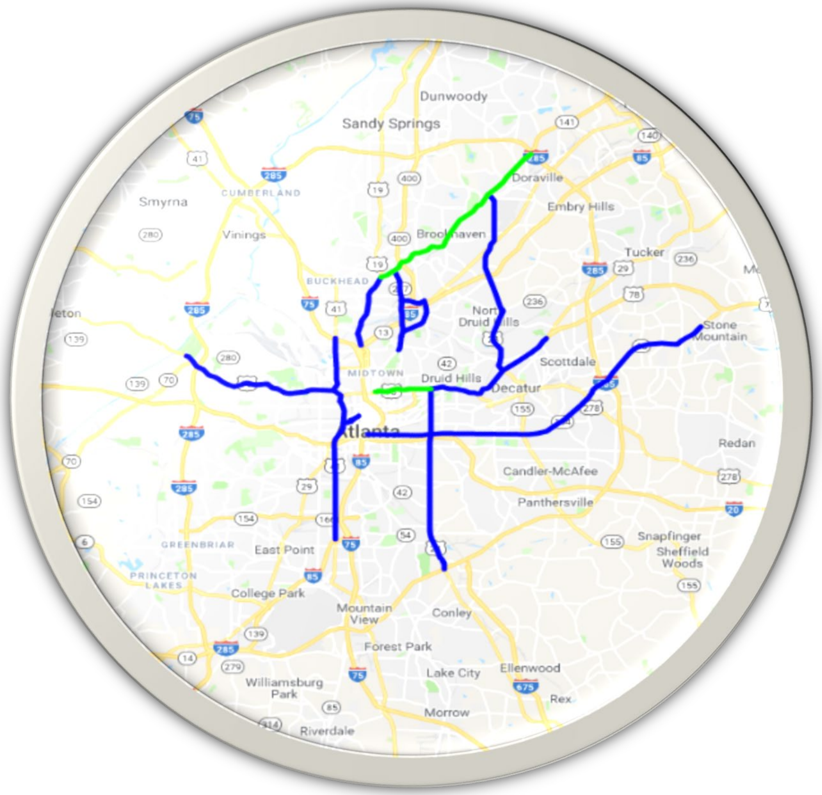
Photo Credit: http://smartcities.gatech.edu/georgia-smart

GDOT Deployments

Current



Phase 1



Phase 2

Photo Credit: GDOT

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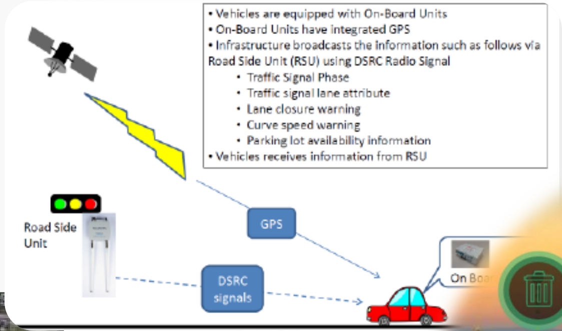
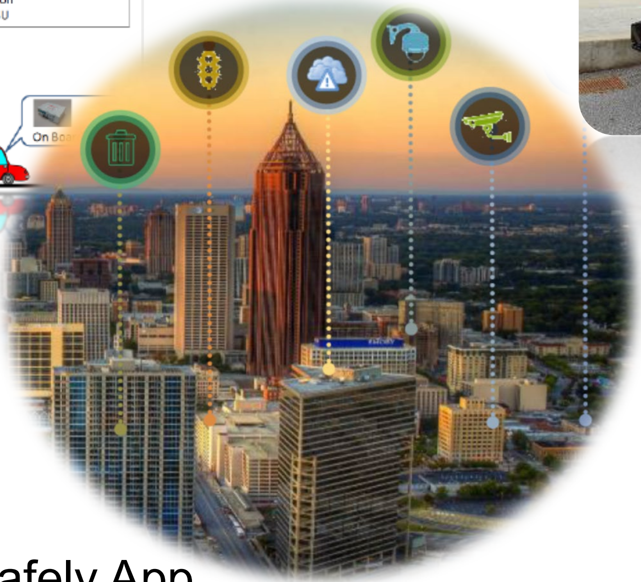
North Avenue Smart Corridor

Connected Vehicle



Automated Vehicle Demonstration



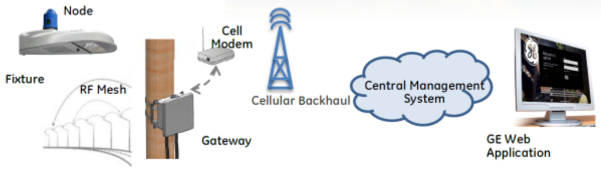
Vehicle Detection

Bike and Pedestrian Detection

Smart Waste System

Travel Safely App

Smart Lighting



Source: http://www.itsga.org/wp-content/uploads/2017/10/2017-annual-meeting-4A-CoA-Smart-City-Deployments-2017-ITS-GA-Annual-Meeting-lord.pdf

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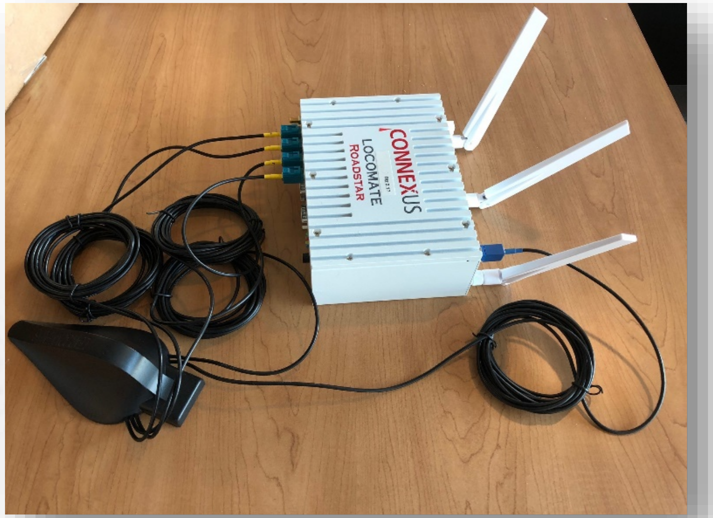
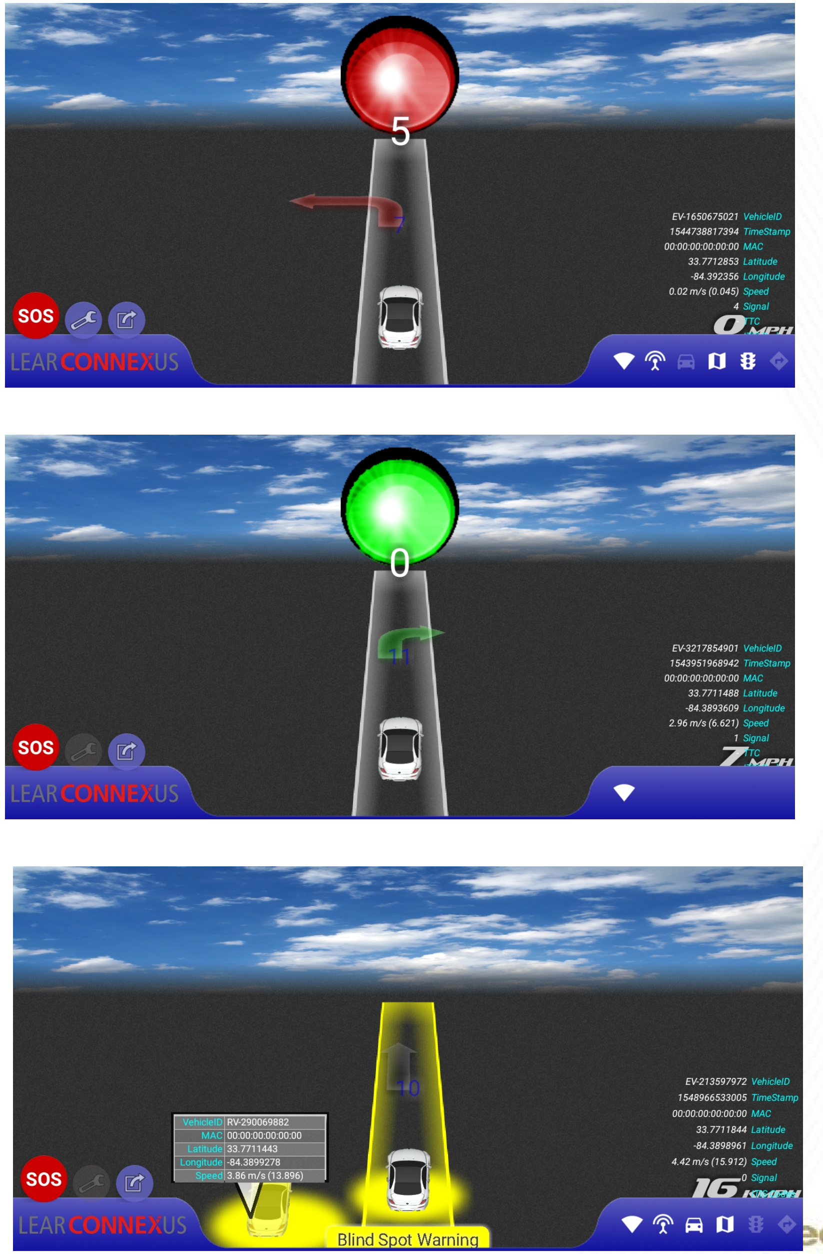
Connected Vehicle Equipment

Road Side Unit (RSU)



On Board Unit (OBU)



App Interface

Photo Credit: GDOT

Research Objective and Motivation (1)

What?

