TranLIVE

Annual Report | 2014

Transportation for Livability by Integrating Vehicles and the Environment

Prepared for the University Transportation Centers Program
Office of the Assistant Secretary for Research and Technology
U.S. Department of Transportation

Funding period January 1, 2012 through October 31, 2014

In Memory of

Michael Dixon

Michael Dixon

University of Idaho civil engineering professor and TranLIVE collaborator Michael Dixon suddenly and unexpectedly passed away of an apparent heart attack May 7, 2014.

Mike was a vital part of the University of Idaho's TranLIVE transportation research team working within the National Institute for Advanced Transportation Technology (NIATT). Mike's research focused on emerging traffic detection techniques and technologies, intelligent transportation systems and transportation systems modeling. He was an active member of the Transportation Research Board's Committee on Highway Capacity and Quality of Service, and served in several leadership roles on that committee. He collaborated with a number of researchers from around the U.S. and was highly regarded.

He was widely published and was an acting principal investigator on several large research projects. His grant work in progress included: Improving Pedestrian and Bicycle Safety by Identifying Critical Intersections and Street Segments; Modeling Passing Behavior on Two-Lane Rural Highways: Evaluating Crash Risk under Different Geometric Configurations; and Daily Travel Feedback to Encourage Eco-Routing.

Mike taught several key courses on transportation engineering and traffic systems. During his time at the University of Idaho he developed several online training modules and instructional software tools to help students better understand traffic systems design. He was also the current advisor to over 20 undergraduate and graduate civil engineering students.

Mike was both an avid cyclist and winter sports enthusiast and loved taking his family skiing in McCall. He and his children participated in the annual Seattle to Portland Bicycle Classic, one of the biggest recreational bicycle rides in the country. Mike and his family are members of the Church of Jesus Christ of Latter-day Saints. He is survived by his wife, Cecily, and their eight children.

Table of Contents

Transportation for Livability by Integrating Vehicles and the Environment (TranLIVE)
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On the cover: U.S. Department of Transportation Secretary Anthony Foxx behind the wheel of the University of Idaho Vandal formula hybrid racecar. Secretary Foxx visited the University of Idaho in the fall of 2014 for a roundtable discussion with students on the future of the transportation system.

Director’s Letter

TranLIVE: A Time to Look Back and to Look Forward

As we are working on TranLIVE Year-1 annual report, the U.S. Congress is continuing its debate on the newer version of legislation that authorizes our nation’s transportation program. Many of the decisions that will form this legislation deal with how our transportation system will be funded, planned, designed, operated, and maintained. The U.S. Congress will define the research and education program that will support the research to develop new knowledge and technologies that are essential to our future transportation system – TranLIVE is an integral part of this deliberation.

Looking back at what the TranLIVE consortium has accomplished in its first year, we are all proud of the contribution that we have made to the research and education program through the funds we have received from the U.S. Department of Transportation’s University Transportation Centers Program. In this Year-1 report, we look back at the students and faculty that have made our program such a success. By the end of our first year, nearly 200 students, faculty, and staff participated in one or more parts of TranLIVE education, research, workforce development, and technology transfer outreach program.

To provide you with a perspective of what we’ve done during the past year, we present you with a summary of our research activities covering different TranLIVE focus areas such as eco-driving and eco-routing, eco-traffic signal systems, connected vehicle applications, security and survivability of connected vehicle communication architecture, and biofuel technology and production. We also present some highlights of our education, workforce development, and technology transfer outreach activities. Through these presentations we share with you what vehicle technology and applications we have developed to promote a cleaner environment and reduce our dependence on foreign oil.

In TranLIVE, we keep our students at the center of all of our programs, to make sure that we are meeting their needs and are providing them with the tools that they need to become high quality professionals. We provide our students with the opportunity to test their engineering designs and research results in a variety of student competitions. In 2014 our students won first place in International Society of Automotive Engineers (SAE) Formula Hybrid Competition, founded and run by the Thayer School of Engineering at Dartmouth College. Our students also placed third in the annual Society of Automotive Engineers Clean Snowmobile Challenge.

The collaborative activities and accomplishments over the past year provide us with a solid base from which we can continue into the future. I encourage you to read through this report and discover more about what we have done in our first year and how we are continuing to move into the future.

Respectfully yours,

Ahmed Abdel-Rahim
TranLIVE UTC Director

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Josias Zietsman
Texas A&M Transportation Institute

TranLIVE Advisory Board Meeting January 12, 2014 in Washington, D.C.

