National Institute for Advanced Transportation Technology

NIATT

ANNUAL REPORT

PREPARED FOR UNIVERSITY TRANSPORTATION CENTERS PROGRAM
RESEARCH AND INNOVATIVE TECHNOLOGY ADMINISTRATION
U.S. DEPARTMENT OF TRANSPORTATION

University of Idaho

FUNDING PERIOD JULY 1, 2015 THROUGH JUNE 30, 2016—FY16

THEME: Advanced Technology for Sustainable Transportation

MISSION

Develop engineering solutions (knowledge and technology) to transportation problems for the state of Idaho, the Pacific Northwest, and the United States, and to prepare our students to be leaders in the design, deployment, and operation of our nation's complex transportation systems.

VISION

Our vision is to be one of the premier transportation research and education programs in the United States.

- We are a national leader in developing technology to reduce congestion on arterials, improve the quality and economic viability of biofuels, and reduce the environmental impacts and improve the fuel economy of motorized vehicles (including passenger cars, transit vehicles, and recreational vehicles).
- NIATT faculty and students engage in multidisciplinary research to solve challenging, practical, and relevant transportation problems that have regional and national significance. We create interdisciplinary research and development teams of undergraduate and graduate students, mentored by expert faculty. To ensure our work is relevant and responsive to stakeholder needs, we seek collaborative partnerships with organizations such as the Federal Highway Administration, the Federal Transit Administration, the Idaho Transportation Department, and others committed to our values to work on problems of mutual interest. This practice engages our students in meaningful, experiential, learning-centered environments that add value to their education.
- By taking this approach, we integrate our research with the educational mission of the University. At the same time, our research results in technology that satisfies the needs of our customers, both by informing their actions and decisions and by providing them with useful products. We also provide life-long learning opportunities for transportation professionals in Idaho and the Northwest at all levels of practice.
- NIATT's work is carried out in the context of a commitment to preserving and protecting natural and pristine environments. Our research on, and development of, clean vehicles, alternative fuels, and efficient traffic control systems contributes to the sustainability of these environments.

On the cover: Cade Smith of the University of Idaho Clean Snowmobile Team

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To access an electronic copy of this report and to read more about the research, education, and outreach activities in which our students and faculty, we invite you to visit **http://NIATT.org**

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Credits: Jeff Jones, Enas Amin, Chuck Jaworski, Julene Ewert

From the Director

As the National Institute for Advanced Transportation Technologies (NIATT) celebrates our twenty-fifth year as a member of the University Transportation Centers program, we are proud to report on the center's accomplishments and ongoing work. It is a great pleasure for me, in my third year as NIATT director, to work with the faculty, staff, and students who are dedicated to our center's mission.

The challenges we face are great. Our country has outgrown its transportation infrastructure, and in the coming years choices must be made in a number of areas. NIATT's research focus positions us to be a leader in the work on transportation solutions as we explore what is possible, practicable, and in the public service by pursuing projects in line with our theme of "advanced technology for sustainable transportation."

In particular, NIATT researchers work in the areas of traffic controls, clean vehicles and alternative fuels, transportation safety and policy, and the intersections of these areas. It is our synergistic network of researchers, funding, and private and public partners and stakeholders that empowers us to build what is new and necessary for our country's transportation system.

And while we remain focused on tomorrow's challenges, it's encouraging to reflect on some of our significant accomplishments. A few of these include:

- In collaboration with the Federal Highway Administration (FHWA), in a multidisciplinary research effort that involved research teams from civil, mechanical, electrical, and computer engineering disciplines, NIATT developed a traffic simulation system that is now used in 19 states and allows engineers to integrate traffic control hardware into a simulation environment.
- NIATT developed a new technology for traffic control systems using state-of-the-art network-based distributed processing, incorporating new sensors in a plug-and-play system that supports the FHWA's connected-vehicle initiative. A real-time weather responsive system that uses the FHWA Clarus weather data system is one result.
- Partnering with FHWA, Idaho Transportation Department (ITD), private controller manufacturers (Econolite), and several other universities, NIATT developed a software-in-the-loop simulation (SILS) environment. The system supports the USDOT's advanced research, education, and workforce development programs as it provides the tools needed to assess real-time transportation system performance.
- NIATT has several patents in the areas of accessible pedestrian signaling and efficient vehicle drive trains.
- The NIATT Clean Vehicle Technology group has become a national leader in alternative/renewable fuels production and use, and clean vehicle research.

NIATT's work is nationally and internationally recognized, and while we keep our research relevant and deliverable, we remain committed to preserving and protecting the natural and pristine environments of Idaho and the Pacific Northwest. To that end, we communicate our findings through events and publications, and we provide lifelong learning opportunities for transportation professionals in Idaho and the Northwest at all levels of practice.

This annual report highlights research projects from FY16 from each of our research centers: the Center for Transportation Infrastructure, the Center for Traffic Operations and Control, and the Center for Clean Vehicle Technology. We also highlight our educational activities with a special emphasis on our exceptional students and their involvement. For, while we offer career-building opportunities for our students, it is their contributions that make our work possible and worthwhile.

As NIATT's work continues, we look forward to many more years producing sustainable mobility research and educating tomorrow's transportation professionals. We invite you to read on about our activities and plans for the future.

Sincerely,

Ahmed Abdel-Rahim

> "Transportation is a foundation for long-term economic recovery. Without a strong, flexible, and vibrant system, people cannot get to their jobs, goods cannot be delivered, and businesses cannot compete globally. Sustainability of the total transportation system is coming increasingly into focus."

> "NIATT's work is carried out in the context of a commitment to preserving and protecting natural and pristine environments. Our research on, and development of, clean vehicles, alternative fuels, and efficient traffic control systems contributes to the sustainability of these environments."

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Annual Advisory Board Meeting

NIATT's annual Advisory Board meeting was held over two days in April 2016, allowing the board members to attend the 23rd annual University of Idaho Engineering Exposition on April 29, 2016.

Date	**2016 ADVISORY BOARD AGENDA**
Wednesday, April 27	NIATT Welcome Reception and Dinner Student Presentations
Thursday, April 28	Continental Breakfast
	Moving NIATT Forward - Seizing Opportunities NIATT Metrics: Students and Submitted Funding
	Research Updates Mike Dixon Memorial Update Seizing Opportunities: Infrastructure
	Lunch
	FAST ACT Research Priorities Discussion
	Closing Session: Focus on Next Year
Friday, April 29	Engineering Expo

On Wednesday, April 27, 2016, NIATT held a dinner for more than forty guests in the Palouse Room at the Best Western University Inn to welcome board members and other participants. Ahmad Hammad, Marvin Ramirez, Nick Schlotthauer, Riannon Zender, and Kushal Patel made presentations on their experiences working in NIATT and their current project work.

On Thursday, the advisory board meeting opened with a discussion of NIATT's progress. That was followed by presentations from NIATT researchers seeking funding for the 2016-2017 academic year. The board members discussed the projects and made recommendations for funding for the next fiscal year.

Members of the advisory board and NIATT principal investigators discuss a presentation. From left to right: Ned Parrish, Michael Lowry, Emad Kassem, Jim Larsen, Gary Duncan, Tom LaPointe, and James Colyar.

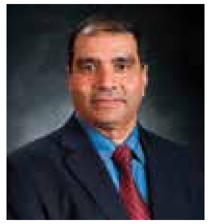
Management Structure

The National Institute for Advanced Transportation Technology (NIATT) has been a proud member of the University Transportation Centers (UTC) Program since 1991, when it was established under the Intermodal Surface Transportation Efficiency Act. NIATT serves as a center of excellence for transportation research, education, and technology transfer in the state of Idaho, the Pacific Northwest, the Intermountain regions, and the United States. NIATT is located on the University of Idaho campus, having received institute status in 1998 in recognition of its university-wide, multi-disciplinary activities.

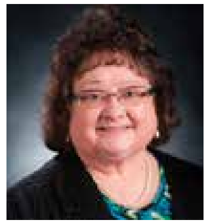
National Institute for Advanced Transportation Technology

- Center for Traffic Operations and Control
- Center for Clean Vehicle Technology
- Center for Transportation Infrastructure

Although the UTC Program primarily supports the work of NIATT's Center for Traffic Operations and Control and the Center for Clean Vehicle Technology, the UTC funding has a positive impact on the entire institute and our ability to deliver transportation technology. In addition, UTC funds are supplemented from a variety of sources, including the Idaho Transportation Department (ITD), the Idaho Department of Water Resources, the U.S. Departments of Energy and Defense, and the Federal Highway Administration, among others. Research in the Center for Transportation Infrastructure is supported mainly by the cooperative agreement between NIATT and ITD.


Ahmed Abdel-Rahim
Director, NIATT
Professor, Civil Engineering


Chuck Jaworski
Assistant to the Director, NIATT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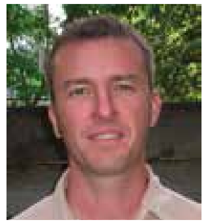
J. R. Brabb
IT Analyst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Engineering

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Associate Professor, Mechanical Engineering

UTC Research

As do all University Transportation Centers, NIATT uses its strategic plan to set the framework for research selection and implementation. NIATT's most recent strategic plan, approved in 2007 by the USDOT, describes four objectives, two of which are directly related to research:

> **Objective 1:** Develop arterial traffic management tools that can be used by practitioners and researchers to manage congestion and improve safety.
>
> **Objective 2:** Improve the quality and economic viability of biofuels, and reduce the environmental impacts and improve the fuel economy and safety of motorized vehicles (including passenger cars, transit vehicles, and recreational vehicles) to protect the natural and built environment.

Objective 1 directs the research activities of NIATT's Center for Traffic Operations and Control (CTOC), while Objective 2 guides the research for NIATT's Center for Clean Vehicle Technology (CCVT).

The strategic plan outlines several strategies under each objective, defining the way we plan to meet those objectives.

The research conducted at NIATT relies on the knowledge and strengths of our researchers. Each project involves both graduate and undergraduate students, who have the opportunity to conduct basic and/or applied research, the products of which are judged by experts, contributing to the body of knowledge in transportation while earning their degrees.

STUDENT HIGHLIGHTS ON PROJECTS

Center for Transportation Infrastructure

Project: Guidance to Assist Local Highway Jurisdictions in Evaluating Route Requests for Trucks Up to 129,000-Pounds (KLK578)

Principal I vestigator: Ahmed Ibrahim

Co-Principal Investigators: Richard Nielsen, Ahmed Abdel-Rahim, Nicholas Saras, and Meagan Larrea

ITD Project Manager: Jeff Marker

FHWA Project Advisor: Lori Porreca

Idaho Transportation Department Funding: $49,285

This guide has been prepared by NIATT for use by local highway jurisdictions when evaluating 129,000-pound route requests in compliance with Idaho Code 491004A (1), which states "the authority having jurisdiction may designate routes for vehicles not exceeding 129,000-pounds, utilizing criteria established by the board based upon road and bridge structural integrity and engineering standards." Each section of this guide covers one of four categories used to evaluate route requests. Before a route request is approved, the conditions in all four categories must be met and satisfied.

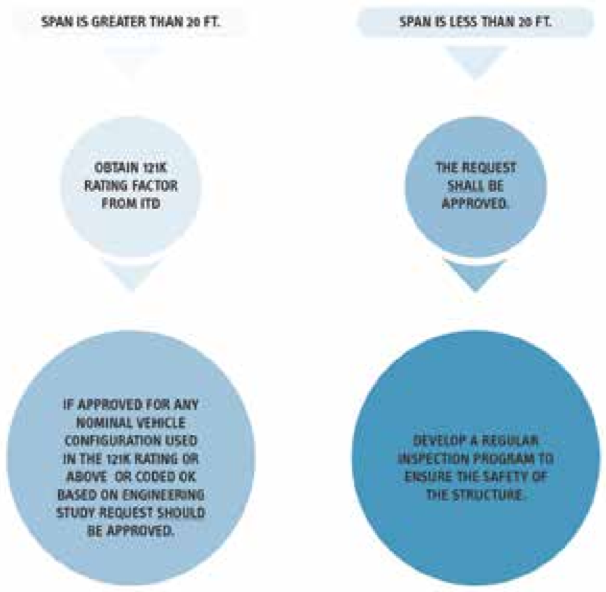


Figure 7: Steps to assess bridges and culverts for 129,000-pound truck request.

