EVALUATING THE EFFECT OF CONNECTED AND AUTOMATED VEHICLES ON TRAFFIC SAFETY

By

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UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

North Carolina Department of Transportation
Virtual Research & Innovation Summit

INTRODUCTION

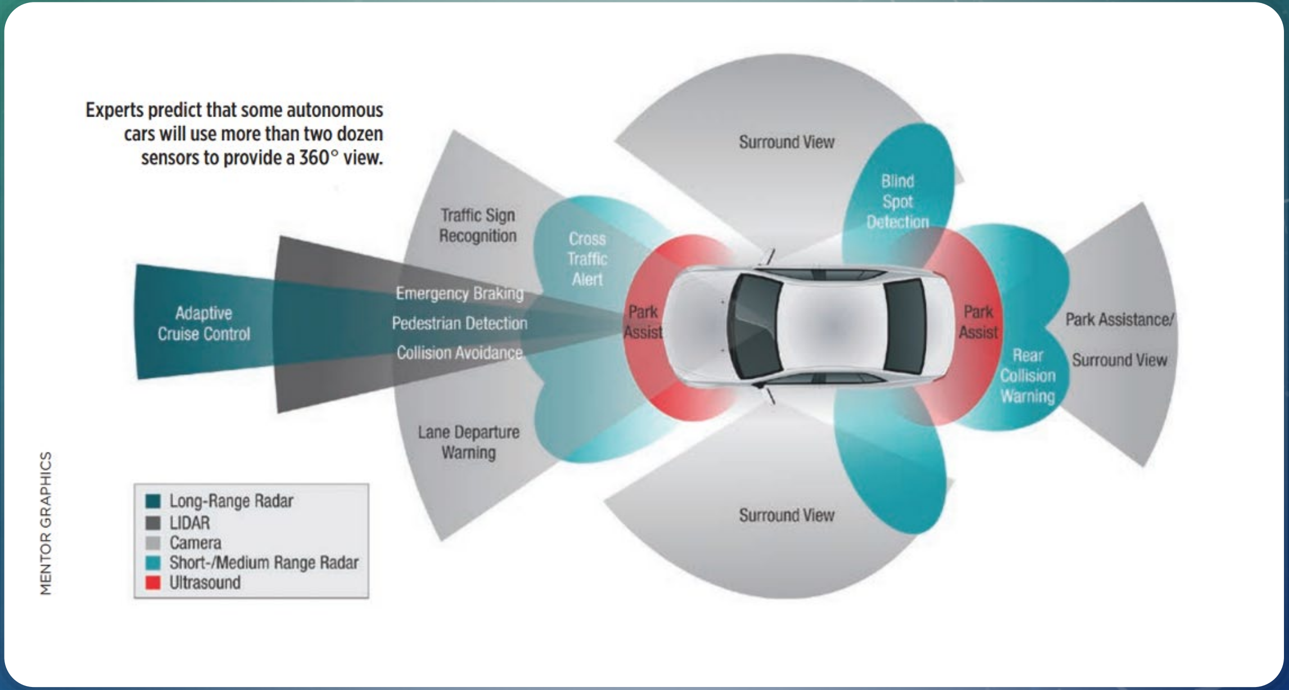
~37,000 deaths due to crashes in 2018

Driver error contributes to 94% – 96% of crashes

~4.5 million CAVs are expected on roads by 2035

~500% increase in lane capacity

~90% crash reduction predicted with the penetration of Connected & automated vehicles (CAVs)



Source: https://saemobilus.sae.org/automated-connected/feature/2019/02/fusing-sensors-for-the-automateddriving-future

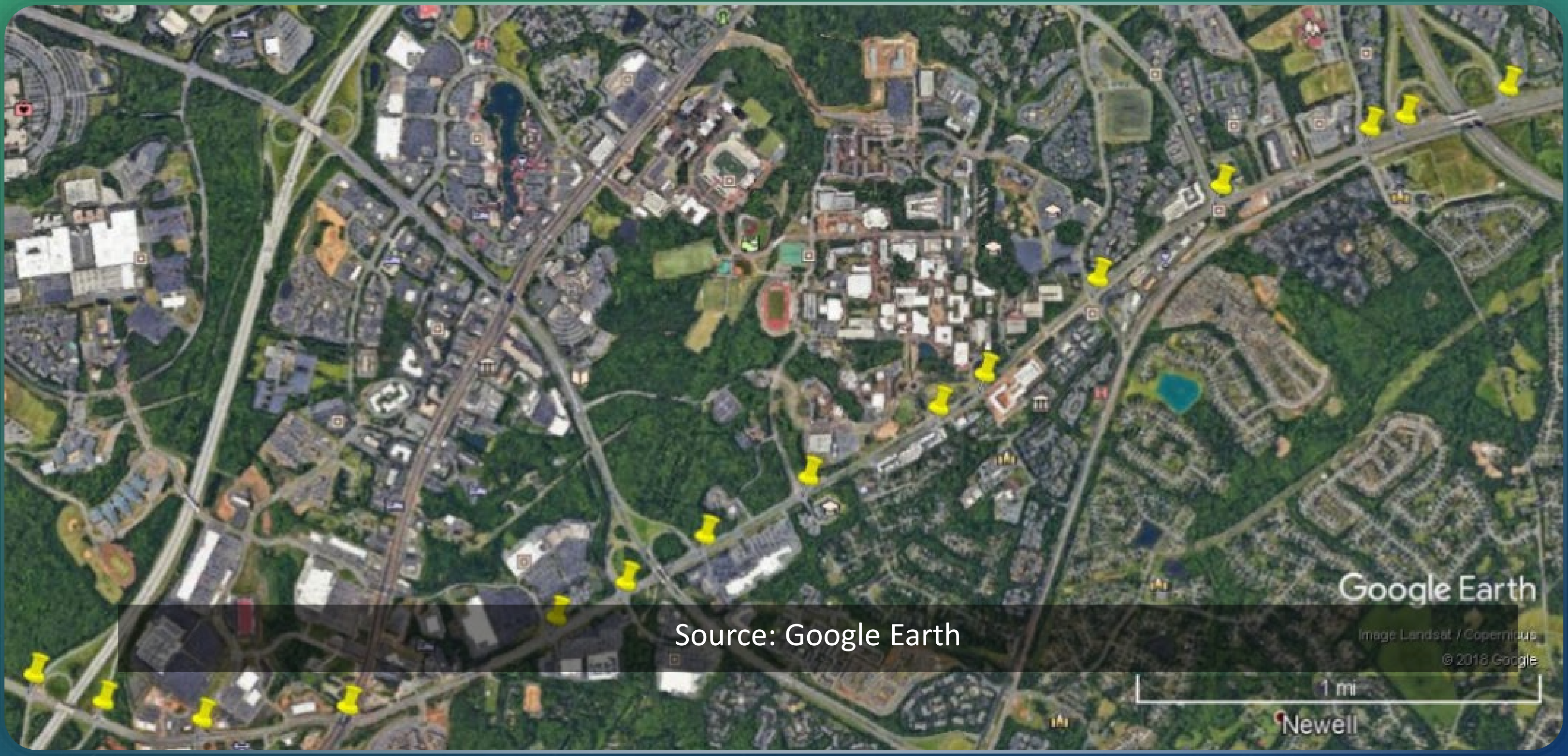
MOTIVATION

- Human driven vehicles: How safe (or unsafe) are they?
- Rear-end crashes most common involving CAVs
- However, low acceptance level (21%) of CAVs amplifies
- Liability in a crash involving CAVs
- Human supervision for testing

OBJECTIVES

- Developing a calibrated VISSIM model
- Investigating the impact of CAVs on traffic safety

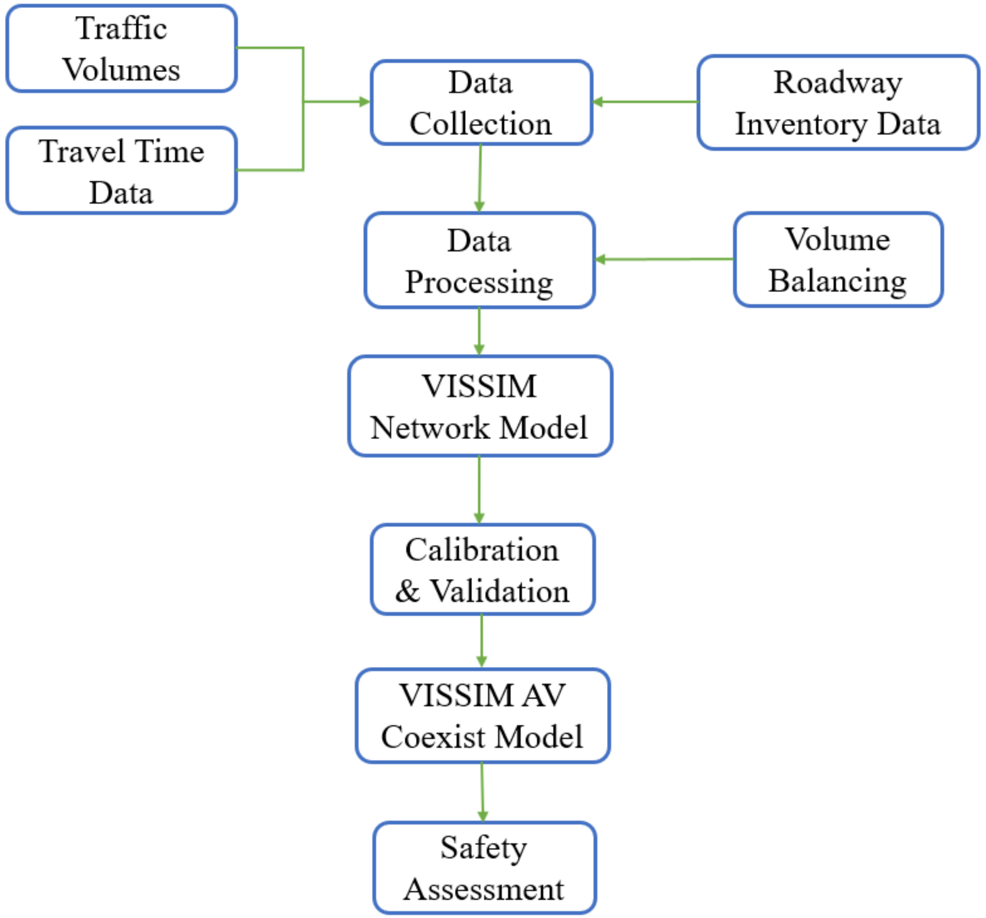
STUDY AREA



Source: Google Earth

- 2.5-mile corridor on NC-49
- Fifteen intersections
- Fourteen segments
- Base year – 2018
- AM, PM & Afternoon peak hours