Hybrid traffic simulation model - mix of preprogrammed and real-time data-driven intersections

1

How ?

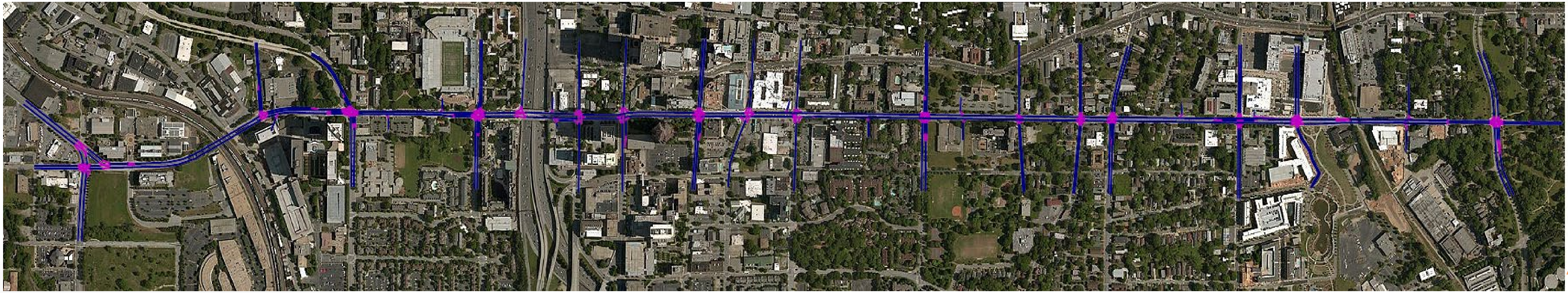
An optimized real-time architecture that:

- Uses in-field detectors, SPaT, and BSM data to drive simulation signals and demand
- Generates travel-time, energy, and emissions KPIs in real-time

Research Objective and Motivation (2)

Why?

Assess feasibility of using a real-time data-driven transportation simulation model to provide dynamic operational feedback in a real world environment



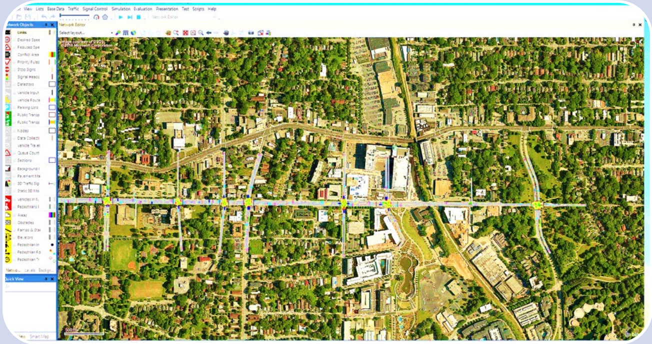
2

Vissim Simulation Model, North Ave Corridor

***Really why*: Improve the quality of life of city stakeholders – residents, employees, and visitors**

Fields of Focus Towards Smart City Vision


3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4

Smart City Vision

Integration of smart technologies with physical infrastructure

Real-Time Traffic Simulation Model

Real-time data integrated into operational analysis

Handling Large Amount of Data

Use of big data concepts for injecting data into simulation

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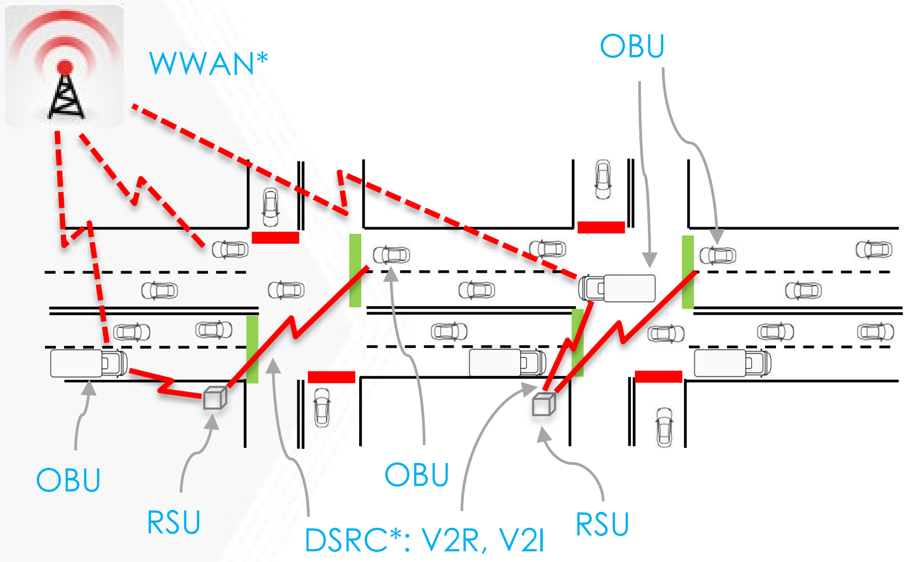
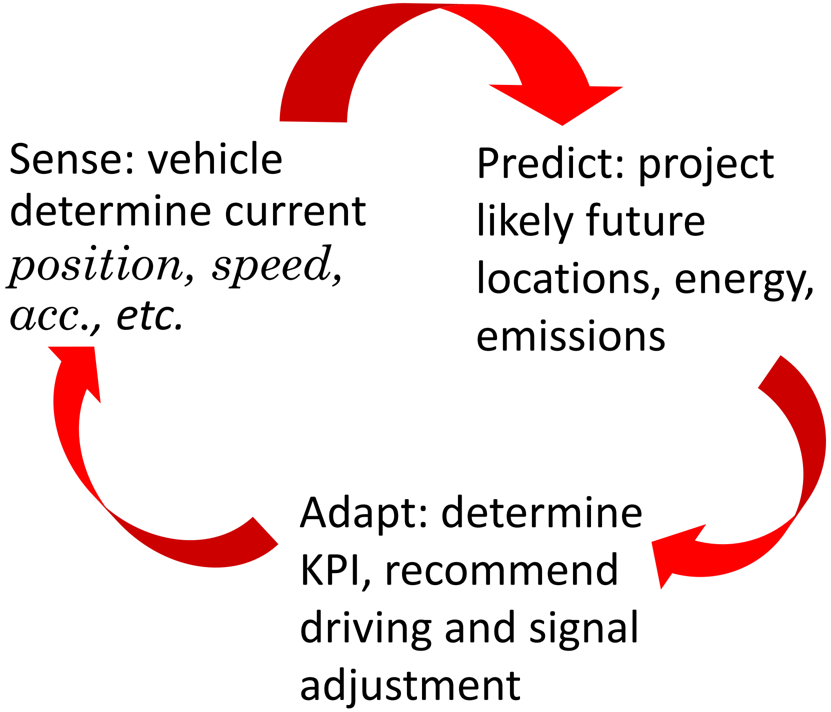
North Avenue Test Bed – DDDASApproach

DDDAS – Dynamic Data Driven Application Systems



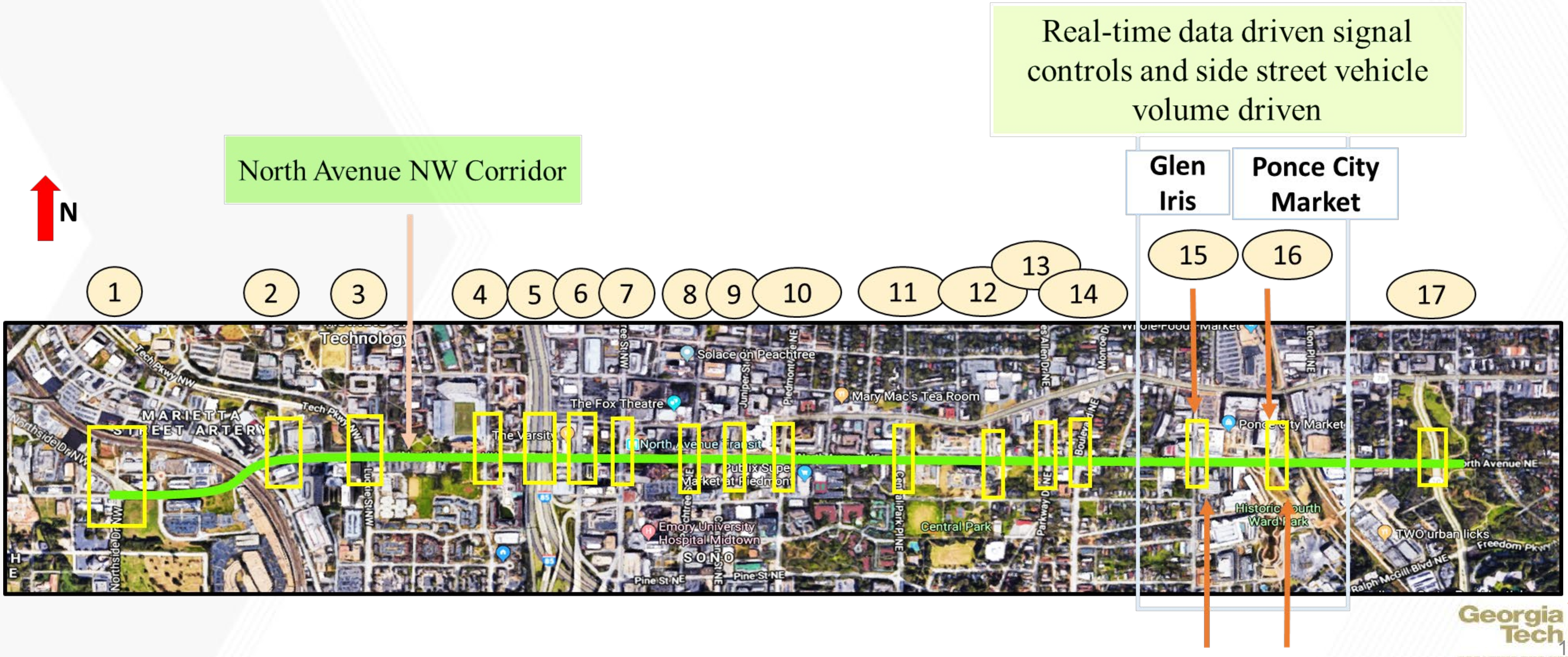
RSU - Roadside Unit
OBU – Onboard Unit
DSRC – Dedicated Short Range Communication
V2R – Vehicle to Roadside Communication
WWAN – Wireless Wide Area Network

