Research Project Work Plan

for

IMPROVING ADAPTIVE/RESPONSIVE SIGNAL CONTROL PERFORMANCE: IMPLICATIONS OF NON-INVASIVE DETECTION AND LEGACY TIMING PRACTICES

15-001

Submitted by

Edward J Smaglik
Associate Professor

Northern Arizona University
Box 15600
Flagstaff, AZ 86011

for

Oregon Department of Transportation
Research Unit
200 Hawthorne Ave. SE, Suite B-240
Salem, Oregon 97301-5192

June 2014

Revised: Late June, 2014

Research Project Work Plan
for

IMPROVING ADAPTIVE/RESPONSIVE SIGNAL CONTROL PERFORMANCE: IMPLICATIONS OF NON-INVASIVE DETECTION AND LEGACY TIMING PRACTICES

1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301 Phone: (503) 986-2700

Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator(s)

Edward J Smaglik, Associate Professor
Department of Civil Engineering, Construction Management, ad Environmental Engineering
Northern Arizona University
Box 15600
Flagstaff, AZ 86011 Phone: 928-523-1431 (w)
928-310-4672 (c)

1.3 Technical Advisory Committee (TAC) Members

[Names, Affiliations] [*indicate which member is Chair, research proposer*]

1.4 Friends of the Committee (if any)

[Names, Affiliations]

1.5 Research Coordinator

Jon Lazarus Phone: 503-986-2852

1.6 Project Champion

Douglas Bish Phone: 503-986-3594

2.0 Problem Statement

ODOT is turning towards adaptive/responsive signal control strategies to improve the operational performance of coordinated corridors and networks. However, these newer control strategies require more information from the detection systems than more traditional control strategies. This requirement for higher resolution detection data could be addressed through the selection of in pavement detection; however, due to the capital costs associated with in-pavement detection systems ODOT is increasingly selecting non-invasive or passive detection systems such as video cameras, micro-wave, radar, or micro detection pucks, which are also easier to install and maintain.

These non-invasive systems are currently performing below those standards established by the use of in-pavement detection. As such, ODOT is currently operating adaptive and responsive signal control by applying legacy timing and installation practices, and in doing so is not maximizing the benefits of its investment in advanced control strategies. The use of passive detection can degrade optimal intersection performance up to 20%, resulting in longer delays to the public, inefficient use of cycle time, increased traffic queuing, increased fuel consumption, increases risk of traffic crashes due to congestion and results in sub-optimal signal operations.

Current ODOT standards of practice for purchase, installation, layout and timing of non-invasive systems requires updating. More realistic costs, installation practices, detection zone layouts and timing parameters are needed in order to capture the full measure of the more powerful data driven traffic signal controller systems currently being deployed throughout the State of Oregon.

2.1 Background and Significance of Work

While much research has focused on the proper placement and setup for non-invasive detection, most of this work has focused on vehicle presence, not vehicle counts ([i], [ii]). Given that advanced traffic signal control systems rely on both of these outputs to run their algorithms, knowledge regarding proper configuration of these units for presence and count detection is necessary and generally not available in the literature. A literature search found one document regarding the configuration of a puck system for counting, though none was located for other methods ([iii]). Furthermore, nothing is available that attempts to connect alternative detection strategies with timing plans for advanced traffic signal control systems.

The industry appears to have realized that this is a pressing issue and there are several active funded projects to address some aspects of the problem, though no projects are taking a quantitative approach to developing vehicle detection guidelines, as is proposed in this work. The project titles along with their abstracts from TRID (http://trid.trb.org/) are listed below, with author comments indicated in bold.