METHODOLOGY


Traffic Volumes

Travel Time Data

Data Collection

Roadway Inventory Data

Data Processing

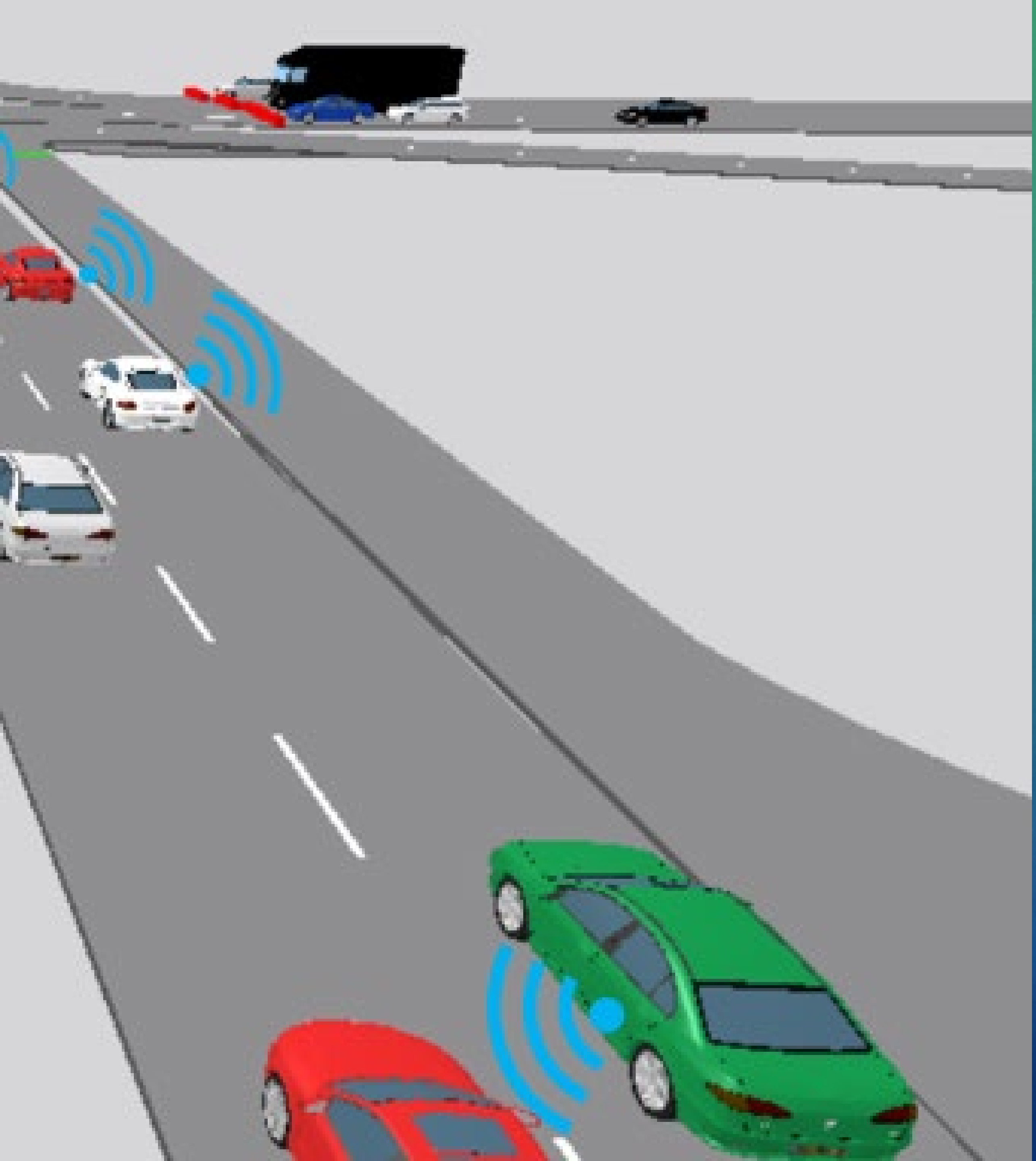
Volume Balancing

VISSIM Network Model

Calibration & Validation

VISSIM AV Coexist Model

Safety Assessment



VISSIM AV MODEL

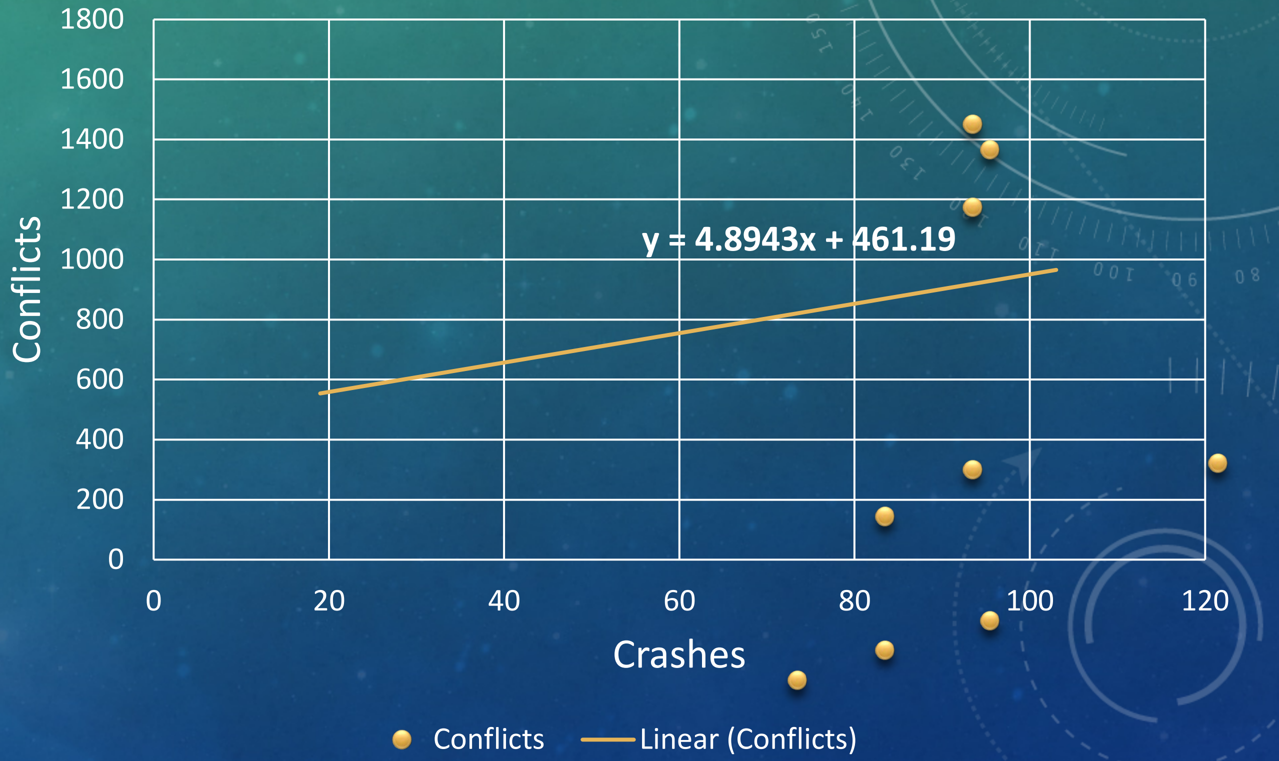
- AV CoExist driver behavior model
  - Car following
  - Lane change
  - Platooning
  - Signal control
- Wiedemann 74 model
- Penetration levels – 0, 20%, 40%, 60%, 80% & 100%
- Conflict points used as surrogate safety measures