* Communication between vehicle, roadside, and cloud may occur via DSRC or other WWAN application (e.g. cellular)



DDDAS Processing Loop

Simulation Model - North Ave Smart Corridor

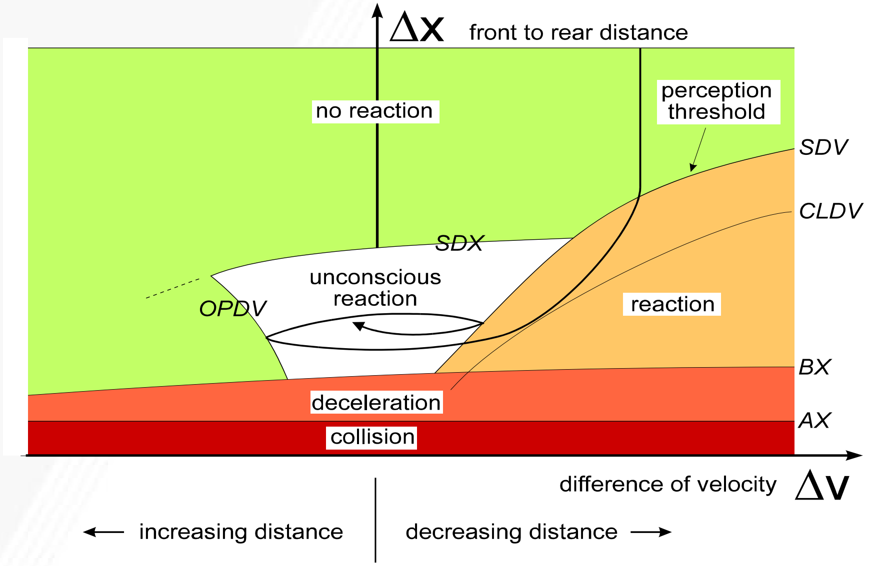


Simulation

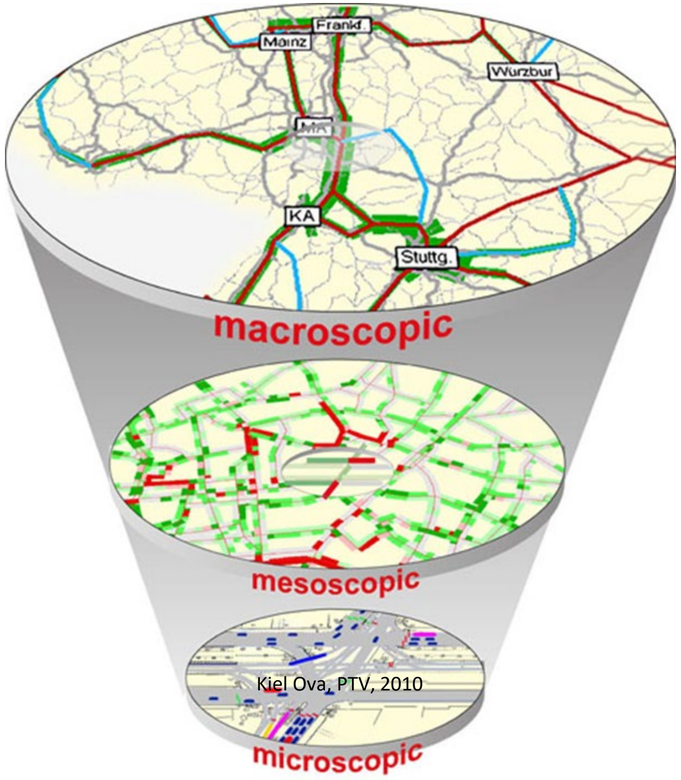
VISSIM - A microscopic, stochastic traffic simulation model that represents the real world dynamic traffic environment for freeways and streets

Models individual vehicle behavior, various traffic control devices, intersections and interchanges, dynamic demands, flexible network layouts, roadway geometry, merging, vehicle routing, etc.

Utilizes Psycho-physical car following model (Prof. Wiedemann, 1974 and 1999)



Kiel Ova, PTV, 2010



Kiel Ova, PTV, 2010

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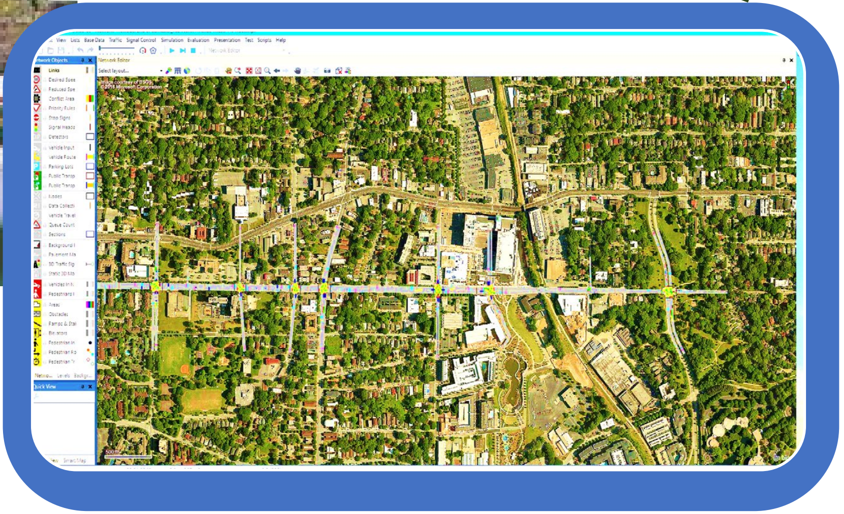
Model Architecture Primary Components

1 Inject real-time data into the simulation model

5

2 Run the traffic simulation model



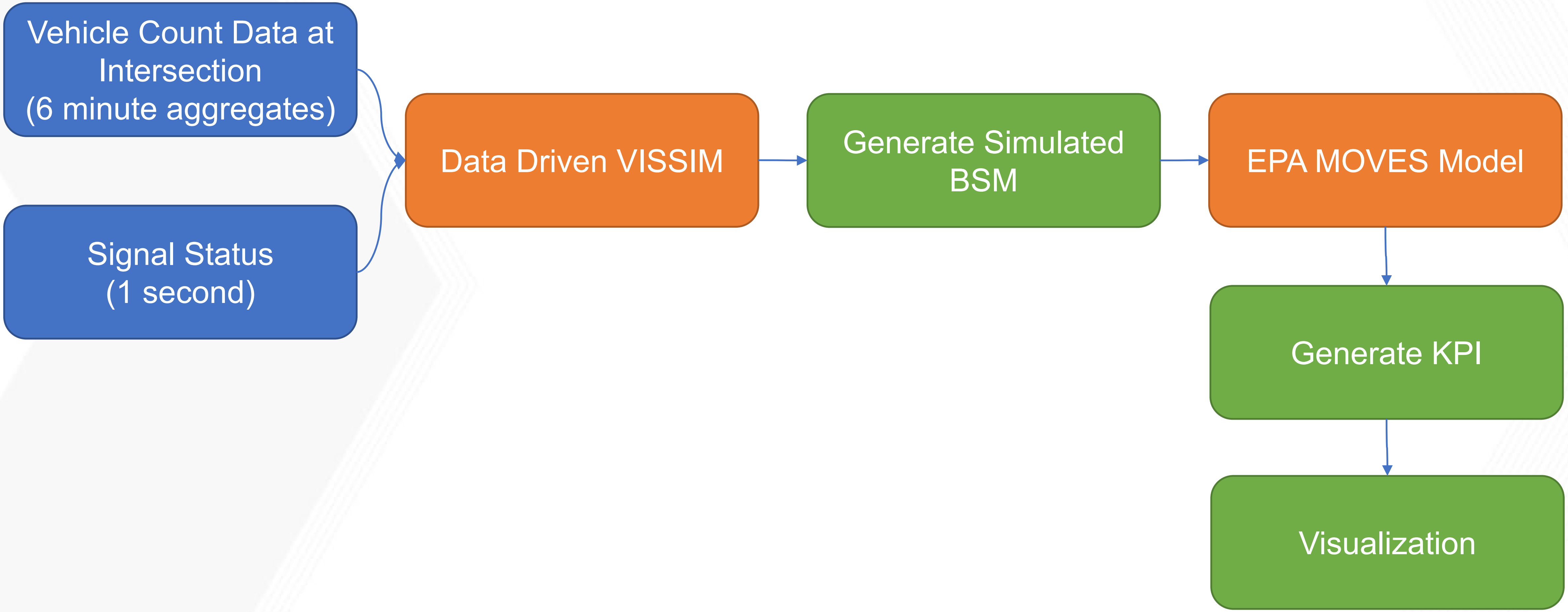
2

3 Generate and visualize KPIs

6

- Dynamic link between three tasks
- Simulation runs faster than real-time operations

