

# Multi-Modal Intelligent Traffic Signal System

## Development of Concept of Operations, System Requirements, System Design and a Test Plan

### Project Plan

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#### Introduction

The University of Arizona has teamed with California PATH) and technical experts from connected vehicle system equipment manufacturers (Savari and Kapsch), a traffic signal control system supplier (Econolite), an SAE J2735 communications standards expert (SCSC), and a commercial vehicle technology company (Volvo Technologies) ) to design a multi-modal intelligent traffic signal system that will operate in a connected vehicle environment.

Traffic signal control has experienced very few fundamental improvements in the past 50 years. The principles of movements controlled by intervals of phases and the use of point detection have formed the basis for all traffic signal control. Advances in detection have primarily addressed the application of new technologies such as video, radar, and electromagnetic, or in the detection of pedestrians and bicycles. Advances in signal control logic have primarily focused on enhancing priority control for transit vehicles or adaptively adjusting timing parameters. Tools and methods have been developed to enable traffic engineers' better use of traffic signal control, but the fundamental logic and operations of the controller have not changed.

Traffic signal control in most urban areas today is dynamic (actuated) in nature and coordinated with other intersections to enable smooth flow, or progression, of traffic. However, these systems depend on loop detectors or video based systems that are located at fixed locations in space to call and extend signal control phases. These detection systems provide basic information such as vehicle count, occupancy, and/or presence/passage information. This limits the use of advanced logic that can potentially be built into modern day traffic signal controllers.

Modern traffic control management systems provide the ability to monitor signal operations, change signal control plans by time of day or in a traffic responsive manner, and some provide adaptive signal timing where the signal timing parameters are adjusted based on traditional vehicle detector data. Traffic management systems provide a traffic engineer the ability to manipulate signals from a central traffic control center, but have limited strategic control capability and rely heavily on the innovation and skill of the traffic signal engineer user.

The advances in Connected Vehicle technologies provide the first real opportunity for transforming traffic signal control in terms of the traffic signal controller logic,

operations, and performance. The advent of DSRC in vehicular communication provides a critical component that, when coupled with meaningful messages (SAE J2735), has the potential to provide detailed information required for intelligent traffic signal control. DSRC can be leveraged to provide real-time knowledge of vehicle class (passenger, transit, emergency, commercial), position, speed, and acceleration on each approach. The widespread availability of other wireless communications media, such as WiFi, 3G/4G, and Bluetooth enable Smartphones, provide coverage for other users, including pedestrians and bicycles. The potential for safer and more efficient multi-modal traffic signal operations is finally possible.

The past several years have seen considerable innovative research and development into the use of Connected Vehicle technology for traffic signal control. The use of connected vehicle probe data in the development of signal control strategies has been limited. Most of the work has been i) on the potential and limitations of probe data to describe operating conditions in a road network and its relationship to signal control<sup>1</sup>, and ii) the potential of using probe data for providing real-time information to drivers, e.g., pilot implementation of speed advisories on head-up displays in Germany<sup>2</sup>. Ongoing work at the University of Virginia as part of the FHWA Pooled Fund study has proposed the use of probe data for better queue management and clustering of vehicle platoons<sup>3</sup>. Also, in a California PATH study aiming to develop a dynamic all-red extension strategy to reduce red-light-running (RLR) collisions, it was found that using vehicle trajectory data approaching the intersection can improve the prediction of RLR occurrences by up to 40%, compared with conventional point detection from loops.<sup>4</sup> There has been additional development work related to communication standards (SAE), automotive industry developments (CAMP), commercial vehicle systems (CVII), and other efforts to develop transit concepts of operations and emergency services operations. All of these efforts provide critical input into the design of a Multi-Modal Intelligent Traffic Signal System.

The US DOT Mobility Applications template process has identified a minimum set of applications, or capabilities, that a Multi-Modal Intelligent Traffic Signal System should contain. These include:

- Intelligent Traffic Signal System (ISIG)
- Transit Signal Priority (TSP)
- Mobile Accessible Pedestrian Signal System (PED-SIG):
- Emergency Vehicle Preemption (PREEMPT)
- Freight Signal Priority (FSP)

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<sup>1</sup> Head, L. "Traffic Control in a VII Environment", Traffic Signal Systems Committee Workshop, TRB Annual Meeting – Washington, DC, Jan 2008.

<sup>2</sup> TRAVOLUTION prototype, Ingolstadt, Germany, [http://www.haeuwachits.info/press/press\\_detail.asp?pid=20&aid=842](http://www.haeuwachits.info/press/press_detail.asp?pid=20&aid=842).

<sup>3</sup> Venkatanarayana, R., H. Park, B. Smith, C. Skerrit and N. Ruhter, "Application of IntelliDrive to Address Oversaturated Conditions on Arterials," 90<sup>th</sup> TRB Annual Meeting, Washington DC, Jan 2011.

<sup>4</sup> Wang, L., L. Zhang, WB Zhang, and K. Zu, "Red Light Running Prediction for Dynamic All-Red Extension at Signalized Intersection," 12<sup>th</sup> IEEE ITSC Conference, St Louis, MO, Oct 2009.

The Intelligent Traffic Signal System application concept envisions the use of high fidelity real-time data to predict lane dependent platoon and vehicle flow together with data from transit vehicles, freight (trucks), pedestrians, and emergency vehicles to find a system-wide optimal control plan. This application embodies the overall objectives of a Multi-Modal Intelligent Traffic Signal System where information from Transit vehicles (passenger count, schedule adherence or headway compliance, service level), Pedestrians (visually impaired, physically disadvantaged), Emergency Vehicles (position, heading, number of vehicles), and Freight (trucks) are present in the system. The interaction of these applications provides the opportunity and the challenge to provide a transformative capability that will finally (after more than 50 years) change the fundamentals of traffic signal control.