SAFETY ASSESSMENT

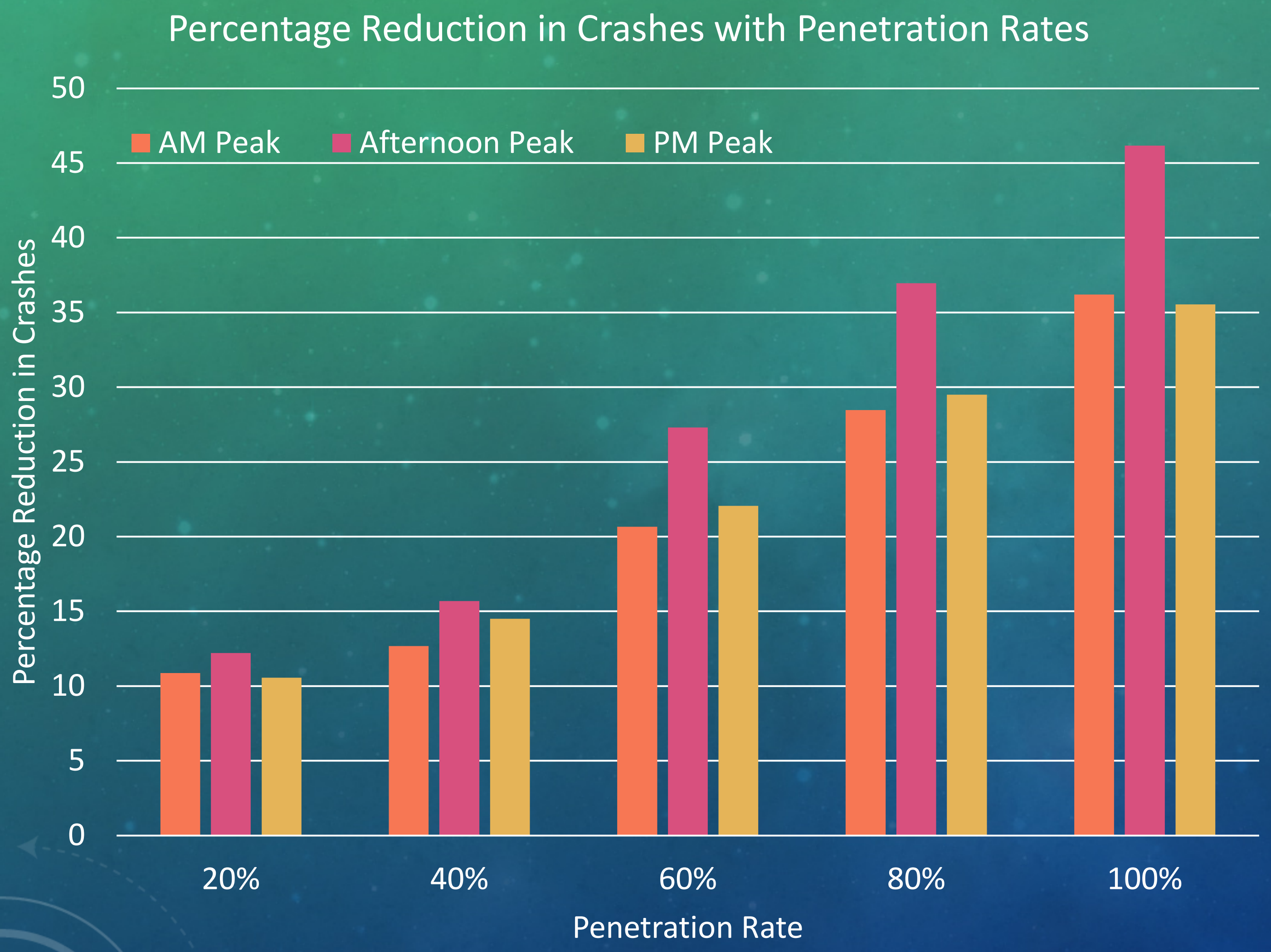
Surrogate Safety Assessment Model (SSAM) was used for safety analysis

  - Post Encroachment Time = 1.5 seconds
  - Time to Collision = 2 seconds

- Extracting the annual number of crashes for each segment
- Establishing conflict to crash relationship
- Predicting the number of crashes



RESULTS & DISCUSSION



- 35%-45% reduction in the number of crashes at 100% penetration
- Significant improvement after 40% penetration rate

CONCLUSIONS

- Enhanced safety with an increase in the penetration of CAVs
- Better results for penetration rates over 40%
- Time of the day impacting crash reduction
- Traffic congestion accounting for more conflicts

FUTURE SCOPE

- Exploring the CoExist model further for higher level automation
- Investigating the impacts of AADT on traffic safety in CAV environment

ACKNOWLEDGEMENT

- Partially based on projects funded by the United States Department of Transportation and North Carolina Department of Transportation

- Charlotte Department of Transportation for providing the data needed for this study

RESEARCH & DEVELOPMENT

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Estimating AADT on All Local Functionally Classified Roads in NC

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Kent L. Taylor, P.E.

IDEAS Center
Infrastructure, Design
Environment & Sustainability

Study Outline

- Traffic count programs – mostly focus on higher functional class roads
- Limited data available for local functionally classified roads

Source: http://www.tstdata.com/services.html

Problem

Reliable estimation of AADT on local functionally classified roads?

Need

HSIP requirement

Safety challenges

Road maintenance and funding prioritization

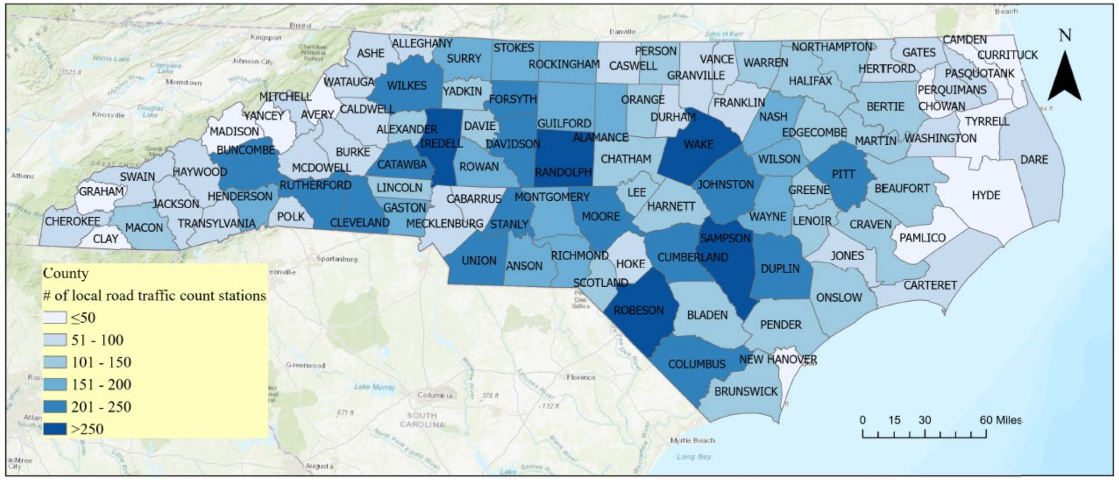
Research Design

Literature review/survey
Potential variables – surrogate data
Sustainable and repeatable model
Error analysis and sampling
Future applications

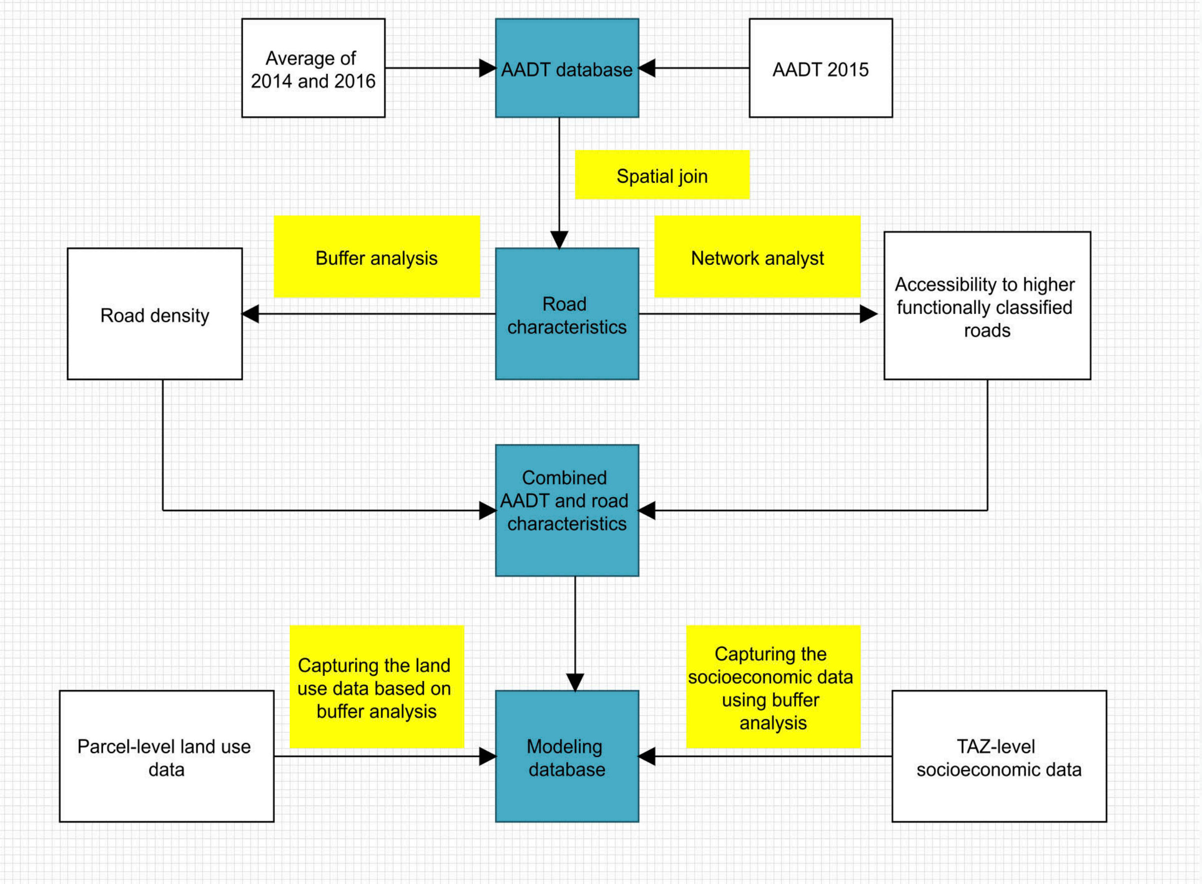
Research Design

- to review AADT estimation methods for functionally classified major, minor, and local roads, along with how other state DOTs are meeting the HSIP AADT requirements
- to examine the influence of road network, socioeconomic, demographic, and land use characteristics on local roads AADT
- to develop sustainable and repeatable methods to estimate AADT for local functionally classified roads
- to monitor requirements to validate and calibrate the models to improve their predictive performance