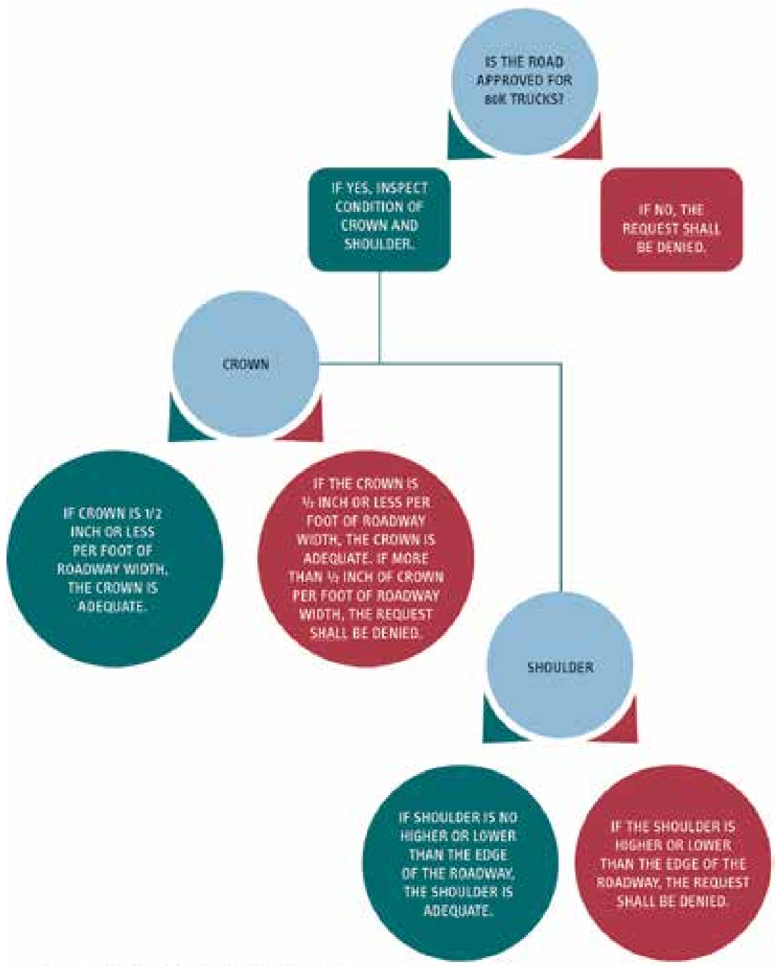


Figure 12: Steps to assess gravel roads.

Section 1: Offtracking provides guidelines to assess offtracking limitations for the route based on the roadway's geometric characteristics;

Section 2: Bridges and Culverts provides guidelines for examining the structural health of bridges and culverts along the route;

Section 3: Pavement and Gravel Roads provides guidelines for examining the condition of pavement and gravel roads on the route;

Section 4: Crash Data and Safety Evaluation provides procedures and guidelines for conducting a safety evaluation for the proposed route based on crash history.

This guide is limited to providing assistance in the above four engineering-based categories only. Local highway jurisdictions may need to consider other factors beyond the scope of this guide such as the following:

- Spring breakup concerns
- Existing and needed chain-up areas
- Compatibility of the runaway truck escape ramps (if any)
- Current and future roadway improvement projects (if any)
- Shoulder width including condition of shoulder of paved and gravel roads
- Conflicts with pedestrians
- Adjacent land use such as schools, parks, community centers, retirement communities, and other residential areas
- Current and future development projects
- Possible impact of truck traffic on businesses, particularly travel through a downtown area

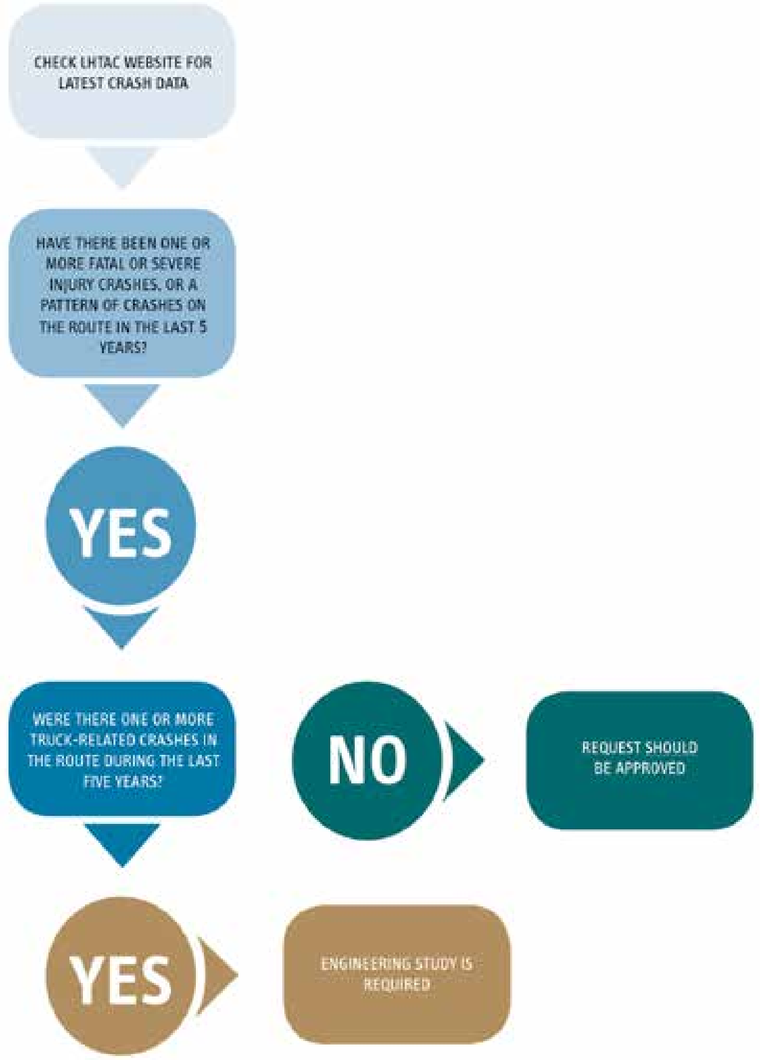


Figure 13: Steps to conduct crash data safety evaluation.

Project: Evaluation of Fiber-Reinforced Asphalt Pavements — Phase 1: Laboratory Study (KLK568)

Student Involvement: **Ahmed Muftah** (graduate student, civil engineering)

Principal Investigator: **Fouad Bayomy**

ITD Project Manager: **Dan Harelson**

FHWA Project Advisors: **Kyle Holman**

Idaho Transportation Department Funding: $119,932

One of the most popular methods to increase concrete strength and reduce cracks is fiber reinforcement, a technique widely investigated for Portland Cement Concrete (PCC) since the 1950s. Even though hot mix asphalt (HMA) accounts for approximately 94% of the paved roadways in United States, previous research conducted using fibers in dense-graded asphalt mixes was limited and did not bring a clear conclusion about the benefits of fibers in HMA.

ITD had a project to improve and rehabilitate a 3.22-mile section of US-30 at Montpelier in south Idaho. This road section is a truck route that experienced severe cracking and rutting. To minimize rutting and cracking, the project team suggested using fibers to improve the HMA surface layer. ITD decided to use three fiber vendors and divided the construction project into four sections of equal length: one section to be built with conventional unmodified Hot-Mix Asphalt (HMA), and the other three sections with fiber-modified mixes. The three types of fibers used included a polypropylene and aramid fiber blend from Forta Fi Corporation; aramid fibers wax treated by a proprietary process, referred to as ACE fibers, from Surface-Tech, Inc.; and glass fibers from Nycon Corporation. The mix design of the HMA for the project, developed and conducted at the National Center for Asphalt Technology at Auburn University, included 47% RAP from the existing roadway.

The study's main goal was to evaluate the performance of fiber-modified mixes using standard lab tests. A second goal was to develop the mixes' material properties using AASHTOWare Pavement ME Design software to predict and compare their expected field performance.

PhD student Ahmed Muftah checks the mix temperature during construction of the fiber project on US-30

Plant mix samples were collected midway through each section's production to ensure no overlap of fiber mixes during the transition from one section to another. In addition to the loose plant mix samples, field cores extracted and delivered to the lab were used to evaluate and verify the mix's volumetrics using Gyratory samples. Also, X-ray tomography evaluated the degree of dispersion and uniformity of fiber distribution.

All results of the lab tests, along with the particulars of structure design, traffic, and climatic data, were run on the AASHTOWare software for the four pavement sections, allowing for a field-performance comparison.

Key Findings

- Results verified the job mix formula for all mixes and confirmed that the fibers did not alter mix design. Also, volumetric analysis of field cores verified the field compaction.
- Rutting resistance as measured by Flow Number, Asphalt Pavement Analyzer (APA), and Hamburg Wheel Tracking (HWT) tests of the fiber mixes were comparable to the control mix. Fiber-modified mixes did not show significant improvement over the control mix. ANOVA statistical analysis was used on HWT and Flow Number tests, and it confirmed that there is no significant difference in the rutting performance.
- For the fatigue cracking (bottom-up and top-down cracking), the fibers did not add significant tensile strength. This result coincided with other reported studies.
- Similar to the fatigue evaluation, the fracture work density of the fiber mixes measured at low temperature did not show significant improvement of the fiber mixes to resist low-temperature cracking.
- Performance prediction using the AASHTOWare Pavement ME Design software confirmed the above conclusions. This is intuitively expected since the only variables that are changed for the software runs were the material properties. All other design inputs, including pavement structure, traffic, and climate, were kept the same for all runs.

Process of injecting fibers into the mix in the asphalt plant.

Project: Performance Evaluation of Asphalt Pavement Mixes in Idaho that Contain High Percentages of Recycled Asphalt Pavement (KLK563)

Student Involvement: **Ahmed Muftah** (graduate student, civil engineering)

Principal Investigator: **Fouad Bayomy**

Co-Principal Investigators:

Idaho Transportation Department Funding: $76,066

The use of recycled asphalt pavement (RAP) in hot mix asphalt (HMA) or warm mix asphalt (WMA) is potentially beneficial to both the environment and the economy. Virgin aggregate and asphalt binders can be conserved to reduce construction costs, energy consumption, and greenhouse gas emissions. Currently, ITD regulates the amount of RAP that a contractor may use, depending on the source of RAP, its fractionation, and the "lift" of the pavement at which RAP is used.

This study is to verify ITD guidelines for using RAP in HMA. It evaluates the effects of various percentages of RAP on mix designs, laboratory performance, and predicted field pavement performance in terms of resistance to rutting, fatigue cracking, and thermal cracking. The project also makes recommendations that ITD could consider for updating its current RAP specifications to improve asphalt pavement performance.

Key Findings

- Resistance to rutting due to lateral shear failure increased as RAP percentage increased. Lab tests also indicated that the current practice of binder grade adjustment cannot account for the stiffening effect of RAP, and indicated that the blending of RAP binder and virgin binder may not be thorough or complete. The aggregate structural stability of RAP mixtures was comparable to or slightly better than that of the control mix. Overall, RAP mixes performed the same as or better than the control mix in terms of rutting resistance.
- The fatigue cracking resistance of mixtures with a low percentage (i.e., 17%) of RAP was comparable to that of the virgin mix. However, the effects of high percentage of RAP (more than 17%) on fatigue cracking depended on the target PG of virgin binder.
- The addition of RAP (either a low or high percentage) could adversely affect the thermal cracking resistance of RAP mixtures.
- When the virgin binder grade was too low to be available in the market or too costly, the use of a higher grade did not seem to compromise the material's performance.
- The AASHTOWare Pavement ME Design predictions for the performance of pavements that contained different RAP percentages followed the trend of the laboratory properties, because the performance models within the AASHTOWare Pavement ME Design software also utilize these properties.

Alternatively, if it is difficult to include a cracking performance test in a mix design, the empirical model to determine the low temperature grade of virgin binder for RAP mix is recommended to use instead of the grade bumping and blending chart. The developed procedures for virgin binder selection are as follows:

1. Design a control mix without RAP to meet ITD specification with a binder of target PG.
2. Estimate fracture work density of control mix at low temperature (FWDlow_control) based on the equation shown in Figure 1:

$$FWD_{low\_control}=9.437+0.179P_{RAP}-5.209AV+6.690VMA_{control}+1.475PG_{target\_low}-0.513PG_{target\_high}$$

where:

$FWD_{low\_control}$ = Fracture work density of control mix at low temperature, psi.
P_{RAP} = Percentage of RAP, percent; 0 percent in this case.
AV = Design air void, 4 percent in most cases.
$VMA_{control}$ = Void in mineral aggregate of control mix, percent.
PG_{target_low} = Low temperature grade of target binder.
PG_{target_high} = High temperature grade of target binder.