Simplified Architecture



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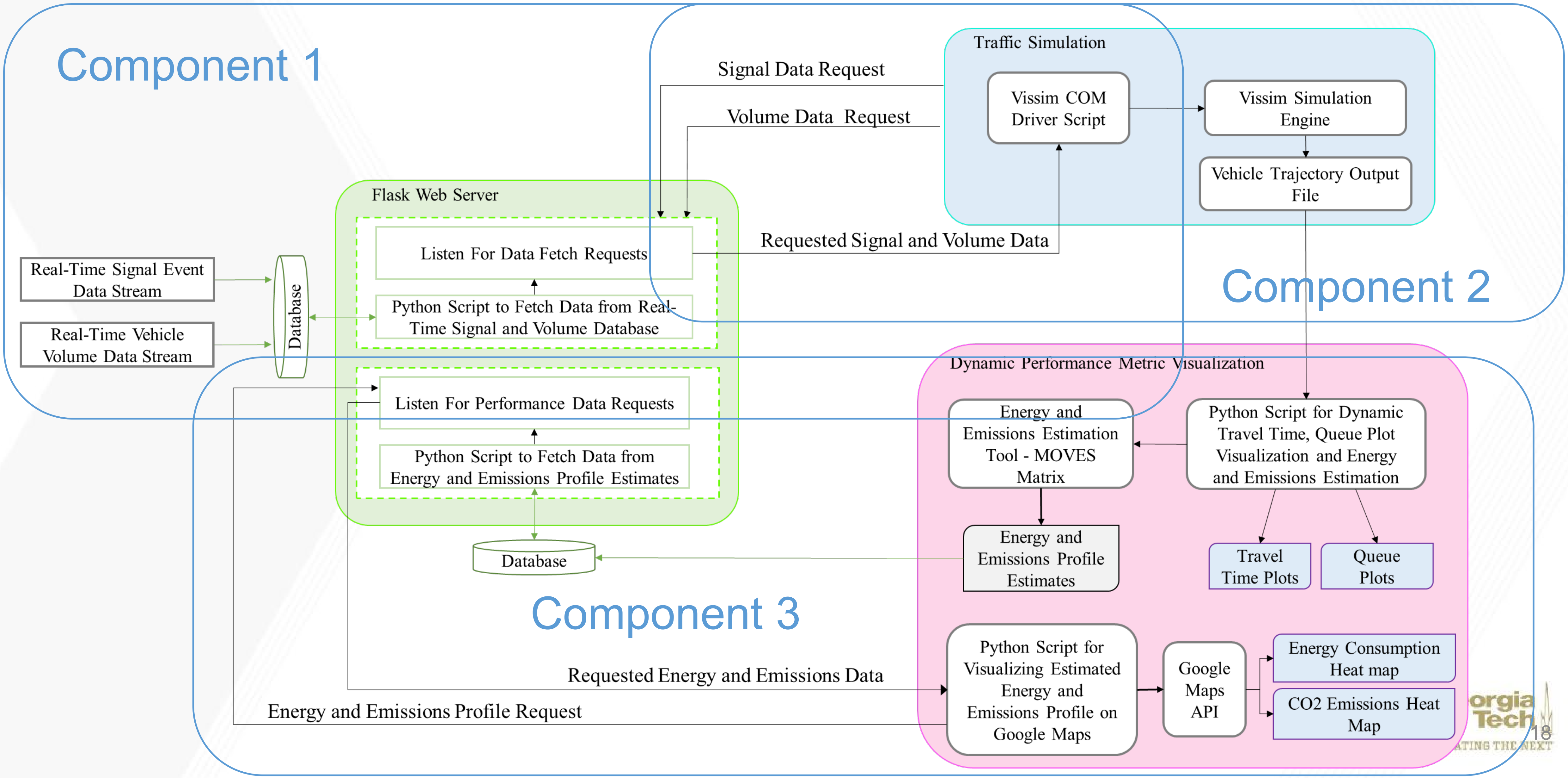
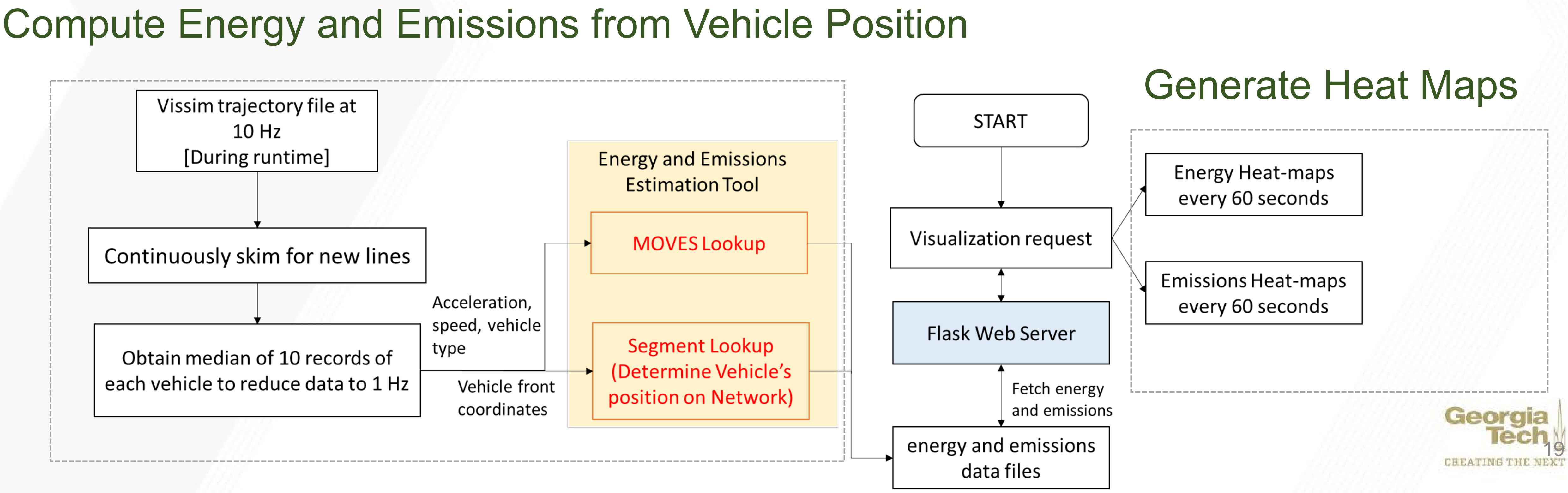
Complete Model Architecture



Model Architecture Components: Dynamic KPIs

Energy-Emission Computation Architecture

Energy and CO2 emissions profile based on Motor Vehicle Emission Simulator (MOVES)matrix is estimated in real-time using data from the trajectory output file



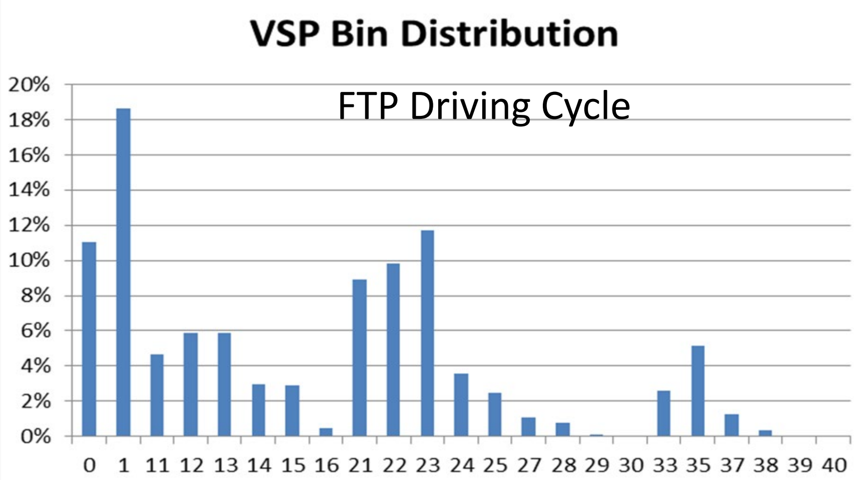
Energy and Emissions

- The USEPA's MOVES model predicts energy consumption and emissions as a function of vehicle onroad operating conditions, expressed as vehicle-specific power (VSP)
- The modeling approach developed by Georgia Tech yields a huge multi-dimensional matrix of emission rates, from which individual vehicle and fleet emission rates can be quickly derived and applied at any modeling scale