Data Collection & Data Processing



- 12,899 local road traffic count stations
- Road characteristics
- Socioeconomic and demographic characteristics
- Land use characteristics



Average of 2014 and 2016

AADT database

AADT 2015

Spatial join

Buffer analysis

Network analyst

Road density

Road characteristics

Accessibility to higher functionally classified roads

Combined AADT and road characteristics

Capturing the land use data based on buffer analysis

Capturing the socioeconomic data using buffer analysis

Parcel-level land use data

Modeling database

TAZ-level socioeconomic data

Modeling Local Road AADT

Ordinary Least Square Regression (OLS)

Geographically Weighted Regression (GWR)

Kriging Interpolation

Inverse Distance Weighting (IDW)

Natural Neighbor Interpolation (NN)

Statistical Methods

Descriptive analysis of local road data

Identify potential explanatory variables influencing local road AADT

Check for multicollinearity between explanatory variables

Develop local road AADT estimation models

Regression/Spatial interpolation

Validate the models

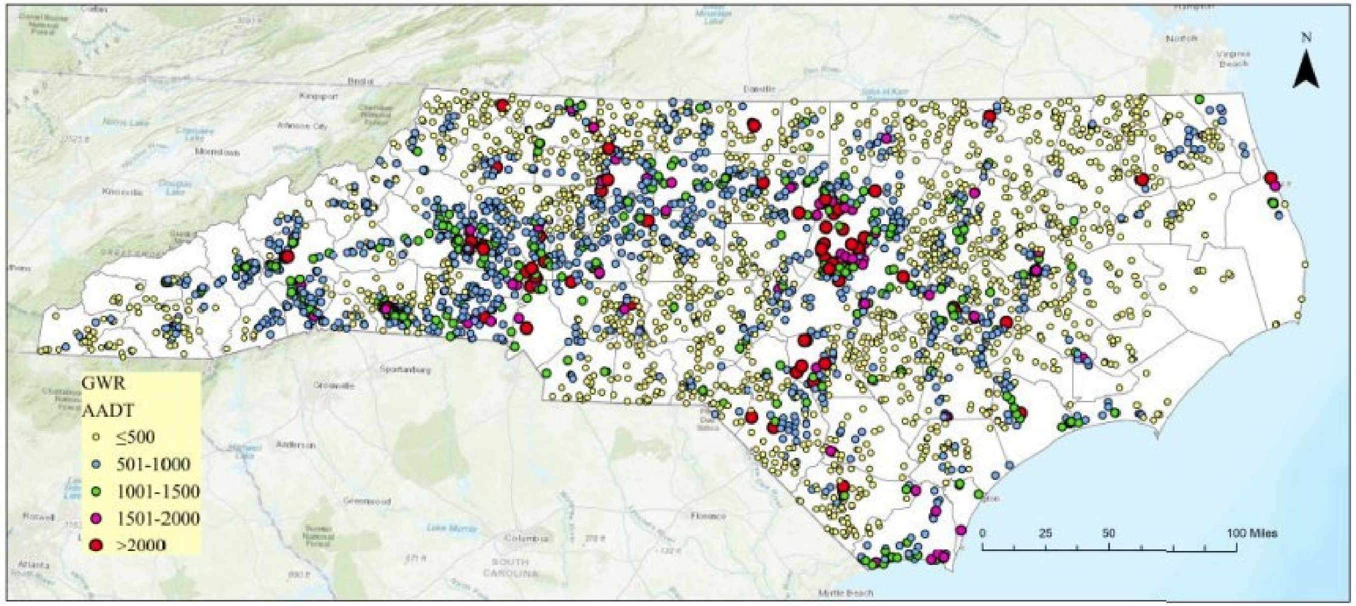
Estimate local road AADT at non-covered locations

Geographically Weighted Regression (GWR)

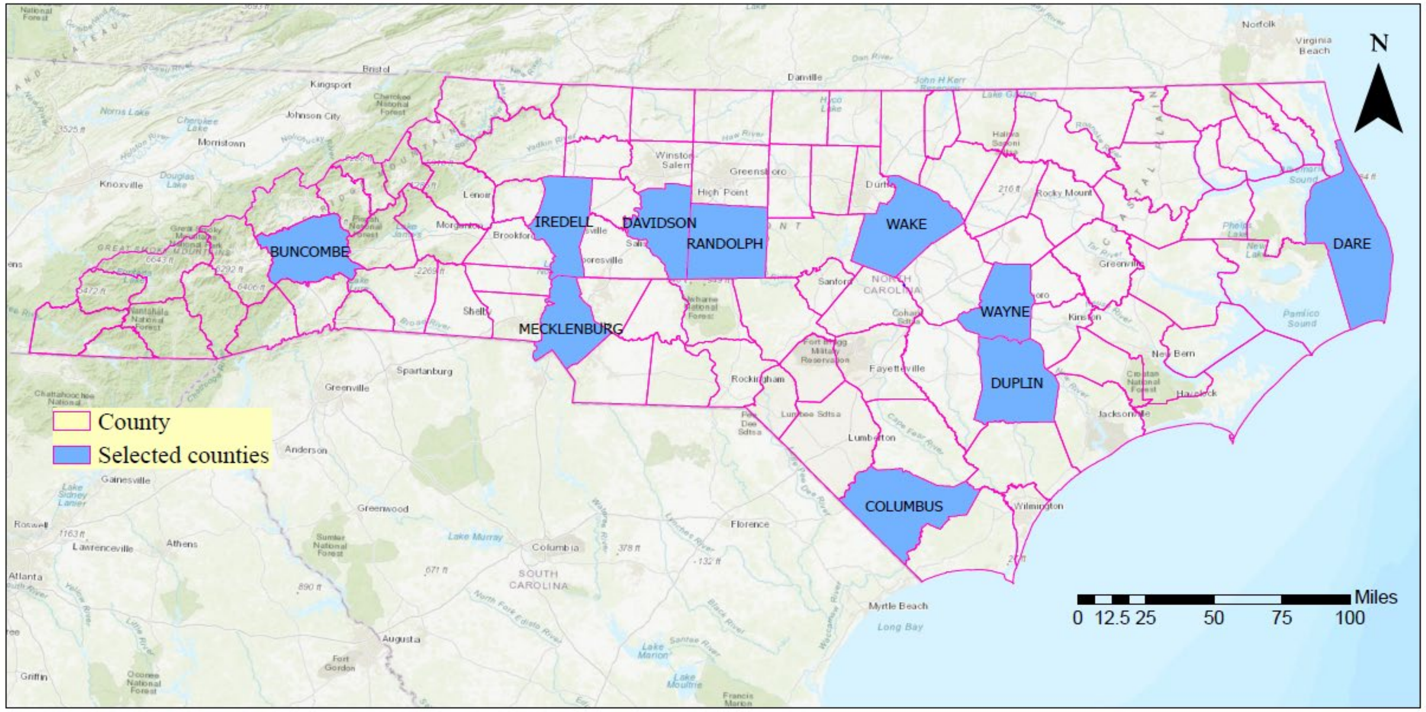
Variable/ Parameter	Minimum	Median	Mean	Maximum	Standard deviation
Intercept	1.061	2.724	2.708	3.9	0.43
Speed limit	-0.022	-0.005	-0.005	0.026	0.007
Road density	-0.014	0.014	0.014	0.053	0.01
Dis-Nonlocal	-0.333	-0.04	-0.044	0.132	0.058
AADT- Nonlocal	$-2.4*10^{-5}$	$7.22*10^{-6}$	$7.92*10^{6}$	$6.69*10^{-5}$	$8.67*10^{-6}$
Industrial	-1.355	0.009	0.003	1.049	0.117
Office	-1.298	-0.008	-0.027	0.739	0.15
Government	-1.472	-0.004	-0.022	0.71	0.153
Population density	$-2.3*10^{-3}$	$2.4*10^{-4}$	$4.15*10^{-4}$	$8.6*10^{-3}$	$7.2*10^{-3}$
R-square	0.44				
AIC	6658				
# of neighbors	254				
MAPE	82.1				
MPE	-42.1				
RMSE	730				

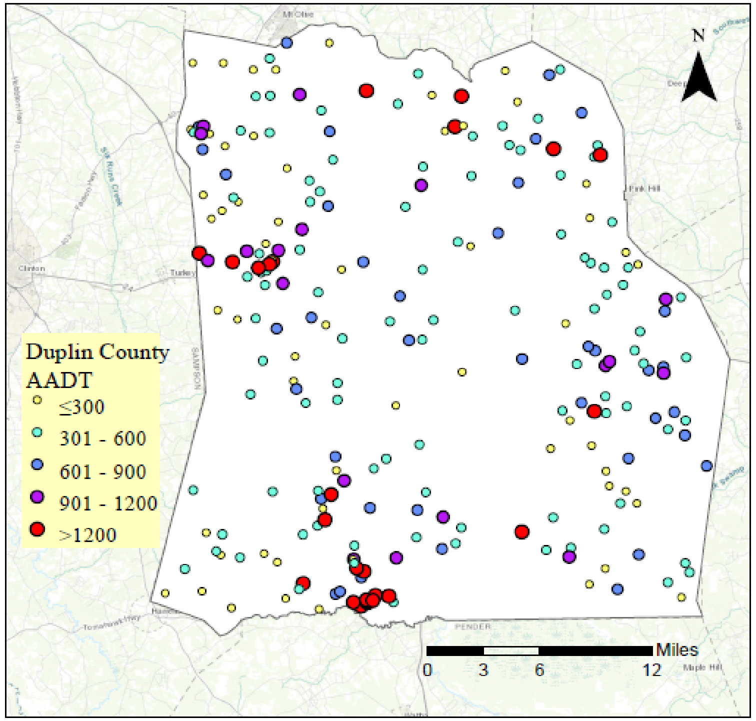
Validation Results

Measure	OLS	GWR	Kriging	IDW	NN
MAPE (%)	86.1	82.1	84.1	120.9	89.2
MPE (%)	-44.2	-42.1	-44.2	-96.8	-47.2
RMSE	771	733	733	726	743