Figure 1. Prediction of Fracture Work Density of Control Mix at Low Temperature

3. Design RAP mix to meet ITD specification with a binder of PG_{virgin_high} and any low temperature PG, because the low temperature PG of binder does not significantly affect the volumetrics of a mix. Keep the high temperature PG of the target binder for the RAP mix. The benefit of using high temperature PG of the target binder for the RAP mix is to avoid change of use of the polymer modified binder, if any, to an unmodified binder if a softer virgin binder was selected and the rutting performance is ensured.
4. Determine the low temperature PG of virgin binder for RAP mix using the equation in Figure 2, based on RAP mix's design air void, VMA, P_{RAP}, $FWD_{low\_control}$, and PG_{virgin_high}

$$PG_{virgin\_low}=(FWD_{low\_control}-9.437-0.179P_{RAP}+5.209AV-6.690VMA_{RAP}+0.513PG_{virgin\_high})/1.475$$

where:

$FWD_{low\_control}$ = Fracture work density of control mix at low temperature from Step 2, psi.
P_{RAP} = Percentage of RAP, percent.
AV = Design air void, 4 percent in most cases.
VMA_{RAP} = Void in mineral aggregate of RAP mix, percent.
PG_{virgin_low} = Low temperature grade of virgin binder.
PG_{virgin_high} = High temperature grade of virgin binder.

Figure 2. Virgin Binder Selection of Low Performance Grade for RAP Mixes

Project: Calibration of the AASHTOWare Pavement ME Design Performance Models for Flexible Pavements in Idaho (KLK572)

Principal Investigator: Fouad Bayomy

Co-Principal Investigators: Emad Kassem

Post-Doc Research Fellow: Ahmed Muftah

ITD Project Manager: Mike Santi

FHWA Project Advisor: Kyle Holman

Idaho Transportation Department Funding: $338,037

The Mechanistic-Empirical Pavement Design Guide (MEPDG) is a comprehensive tool for the analysis and design of new and rehabilitated flexible and rigid pavement structures based on mechanistic-empirical principles. In 2009, ITD collaborated with NIATT to launch the first implementation project as ITD Research Project No. RP193 (KLK557). As a follow-up, ITD contracted with ARA to develop an implementation plan for the new design guide.

The MEPDG research version software has been modified and is now known as the AASHTOWare Pavement ME Design or "ME software." It predicts pavement performance based on field data from long-term pavement performance (LTPP) sections all over North America. The main objective of this project is to develop local calibration factors for the ME software models for flexible pavement design in Idaho, which will allow for the system's successful implementation in the state.

With the final report scheduled for delivery in December, 2017, the NIATT research team is executing the project through a series of tasks, including reviewing the ME software models and and evaluating the design inputs required. In coordination with ITD, the team is selecting pavement sections representative of the different Idaho districts. These sections cover a range of environmental conditions, traffic levels, and subgrade strengths.

AASHTOWare® Pavement ME (Mechanistic-Empirical) Design

Version 2.3.1 (Revision 56)

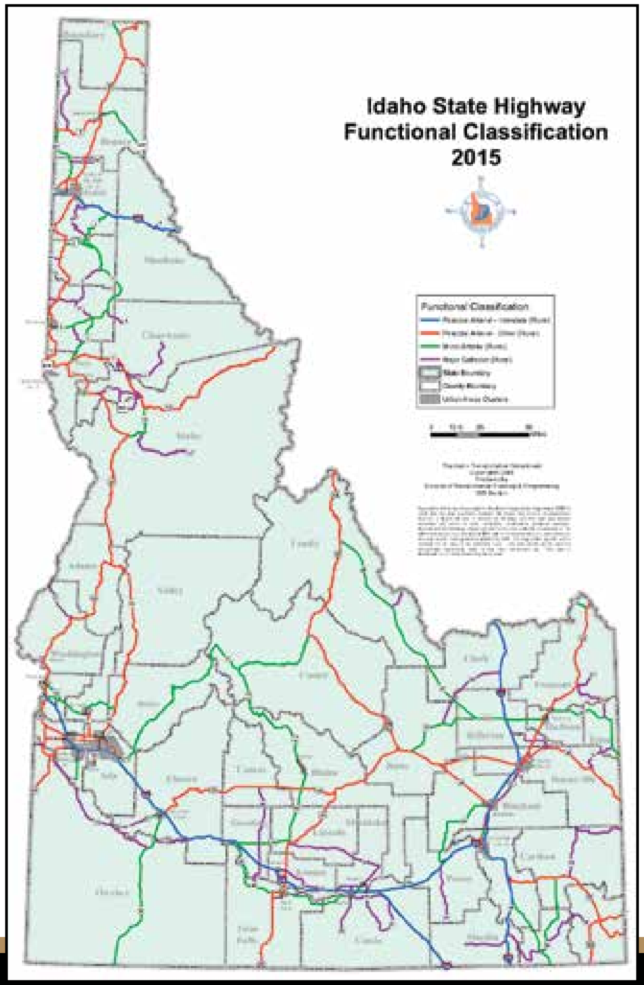
☐ Reset ME Design to default screen position

ME Design software to design flexible pavements in Idaho

Creep compliance and indirect tensile (IDT) strength testing results will be added to the existing ITD material database, and a new performance database will be developed using the LTPP database and the Idaho Pavement Performance Management Information System (PPMIS). The software will be run with different trial sets of calibration coefficients for each of the four distress models to find the best combination of calibration factors. The set that produces a higher precision and lower bias for each distress model compared to the nationally calibrated models will be selected, and the resulting calibrated models will be statistically validated.

A summary of findings and draft calibration factors will be submitted to ITD for review before completing the final report and developing a training workshop. This way, ITD review comments and recommendations will be incorporated into both the final report and the training workshop. These will be presented at a suitable location where access to the software is available.

The project deliverables will help ITD engineers implement the new AASHTO design procedure in the state, and they will be able to use the results directly to run the ME software.



State routes used for software calibration on the Idaho Road Network

Video log used for pavement performance data

Center for Traffic Operations and Control

Project: Evaluation of Vehicle Detection Systems for Traffic Signal Operations (KLK569)

Principal Investigators: Riannon L. Zender, Kevin Chang, Ahmed Abdel-Rahim

ITD Project Manager: Bruce Christensen

FHWA Project Advisor: Lance Johnson

Idaho Transportation Department Funding: $149,867

There are many vehicle detection systems used for intersection traffic signal operations that utilize inductive loop detectors (ILD). ILDs require installation into the roadway surface. Saw-cutting of pavement, lane closures, and maintenance staff working in or adjacent to traffic are common attributes. Multiple loops are usually required to equip one location, and routine resurfacing of the roadway may require reinstallation of these sensors. The ILDs are also subject to stress from traffic and weather.

Many new detection technologies have been introduced over time as an alternative to ILDs. Some of these sensor types include video image processors, microwave radar, video radar hybrids, and thermal sensors. These detection systems do not require installation on or into the roadway surface, and instead are mounted overhead on mast arms, signal poles, or on the side of a roadway and are considered non-intrusive technologies (NIT).

The safety of a signalized intersection is tied closely to the accuracy of its detection system. There are two types of possible detection errors that may occur with any detection system: missed detections and false detections. During a missed detection, a sensor fails to detect the presence of an actual vehicle, which can lead to a skipped phase. A false detection occurs when the sensor erroneously acknowledges the presence of a vehicle when one is not physically present. Missed and false detections create inefficiencies, and detection systems that minimize both types of errors are ideal and desired.

This project, initiated by ITD, presents the findings from the systematic evaluation of nine commercially available NIT traffic detection systems beginning in February 2015. The systems include four video-based detectors, two microwave radar detectors, one thermal image sensor, and two video-microwave radar hybrid detectors. These systems were installed at the stop bar zone of a signalized intersection under six unique conditions: (a) daytime, (b) nighttime, (c) favorable conditions, (d) windy conditions, (e) rainy conditions, and (f) snowy conditions. In addition, two detection zones were established: one for the through and right-turn movements (Zone 1) and one for the left-turn lane (Zone 2).

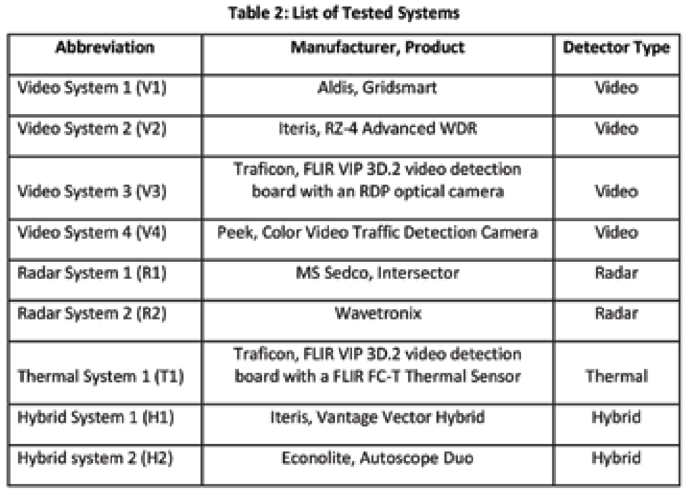
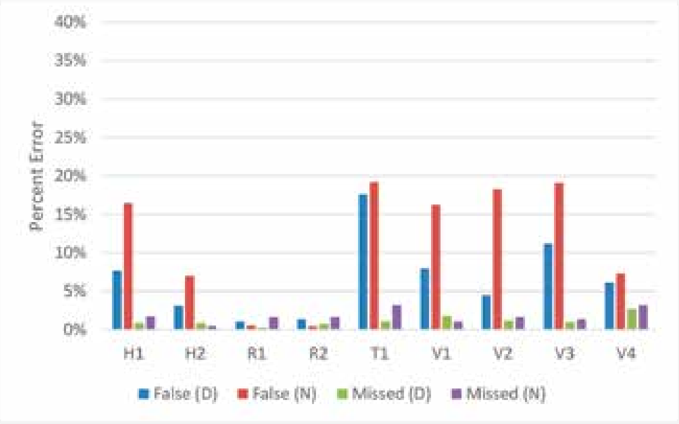
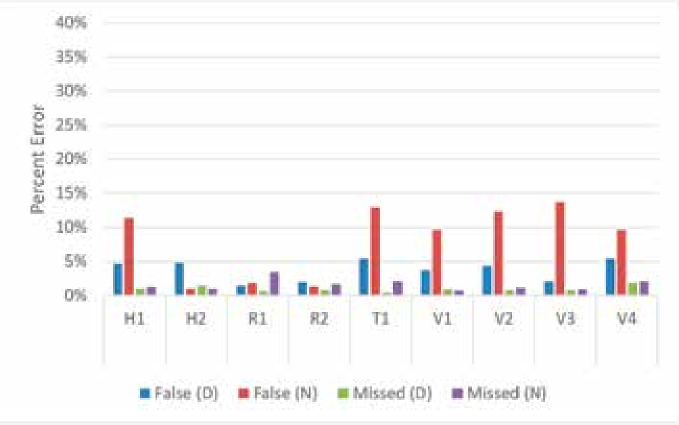


Table 2: List of Tested Systems

Abbreviation	Manufacturer, Product	Detector Type
Video System 1 (V1)	Aldis, Gridsmart	Video
Video System 2 (V2)	Iteris, RZ-4 Advanced WDR	Video
Video System 3 (V3)	Traficon, FLIR VIP 3D.2 video detection board with an RDP optical camera	Video
Video System 4 (V4)	Peek, Color Video Traffic Detection Camera	Video
Radar System 1 (R1)	MS Sedco, Intersector	Radar
Radar System 2 (R2)	Wavetronix	Radar
Thermal System 1 (T1)	Traficon, FLIR VIP 3D.2 video detection board with a FLIR FC-T Thermal Sensor	Thermal
Hybrid System 1 (H1)	Iteris, Vantage Vector Hybrid	Hybrid
Hybrid system 2 (H2)	Econolite, Autoscope Duo	Hybrid





Results indicate that false detections for almost every system increased at night. In terms of system type, false detections for both radar systems did not exceed 1.9 percent. Radar systems were the only system type that exhibited a low level of false detection during both day and night.