The objectives of this project are:

- To develop a concept of operations, systems requirements and system design for a comprehensive traffic signal system that services multiple modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets and pedestrians; and
- To prepare for field testing/demonstration of the developed Multi-Modal Intelligent Traffic Signal System.

***Deliverables:***

- Task 1: Project Plan, 3/29/2012
- Task 2: Concept of Operations, 8/16/2012
- Task 3: System Requirements Document, 12/6/2012
- Task 4: System Design Document, 1/17/2013
- Task 5: Deployment and Field Test Plan, 2/28/2013

**Task 1 – Project and Systems Engineering Management**

The purpose of this task is to provide project management support for all tasks described in this scope of services.

***Deliverable: Project Management Plan***

***Deliverable: Monthly Progress Reports and Quarterly Update Conference Calls***

**Task 2 – Develop Concept of Operations (ConOps)**

A Concept of Operations (ConOps) captures the stakeholders views of the system being developed and is written so that it can be easily reviewed by the various stakeholder communities. The Concept of Operations will provide a vision and a roadmap for the development, deployment, operation and maintenance of future Multi-Modal Intelligent Traffic Signal Systems. It will identify clear goals for a Multi-Modal Intelligent Traffic Signal System to achieve to support a transformation of traffic signal control from today's technology into a safer and more efficient system for the future. It will identify opportunities for early deployment and adoption as an enabling technology that will support wide scale technology adoption.

***Deliverable: Report on Assessment of Relevant Prior and Ongoing Research***

***Deliverable: Stakeholder Workshop Report***

***Deliverable: Concept of Operations Document***

#### Task 2.1 – Assessment of Relevant Prior and Ongoing Research

The Research Team will prepare a Report on Assessment of Relevant Prior and Ongoing Research that will identify the literature and project sources. This report will be structured to include traffic control algorithms and strategies, standards and technology developments, past and on-going projects, US DOT and AASHTO strategic plans, and other sources of Connected Vehicle activities that could influence the development of a Multi-Modal Intelligent Traffic Management System.

#### Task 2.2 – Solicit Stakeholder Input on Transformative Goals, Performance Measures and User Needs

The Research Team will conduct two (2) stakeholder meetings, plus informal solicitations from relevant stakeholders, to identify transformative benefits for the application, corresponding performance measures, and user needs for the application. The first stakeholder meeting will include key stakeholders representing different classes of users, owners, and operators. The second stakeholder meeting will be conducted as a webinar where a larger and broader group of participants can be included. The Research Team will develop a report summarizing the findings of the workshop.

#### Subtask 2.3 – Develop Concept of Operations (ConOps)

The Assessment of Relevant Prior Research, Stakeholder Inputs and Research Team vision will be used to develop the Concept of Operations. The Concept of Operations document is intended to capture the stakeholders' views and is to be easily readable by the stakeholder community. The Research Team will follow the IEEE Standard 1362-1998 format. A Concept of Operations Walkthrough will be conducted to review the document with critical stakeholders.

### **Task 3 – Develop System Requirements (SyRS)**

The System Requirements form the basis for the design, implementation, testing, and acceptance of any system. Each requirement places a cost on the system, hence it is important that a minimum set of requirements be defined and that each requirement be verifiable and traceable to its origin, such as to a need identified in the Concept of Operations. Requirements can be related to system functionality, the technology available to build the system, functional performance, acquisition and operating cost, the system-ilities that include reliability, maintainability, availability, and trade-offs between performance and cost/utilization. Requirements must also be testable so that the developed system can be verified to satisfy the requirements. Requirements are based on sound understanding and analysis of the problem.

The will develop a set of system requirements based on the Concept of Operations. The requirements will be developed following the guidance in IEEE Standard 1233-1998, IEEE Guide for Developing System Requirements Specifications and using the DOORS

requirements management tool that supports requirements tracking and management. The Research Team will prepare Walkthrough Workbooks and will conduct a Requirements Review Meeting. Based on the comments received in the Requirements Review the System Requirements will be revised and Comment Resolution Report will be developed and delivered.

***Deliverable: System Requirements (SyRS) Document***

#### **Task 4 – Conduct System Design**

Based on the Concept of Operations and the System Requirements, high-level system designs will be developed based on deployment on the existing Arizona and California test beds. The high level designs will be represented considering several stakeholder views. These views include the users (multi modal travelers), operators, maintainers, and managers (owners). Since each of the field sites is currently based on different technology, the high level design will seek to identify common and custom design features required for the respective implementation.

Each design will include a detailed deployment specification that includes hardware components, software components, software artifacts (e.g. J2735 MAPs, traffic signal controller databases) interfaces, messages, backhaul communications, and power for the respective network topology. Each design will include a requirements allocation view to ensure that each design meets the requirements. Each design will be evaluated with respect to the requirements.

***Deliverable: System Design Document***

#### **Task 5 – Prepare a Deployment and Field Test Plan**

The Research Team will develop Field Deployment and Test Plans for both the California and Arizona test networks. Each Field Deployment Plan will include a schedule and cost estimate and identification of any specific issues that need to be addressed for the respective network. A common Test Plan will be developed for both test beds. It is possible that one or more of the Dynamic Mobility Applications (e.g. Intelligent Traffic Signal System, Transit Signal Priority, Mobile Accessible Pedestrian Signal System, Emergency Vehicle Preemption, and Freight Signal Priority) might not be operational in one of the test networks, but an important goal of this project is to demonstrate the ability to provide the same functionality on different implementations and networks.

***Deliverable: Deployment and Field Test Plan***