County-level Modeling

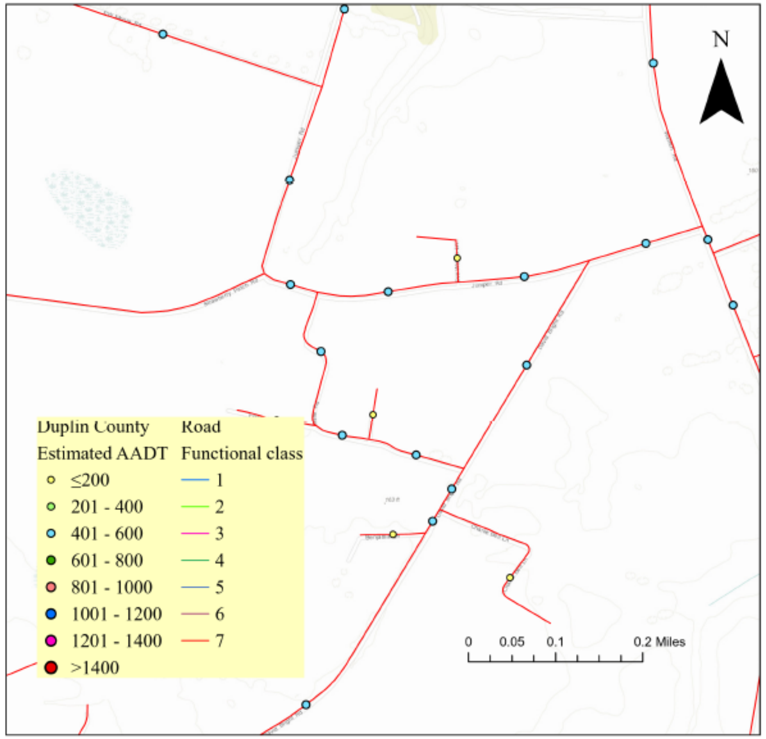


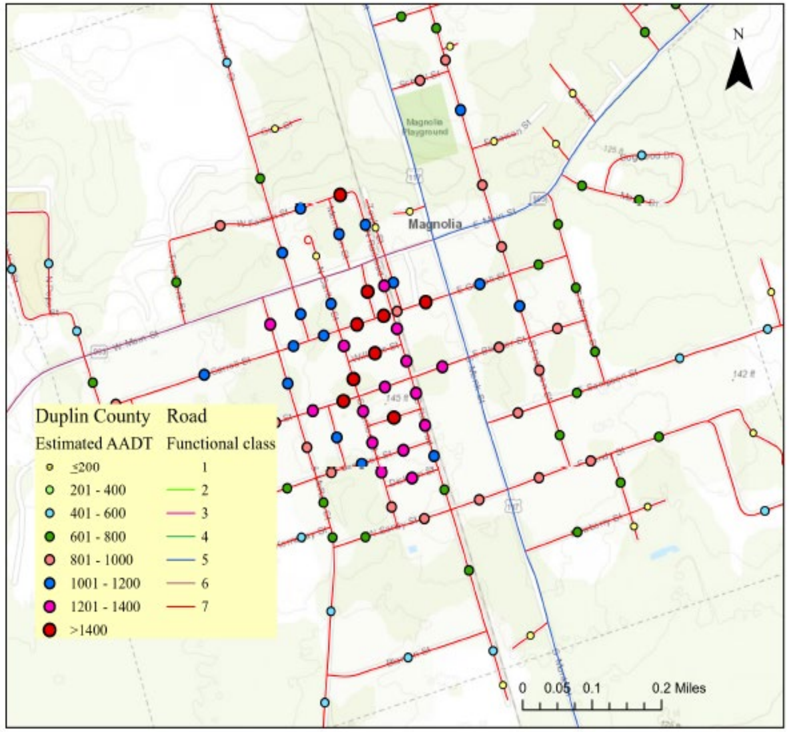


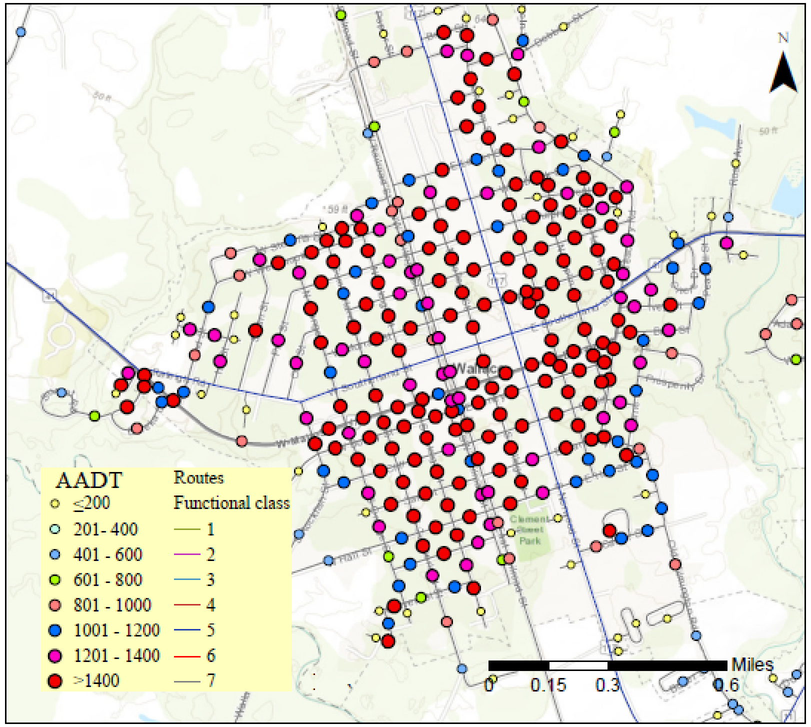
Statewide Model Vs County-level Models

County	GWR						OLS					
	Statewide			County-level			Statewide			County-level		
	MAPE	MPE	RMSE	MAPE	MPE	RMSE	MAPE	MPE	RMSE	MAPE	MPE	RMSE
Buncombe	46.2	-1.5	908	68.1	-36.2	822	48.2	- 4.4	936	72.8	-35.8	919
Columbus	74.2	-38.4	374	78.3	-25.2	368	70.1	-38.2	289	79.11	-35.6	431
Dare	73.1	-22.3	808	91.9	-76.2	641	73.1	-21.2	1,154	94.6	-68.6	752
Davidson	92.1	-59.1	641	79.3	-30.9	867	81.1	-42.7	833	85.6	-34.1	892
Duplin	57.1	-19.2	478	60.1	-19.8	399	51.2	-4.2	478	52.6	-20.2	452
Iredell	91.9	-34.2	1011	92.9	-32.1	888	98.4	-48.5	1,370	95.2	-46.4	883
Mecklenburg	47.4	-1.20	1,224	60.1	-19.2	954	38.3	-16.5	1370	98.2	-46.4	1,111
Randolph	68.2	-18.8	813	92.5	-32.1	792	63.5	-12.8	772	111.9	-81.2	868
Wake	120.1	-84.1	1,055	120.1	-86.2	962	88.6	-32.5	1,254	120.0	-88.3	993
Wayne	83.1	-28.2	713	108.0	-71.1	820	77.8	2.54	868	85.9	-55.8	852

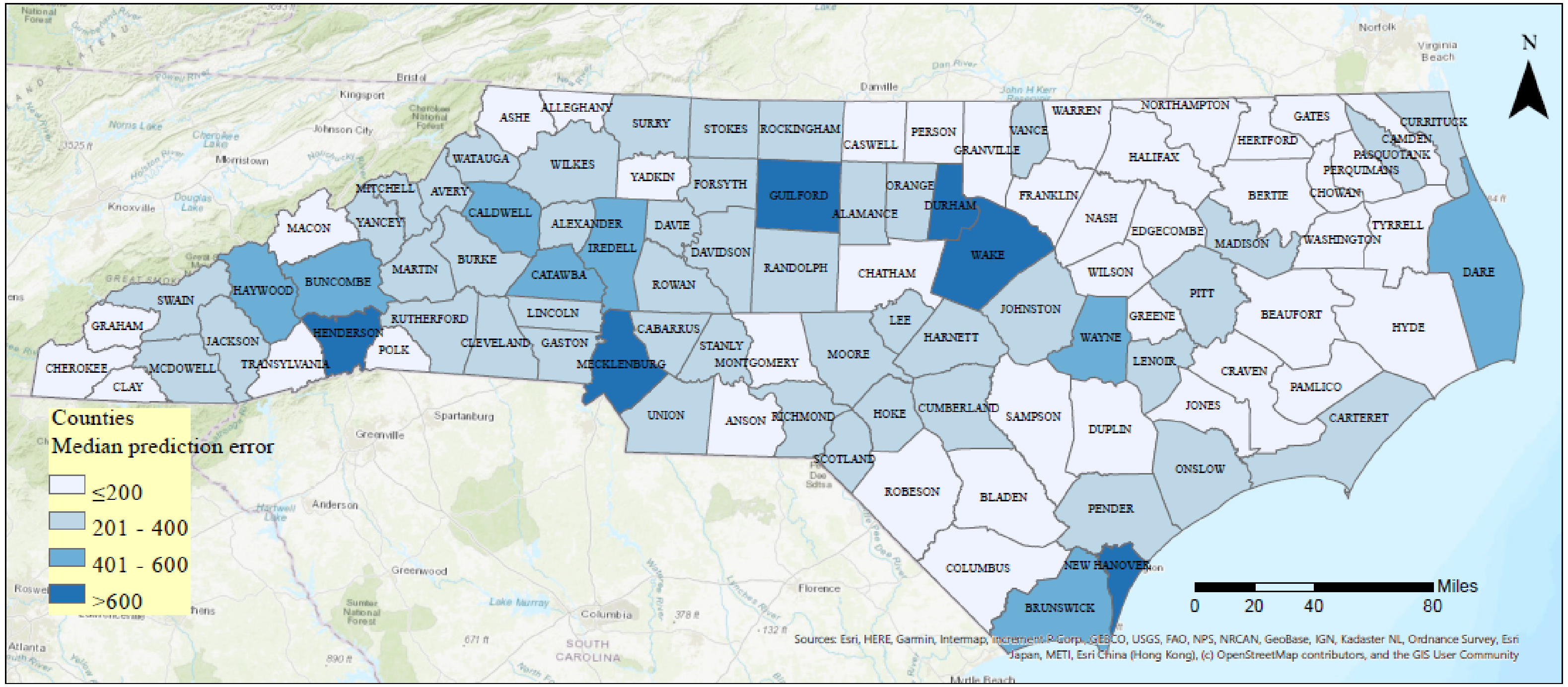
Sample Predictions at Non-covered Locations