TranLIVE University Transportation Center UTC Consortium

The University of Idaho in Moscow, Idaho leads the TranLIVE Tier 1 University Transportation Center, which is funded by the Department of Transportation's (DOT) Office of the Assistant Secretary for Research and Technology. The University of Idaho has research at four partner universities, Old Dominion University, Syracuse University, Texas Southern University, and Virginia Polytechnic Institute and State University.

Ahmed Abdel-Rahim
University of Idaho

Mecit Cetin
Old Dominion University

Hesham Rakha
Virginia Polytechnic Institute and State University

Ossama Salem
Syracuse University

Lei Yu
Texas Southern University

University of Idaho | TRI Transportation Research Institute | VirginiaTech Transportation Institute | TSU Texas Southern University | Syracuse University LCSmith College of Engineering and Computer Science

Research

TranLIVE (Transportation for Livability by ntegrating Vehicles and the Environment) is a university research collaboration focused on developing technologies to reduce the environmental impact of the transportation system.

TranLIVE's mission is to achieve the objectives of a cleaner environment and greater energy independence through research dedicated to:

I. ECO-DRIVING AND ECO-ROUTING
II. ECO-TRAFFIC SIGNAL SYSTEMS
III. CONNECTED VEHICLES CYBER SECURITY
IV. BIO AND RENEWABLE FUELS
V. OTHER ASSOCIATED RESEARCH

TranLIVE's mission is accomplished through work derived to address four primary goals:

Goal 1:
Integrate real-time data systems and advanced transportation applications to better manage congestion while minimizing environmental impacts.

Goal 2:
Develop modeling, simulation, and visualization tools that assess energy, environmental, and emission impacts of transportation systems to support transportation decision making at the local, regional, and national levels.

Goal 3:
Increase the number of students in our research and education programs and use advanced curriculum design to enhance the transportation workforce.

Goal 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.

TranLIVE Featured Highlights

Kyoungho Ahn & Hesham Rakha

Developing Eco-Adaptive Cruise Control Systems

Investigator(s): Hesham Rakha & Kyoungho Ahn   Consortium Partner: Virginia Tech

The study demonstrates the feasibility of two eco-driving applications which reduce vehicle fuel consumption and greenhouse gas emissions: an eco-drive system and Eco-Lanes applications. In particular, the study develops an eco-drive system that combines eco-cruise control logic with state-of-the-art car-following models and evaluates Eco-Lanes and SPD-HARM applications and investigates the potential of developing an eco-drive system that combines an ECC system with state-of-the-art car-following models. The system makes use of topographic information, the spacing between the subject and lead vehicle, and a desired (or target) vehicle speed and distance headway as input variables. The study demonstrated that the proposed system can significantly improve fuel efficiency while maintaining reasonable vehicle spacing. One of the test vehicles, a 2011 Toyota Camry, saved 27 percent in fuel consumption with an average spacing of 47 m along the I-81 study section. The study found that the car-following threshold setting significantly affects the fuel economy and the spacing between vehicles.

Furthermore, the study also demonstrated that a dynamic car-following spacing threshold significantly reduces the average vehicle spacing compared to a fixed car-following spacing threshold. The study also evaluated the impacts of variable vehicle power and found that vehicle operations at lower power demands significantly enhance vehicle fuel economy (up to 49 percent). The study finally demonstrated that non-ECC-equipped vehicles can significantly reduce their own fuel consumption just by following a lead ECC-equipped vehicle.

This research also investigated the feasibility of Eco-Lanes applications that attempt to reduce system-wide fuel consumption and GHG emission levels through lane management strategies. The study focused its efforts on evaluating various Eco-Lanes and SPD-HARM applications using the INTEGRATION microscopic traffic simulation software. The study demonstrated that the proposed Eco-Lanes system can significantly improve fuel efficiency and air quality while reducing average vehicle travel time and total system delay.

For this case study, the proposed system reduced travel time, delay, fuel consumption, HC, CO, and CO2 emissions by 8.5%, 23%, 4.5%, 3.1%, 3.4%, and 4.6%, respectively, compared with the base case scenario. The study also examined the feasibility of a predictive Eco-Lanes system. This system predicts the onset of congestion and starts the Eco-Lanes system before congestion occurs. The simulation study found that the 30-minute predictive Eco-Lanes system produced greater reductions in fuel consumption and CO2 emissions compared with the non-predictive Eco-Lanes system.