The false detection results for Zone 2 were generally higher than Zone 1 for both day and night. Error results ranged from a low of 0.5 percent (radar, nighttime) to 19.2 percent (thermal, nighttime). The increase in error percentages was partially attributed to left-turning vehicles from the side street cutting across the left-turn lane of the subject approach when it was unoccupied. Missed detections in both zones were comparably lower than false detections during day and night.

The results indicated that inclement weather does negatively affect these system types to varying degrees, particularly with regard to false detections. In Zone 1, the percentage of false detections during wind, rain, or snow was almost universally higher than during favorable conditions. In Zone 2, false detections during wind, rain, or snow was higher than during favorable conditions for every comparison, with the percentage difference exceeding 30 percent in one case.

It can be concluded that there is no single system that universally performs better than all other systems; depending on the time of day or weather condition, many of the system types tested could claim that their technology outperforms all others. However, based on the percentage of false and missed detections for all of the products representing the different system types, there are opportunities for further improvement and enhancement. The acceptable tolerance level ultimately must be decided upon by the agency operating a particular signal, and it is recommended that specific performance standards be defined when soliciting signal detection equipment.

Project: Evaluation of IdaShield Sign Safety Benefits at Highway-Rail Crossings in Idaho (KLK567)

Principal Investigators: Michael P. Dixon and Brian Dyre

Co-Principal Investigators: J. D. Wulfhorst, Ahmed Abdel-Rahim, Alex Grover, Mark Meyer, Monica A. Reyna, and Barbara E. Foltz

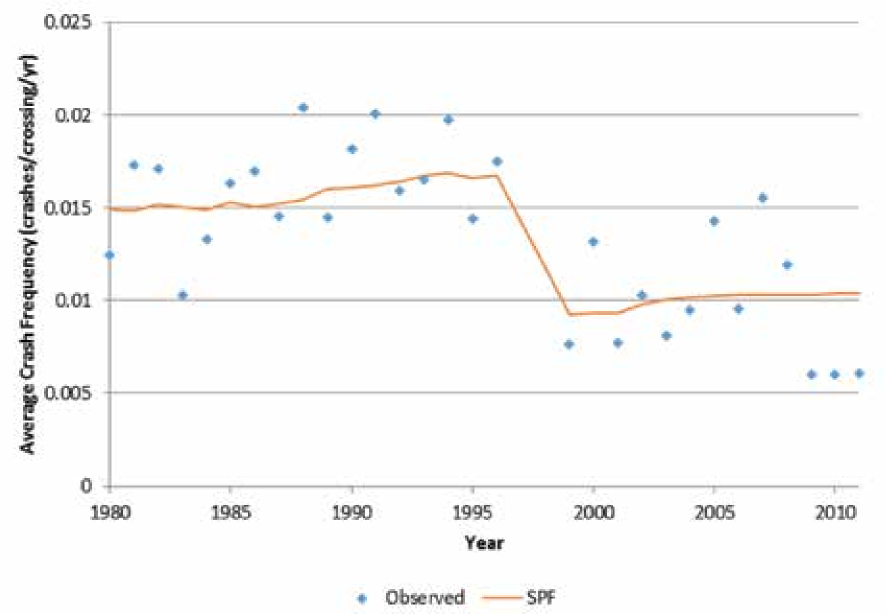
ITD Project Manager: Sajonara Tipuric

FHWA Project Advisor: Lance Johnson

Idaho Transportation Department Funding: $51,579

This report assessed the effectiveness of an object marker called the "IdaShield" used in Idaho at passive (non-signalized) railroad crossings to improve crossing visibility and traffic control compliance. The IdaShield is a highly reflective sign consisting of a crossbuck and, mounted below it on the same post, a "shield" of red-and-white, both of which display diamond grade reflective strips. The edges of the shield are bent backward at a 45⁰ angle to reflect train headlights onto the roadway. In the late 1990s, 1,341 of these signs were installed in Idaho. Our study assessed the shield's effectiveness using three measures:

1. Statistical analysis of historical crash data preceding and following the installation of the IdaShield marker.
2. Assessment survey measuring user understanding of the IdaShield and changes in user response due to the IdaShield.
3. Simulated driving test environment that exposed participants to various controlled circumstances related to highway railroad crossings.



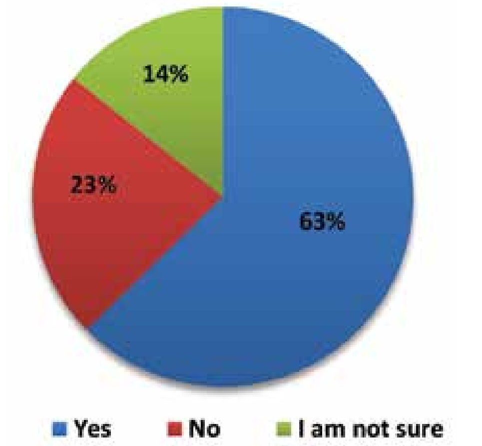
Comparison on observed and predicted (SPF) crash frequencies before-and-After IdaShield installation

The findings from our research show that the IdaShield does positively impact safety. Average crash frequency significantly reduced after IdaShield installation. Users understood the IdaShield's purpose and most felt it improved the visibility of crossing markings. In addition, the driver simulation test indicated some positive changes in driver behavior at crossings when IdaShields are present. The crash data analysis provided the strongest evidence of the IdaShield's effect, while the user survey and driver simulation data provided more detailed understanding of this evidence by pointing to IdaShield benefits for YIELD sign traffic control.

Based on our findings, we recommend the following:

- Because the IdaShield produces positive overall outcomes on driver safety and does not have any apparent negative effects, the signage should continue to be required at crossings controlled through a YIELD sign at passive at-grade railway crossings in Idaho.
- When combined with a STOP sign, the safety effect of IdaShield does not seem to be significant. As a result, we recommend that IdaShield signs not be required at passive at-grade railway crossings when a STOP sign is present.
- It is recommended that ITD work with the national committees to amend the national standard for signage at public passive Railroad/Highway Grade Crossings in the MUTCD and to include the IdaShield as an approved object marker.

Idashield



Percentage of drivers indicating increased visibility

Project: Improving Safety at Signalized Intersections during Inclement Weather Conditions - A Real-Time Weather-Responsive System (KLK561)

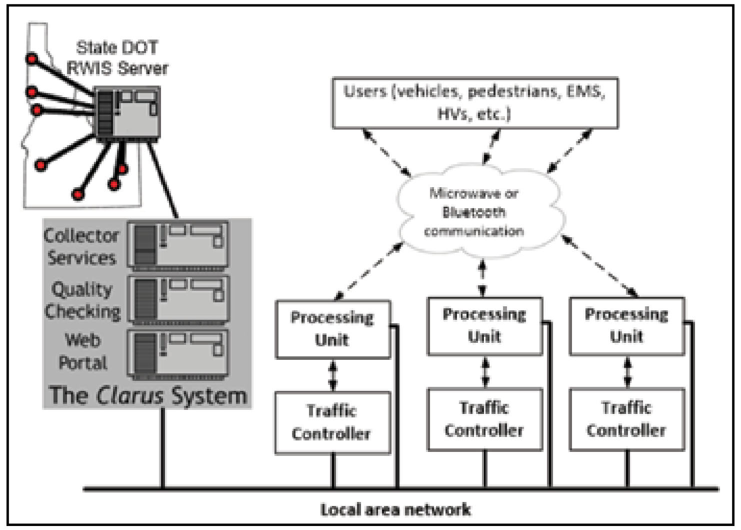
Principal Investigators: Ahmed Abdel-Rahim, Axel Krings, and Ahmed Serageldin

ITD Project Manager: Brent Jennings

FHWA Project Advisor: Lance Johnson

Idaho Transportation Department Funding: $90,659

This report presents a prototype of a secure and reliable real-time weather-responsive system with the intent of improving the safety and efficiency of traffic signal system operations during inclement weather conditions. The prototype's two tasks include accessing real-time weather information and adapting signal timing in response to inclement weather.



Communication Architecture for the System

Development of the prototype and the control software followed a standard systems engineering process that included six steps:

1. Review of Resources.
2. Define System Specification.
3. System Design.
4. Data Interface and Analysis.
5. Developing the Testing Environment.
6. Verification and Timing Analysis.

The prototype system architecture includes a microprocessor that is external to the traffic controller and that receives and analyzes the weather data, then communicates necessary signal timing changes to the traffic controllers. Current technology supports the proposed system development, and tests verified that the necessary read-and-write capabilities are available from the microprocessor to any NTCIP-compliant traffic controller.

The weather data is accessed through the FHWA's Clarus system web interface, through ITD's weather station data server, and through a weather sensing station installed locally at the intersection. Different observation types reported in the weather data are used to determine air and surface temperature, roadway surface condition status, precipitation type and rate, and visibility level at or near the sensing station. The availability and accuracy of the data reported by different weather stations provided reliable estimates of the weather, road surface condition, and visibility level needed for weather-responsive traffic signal system applications.

The weather-responsive system developed in this project has five innovations.

1. The system achieves its potential using current traffic controller and cabinet technologies.
2. The system conforms with future applications in the FHWA's connected-vehicle initiative.
3. Minimal hardware is required for full system implementation.
4. Computer-driven algorithms implement signal control decisions using weather data.
5. The proposed system architecture uses two revolutionary software design approaches: design for survivability and software performance measurement at the task level.

In addition, the software design incorporates self-diagnostic techniques for fault detection and recovery to maximize survivability and security. Because the proposed system has very similar computational requirements to other field traffic control applications, it represents a major milestone in the development of secure and dependable real-time traffic control systems.

The system was initially tested in a hardware-in-the-loop simulation environment. It was also field implemented at an intersection in the city of Moscow, Idaho. The simulation results indicated that the system reduces the potentials for crashes while having minimal impact on delays and stops. The results showed that the system, on average, reduces the potentials for rear-end crashes, crossing crashes, and lane change crashes by 5.7 percent, 31.3 percent, and 6.3 percent, respectively. The results from the field implementation were consistent with those obtained from the simulation model. They show that, when the snow/ice signal timing plan was implemented with longer yellow and all red intervals and increased passage time values, the number of vehicles running the red light during snow and ice conditions dropped significantly from 7.94 percent for passenger vehicles and 14.18 percent for commercial vehicles to 3.5 percent for passenger vehicles and 7.81 percent for trucks. This significant reduction in the number of red-light runners improves the safety of the intersection operations during inclement weather conditions.

The actuated control parameters presented and tested as part of this study can be used by ITD district traffic engineers to develop snow/ice signal timing plans for isolated intersections throughout the state. The system presented in this study is ready for implementation at the local intersection level. However, more research and development are needed before a state-wide weather responsive system can be implemented. While the state's weather station provides a good source of weather data for the proposed weather responsive traffic signal system, using weather data from weather stations that are located at the signalized intersections improve the reliability of the weather responsive traffic signal system.

Left: Field installation of the local weather station. Right: Components of the local weather station.

Project: Guidelines for Eco-Traffic Signal System Operations in Small and Medium Size City Environments (KLK915)

Dissertation by: Sherief Elbassouni - University of Idaho

Project PI: Ahmed Abdel-Rahim and Kevin Chang

TranLIVE University Transportation Center Funding: $217,543

Although corridor traffic in small and medium size cities does not experience the high levels of congestion typically present in large urban areas, it generates a considerable amount of emissions and vehicle pollutants that negatively affect the environment. This dissertation's goal is divided into four parts:

- **Synthesize fuel consumption and emission modeling tools**. The first part covers traffic-related pollutants; emission factors and data and the different methods used to obtain them; and examples of the currently available emission inventories. The second part presents a review of fuel consumption and emission models suitable for modeling corridor traffic operations, covering three analysis levels: microscopic, mesoscopic, and macroscopic.
- **Model vehicle performance at signalized intersection approaches using GT-SUITE.** This advanced engine modeling software offers a versatile toolbox for simulating vehicle dynamics. Results show that the fuel consumption and environmental cost of stops are highly dependent on the corridor operating speeds and increase as speed increases. Also, aggressive driving with high acceleration rates yields much higher fuel consumption rates and cost. NO_x emissions increased in the mild to normal acceleration range and decreased in the aggressive acceleration range. HC and CO emissions increased by increasing the acceleration rates. Public awareness campaigns about the high cost of aggressive driving practices can contribute significantly to reducing corridor fuel consumption and environmental cost.
- **Develop guidelines on how to optimize corridor management plans to minimize corridor emissions and fuel consumptions in small and medium size cities.** Corridor signal timing plans that are not optimized can cause an abundance of vehicle emission pollution. Prolonged idling can decrease fuel efficiency for users. Multiple optimized signal timing plans were used to determine the most efficient optimization. TRANSYT-7F and PTV VISTRO, optimization software tools, were used in the analysis. Signal timing plans from both tools were simulated microscopically in INTEGRATION to produce estimates of fuel consumption, vehicle emissions and other environmental effects, and several operational measures of effectiveness.