Error Analysis and Sampling Requirements



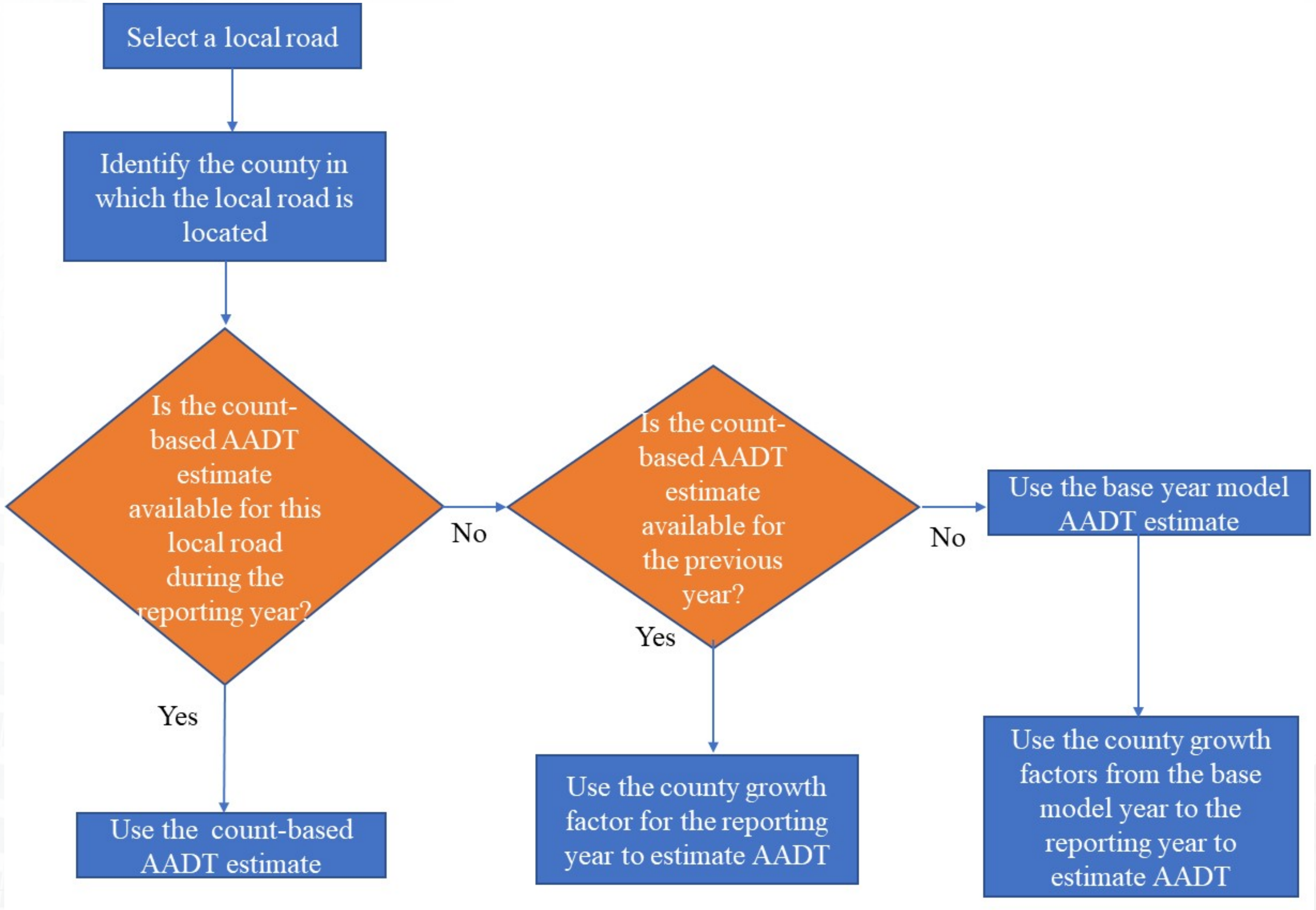
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Median prediction error distribution by county

The sample size requirement was assessed based on non-covered locations and the number of local road traffic count stations in each county

- Recommended sampling based on speed limit and link connectivity

Application of Growth Factors to Estimate Local Road AADT



Select a local road

Identify the county in which the local road is located

Is the count-based AADT estimate available for this local road during the reporting year?

Yes

Use the count-based AADT estimate

No

Is the count-based AADT estimate available for the previous year?

Yes

Use the county growth factor for the reporting year to estimate AADT

No

Use the base year model AADT estimate

Use the county growth factors from the base model year to the reporting year to estimate AADT

Major Findings / Conclusions

- Five different methods were investigated and validated; GWR method performed relatively better when compared to the other methods
- GWR can incorporate the effect of spatial variations in data, by geographic location, when estimating the local road AADT
- Errors in the estimated local road AADT are lower at stations with a higher number of nearby local road traffic count stations
- County-level models with land use variables yield relatively better local road AADT estimates than the statewide models

Recommendations

- Collect traffic counts and estimate spatially distributed count-based local road AADT data at 12,000 (based on the speed limit) to 22,000 (based on link connectivity, beginning and ending features) different stations biennially

- Count-based AADT at a minimum of 30 traffic count stations in each county

- Use of county-level growth factors based on count-based local road AADT data for future AADT estimations

- Update the base year local road AADT estimation model once in every five years (aligning with the statewide travel demand model or census data updates)

Acknowledgments

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NORTH CAROLINA
Department of Transportation

Research & Innovation Summit - 2020

Mobility Implications of CAV Lane Reservation in Mixed Traffic Environment

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Billy Williams, Ph.D., Eleni Bardaka, Ph.D.

ITRE

Outline

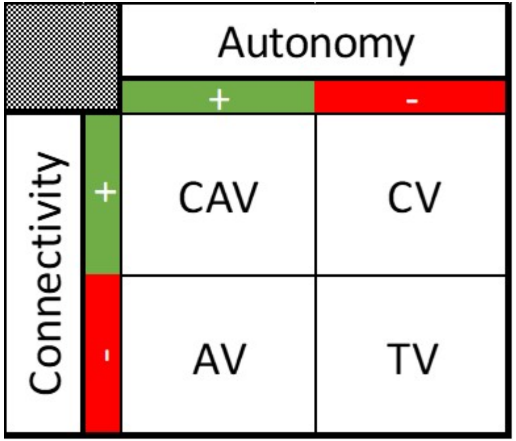
- Introduction and problem statement
- Modeling AVs and CAVs
- Scenarios investigated
- Findings
  - Throughput
  - Travel Rate
  - Fundamental Diagram
- Summary

Introduction

- AVs and CAVs are expected to drastically impact efficiency, safety, and the environment
- High MPR – consensus on the potential impacts
- Low MPR – discord on the potential impacts
  - Interaction with unequipped vehicles
  - Platooning opportunities
- A sensible solution - having the equipped vehicles operate in a dedicated lane

Methodology

- Simulation based – SUMO
- Longitudinal behavior modeling
    - TVs & CVs – Wiedemann 99
    - AV – Xiao et al
    - CAVs – Xiao et al & Milanes and Shladover



		Autonomy	
		+	-
Connectivity	+	CAV	CV
	-	AV	TV

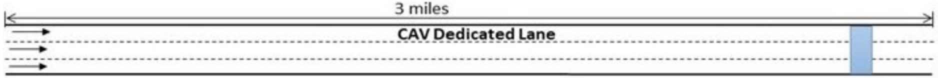
Scenarios Investigated

- Market share – 21
- Ramp volume – 3 (5%, 15%, and 25%)
- Demand level – 3 (low, medium, and high)
- Access/Egress Length – 3 (3000ft, 4500ft, unlimited)