1. Idaho DOT: *Traffic Detection Systems Performance Evaluation*
    a. This project will be testing the detection systems currently being used by the Idaho Transportation Department (ITD) for accuracy. The best performers in terms of minimum delay and maximum safety will be quantified. The outcome of the research will provide guidance for the development of a performance based specification for traffic detection equipment. This will eliminate poor performing equipment from the state system.
    - **The development of criteria to quantify the performance of ITD detection units may be of interest to this work; however this work does not bridge the gap between detection performance and advanced system operations.**
2. Purdue NEXTRANS: *Increasing Accuracy of Vehicle Detection from Conventional Vehicle Detectors - Counts, Speeds, Classification, and Travel Time*
    a. The ultimate objective of this study is to develop techniques that will improve the measurement accuracy of a given detector station both at the time of installation and throughout its working lifetime. Until recently it has been difficult to validate the detector measurements, but the research team has developed a suite of tools that will greatly facilitate such validation. These improved measurements will in turn improve real time traffic control (e.g., ramp metering and traveler information), vehicle classification, and aggregate performance measures from the vehicle detector infrastructure.
    - **These techniques for long term evaluation of detector performance may be suitable for including in the guidebook deliverable, presuming they are germane to ODOT detection goals.**
3. Louisiana DOT: *DOTD Support for UTC Project: Traffic Counting Using Existing Video Detection Cameras*
    a. This study will evaluate the video detection technologies currently adopted by the city of Baton Rouge, Louisiana and the Louisiana Department of Transportation and Development (LADOTD) with the purpose of establishing design guidelines based on the detection needs, functionality, and cost. The study will also develop a mechanism for integrating traffic count data from video cameras at intersections in the Baton Rouge Metropolitan Area into a database that can be used to supplement traffic count information. The main objectives of this research are to conduct a review of similar studies by other researchers, make an inventory of the intersections in the Baton Rouge Metropolitan Area where video cameras are installed, Select sample of intersections from the inventory, collect traffic data from the selected signalized intersections using the video detection system installed on site and other reliable method to provide ground truth data, assess the capabilities of the existing video detection systems use to analyze the data, and determine the accuracy of the video detection system through a comparison with the ground truth data.
    - **This first goal of this project appears to be a somewhat qualitative approach to one of the goals of this work plan, however the depth of the scope (presence, count, both?), among other things, is a bit unclear.**

    At the onset of this project, the research team will reach out to the groups working on each of these projects in an attempt to understand the work in greater detail, and to determine how best to leverage the results of others to improve the impact of this work plan.

3.0 Objectives of the Study

This research will develop a realistic installation guideline that supports the requirements of advance traffic signal controller operations, hybrid detection installations, and non-invasive detection optimization. This guideline shall provide prototypical detection configurations and new timing standards with the goal of reducing or eliminating performance degradation. These guidelines will include a cost analysis that appropriately considers equipment and installation costs as well as the cost of increase delay to the motoring public due to the degradation of signal performance. The costs of this delay can be as much as ($18 per delay hour per/day per passenger vehicle) and as much as ($70 per delay hour per/day per interstate transit vehicle).

3.1 Benefits

This research will benefit ODOT and many other transportation agencies by facilitating better more informed decisions as to the true costs of alternative detection systems applied to adaptive/responsive signal control. Agency decision makers may use the material to determine the value of adding a chosen detection system in a piecemeal manner or to replace legacy systems with the newer non-invasive, or hybrid system(s). This cost evaluation will provide a better picture of the expectations of the replacement process, bringing to light currently hidden or unaccounted for cost associated with these systems.

Traffic signal staff will have a guideline that will promote improved operational performance for advanced control systems. Staff will have an improved ability to interpret level of volume and flow rates from passive detection systems similar to those experienced from legacy induction loop systems. Adaptive/responsive traffic signal operations could improve as much as 20% when accurate detection functions are restored to the bench mark levels of legacy induction systems.

4.0 Implementation

Many practitioners are likely unaware of the discrepancies in the operational performances of non-invasive detection systems when compared to the legacy induction loop systems. These discrepancies should not discourage the use of non-invasive detection systems; rather they should be compensated for in the deployment of new systems or retro-fit of existing systems to enhance the performance of advanced traffic signal operations.

To address this incongruity, the products and subsequent dissemination of this research will include the following:

- An apples to apples comparison of different detection systems based upon the data assimilated in this work.