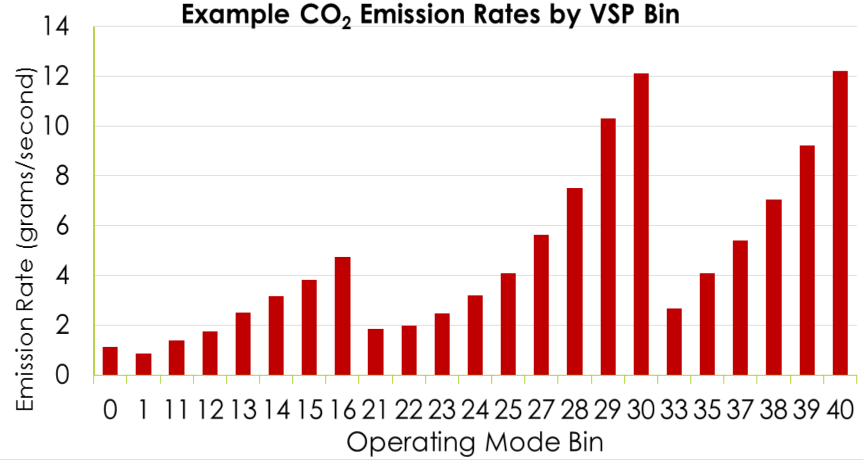
$$VSP = \left(\frac{A}{M}\right)v + \left(\frac{B}{M}\right)v^2 + \left(\frac{C}{M}\right)v^3 + \left(\frac{m}{M}\right)(a + g * \sin\theta)v$$

VSP = Vehicle Specific Power (KW/metric tonne)
M = Fixed mass factor for the sourceType (tonnes)
m = Source mass (tonnes)
A = Rolling resistance (kW/meter/second)
B = Rotational resistance (kW-sec2/meter2)
C = Drag coefficient kW-second3/meter3
v = Vehicle velocity (meters/sec)
a = Vehicle acceleration (meters/second2)
g = Gravitational acceleration (9.8 m/second2)
Ɵ = Road grade angle (radians or degrees, as needed)

Energy and Emissions



X



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Energy Consumption

FTP Cycle:
63,684 kJ
60,361 BTU
0.52 Gallons

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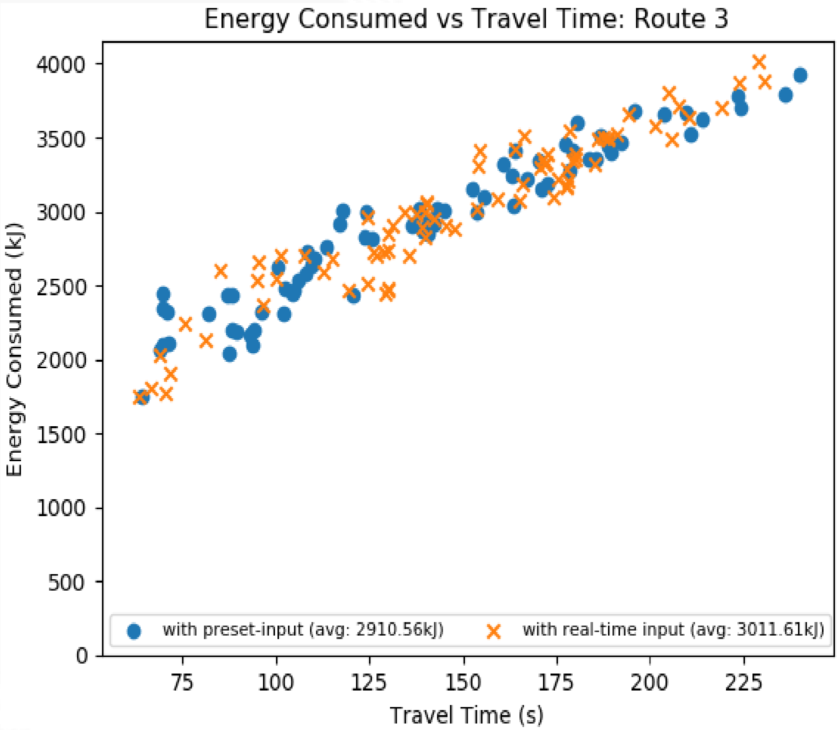
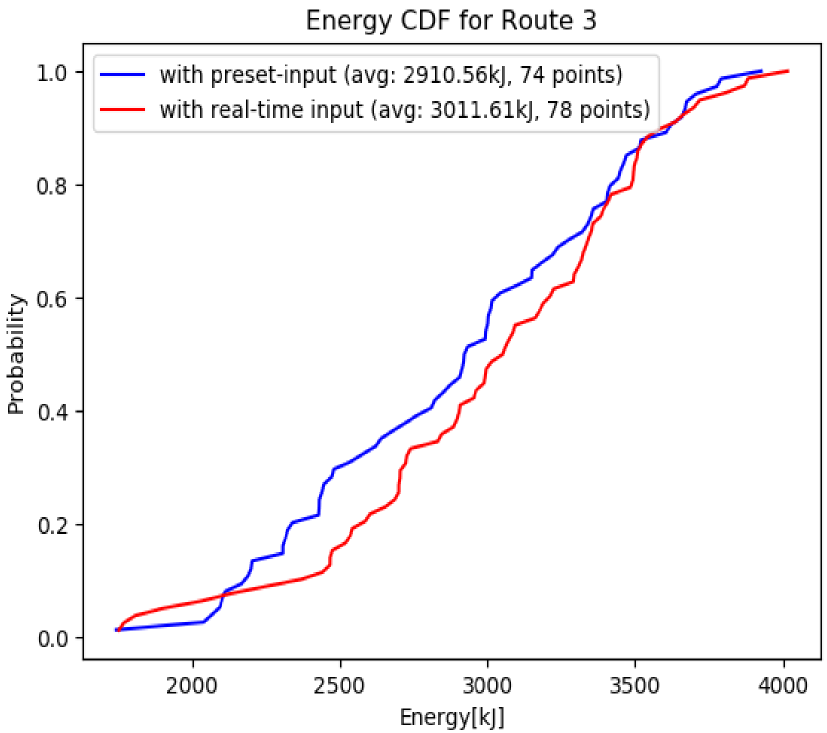
Result and Discussion: Model Sensitivity to Real -Time Input

Energy and Emissions

- Energy and emissions estimated from preset and real-time inputs were compared
- Results were comparable as shown in the scatterplots and CDF





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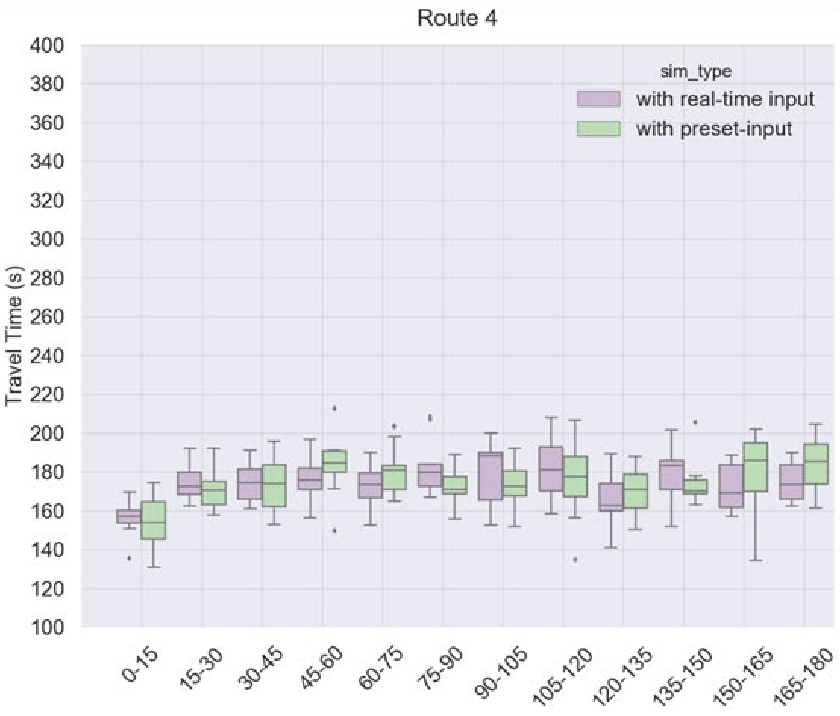
Result and Discussion: Model Sensitivity to Real -Time Input

Vehicle Travel Time

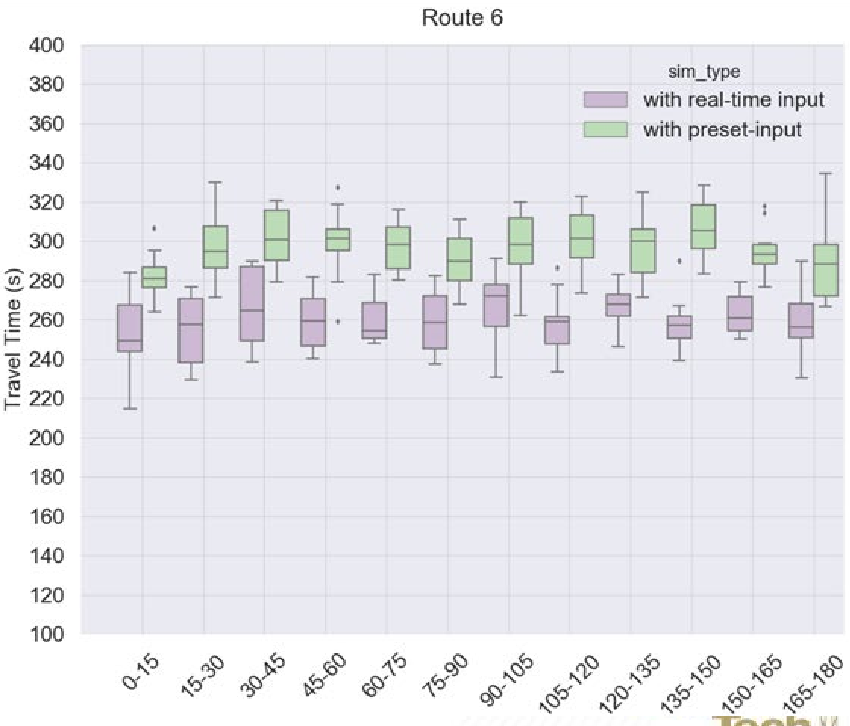
- Travel times compared for 10 random seeds of simulation with preset and real-time inputs
- *Travel times varied within plausible bounds*