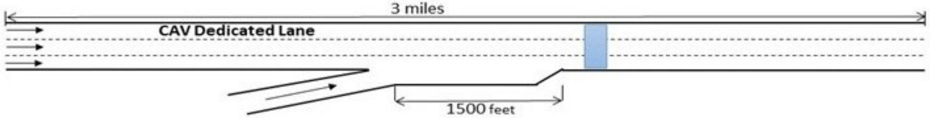
Study Sites

Three Freeway Segments

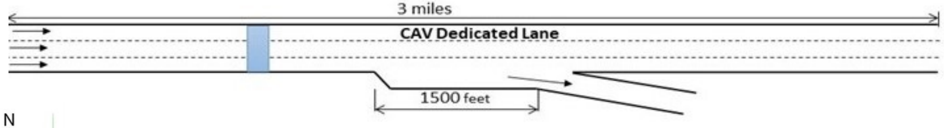
- Basic
- Merge
- Diverge



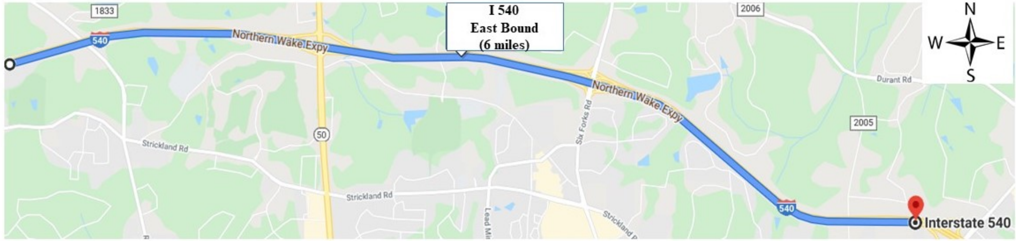
(a) Freeway Basic Segment

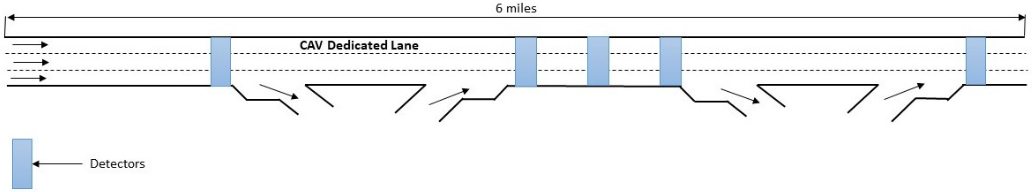


(b) Freeway Merge Segment



(c) Freeway Diverge Segment



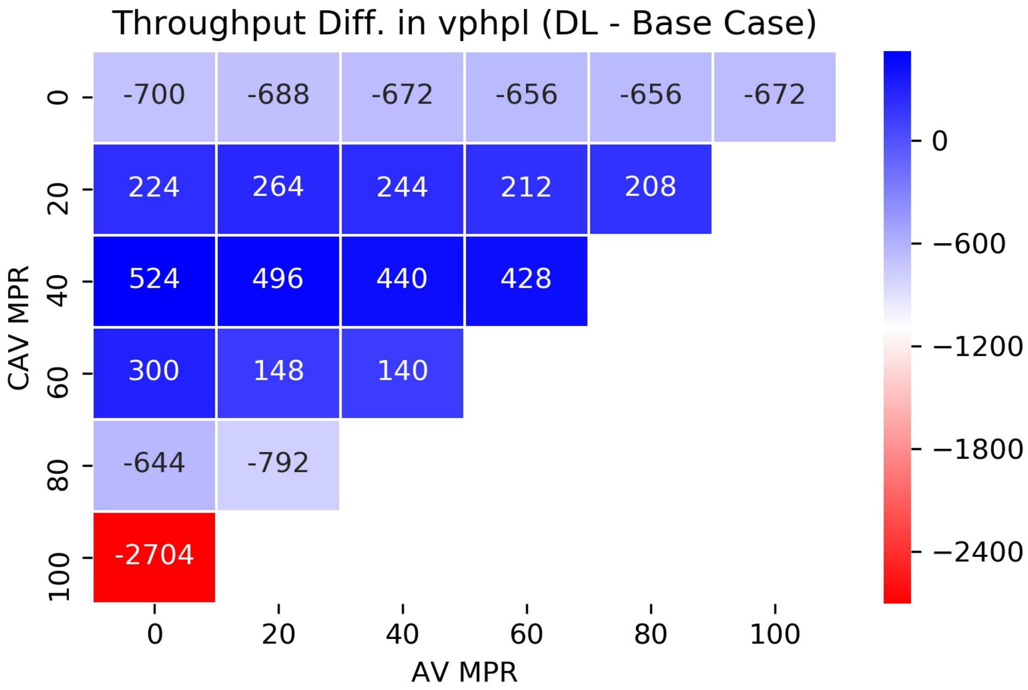


Freeway Facility

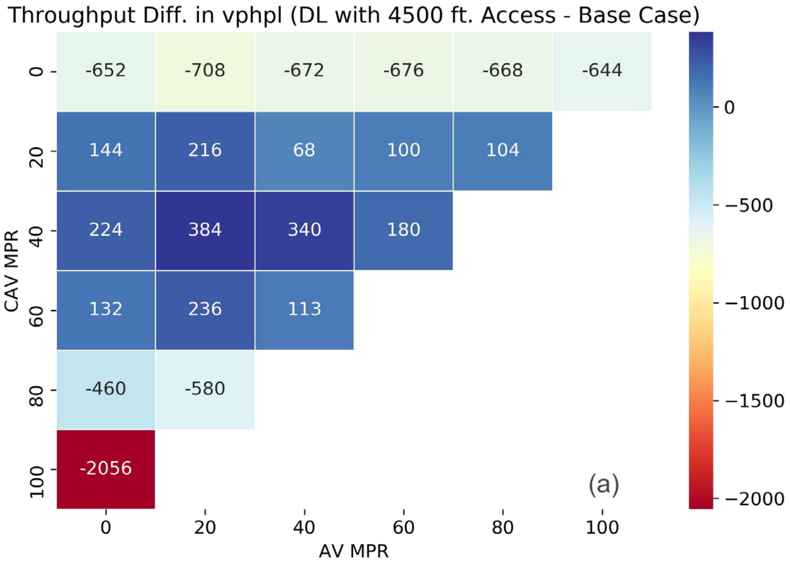
- I-540
- ~ 6 miles
- On/Off Ramps

Results and Analysis – Basic Segment

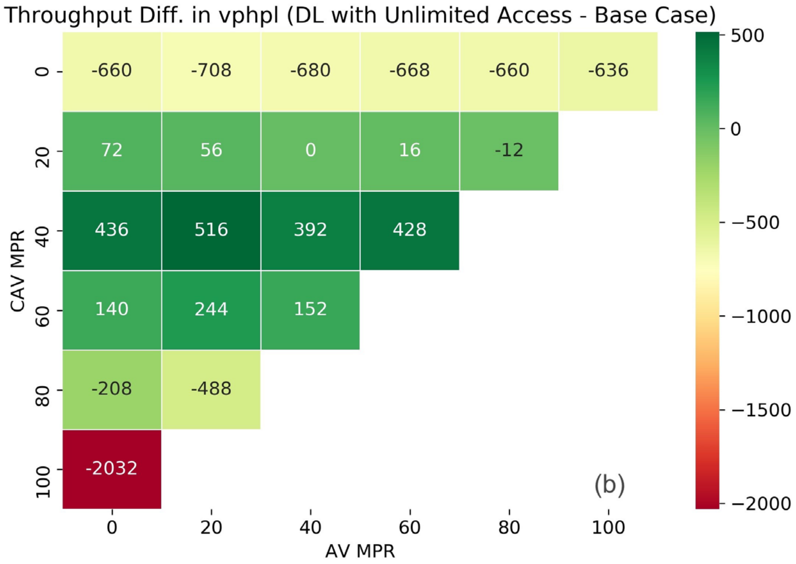
- CAV MPR insights:
  - Increases (20%-60%)
  - Decreases <20% and >60%
  - Optimal at 40%
- AV MPR insights:
  - The higher AVs the lower the increase in throughput



Results and Analysis – Merge Segment

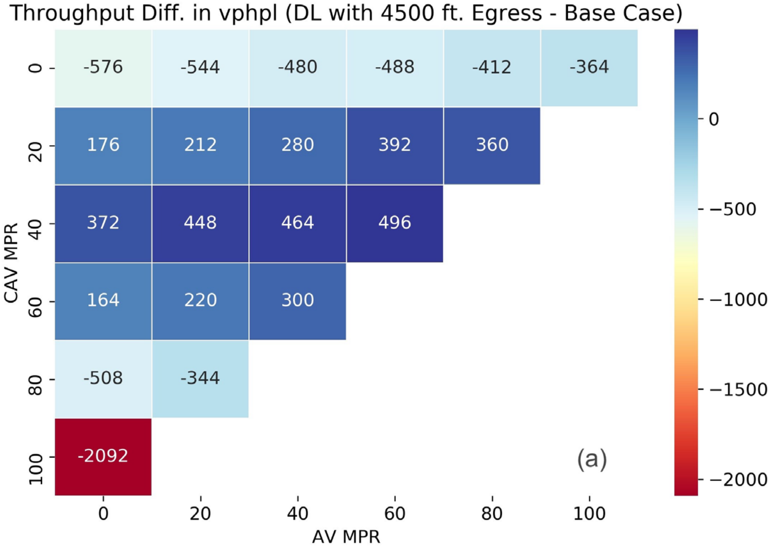

Throughput Diff. in vphpl (DL with 4500 ft. Access - Base Case)

CAV MPR \ AV MPR	0	20	40	60	80	100
0	-652	-708	-672	-676	-668	-644
20	144	216	68	100	104	
40	224	384	340	180		
60	132	236	113			
80	-460	-580				
100	-2056					


Throughput Diff. in vphpl (DL with Unlimited Access - Base Case)