Fuel Consumptions, Emissions, Delay, and Number of TRANSYT-7F Cases

	Cycle Len. (sec.)	% Band / Cycle	Travel Time (sec.)	Speed (mph)	No. of Stops	Delay (sec.)	Fuel, (g/ sec.)	HC 10^-^{3} (g/sec)	CO, (g/ sec.)	NO_x 10^-3 (g/ sec.)	CO_2, (g/ sec.)
1.0D 0.0S	60	**.29**	**175.99**	**28.45**	1.98	**43.74**	1.43	2.47	.06	3.26	3.24
0.0D 1.0S	180	.21	223.24	23.21	**1.43**	90.96	**1.16**	**1.82**	**.04**	**2.26**	**2.65**

Fuel Consumptions, Emissions, Delay, and No. of Stops for the TRANSYT-7F Cases

	Cycle Len. (sec.)	Travel Time (sec.)	Speed (mph)	No. of Stops	Delay (sec.)	Fuel, (g/sec.)	HC 10^-^{3} (g/sec.)	CO, (g/ sec.)	NO_x 10^-^{3} (g/sec.)	CO_2, (g/ sec.)
Progression and Control Delay	110	181.63	27.83	**1.64**	49.36	1.35	2.07	.047	**2.82**	3.07
Fuel Consumption Only	110	217.28	23.33	2.46	84.98	**1.29**	2.14	.050	2.86	**2.92**
Progression and Fuel Consumption	110	**177.17**	**28.59**	1.73	**44.88**	1.37	**2.05**	**.047**	2.90	3.13

- **Develop signal control parameter guidelines for isolated intersections to minimize stops, fuel consumption, and emissions, focusing on advanced controller settings such as rest-on-red, rest-on-green, and delayed detection.** Seven signal control cases were tested. The Trafficware Synchro 9 optimized case resulted in the worst delay per vehicle, stopped delay per vehicle, average queue length, maximum queue length, fuel consumption, CO emission, and NOx emission. Alternatively, the case of right turn on red for both major and minor streets showed the lowest values for average number of stops per vehicle, the average delay per vehicle, fuel consumption, CO emissions, and NOx emissions for the whole intersection. This also reinforces all the prior findings about the negative impact of vehicle stops on the measure of effectiveness, fuel consumption, and emissions. The study offers a variety of insights toward optimized signal control parameters.

Project: Security and Survivability of Real-Time Communication Architecture for Connected-Vehicle Eco-Traffic Signal System Applications (KLK903)

Principal Investigator: Axel Krings

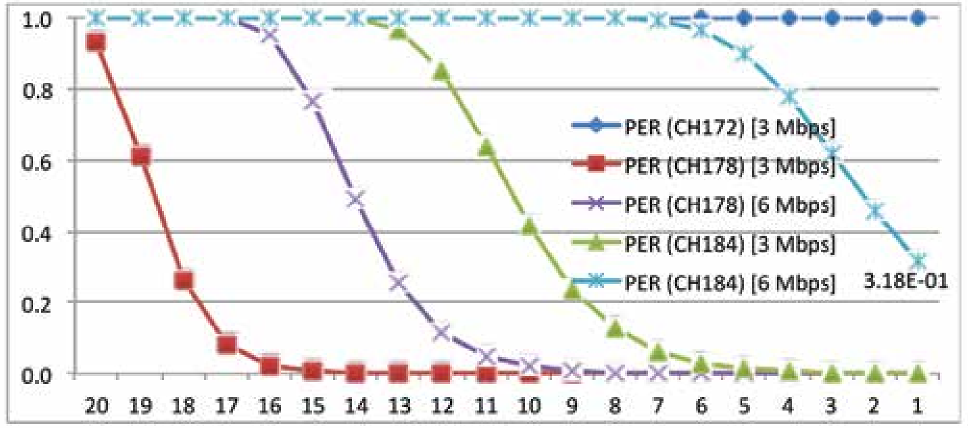
Co-Principal Investigators: Ahmed Serageldin, Ahmed Abdel-Rahim, and Michael Dixon

TranLIVE University Transportation Center Funding: $119,998

While improving the environmental efficiency of traffic signal system operations is the main focus of research in connected-vehicle eco-traffic signal systems and applications, the infrastructure itself is exposed to an array of security threats. From cyberspace to direct physical manipulations, threats manifest not only because connected-vehicle communications rely heavily on wireless technology such as DSRC, but also because the infrastructure includes a wide range of devices, technologies, and communication protocols vulnerable to attack.

It is suggested that such systems should be designed and analyzed using the philosophy of Design for Survivability, in which security and survivability considerations are designed directly into the applications and their operations. To this end, it's necessary to explore fault models and to describe an architecture that leads to actual implementations of survivable systems.

A model to analyze and quantify the reliability of Connected Vehicles safety applications was introduced. Next, an approach was derived to utilize channel redundancy to mitigate against the impact of communication jamming, which was the malicious act under consideration. The research resulted in the specification of a communication architecture that uses the concept of channel redundancy and message dissimilarity to increase resilience against jamming attacks in pathological, human-induced attacks.

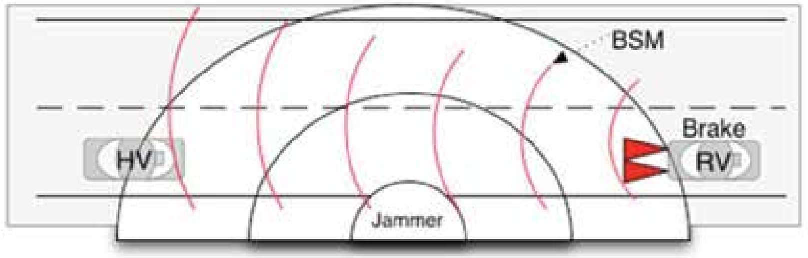


Packet Error Ratio (PER) of safety message i (x-axis) using 3Mbps and 6Mbps for different channels affected by constant jamming

Other findings include:

- The concept of dissimilarity of communication mechanisms has been used to increase resilience against interference as the result of both natural phenomena and malicious acts.
- The dual or triple redundant mechanisms described do not introduce concepts that deviate from existing standards.
- The redundancy schemes introduced overcome the impact of jamming, assuming that the jammer capabilities are limited to the technical specifications of the vehicles' on-board unit transmission power model.
- The dual-redundant scheme using CH172 and CH178 can provide effective Forward Collision Warning (FCW) application reliability in the presence of jamming. This is the case for either using 3Mbps or 6Mbps communication.
- In triple redundancy we suggest using CH184 for data rates no higher than 3Mbps for DSRC safety applications.
- Given the results for the unreliability of 12Mbps communication, we conclude that the use of this data rate is also not advisable for DSRC safety applications that may be exposed to jamming attacks.

The project's outcome extends real-time control capabilities to positively affect safety based on situation awareness, and the impact will be noticeable as the community reviews the published results.



Forward Collision Warning (FCW) under jamming

Project: Performance Monitoring for Safe and Livable Communities: Fusing Data to Improve Arterial Operations for All Users (KLK843)

Michael Dixon, Michael Lowry, and Randal Brunello

PacTrans University Transportation Center Funding: $190,000

This project seeks to investigate the developments of and the potential for different methodologies for gathering arterial traffic performance data. In the effort to build more livable communities, this data is essential, but gathering, organizing, and applying it has, historically, been a difficult task. This report is organized around product areas, which are 1) an open-source tool to monitor dynamic performance measures from high resolution traffic controller data, 2) a practical and accurate tool for estimating bike volumes, 3) cost-effective pedestrian detection, 4) inexpensive and quickly applied tools to extract probe vehicle data, and 5) a pragmatic approach to accurately estimate signalized intersection turning movements. Each chapter of this report is an autonomous effort in studying one of these areas in particular.

Performance measure calculation using high-resolution data

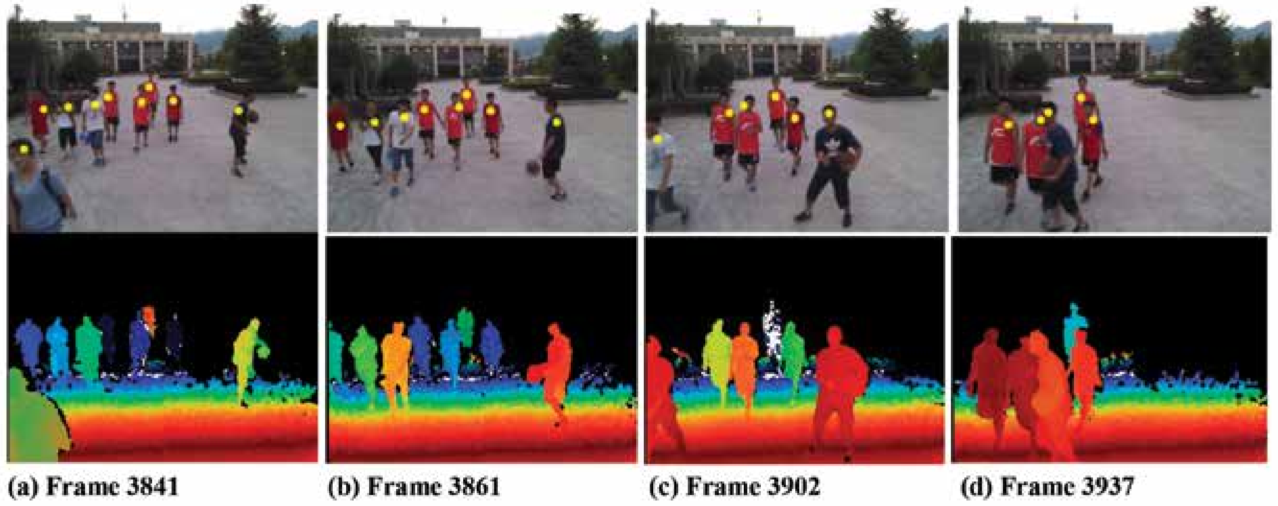
Chapter 2 proposes a tool that facilitates future performance measurement research related to traffic signal systems. The tool imports data from a simulation data source for experimentation in varied ideal settings or from field traffic signal systems for more rigorous application testing.

Using origin-destination centrality to estimate directional bicycle volumes

Chapter 3 uses origin-destination centrality to estimate directional bicycle volumes. Limited input data, simple site specific calibration, trivial modeling requirements, and practical accuracy make this method very attractive relative to proposed alternatives. In addition, this research provides the tools to import input data, process the data, estimate the bicycle volumes, and visualize the results with add-on applications created for industry-standard off-the-shelf software.

Pedestrian livability and Microsoft's Kinect

Chapter 4 proposes an efficient pedestrian detection method for crowded scenes by fusing RGB and depth images from Microsoft's ®Kinect. The results of the study demonstrate the feasibility of using the low-cost Kinect device and a proposed detection method for real-world pedestrian detection in crowded scenes.


(a) Frame 3841 (b) Frame 3861 (c) Frame 3902 (d) Frame 3937

Examples of successful detecting and tracking pedestrians for scenario 3 (Yellow solid circle locating one pedestrian), RGB image on top while corresponding depth image on bottom

Bluetooth data collection system for planning and arterial management

Chapter 5 documents the research and development of an inexpensive portable wireless roadside data collection system using probe vehicles, whose movements are monitored using Bluetooth technology. The system addresses industry needs for low-cost portable traffic monitoring and supports travel time, origin-destination, and delay performance measures.

Effective turning movement volume estimation for intersection analysis using Gauss-Jordan elimination

Chapter 6 presents a method that solves for turning movement volumes using Gauss-Jordan elimination row operations (e.g., row swapping, multiplying rows by non-zero constants, and adding a factor of one row to another row). Because the method is founded on direct implementation of basic matrix analysis row operations, the solution process is easy to implement. Three data sets validate the method's accuracy, with and without detection error, showing the method can be sufficiently accurate for professional applications in planning, design, and operations.

Arterial system performance measurement is important for assessing steps considered or taken to accomplish goals directed toward greater community livability. Several tools and methods were developed to collect, import, and process, and to estimate performance measures. These tools were tested to prove their feasibility, and each chapter provides an insightful and detailed evaluation of these products.