- Searchable database / spreadsheet with data collected in this project for additional investigations not covered by the scope of this work
- Guidance on prototypical detection configurations and improved timing standards with the goal of reducing or eliminating performance degradation due to vehicle detection, including a cost analysis that appropriately considers equipment and installation costs as well as the cost of increase delay to the motoring public due to the degradation of signal performance.
- Draft new sections to be considered for the Oregon Traffic Signal Timers manual and the Traffic Signal Design Manual to provide guidance on this to ODOT staff, local agency staff and consultants around the state.
- Dissemination of project deliverables to academic journals and conferences (local and national).

5.0 Research Tasks

Task # 1: Literature Review

A brief literature review will be conducted with the goal of determining the current understanding and state of practice of the inter-relationship of adaptive/coordinated traffic signal system detection and timing strategies. Questions involving detector type, zone length and placement, accuracy, and maintenance will be considered as well as the impact of these criteria on critical timing parameters such as passage time and other adaptive timing threshold values. Specifically, the link between detector performance and intersection control will be investigated as part of this task. Additionally, no fewer than 5 managing agencies will be contacted to investigate policies and procedures they may have in place to address these issues. Lastly, the investigative teams of the active research projects listed in section 2.1 will be contacted to gain an understanding of how their work can be leveraged in this project.

Time Frame: 1 September 2014 – 30 November 2014

Responsible Party: Smaglik and Sharma, NAU, PSU, and Iowa State facilities

Cost: $14,000

Deliverable: Quarterly progress report documenting findings of the literature and associated investigations

TAC Decision/Action: Review and comment on progress report as appropriate.

Task # 2: Sampling and Data Collection Plan

Knowledge gained in the literature review will be used to guide the selection of no fewer than 5 and as many as 10 potential locations for the collection of intersection and detection performance measures. TAC guidance will be solicited in the selection process to identify locations that would be critical to the research project. Focus will be placed on intersections operating the advanced features of the Voyage software platform using video detection since this is the most common applications of advanced intersection control in Oregon, however all combinations of invasive and non-invasive detection will be considered at adaptive signal locations. Additional consideration will be paid to locations with detection and cabinet solutions that would aid in the collection and management of performance measure data, with a focus on developing a time

stamped video and corresponding data log to assist in manual ground truthing and database development.
Time Frame: 1 December 2014 – 31 January 2015
Responsible Party: Smaglik with assistance from Sharma and Kothuri, NAU and PSU facilities
Cost: $15,250
Deliverable: List of preferred intersections along with acceptable alternates for data collection, as well as proposed methods of data acquisition
TAC Decision/Action: Approval of intersection selection

Task # 3: Data Acquisition Equipment Development, Assembly, Testing and Scheduling
Based upon the sites selected and their operational characteristics, data acquisition equipment will be procured, assembled, and beta tested at one location. Testing will focus on a successful interface between the cabinet and data collection unit, as well as various detection devices. No fewer than two acquisition devices will be developed, and they will utilize off the shelf traffic control equipment as much as possible to facilitate integration with control cabinets. The devices will have the capability to log time-stamped phase and detector data (exact input capacity will be defined by size of intersections to be monitored) to a digital log temporally matched to a digital video (with time and perhaps detector status overlay). Lastly, a schedule of data acquisition deployments will be developed taking into account the detection characteristics of the sites. If the selected locations have multiple concurrent data streams which can then be digitally analyzed through data mining (i.e. looking for times when concurrent monitoring systems of the same detection zone don't match), much more data can be collected overall than if we have to manually reduce the video (students watch the video and note discrepancies visually).
Time Frame: 1 February 2015 – 31 March 2015
Responsible Party: Smaglik with assistance from Sharma and Kothuri, NAU, PSU Facilities and ODOT intersections
Cost: $22,500
Deliverables: (1) Quarterly progress report 28 February 2015; (2) Upon completion of the task, a technical memo will be sent to the TAC describing any outstanding issues going forward, as well as a detailing a schedule for data collection at designated locations
TAC Decision/Action: Review and comment on deliverables as appropriate.