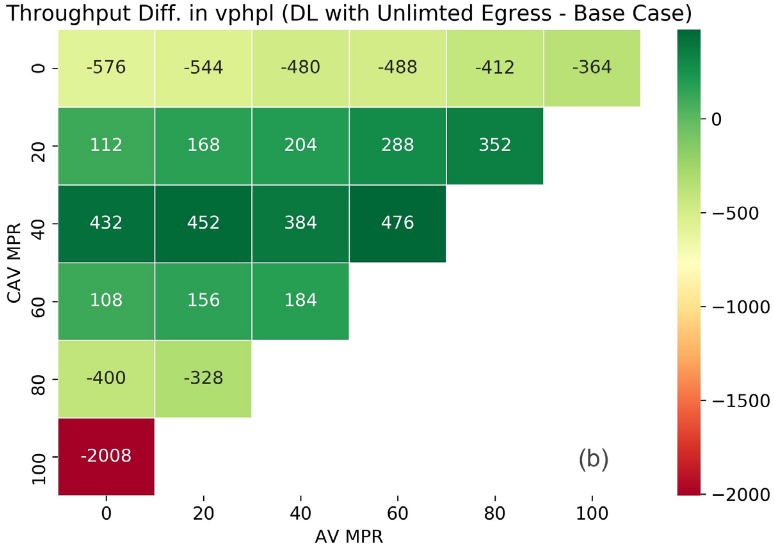
CAV MPR \ AV MPR	0	20	40	60	80	100
0	-660	-708	-680	-668	-660	-636
20	72	56	0	16	-12	
40	436	516	392	428		
60	140	244	152			
80	-208	-488				
100	-2032					

Results and Analysis – Diverge Segment



Throughput Diff. in vphpl (DL with 4500 ft. Egress - Base Case)

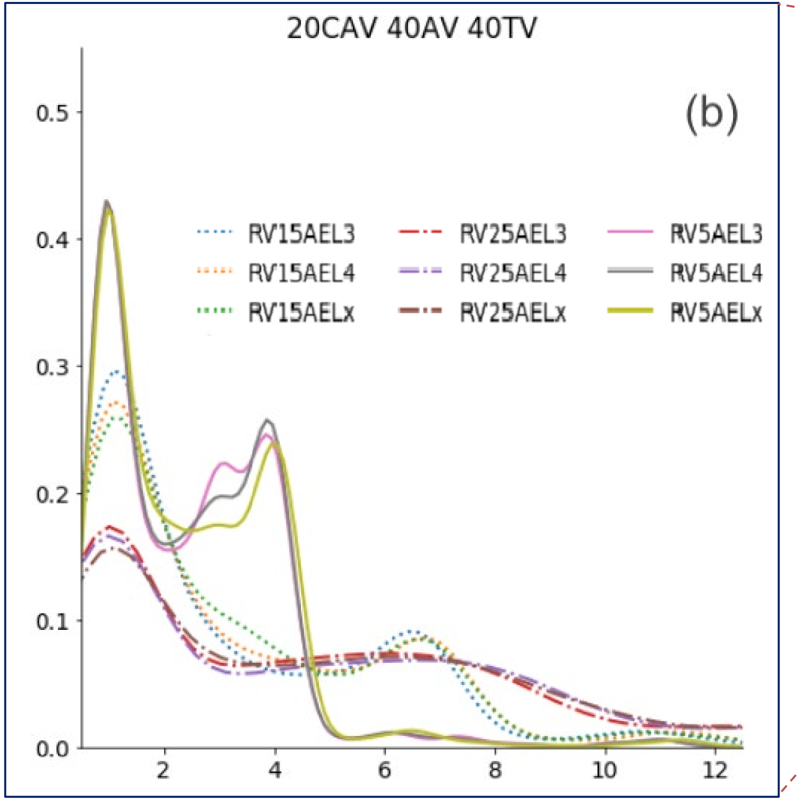
CAV MPR \ AV MPR	0	20	40	60	80	100
0	-576	-544	-480	-488	-412	-364
20	176	212	280	392	360	
40	372	448	464	496		
60	164	220	300			
80	-508	-344				
100	-2092					

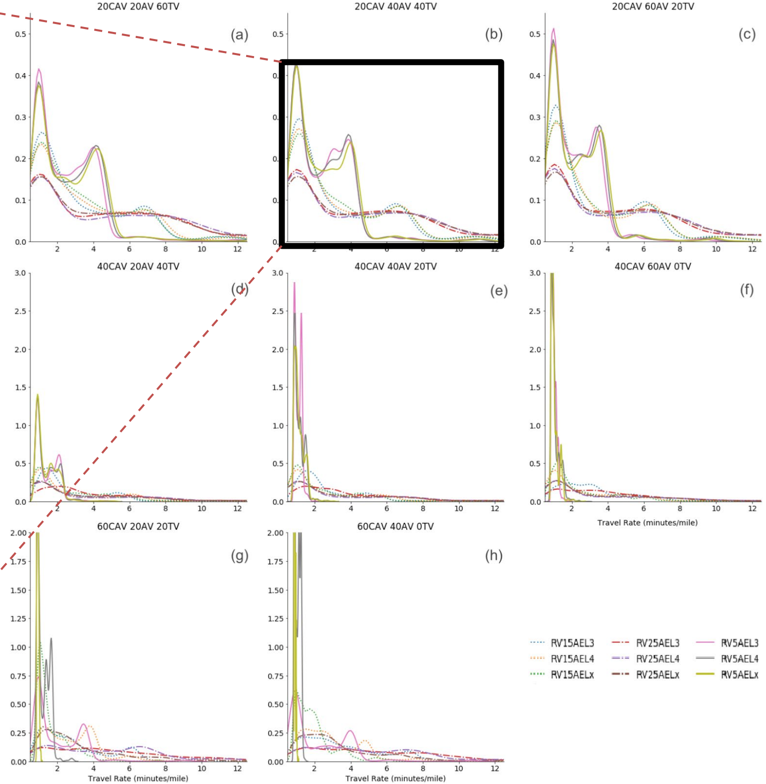


Throughput Diff. in vphpl (DL with Unlimted Egress - Base Case)

CAV MPR \ AV MPR	0	20	40	60	80	100
0	-576	-544	-480	-488	-412	-364
20	112	168	204	288	352	
40	432	452	384	476		
60	108	156	184			
80	-400	-328				
100	-2008					

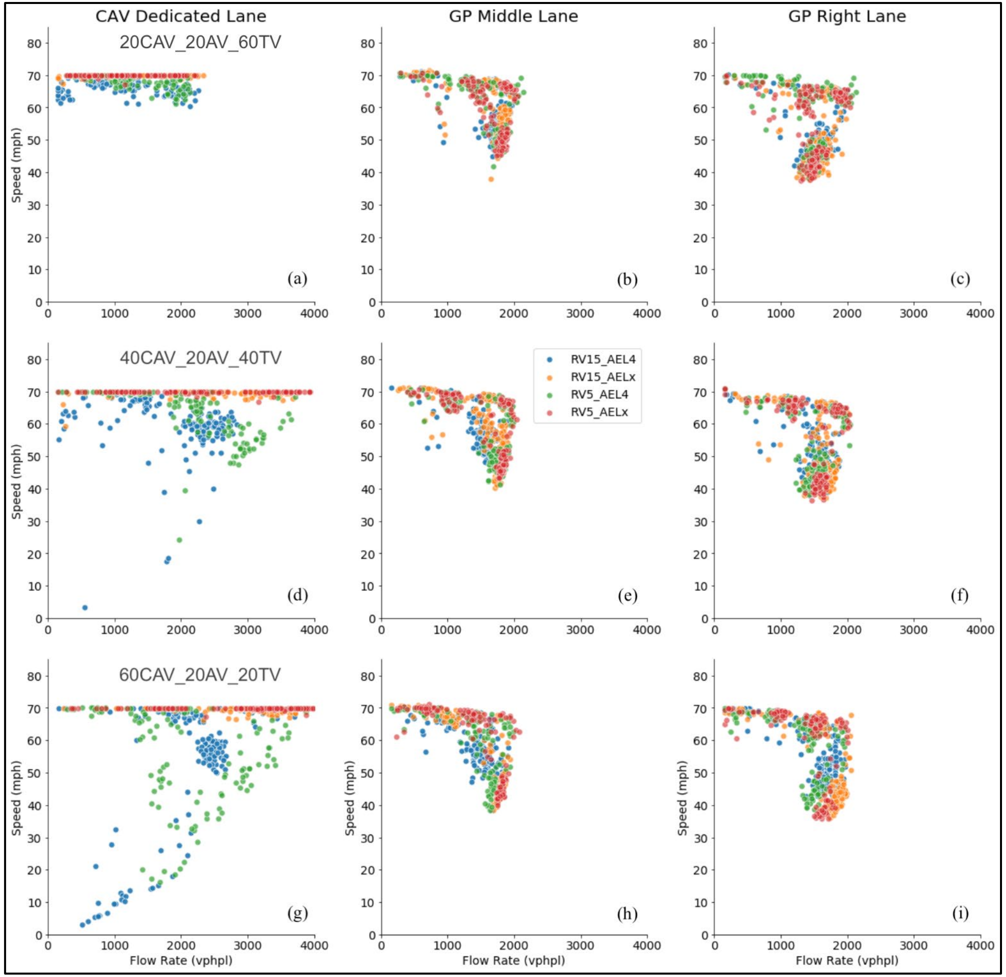
Results and Analysis – Travel Rate





Results and Analysis – FD

- GP Lanes
  - Similar pattern exists between the two lanes
  - High CAV MPR → more scatter
  - Impacted by both ramp volume and access/egress lengths
- Dedicated Lane
  - Access/egress lengths drastically impact the scatter of the fundamental diagram
  - Impact of MPR and Ramp Volume



Conclusions

- Simulation result indicate that reserving a lane for CAVs is beneficial when MPR is 20%-60% and optimal at 40%.
- Outside of this range, throughput degrades significantly due to congestion on either the dedicated or general-purpose lanes.
- Mandating CAVs to operate exclusively in the dedicated lane negatively impacted the throughput at the medium and high feasible ranges (40%-60%) but proved beneficial at the low CAV MPR of 20%.
- TRD and FD analyses demonstrated that the operation of dedicated lane is impacted by access/egress lengths, and ramp volume.

Thank You

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