Average Vehicle Travel Time versus Simulation Time Intervals Plots for

(a) Westbound Route 4



(b) Eastbound Route 6



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Status…

- Digital Twin is Possible - Dynamic integration of real-time field data
- Critical Component is the Data Streams (Volume, Variety, Velocity, and Veracity)
  - Data Sources
  - Level of aggregation
    - Time
    - Space
  - Missing data streams
    - Temporary
    - Permenant
  - Data accuracy
  - Data storage

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Next Steps

- Scaling – moving toward distributed simulation solution
- Validation of KPIs - Energy and CO_2 emissions generated from the simulation model to be compared with in-field connected vehicles
- Fast-forward simulation!

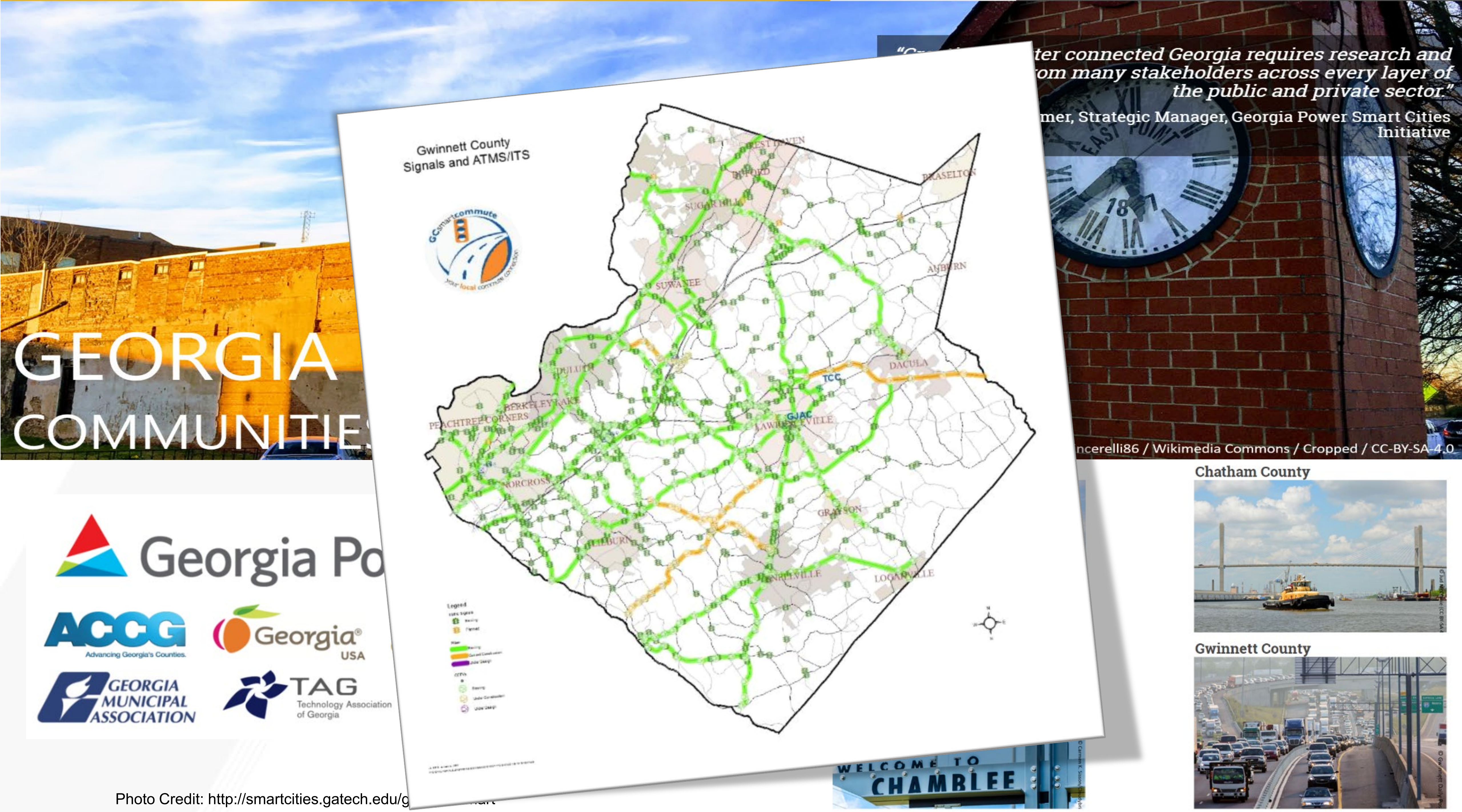


Photo Credit: http://smartcities.gatech.edu/g

Connected Vehicle Technology Master Plan

Gwinnett Transportation

Project Vision

- Set the standard for the application of connected vehicle technology
- Improve traffic congestion and reduce crashes
- Have broad applicability across the Atlanta Region and Country
- Support goals of the recent Comprehensive Transportation Plan, Connect Gwinnett Transit Plan, and Intelligent Transportation Systems Master Plan update

Photo Credit: GDOT

Peachtree Industrial Boulevard Smart Corridor

- Infrastructure maintained by Gwinnett County
- Has activity centers and rural sections
- Passes through 7 cities
  - Norcross, Peachtree Corners, Berkeley Lake, Duluth, Suwanee, Sugar Hill and Buford
- 6 fire stations within 1.5 miles
- Identified for Transit system expansion

