2019 NSF RET Project: Modeling of Signalized Intersection Design and Impacts

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Project Summary

The operation of signalized intersections and connected arterial is often complex, involving competing vehicular and pedestrian movements under uncertain traffic conditions. Appropriate methodologies of geometric and phase timing design of signals and impact analysis require the behaviors of drivers and traffic arrival patterns at each signalized intersection to be modeled in a form that can be easily manipulated and optimized. However, the performance of the adaptive signal control system is highly dependent upon on the range and accuracy of detectors such as inductive loop that are installed at fixed locations on approaches but actually incapable of providing correct traffic information beyond the detection areas.

The ***big idea*** of the RET project is to explore the potentials of applying the emerging technologies such as connected vehicles (CV) as a "floating on-vehicle sensing" technology to overcome the weakness of the traditionally fixed-located detectors. This may not only bring the benefit to significantly improve the accuracy of traffic arrival patterns for increasing the traffic control efficiency, but also bring the potential to achieve eco-driving control schemes that integrate the minimal fuel consumption and/or vehicle emission. The research ***challenge*** lies in the understanding of the CV-based on-vehicle floating sensing mechanism and methods for assessment of the effectiveness of such an advanced signal control system design.

Numerous studies can be retrieved from literature review, including the faculty mentors and their graduate students' research efforts on the subject. However, it remains challenging in development of a simulation-based scenarios to facilitate the understanding of the cause-and-effect mechanism between accuracy of CV-based sensing data and measurement of effectiveness (MOE) to achieve the multifold signal control objective (i.e. efficiency, energy saving and reduced emission). Accordingly, the following ***guiding questions*** are addressed through the RET project:

- How to design signal control phase timing schemes with traditional detection technologies and data collection techniques?
- Assuming the CV technology can provide accurate trajectory of the vehicles, how to extract useful information from the mobility trajectories (e.g., speed, headway)?
- How to model the extracted trajectory data into the information depicting traffic stream characteristics (e.g. flow rate, density, arrival pattern)?
- How to use the trajectory data and modeled information to design responsive signal control phase timing schemes?
- How to evaluate the MOEs of the design alternatives using simulation tool?
- How to use the simulation-based results to interpreter the cause-and-effect mechanism?
- How to associate the traffic operation with vehicular energy consumption and emission reduction in performance assessment?
- How to understand the mathematics role in formulating research questions and solution development as well as transferring the outcome into classroom teaching?

Training Provided

The project is to help the RET teachers to gain hands-on experience in understanding the cause-and-effect mechanism about the operational, energy and emission impacts of the signal design with new technologies. The teachers will be trained to learn related math modeling and simulation-based analytics of a real-world signalized intersection and its connected corridor, including geometric and algebraic methods, and fundamental statistical techniques involved in the optimization analytic procedure, which are usually offered in secondary and community colleges. The intersection of Martin Luther King Dive and Reading Road, Cincinnati, Ohio will be selected as the case study site. **Figure 1** visualizes major components of the traffic signal design and operation.