Project: Data Collection and Spatial Interpolation of Bicycle and Pedestrian Data (KLK808)

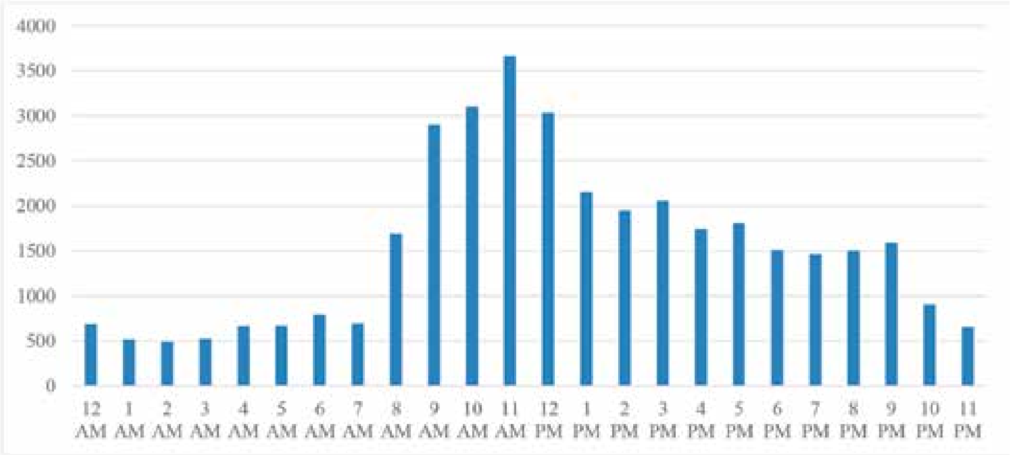
Principal Investigator: Michael Lowry

Co-Principal Investigators: Ryan McGrath, Seth Cool, Ryan Cook, and Mitch Skiles

PacTrans University Transportation Center Funding: $60,000

Cities and state Departments of Transportation (DOTs) struggle to collect and use bicycle and pedestrian data in effective and meaningful ways. Monitoring non-motorized traffic is still in its infancy compared to the well-developed practice of monitoring motorized traffic. The goal of this project was to provide guidance for improving manual bicycle and pedestrian count programs and investigate the feasibility of cutting-edge sensor technology. To this end, five independent studies were pursued to: 1) evaluate the state-of-the-practice of manual bicycle and pedestrian count programs, 2) assess the error associated with manual count programs, 3) develop a process for using manual count data for safety analysis, 4) explore the feasibility of using moving Bluetooth sensors to collect bicycle and pedestrian data, and 5) investigate the potential for installing Bluetooth sensors on public buses to gain better understanding of pedestrian interaction with public transportation.

For the first study, an online questionnaire was sent to transportation specialists across the country and eleven communities were contacted for phone interviews. The respondents reported many communities are not using automatic counters, not using adjustment factors, counting infrequently, for short two-hour periods, and rarely for more than one day. Although occasionally or regularly conducting manual counts has a variety of benefits, the stated goals of the count programs are not best served by snapshot counts. On the other hand, some of the stated reasons for conducting manual counts seem compatible with the activities underway.



Bluetooth detections by hour

For the second study, measurement error was assessed through a controlled field experiment with 25 counters at 5 intersections. Lower measurement error rates were observed when using a 4-movement data collection technique compared to a more complicated 12-movement technique; however, the differences were not statistically significant. The overall median absolute percent error for the 12-movement technique was 27 percent and 7 percent for bicyclists and pedestrians, respectively.

For the third study, a new method was developed to evaluate bicycle infrastructure plans in terms of exposure to dangerous situations. A typology of 23 dangerous situations for bicyclists was identified through a literature review, and a geographic information system (GIS) tool was created to analyze some of the situations and provide a means to compare proposed improvement projects. The tool and process are demonstrated for a case study community, and results suggest that the proposed bicycle master plan would decrease exposure for various dangerous situations.

For the fourth study, we explored the feasibility of using moving Bluetooth sensors to collect bicycle and pedestrian data. Fifty-three people were provided a smartphone app that tracked their location via GPS every 7 seconds for 10 days. The app also collected, via Bluetooth, the media access control address (MAC address) of any intercepted device within 100 feet. The intent of the study was twofold, first to explore the potential of using this passive data collection technology to replace traditional travel diaries, and second, as a means to collect a richer data set of travel patterns by matching intercepted MAC addresses across the city, perhaps as a precursor to the data that might be collected through vehicle-to-vehicle communications. Every night, the participants logged into a website to verify their travel information. Our model predicted mode with 77 percent accuracy and purpose with 54 percent accuracy. Over 3,000 devices were intercepted via Bluetooth and recorded over 300,000 GPS points. By matching MAC addresses across town, our data processing algorithms identified over 600 trips.

For the fifth study, smartphones with the GPS/Bluetooth app were placed on buses traveling between the University of Washington campus and South Lake Union Neighborhood in Seattle. During the study 11,041 devices were intercepted. After data processing we determined that 403 bus riders were intercepted. This study showed that the number of passengers carrying active wireless devices is sufficient to provide a sizable sample of the population, and that the boarding and alighting location of passengers can be inferred from detection time and GPS location.

(a) Sensor with auxiliary battery (b) Sensor placement. Static sensor setup and placement

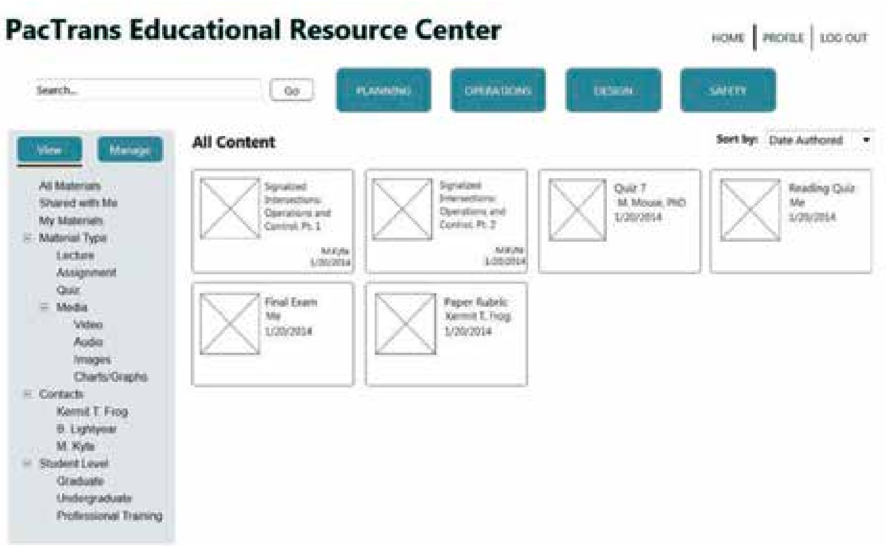
Project: Refinement and Dissemination of a Digital Platform for Sharing Transportation Education Materials (KLK804)

Principal Investigator: Kevin Chang

PacTrans University Transportation Center Funding: $140,000

There are approximately two hundred Introduction to Transportation Engineering courses taught annually in the US but little evidence to suggest that teaching materials (other than textbooks) are being shared between the instructors of these courses. The National Science Foundation (NSF) spends millions of dollars annually through the Transforming Undergraduate Education in STEM (TUES) program on the development and testing of teaching methods and materials. Conversations with NSF program managers indicate that they are disappointed with the rate of return on this investment, and would like to see much less development and much more sharing and dissemination of best practices. New NSF programs are emerging specifically on utilizing best practices and understanding the adoption process.

This project's overarching goal was to develop an effective web-based repository where engineering educators could readily share educational materials and best practices. During the initial phase, the research team developed a framework for a prototype website, the PacTrans Transportation Education Resource Center (pTERC), for sharing transportation curriculum and best practices. A research-based action-oriented approach was taken where iteration between development and studies of usability and adoptability of the pTERC system occurred and included: the development and testing of a pilot system, research efforts that supported the development, and the gathering of existing curricular materials to be uploaded to the system.



Screenshot of the repository prototype used in round one of usability testing

This effort relied on Diffusion of Innovations (DI) Theory with a focus on understanding potential adopters' experiences, opinions, and values. Interviews with these individuals and a supplementary analysis of syllabi in relevant courses afforded the initial development of the web-based repository. The results of this initial study suggested tangible and direct means of addressing potential users' perceptions about the repository and the materials included within it.

To provide a usable web-based system, academic- and industry-established user-centered design practices were incorporated in the repository system's development. This included an in-depth needs assessment phase in which college professors were interviewed about their own educational materials-sharing practices. Iterative prototyping and usability testing was built on the data gathered from the needs assessment phase.

Many objectives were achieved and completed as part of this project, though additional testing is recommended. The success of the repository will ultimately depend on each user's perceived usefulness of the materials available in the repository, the decision-making research focused on identifying characteristics of materials that transportation education faculty members implement in their classrooms, the reasons faculty members have for modifying materials, the resources and materials faculty members draw from when modifying materials, and a formal plan that allows for the sustainable and manageable operations of the repository into the future.

Screenshot of an updated user interface

Center for Clean Vehicle Technology

Project: Aerodynamic Effects on Two-Lane Rural Highway Safety (KLK807)

Principal Investigator: Tao Xing

Co-Principal Investigators: **Ahmad Hammad (graduate student) and Ahmed Abdel-Rahim**

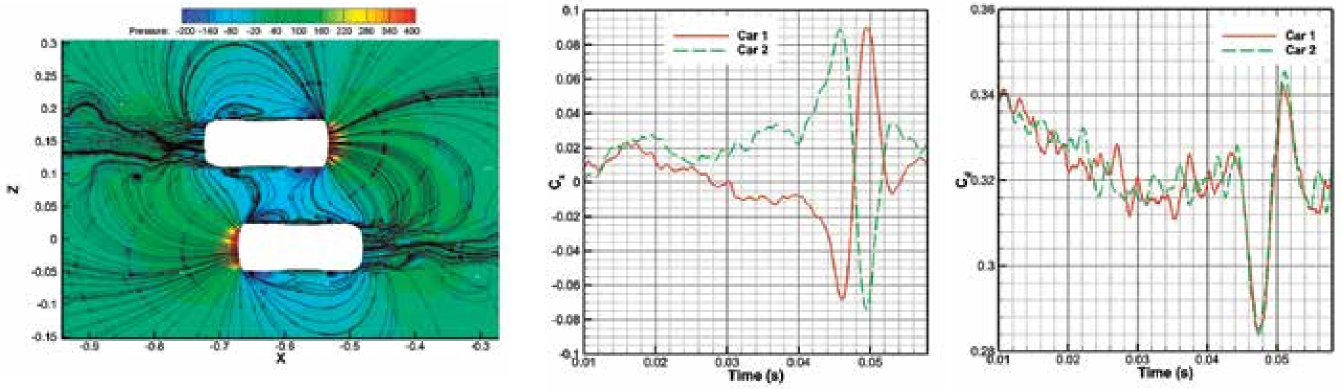
PacTrans University Transportation Center Funding: **$60,000**

Rural roads in the US, compared to urban roads, face a proportionately higher number of fatalities with respect to traffic volume. This risk is most apparent on two-lane undivided rural highways shared by fast-moving cars and trucks, especially in twisty sections with variable winds. Studies investigating the aerodynamics of vehicle interaction and its effect on safety suffer from shortcomings including: 2D models, unsuitable modeling assumptions, coarse grids, and low temporal resolution. This study uses 3D computation fluid dynamics (CFD) models and wind tunnel experimental measurements to investigate vehicle interactions and variations in forces and moments, especially when the size differential between the two vehicles is large.

A passenger car and a truck model (1:25) were designed in SolidWorks and meshed using Pointwise. ANSYS Fluent 17.2 was used to perform CFD calculations, and for simulating, the IDDES (Improved Delayed Detached-Eddy Simulation, Shur et al., 2008) model was used. Cases considered included: single car, single truck, car-car crossing (with and without crosswinds), car-truck crossing, and car overtaking a truck.