Task # 4: Data Acquisition
Data acquisition modules will be deployed to designated locations across the state per the schedule developed in Task 3. Data will be collected such that various operational periods can be analyzed, including mid-day, peak, and transitional operations. No fewer than 3 days of observation per intersection per corridor will be collected to ensure a robust sample for analysis. However, if an automated solution can be identified in Tasks 2 and 3, additional data will be collected. Collected data will be placed into a usable format for analysis.
Time Frame: 1 April 2015 – 30 September 2015

Responsible Party: Kothuri with assistance from Smaglik, ODOT intersections and PSU facilities
Cost: $40,000
Deliverables: (1-2) Quarterly project progress reports 31 May 2015 and 31 August 2015; (3) TRB paper submittal 31 July 2015
TAC Decision/Action: Review and comment on progress reports as appropriate

Task # 5: Data Reduction and Analysis

Data from the field sites will be reduced into a spreadsheet application that can be analyzed in common statistical software. Data will be analyzed to determine breakpoints for degradation in detection accuracies for different configurations of detection. Statistical models quantifying the impacts of conditions such as level of congestion, time of day, truck percentage on the performance of sensor, and vice versa, will be developed.

Cost and benefit analysis to evaluate the impact of the degradation of detection system performance will be conducted using Micro-simulation tools. A set of volume patterns over a typical weekday and weekend will be developed using existing turning movement counts (both from ODOT records and data collected during this project) on a subset of ODOT systems investigated in this work. The signal system performance would evaluated using these volume patterns and superposing the detection error predicted by the statistical models. It is preferable to use state of the practice traffic controllers on-loan from ODOT such that hardware-in-the-loop simulation can be performed to replicate the exact control algorithms as used in the field.

Finally, recommendations will be made on how to incorporate this knowledge into the selection of vehicle detection schemes and resulting timing parameters.

Time Frame: 1 August 2015 – 30 November 2015
Responsible Party: Smaglik and Sharma, NAU and Iowa State facilities
Cost: $43,250
Deliverables: (1) Spreadsheet / database with complete data and cost analysis; (2) Quarterly progress report 30 November 2015 including summary of recommendations
TAC Decision/Action: Review and comment on deliverables as necessary

Task # 6: ODOT Manual Updates

Supplemental draft text will be developed regarding the outcome of the data analyses for consideration of inclusion in the Oregon Traffic Signal Timers Manual and the Traffic Signal Design Manual. This text shall provide prototypical detection configurations and new timing standards with the goal of reducing or eliminating performance degradation. These guidelines will include a cost analysis that appropriately considers equipment and installation costs as well as the cost of increase delay to the motoring public due to the degradation of signal performance. Additionally, an apples to apples comparison of different detection system performances will be provided.
Time Frame: 1 December 2015 – 29 February 2016
Responsible Party: Smaglik, NAU facilities
Cost: $11,500

Deliverable: Updated text for associated ODOT manuals
TAC Decision/Action: Review and comment on submitted text

Task 7: Final Report
A final report describing the study conclusions, and recommendations will be prepared and submitted to ODOT research.
Time Frame: 1 January 2015 – 31 May 2015
Responsible Party: Smaglik, NAU facilities
Cost: $13,500
Deliverable: Draft Report 29 February 2016; Final Report 31 May 2016
TAC Decision/Action: Review and comment on Draft Report; Accept Final Report

The following matrix summarizes the seven work tasks previously identified:

Task	Responsible Party(ies)	Approximate Cost
Task #1: Literature Review *Time Frame:* 3 months *Deliverable:* Quarterly progress report documenting findings of the literature and associated investigations *TAC Decision/Action:* Review and comment on progress report as appropriate	Smaglik & Sharma	*$14,000*
Task #2: Sampling and Data Collection Plan *Time Frame:* 2 months *Deliverable:* List of preferred intersections along with acceptable alternates for data collection, as well as proposed methods of data acquisition *TAC Decision/Action:* Approval of Intersection Selection	Smaglik, Sharma, and Kothuri	*$15,250*
Task #3: Data Acquisition Equipment Development, Assembly, Testing and Scheduling *Time Frame:* 2 months *Deliverables:* (1) Quarterly progress report 28 February 2015; (2) Upon completion of the task, a technical memo will be sent to the TAC describing any outstanding issues going forward, as well as a detailing a schedule for data collection at designated locations *TAC Decision/Action:* Approval of Intersection Selection; Review and comment on progress reports as appropriate	Smaglik, Sharma, and Kothuri	*$22,500*
Task #4: Data Acquisition *Time Frame:* 6 months *Deliverables:* (1-2) Quarterly project progress reports 31 May 2015 and 31 August 2015; (3) TRB paper submittal 31 July 2015 *TAC Decision/Action:* Review and comment on progress reports as appropriate	Kothuri & Smaglik	*$40,000*
Task #5: Data Reduction and Analysis *Time Frame:* 4 months *Deliverables:* (1) Spreadsheet / database with complete data and cost analysis; (2) Quarterly progress report 30 November 2015 including summary of recommendations *TAC Decision/Action:* Review and comment on deliverables as appropriate	Smaglik & Sharma	*$43,250*
Task #6: ODOT Manual Updates *Time Frame:* 3 months *Deliverable:* Updated text for associated ODOT manuals *TAC Decision/Action:* Review and comment on submitted text	Smaglik	*$11,500*