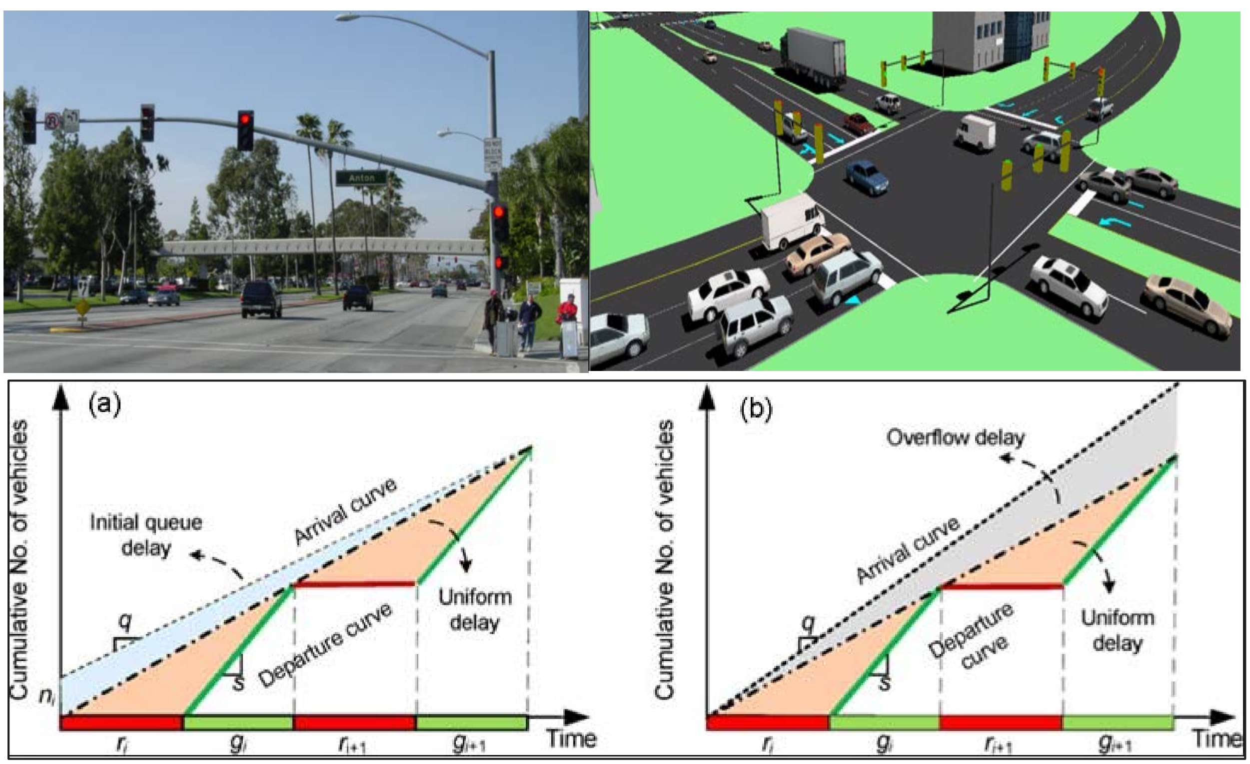

Figure 1: Conceptual Analysis of Traffic Signal Operation and Design

Lastly, the teachers will learn from the faculty mentors and their graduate students' demonstration of their on-going research to better understand the CV impacts on signal control.

Facilities and Equipment to be Used

To cultivate the problem-solving skills, the teachers should be able to identify in the curriculum where infusion of technology makes the learning more vivid. For this purpose, the teachers will be trained to learn advanced data collection techniques using the Intersection Movement Counters, Global Positioning System (GPS) Travel Recorder Data Loggers and VISSIM simulation software. The teachers will be trained to mathematically interpret MOE outcomes using the observed data, and then build the models into the computer simulation system (i.e. VISSIM software), as well as estimate energy consumption and emission under certain traffic operational conditions using MOVES-based mathematical models.

Field Trip

A field trip will be scheduled for the teachers to better understand mobility reliability with live observations along the Uptown Smart Corridor site, in conjunction with an on-going UC Forward Program project. Optionally, a field trip may be arranged to visit the statewide traffic management center (TMC) in Ohio Department of Transportation Center Office in Columbus, Ohio (**Figure 2**), depending on the available cost and budget. This trip is expected to provide an authentic environment for the teachers to perceive the real-world traffic operation and management.

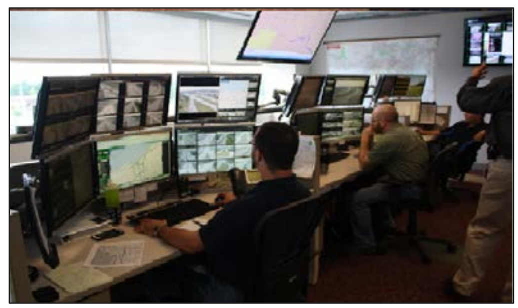

Figure 2: TMC in Columbus, Ohio

Industrial Advisor for the Project

An industrial advisor, Dr. Qingyi Ai from Arcadis U.S., Inc., Cincinnati, Ohio will give the RET teachers a talk about real-world signal control related problem solving procedure and potential impact of the research outcome from the viewpoint of practice. As an option, Mr. Andrew Rohne, Transportation Modeling Manager of Ohio-Kentucky-Indiana Regional Council of Governments (OKI) will give an introduction of the traffic data and its application in transportation planning.

Possible Idea for Developing Classroom Implementation Plan

The teachers could develop a classroom implementation plan around the theme of *"Math: how does it work on real-world traffic signal design problems?".* The course will help students understand the importance of math and science to society through a case study of signal design, including geometric and phase timing designs and their impact analysis. It will use math to: calculate necessary design parameters by using the experimental results; make inferences about the relationship between parameters; conduct data analysis to better understand the traffic condition of the arterial and its impact on the operation, fuel consumption and emission estimates of the concerned signalized intersection. Thus, students will learn the signal operations through usage of math and scientific methods. Moreover, the plan could lead to motivated students' in-depth thinking of the signal design challenges, for example, "how to ensure the design of signal system effective to mitigating congestion while reducing energy consumption and vehicle emission?", "how to best utilize emerging technologies to enhance signal control efficiency?", and "how to evaluate the signal control operation and its impacts?", and so forth.