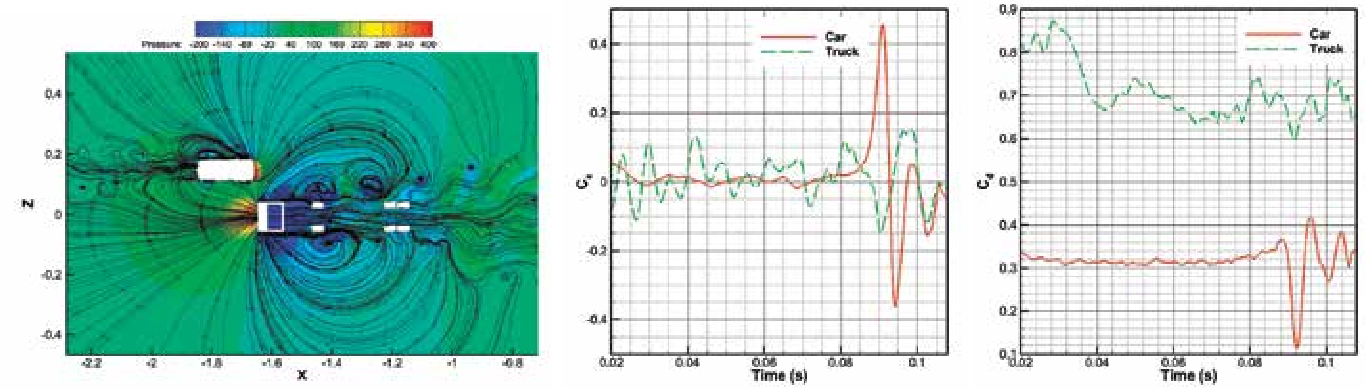
The main CFD results include:

Car-car crossing case:



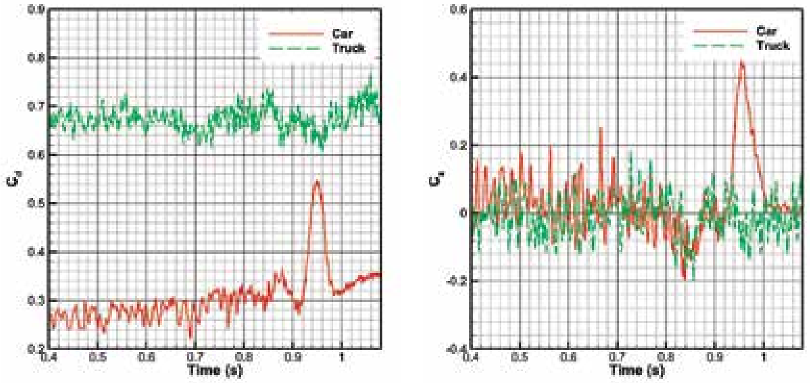
Left: contours of pressure and velocity streamlines at t=0.0470 s (maximum drag excursion.) Drag-coefficient (right) and side-force coefficient (middle) variation during the crossing. Interaction starts at t=0.04 s.

Car-truck crossing case:



Left: contours of pressure and velocity streamlines at t=0.0905 s (maximum lateral force excursion.) Drag-coefficient (right) and side-force coefficient (middle) variation during the crossing. Interaction starts at t=0.072 s.

Car-truck overtaking case:



Drag-coefficient (right) and side-force coefficient (left) variation during the crossing. Interaction starts at t=0.7 s.

The study concluded that interaction starts early between vehicles even before they “meet” each other. Additionally, when a car crosses a truck, the lateral force acting on the car, which swings in direction from side to side during the interaction, shows a fluctuating change of up to 1,000 percent compared to its mean value. And when a car overtakes a truck, the greatest change in forces acting on the car starts happening immediately before the car goes past the truck’s front surface.

Future work should look at CFD simulation of: 1) a car overtaking a truck in the presence of crosswinds, 2) parametric studies to investigate the effect of crosswinds at different incidence angles, and the effect of the lateral separating distance between vehicles on aerodynamics and safety policies, and 3) CFD simulations of trailer aerodynamics.

Education

Objectives 3 and 4 of NIATT's Strategic Plan relate to education:

> **Objective 3:** Increase the number of faculty and students in our research and education programs to enhance the transportation workforce.
>
> **Objective 4:** Transfer the results of our research program to practicing professionals in forms that are usable to them to improve the quality and performance of our workforce.

Awards

Chang Receives Outstanding Educator Award

Kevin Chang received the 2016 Institute of Transportation Engineers (ITE) Outstanding Educator Award for the Western District. This award recognizes Chang as an educator who has shown "extraordinary creativity in teaching, taken exceptional measures to spark student interest in the transportation profession, provided unwavering encouragement for student endeavors, and shown unequaled service to ITE."

Tao Xing Receives the College of Engineering's Outstanding Young Faculty Award

Tao Xing, Assistant Professor in Mechanical Engineering, received the College of Engineering's Outstanding Young Faculty Award at the awards ceremony in May 2015. Dr. Xing also won the University of Idaho's Alumni Award for Excellent Mentor in 2013 and 2014.

Our Students

Dr. Ahmed Abdel-Rahim (right) presents NIATT's Student-of-the-Year award to Ahmed Muftah on November 28, 2016.

NIATT Student of the Year: Ahmed Muftah

NIATT joins in congratulating each UTC's Student of the Year. NIATT's 2016 Student of the Year is the newly-minted Ph.D. Ahmed Muftah. Ahmed received the award at his dissertation defense, where it was announced by his advisor Dr. Fouad Bayomy and NIATT director Dr. Ahmed Abdel-Rahim.

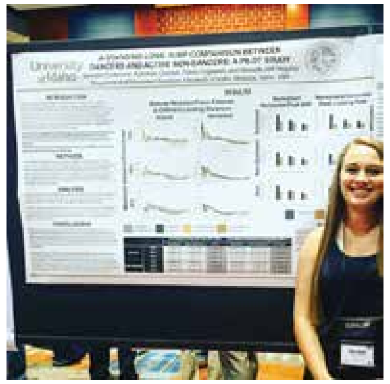
Ahmed is the founder and first president of the Civil Engineers Club at the University of Idaho, a group formed to facilitate communication between civil engineering graduate students and to give them the chance to exchange research ideas and present their work in front of colleagues. He was the vice president of the Muslim Student Association, a member of the University of Idaho's Engineers Without Borders chapter, and a volunteer tutor for international students.

Ahmed's work at NIATT focused on making asphalt pavement and highway technologies more sustainable. One of his graduate projects, in conjunction with the Idaho Transportation Department, evaluated the limits of using Reclaimed Asphalt Pavement (RAP) as highway material, determining that up to 50 percent of old materials can be added, which represents a significant cost savings. His other Ph.D. work researched the application of synthetic fibers in hot mix asphalt. In his free time, he enjoys reading, snowboarding, and camping.

Summer Interns

In 2016, **Freda Sewuese Agbecha** moved to the US as a transfer student from Nigeria to continue her undergraduate work in civil engineering. She chose the University of Idaho, where her elder sister graduated with a degree in computer engineering. Freda worked with Dr. Ahmed Abdel-Rahim as an undergraduate research assistant at NIATT on a project to educate young drivers in the Pacific Northwest about the dangers of distracted driving. Her long-term goal is to acquire the necessary skills to be able to help development in her home country.

Zachary Lipple, working toward a degree in mechanical engineering, is most interested in engine design and testing, as well as finding ways to make the technology for power sports more eco-friendly. During his summer internship at NIATT, he worked with Dr. Kamal Kumar to design and test a small cost-effective rapid compression machine (RCM) that will allow for comparing the thermochemistry of various fuel types in diesel engine combustion.



Kendall Crickmore finished her BS in Exercise Science and Health in August 2016 and plans to attend a graduate program that focuses on concussion prevention research or sports management. Kendall collaborated with Dr. Mostafa Afifi Hegazy (Department of Movement Sciences) and fellow student Kathleen Connor on NIATT research using the Virtual CRASH 3.0 program that led to an article, "The effect of physical maturation on ATV head-on collision outcome: a simulation study," that was submitted to the Transportation Research Board's 96th annual meeting.

Nick Saras, a Boise native, graduated with his BS in civil engineering in 2016 and began graduate work in structures that fall under Dr. Ahmed Ibrahim. His summer internship work with Dr. Ibrahim, Dr. Abdel-Rahim, and the Idaho Transportation Department entailed creating a brochure for local highway jurisdictions to use in determining if their roads are capable of withstanding 129,000 pound trucks.

College of Engineering EXPO - Senior Design Presentations

EXPO is also an excellent venue for the university's partners in industry to converge on the University of Idaho campus to judge the senior design projects, to connect with faculty and other industry partners, and to recruit some of the finest engineering graduates in the nation.

The University of Idaho Engineering Design EXPO is the College of Engineering's signature showcase of our students' innovation and is the Northwest's longest-running, interdisciplinary initiative featuring student innovations. The National Academy of Engineering has recognized the UI Engineering capstone program as one of the best in the nation.

The College of Engineering has developed a program that focuses on teaching students the fundamentals of engineering during their first two years, and then creating opportunities for students to use those fundamentals in the labs while also gaining engineering design experience. Engineering EXPO is the culmination of this education process. Every UI Engineering graduate participates in a senior capstone design course before they head to graduate school or the workforce. This process challenges Idaho engineering graduates to tackle real world issues with the help of industry partners.

The Clean Snowmobile Challenge Team received a Booth Award at the 2016 Engineering Expo.

The Snowmobile Traction Control Team received a Booth Award at the 2016 Engineering Expo. Pictured left to right are Dillon Downing, Scott Damiani, and Chase Smith. The faculty advisors were Michael Santora and Dan Cordon.

Congratulations to the 2016 Clean Snowmobile Team

The team won the Most Sportsmanlike Award at both the 2015 and 2016 competitions. This makes them not only the winningest team of this award (having earned it four times since 2001), but also the only team to have won this award in back-to-back years.

Other awards conferred on the 2016 team include:

- Most Innovative Emissions Design
- Most Likely to be Manufactured
- Best Emissions

First Place Event Awards:

- Design Paper
- Objective Handling
- Fuel Economy

Second Place Event Awards:

- MSRP
- Subjective Handling
- Acceleration

Alumni from Idaho's Clean Snowmobile Team work in industry all over the country, including for Arctic Cat, Polaris, BRP/Evinrude, Wagstaff, Pacaar, Honda, Stihl, and other companies. For the summer of 2016, every non-freshman member of the team was awarded an internship at an engineering company, and the lone senior on the team landed an engineering job in Boise.

The team has completed several outreach events, including three snowmobile shows, campus tours, a presentation for the Idaho State Snowmobile Association, and the NIATT dinner. A NIATT travel grant will allow the team's paper on project management to be presented at the Society of Automotive Engineers' world congress in 2017. The team's advisory role was shared between Dr. Dan Cordon and Dr. Steve Beyerlein.

Zach Avelar, Alex Kiss, Ben Deruwe, Hayden Hulse, Adam Thurgood, Ian Sullivan, Jason Maas, Cade Smith, Brian Gift, Adam Sedgwick, and Zach Lipple

2016 Clean Snowmobile Members

Mark Woodland (Gooding, Idaho)
Co-captain and senior, mechanical engineering

Aaron Eliason (Wieser, Idaho)
Senior, mechanical engineering

Adam Sedgwick (Post Falls, Idaho)
Senior, mechanical engineering

Jason Maas, (Marysville, Washington)
Co-captain and junior, mechanical engineering