Task #7: Final Report *Time Frame:* 5 months *Deliverable:* Draft Final Report and Final Report *TAC Decision/Action:* Review and comment on draft report; Approve final report.	Smaglik	*$13,500*

5.1 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigator shall be responsible for submitting reports of professional-level written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT in electronic format the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

5.2 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

6.0 Time Schedule

The proposed timeline for the project is shown below. Deliverables are listed per the attached legend.

Task	2014						2015												2016					
	FY15												FY16											
	Jul - Sep			Oct - Dec			Jan - Mar			Apr - Jun			Jul - Sep			Oct - Dec			Jan - Mar			Apr - Jun		
1:Literature Review					Q																			
2:Sampling Plan							D																	
3:Equip. Develop.								Q	D															
4:Data Acquisition											Q		T	Q										
5:Data Reduction																	Q							
6:Manual Updates																				Q				
7: Report																				R			F	

*Deliverables
Q – Quarterly Progress Report
T – TRB Paper Submittal
D – Other Deliverable
R - Draft report submitted for ODOT review.
F - Revised report submitted to ODOT for publication. End of contract.

7.0 Budget Estimate

An itemized budget for the project is included here showing expenditures for each task by fiscal year and in total, as well as broken out by expense category.

Task	FY15	FY16	Total
1:Literature Review	$14,000		$14,000
2:Sampling Plan	$15,250		$15,250
3:Equipment Development	$22,500		$22,500
4:Data Acquisition	$20,000	$20,000	$40,000
5:Data Reduction		$43,250	$43,250
6:Manual Updates		$11,500	$11,500
7:Report		$13,500	$13,500
Total for tasks (Contract amount)			**$160,000**
ODOT support/management			
Total for ODOT			

NAU Budget		
Personnel		**Total**
Edward Smaglik, NAU	$	34,465
Graduate Students	$	25,618
Undergraduate Students	$	3,420
Total Salaries	**$**	**63,503**
Fringe Benefits		
Faculty	$	5,308
Graduate Student (GRA)	$	3,192
Undergraduate Students	$	17
Total Fringe Benefits	**$**	**8,517**
Total Personnel Costs	**$**	**72,020**
Travel	$	7,740
Iowa State Subcontract, Sharma	$	10,000
Portland Stats Subcontract, Kothuri / Monsere	$	20,427
Services and Supplies	$	9,517
Student Tuition Waiver (Indirect exempt)	$	9,209
Total Direct Costs for NAU	**$**	**128,957**
Indirect Costs for NAU Activity (26% - Off Campus Rate)	**$**	**31,043**
Total NAU Project Costs	**$**	**160,000**

[i] Bonneson, J. and Abbas, M.," Video Detection for Intersection and Interchange Control", FHWA/TX-03/4285-1, 2002.

[ii] Medina, J.C., Benekohal, R.F., and Chitturi, M. "Evaluation of Video Detection Systems Volume 1: Effects of Configuration Changes in the Performance of Video Detecton Systems", Research Report ICT-08-024, 2008.

[iii] Volling, M. T. and Parker, R. "Count Accuracy of Wireless Magnetometer Sensors Compared to High Accuracy Inductive Loop Counting System." Presented at the 19th ITS World Congress, Vienna, Austria, 2012.