STRIDE | Southeastern Transportation Research, Innovation, Development and Education Center

Technology Transfer Final Report

STRIDE Project O2

Macroscopic Fundamental Diagram Approach to Traffic Flow with Autonomous/Connected Vehicles

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1. Project Description

With the development of automation and connectivity technology, there will be more connected and autonomous vehicles (CAVs) entering the road network. Before all of the existing human-driven vehicles (HVs) are replaced by CAVs, there will be a long transition period where CAVs and HVs are mixed on the roadway. Equipped with vehicle-to-vehicle communication capability, CAVs are expected to improve the road capacity due to smaller reaction times and headways. However, in mixed traffic, the movement of human-driven vehicles are uncertain and unmanageable, which will severely hinder the communication between CAVs. Managing the operation of CAVs in mixed traffic is a struggle. To address this problem, the study proposed a lane-changing algorithm to guide CAV platoons to bypass the slower HVs. The simulation results verified that the proposed algorithm speeds up not only the CAVs but also the HVs, the total travel time decreased, and the highway outflow was improved. The study also found that as CAV penetration rates increased, the urban street capacity may increase or decrease depending upon the reaction time settings. This is important for traffic operators and vehicle industries to be aware of as CAVs become more common.

The advent of CAVs also has the potential to increase vehicle travel demand by improving road capacity and reducing travel and parking costs. However, the extent to which travel demand will increase is still uncertain. This uncertainty makes it challenging to determine how to modify existing road networks to improve travel flow/throughput. To circumvent this challenge, the study used a macroscopic fundamental diagram (MFD) method to identify design solutions that would improve the transportation network.

2. Performance Metrics

Metric	# Completed
OUTPUTS	
Product(s): Number of new or improved tools, technologies, products, methods, practices, and processes created or improved	3
Technical Report: Number of client-based technical reports published	1 (STRIDE Final Report)
OUTCOMES	
Body of Knowledge: Number of trainings for transportation professionals	1 (STRIDE Webinar)
Professionals Trained: Number of professionals participating in trainings	66 (32 attendees, 34 YouTube views)
IMPACTS	
Stakeholders: Number of stakeholders met with to encourage adoption or implementation of product(s)	1
Adoption/Implementation: Number of incidences outputs of research have been implemented or adopted	0

3. Product(s)

Product 1: Methodology - Completed a research paper named “Macroscopic Fundamental Diagram Based Discrete Transportation Network Design” (https://doi.org/10.1155/2020/4951953). The proposed methodology should be useful for city planners. When new roads need to be built to ease traffic congestion, the proposed method can be utilized to determine which links should be built.

Product 2: Algorithm - Completed a research paper named "A Cooperative Bypassing Algorithm for Connected and Autonomous Vehicles in the Mixed Traffic". The proposed algorithm should be helpful to control the autonomous and connected vehicles in a mixed traffic environment. Potential users could be vehicle industry and state Department of Transportation. (This paper was provisionally accepted by *IET Intelligent Transport Systems* subject to major revisions, and the revision manuscript is still under review.)

Product 3: Methodology - Completed a research paper titled "An Analytical Approximation for the Corridor Macroscopic Fundamental Diagram of Mixed Human and Connected and Autonomous Traffic". The research result is useful for the vehicle industry to determine the reaction time of autonomous vehicles, and for the Department of Transportation to determine the penetration rate of autonomous vehicles. (This paper will be submitted to a journal soon.)

4. Body of Knowledge & Professionals Trained

1) STRIDE webinar – July 1, 2020: Dr. Robert Whalin, Jackson State University, and Guojing Hu, PhD Candidate, Jackson State University presented "Macroscopic Fundamental Diagram Approach to Traffic Flow with Autonomous/Connected Vehicles" (32 attendees; 34 YouTube views)

5. Stakeholder Engagement

MEETING DETAILS		NARRATIVE DESCRIPTION
STRIDE representative	Robert W. Whalin, Guojing Hu, and Kejun Wen	On September 30, 2019, 2:00 pm-3:00 pm in the Planning Conference Room of Mississippi Department of Transportation (MDOT) Building, JSU updated STRIDE activities for MDOT, including a presentation on STRIDE project titled "Macroscopic Fundamental Approach to Traffic Flow with Autonomous/Connected Vehicles". After the presentation, the attendees discussed the technical part and the safety problem of the autonomous and connected vehicles.
Date of Activity	9/30/2019	
Type of Activity	in-person meeting	
Location	Mississippi DOT	
Stakeholder(s)	seven researchers from MDOT: Cynthia J. Smith (also from External Advisory Board of STRIDE), Alex Middleton, Evan Wright, William T. Stafford, Rhea Vincent, Benjamin Roberts, Billy Owen	

6. Adoption/Implementation

For Product 1: Methodology - Macroscopic Fundamental Diagram Based Discrete Transportation Network Design

- The proposed methodology will be useful for city planners to determine which new roads can be built to improve road network capacity.
- No one has implemented the product.
- One poster demonstration listed in Item 4 was completed, and one related research paper was published in https://doi.org/10.1155/2020/4951953.

For Product 2: Algorithm - A Cooperative Bypassing Algorithm for Connected and Autonomous Vehicles in the Mixed Traffic

- The proposed algorithm will be useful for vehicle industries to develop CAV lane-changing algorithms in a mixed traffic environment.
- No one has implemented the product.
- Two poster demonstrations listed in Item 4 were completed, and one related research paper was submitted to *IET Intelligent Transport Systems* and is still under review.

For Product 3: Methodology - An Analytical Approximation for the Corridor Macroscopic Fundamental Diagram of Mixed Human and Connected and Autonomous Traffic

- The research result will be useful for the vehicle industry to determine the reaction times of CAVs, and for the DOTs to recommend the CAV penetration rates.
- No one has implemented the product.
- One poster demonstration listed in Item 4 will be conducted, and one related research paper will be submitted to *IET Intelligent Transport Systems*.

7. Broader Impacts

- Since the product has not been adopted or implemented, the existing positive impacts are not clear. When product 1 is adopted, the road network design problem will have more robust solutions, even for uncertain travel demands, and the network throughput will be improved. The impact can be measured by network flow before and after implementing the proposed methodology. No new practices have been resulted in.
- Since the product has not been adopted or implemented, the existing positive impacts are not clear. When product 2 is adopted, CAVs can be guided to move efficiently in the mixed traffic environment. No new practices have been resulted in.
- Since the product has not been adopted or implemented, the existing positive impacts are not clear. When product 3 is adopted, vehicle industries will pay more attention to the reaction time settings of CAVs, especially when the current CAV penetration rate is low. The potential negative impact of CAV reaction time settings can be avoided. No new practices have been resulted in.