Cade Smith (Milford, New Hampshire)
Junior, mechanical engineering

Zach Lipple (Boise, Idaho)
Junior, mechanical engineering

Patrick Paulus (Pocatello, Idaho)
Junior, mechanical engineering

Phoenix Duncan (Coeur d'Alene, Idaho)
Junior, mechanical engineering

Benjamin DeRuwe (Touchet, Washington)
Sophomore, mechanical engineering

Leland Maris (Nampa, Idaho)
Sophomore, agricultural systems management

Joseph Tucker (Rigby, Idaho)
Sophomore, mechanical engineering

Ian Sullivan (Nampa, Idaho)
Sophomore, mechanical engineering

Zac Avelar (Buhl, Idaho)
Freshman, mechanical engineering

Hayden Hulse (Buhl, Idaho)
Freshman, mechanical engineering

Alex Kiss (Banks, Oregon)
Freshman, mechanical engineering

Adam Thurgood (Post Falls, Idaho)
Freshman, mechanical engineering

Junior Ambriz (Meridian, Idaho)
Graduate student, virtual technology and design

Chase Smith (Boise, Idaho)
Senior, mechanical engineering

Brian Gift (Sandpoint, Idaho)
Junior, electrical and computer engineering

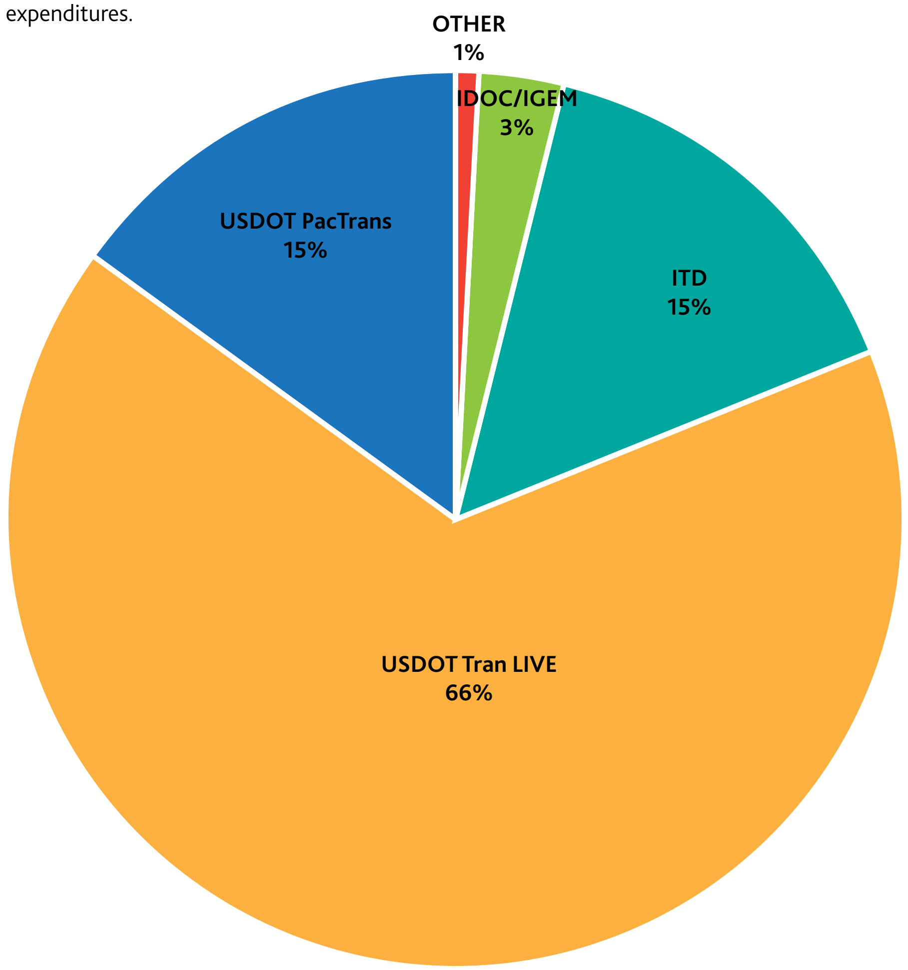
Dillon Savage (Challis, Idaho)
Graduate mentor, mechanical engineering

Josh Barlow, a senior in electrical and computer engineering from Nampa, Idaho, during the handling event.

Financial Report

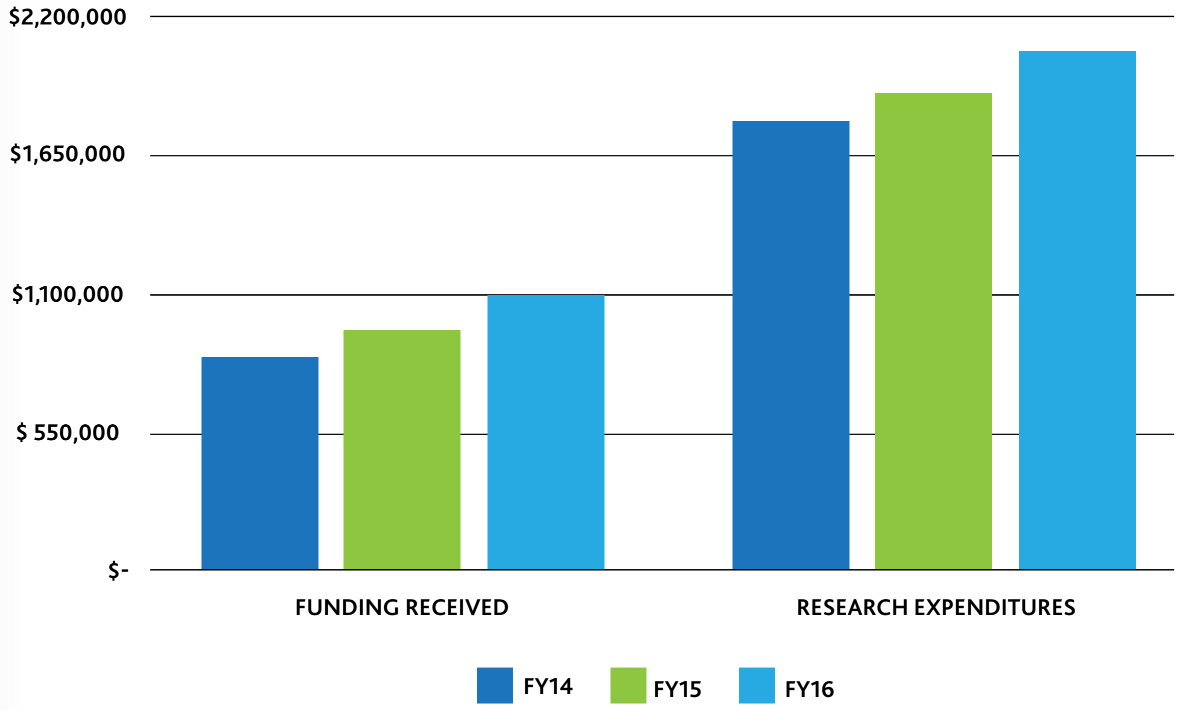
NIATT Funding Sources for Expenditures - FY2016

In fiscal year 2016, 66 percent of NIATT research funding expenditures were sourced from the UTC TranLIVE. The UTC PacTrans and ITD provided an additional 15 percent each, and IDOC/IGEM sourced 3 percent of research expenditures.



NIATT Growth Trends FY2014 - FY2016

The chart below shows the growth trends, in funding received and research expenditures, from fiscal year 2014 to fiscal year 2016.



List of All Projects

PROJECTS BEGUN IN FY2016

KLK067 IDOC IGEM Smart Raised Pavement Marking Integration with Traffic Control Systems
Ahmed Abdel-Rahim CTOC

KLK350 FHWA SHRP2 Education Connection
Kevin Chang CTOC

KLK524 Univ of Alaska Fairbanks – Passing Zone Behavior and Sight Distance on Rural Highways
Kevin Chang CTOC

KLK575 ITD Safety Analysis of School Zones Along Two-Way, Two-Lane Highways
Kevin Chang CTOC

KLK576 ITD Educating Teenage Drivers of the Dangers of Distracted Driving
Ahmed Abdel-Rahim CTOC

KLK578 ITD Guidance to Assist Local Highway Jurisdictions in Evaluating 129,000 Pound Route Requests
Ahmed Ibrahim CTI

KLK579 ITD Portland Cement Concrete Material Characterization for Pavement ME Design Implementation in Idaho
Ahmed Ibrahim CTI

COMPLETED PROJECTS FY2016

KLK561 ITD Improving Safety at Signalized Intersections During inclement Weather Conditions – A Real-Time Weather Responsive System
Ahmed Abdel-Rahim CTOC

KLK565 ITD Calibrating the Highway Safety Manual Crash Prediction Models for Idaho's Highways
Ahmed Abdel-Rahim CTOC

KLK566 ITD Passing Lane Safety and Efficiency
Ahmed Abdel-Rahim CTOC

KLK901 USDOT UTC Improve the Environment for a Livable Community: Advance the AERIS Program by Developing and Testing Eco-Traffic Signal System Applications
Ahmed Abdel-Rahim CTOC

KLK903 USDOT UTC Security and Survivability of Real-Time Communication Architecture for Connected-Vehicle Eco-Traffic Signal System Applications
Ahmed Abdel-Rahim CTOC

KLK906 USDOT UTC TranLIVE Pyrolysis Bio-Oil Upgrading to Renewable Fuels
Armando McDonald, David McIlroy, Yinglei Han, Blaise-Alexis Kengne CCVT

KLK907 USDOT UTC Progress in Catalytic Ignition Fabrication, Modeling, and Infrastructure
J. Steciak, S. Beyerlein, R. Budwig, D. Cordon, D. McIlroy CCVT

KLK908 USDOT UTC Formula Hybrid SAE Vehicle
Dylan Rinker, Steve Beyerlein, Edwin Odom, Herb Hess CCVT

KLK909 USDOT UTC Sustainable Transportation: Technology, Engineering, and Science
Jona-than Peterson, Michael Lowry, Kristin LaPaglia, Bradford Tower CTOC

KLK910 USDOT UTC A High-Speed Trapezoid Image Sensor Design for Continuous Traffic Monitoring at Signalized Intersection Approaches
Suat Ay CTOC

KLK911 USDOT UTC Upgrading Biomass Pyrolysis Bio-Oil to Renewable Fuels
Armando McDonald and David McIlroy CCVT

KLK912 USDOT UTC Formula Electric Vehicle
Herb Hess, Steve Beyerlein CCTV

KLK913 USDOT UTC Daily Travel Feedback to Encourage Eco-Routing
Michael Lowry CTOC

CONTINUING PROJECTS THROUGH FY2016

KLK568 ITD Fiber Asphalt Pavements Phase 1
Fouad Bayomy CTI

KLK569 ITD Detection Field Testing
Ahmed Abdel-Rahim CTOC

KLK571 ITD Safety Impacts Using Wider Pavement Marking in Two-Lane Rural Highways in Idaho
Ahmed Abdel-Rahim CTOC

KLK572 ITD Calibration of the AASHTOWARE Pavement ME Design Performance Models for Flexible Pavements in Idaho
Fouad Bayomy CTI

KLK573 ITD Bicycle and Pedestrian Facility Inventory Database
Michael Lowry, Bruce Godfrey CTOC

KLK574 ITD Evaluation, Comparison, and Correlation Between the Idaho IT-144 and AASHTO T-84 Methods for Determining the Specific Gravity and Absorption Properties of Fine Aggregate
Sunil Sharma CTI

KLK800 PacTrans Admin
Ahmed Abdel-Rahim CTOC

KLK801 PacTrans Evaluation of Ultra-Wideband Radio for Improved Pedestrian Safety at Signalized Intersections
Jim Frenzel, Brian Johnson CTOC

KLK802 PacTrans Modeling Passing Behavior on Two-Lane Rural Highways: Evaluating Crash Risk Under Different Geometric Conditions
Kevin Chang, Brian Dyre CTOC

KLK803 PacTrans Crowdsourcing Bicycle Travel Data to Estimate Risk Exposure and Create Safety Performance Functions
Michael Lowry CTOC

KLK804 PacTrans Safety Data Management and Analysis: Addressing the Continuing Education Needs for the Pacific Northwest
Kevin Chang CTOC, Shane Brown (OSU), Cynthia Chen (UW), Ali Hajbabaie (WSU), Robert Perkins (UAF)

KLK805 PacTrans Mixed Use Safety on Rural Facilities in the Pacific Northwest
Kevin Chang, Mustafa Hegazy, Ahmed Abdel-Rahim CTOC

KLK806 PacTrans Mitigation of Lane Departure Crashes in the Pacific Northwest Through Coor-dinated Outreach
Ahmed Abdel-Rahim CTOC

KLK807 PacTrans Aerodynamic Effects on Two-Lane Rural Highway Safety
Tao Xing CCVT

KLK808 PacTrans Spatial Analysis of Bicycle and Pedestrian Data
Michael Lowry CTOC

KLK900 USDOT UTC TranLIVE
Ahmed Abdel-Rahim CTOC

KLK902 USDOT UTC In Situ Transesterification of Microalgal Oil to Produce Algal Biodiesel
Brian He, Zheting Bi CCVT

KLK904 USDOT UTC Operation, Analysis, and Design of Signalized Intersections: A module for the Introductory Course in Transportation Engineering
Michael Kyte, Maria Tribelhorn CTOC

KLK905 USDOT UTC Calibration of Multi-scale Energy and Emission Models
Ahmed Abdel-Rahim CTOC

KLK914 USDOT UTC Eco-Driving Modeling Environment
Ahmed Abdel-Rahim, Karen Den Braven CTOC

KLK915 USDOT UTC Field Implementation and Testing Eco-Traffic Signal System Applications
Ahmed Abdel-Rahim, Axel Krings, Kevin Chang CTOC

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