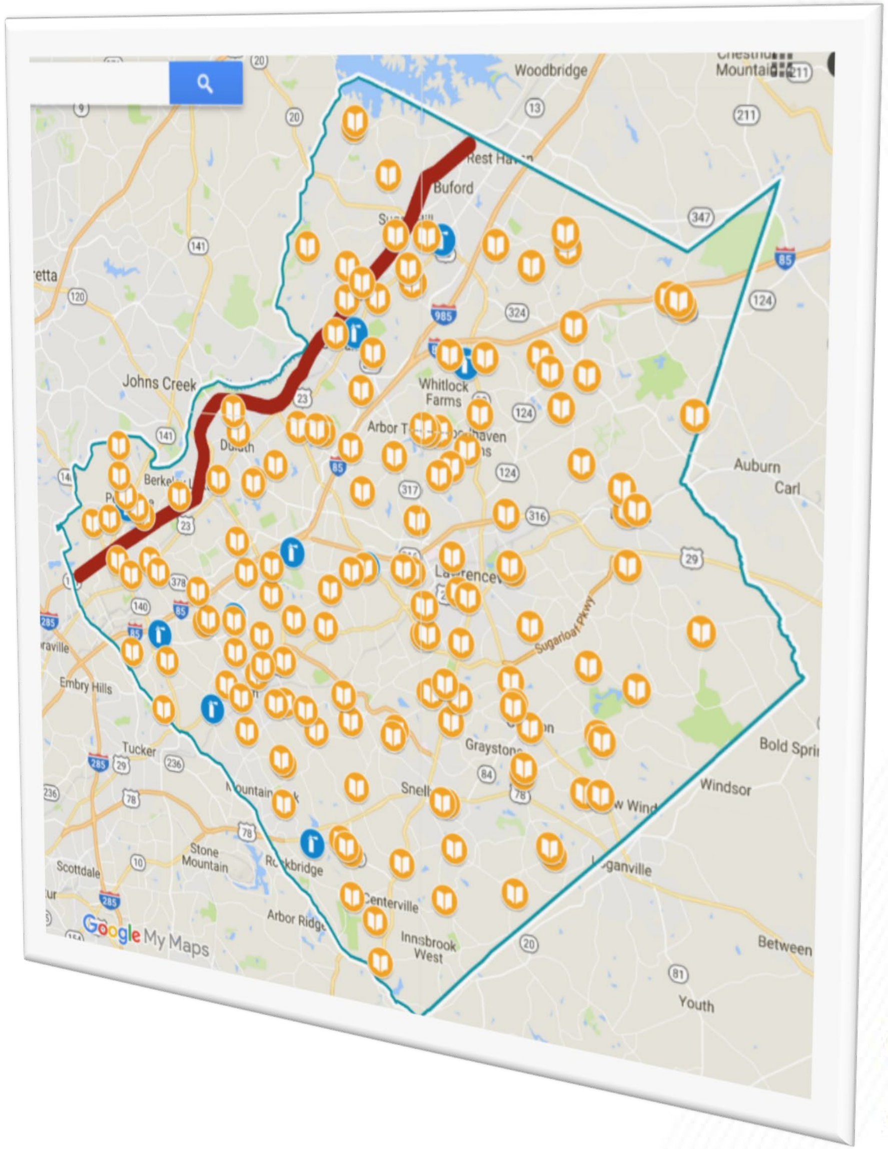
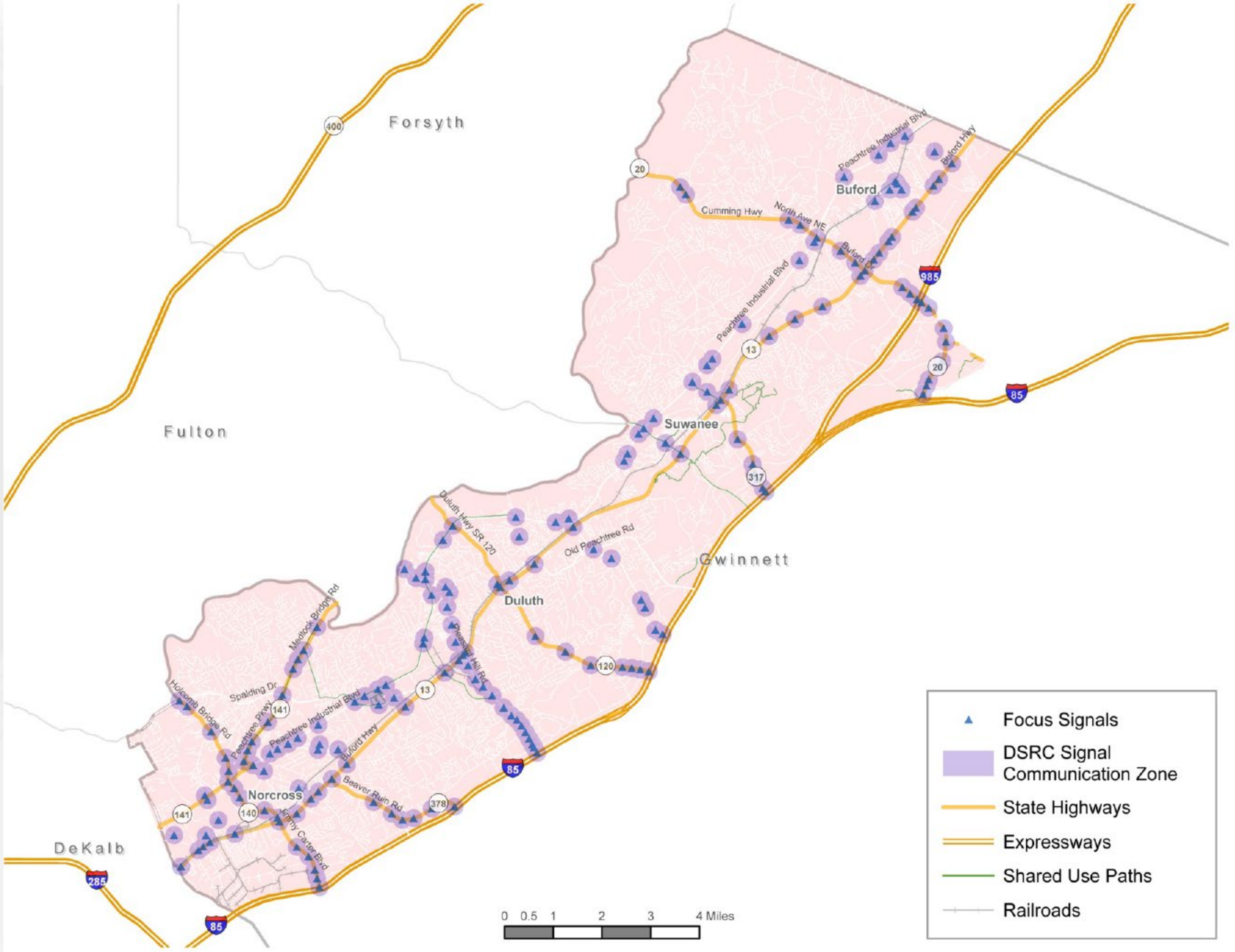


Photo Credit: Gwinnett County

Available Signalized Intersections for CV Deployment Within Corridor Impact Zone



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Potential Applications (Safety and Mobility)

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What?

Evaluate the potential for improvements in safety and operations of emergency response vehicles in and around the Peachtree Industrial Boulevard corridor with Connected Vehicle technology deployment.

- Reduction in delay in response
- Improvement in mobility
- Improvement in safety
- Implementation strategies for maximizing benefits

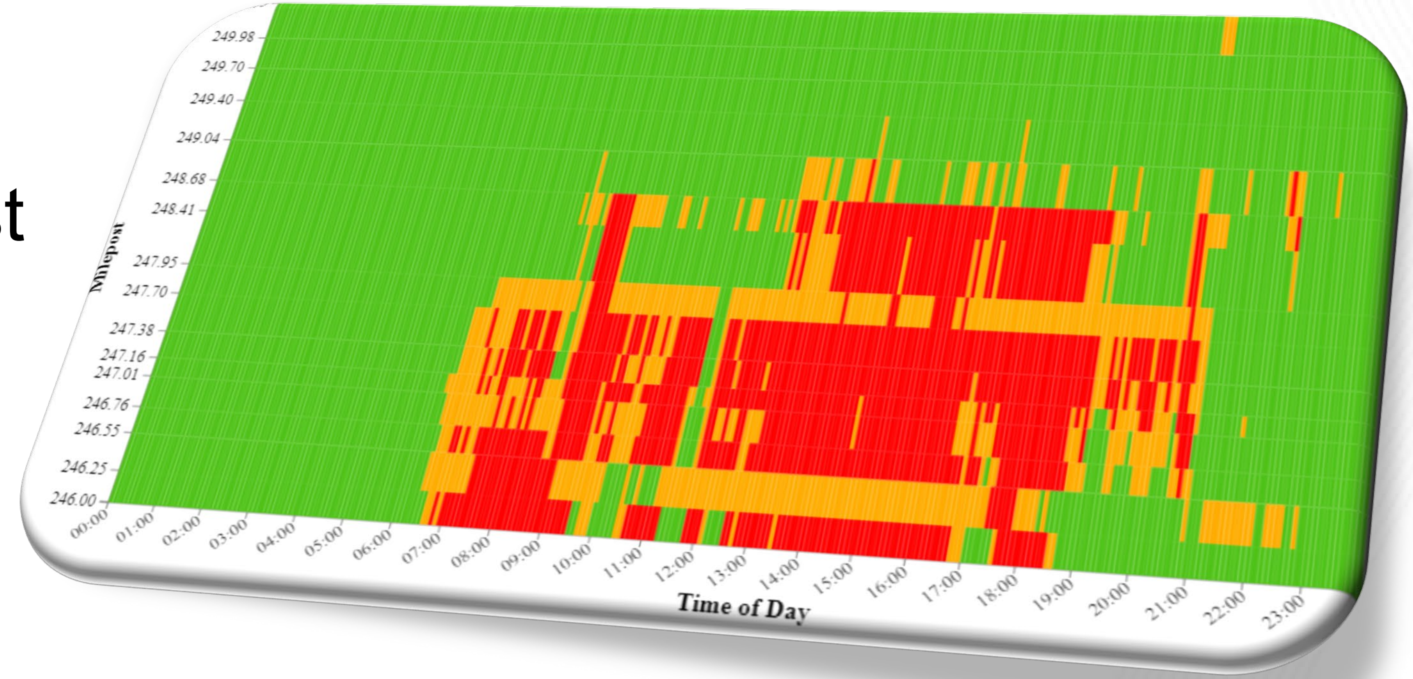
Photo Credit: https://www.cnn.com/2013/04/10/us/georgia-firefighters-hostage/index.html

How?

Bottleneck analysis to identify congestion hotspots for

- Emergency Vehicles
- Passenger Cars

Delay pattern analysis for First Responder Vehicle paths



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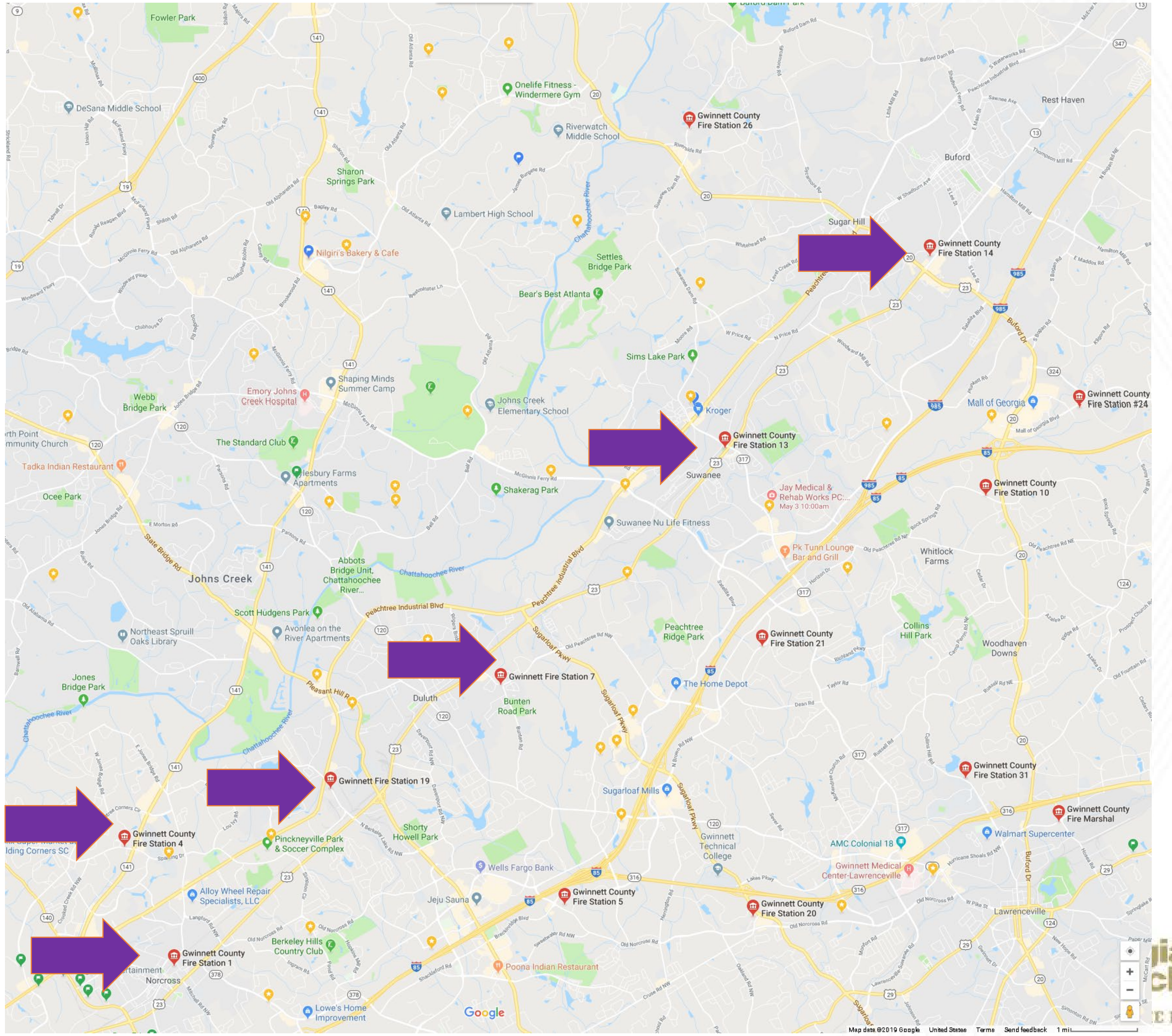
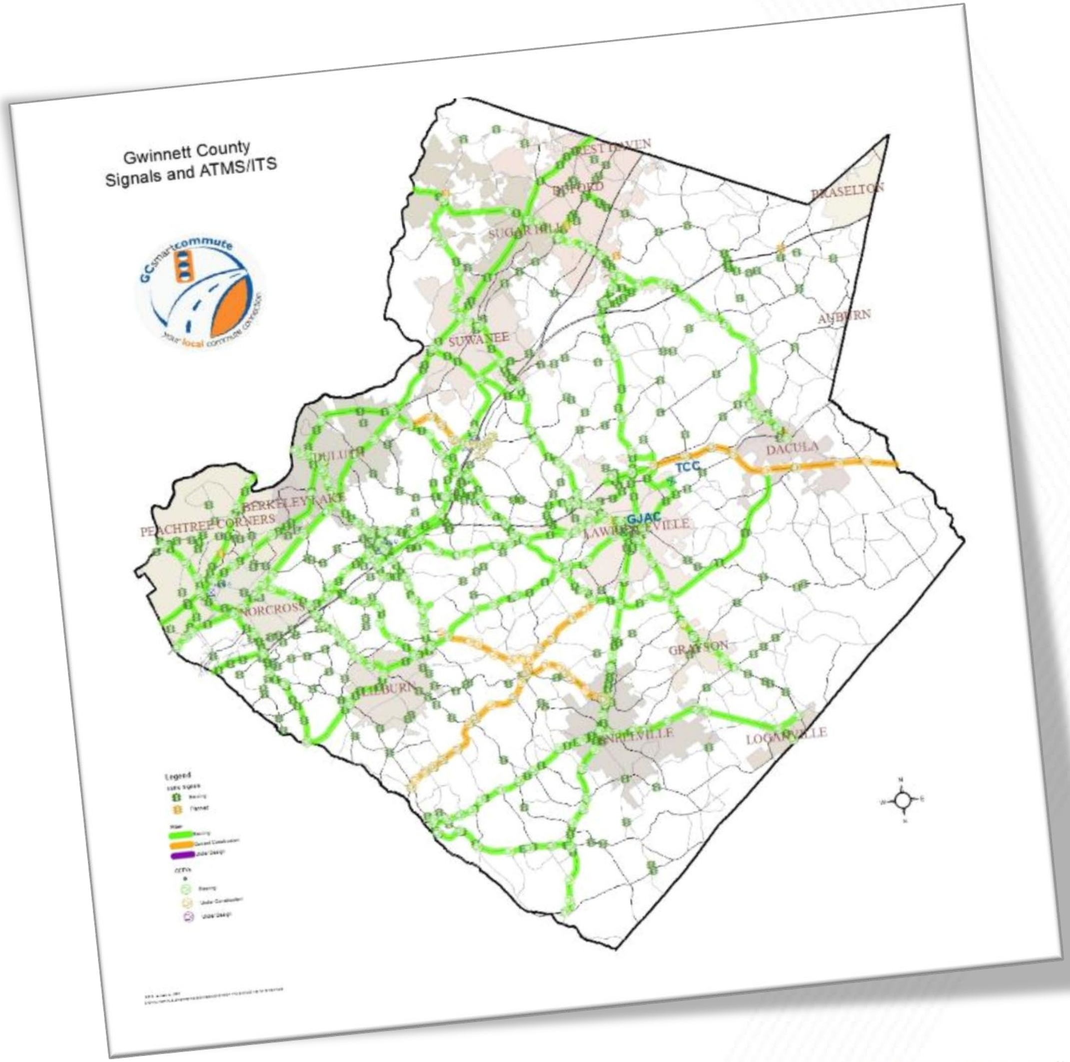
Data

- GPS data collection on 15 Firetrucks from 6 Fire Stations
- GT equipment deployed on Gwinnett county firetrucks
- 2-4 months of second by second location data



Analysis

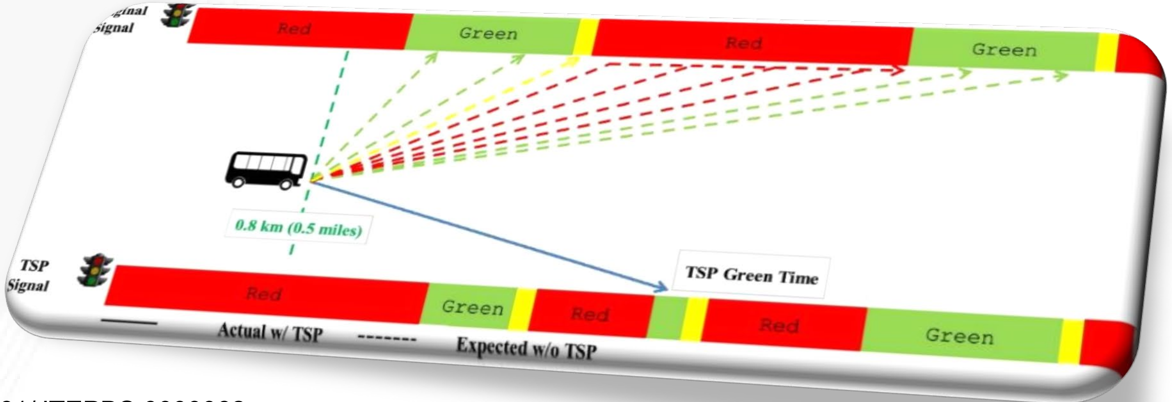
- Delay patterns for Emergency vehicles
- Response request patterns (response logs)
- Multiple firetruck arrival patterns at intersections
- Identification of intersection approaches with
  - Maximum delay
  - High frequency of potential preemption demand



Benefits

Signal Preemption with Connected Vehicle

- Multi-signal look-ahead preemption
- Queue flush downstream of Emergency Vehicle
- Minimization of Congestion Impacts on passenger cars



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https://www.its.dot.gov

https://ascelibrary.org/doi/full/10.1061/JTEPBS.0000062

https://www.semanticscholar.org/paper/GPS-and-ZigBee-based-traffic-signal-preemption-Kodire-Bhaskaran/b1d0e1034d5c147b44f6fcb51ab06d722b30acaa

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Connected Vehicles: Are We There Yet?

Angshuman Guin

angshuman.guin@ce.gatech.edu

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1. *Atkins, 2018. https://www.youtube.com/watch?v=QtFI800e0XU ,*
2. *CEE at Georgia Tech, 2018.*
3. *Candice Lanier, BleepingComputer, 2018. https://www.bleepingcomputer.com/news/government/rapidly-emerging-smart-cities-and-the-associated-risks/*
4. *SICS, https://www.sics.se/science-areas/big-data-analytics-machine-learning-and-optimization*
5. *Katherine Tweed, IEEE Spectrum, 2014. https://spectrum.ieee.org/cars-that-think/transportation/infrastructure/better-traffic-light-simulations-could-cut-travel-time-and-gas-use*
6. *Rapidops, https://www.rapidops.com/services/bi-and-data-visualization/*
7. *Kiel Ova, PTV, 2010.*
8. *IPAT, CEE at Georgia Tech, 2018?*
9. *Storyblocks Videoblocks, https://www.videoblocks.com/video/traffic-signal-street-light-n_aiotgnxile2lfeq*