The study also found that the optimum throttle levels and the optimum eco-speed limits can significantly improve the mobility, energy savings, and air quality of such systems. Furthermore, the study demonstrated that SPD-HARM as an Eco-Lanes application produced reductions in delay, fuel consumption, HC, CO, NO_x, and CO_2 emissions by 7.6%, 6.3%, 23.9%, 26.1%, 17.2%, and 4.4%, respectively, compared with the base case scenario. The t-test results indicated that there were significant benefits to the MOEs when SPD-HARM was operated.

Future research should quantify the potential benefits of using the proposed Eco-Lanes systems on different networks with various vehicle types. Also, further studies are required to characterize the optimum eco-lanes specifications, such as the spatial and temporal eco-lanes boundaries, and to enhance the optimum eco-speed limit algorithms.

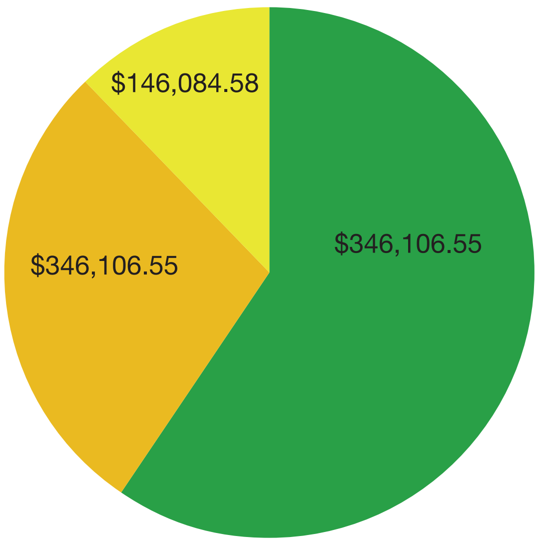
Furthermore, the car-following behavior of non-eco-vehicles should be investigated. Finally, further research is needed to validate the simulation outputs using field tests.

Assesing the Environmental Impacts of Work Zones in Arterial Improvement Projects

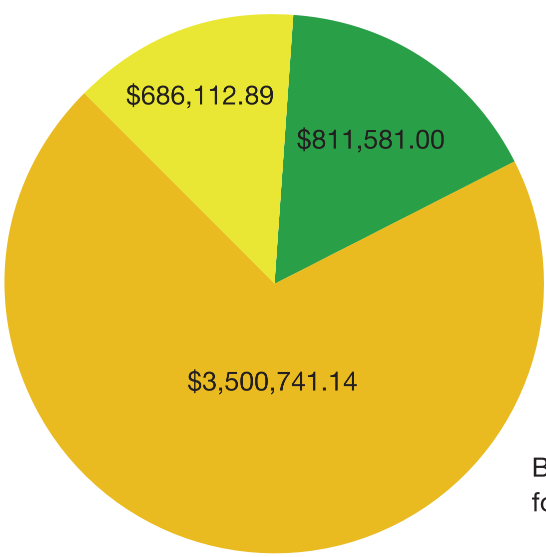
Investigator(s): O. Sam Salem & Sudipta Ghorai
Consortium Partner: Syracuse University

The 2013 Report Card for America's Infrastructure published by the American Society of Civil Engineers (ASCE) reveals that 32% of the country's major arterial network is in "poor or mediocre condition," resulting in an increase of repair and operating cost by $67 billion per year or $324 per motorist. ASCE projected a required investment of $85 billion annually for improving the physical condition of the roads which means a considerable amount of maintenance, repair, and rehabilitation (MRR) activities are on their way. Although preservation treatments help in extending the remaining service life of pavements, they may have substantial environmental impacts due to the acquisition and processing of raw materials, transportation of the materials from extraction to site, manufacturing of the final product, and the use of various equipment during the treatment process. Any energy usage coming from non-renewable fuel sources like diesel, coal, natural gas, gasoline, liquid petroleum gas, and electricity is responsible for greenhouse gas (GHG) emissions which mainly consists of carbon dioxide, methane,
and nitrous oxide.

Accelerated construction techniques are known to have several advantages such as reducing delay and congestion, decreasing safety concerns, and in turn minimizing socio-economic impacts associated with work zones. But it has many disadvantages too, like higher cost, durability issues, design complexity, increased uncertainty, and higher worker fatigue. This research intends to justify the use of accelerated construction from an environmental point of view. Traditional pavement MRR methods (i.e. chip seal, crack seal, fog seal, scrub seal, slurry seal, thin cold mix overlay, thin hot mix overlay, crack and joint seal, full depth slab repair, mud jacking, partial/ full depth joint repair, dowel bar retrofit, diamond grinding and slab replacement) and accelerated MRR techniques (i.e. partial depth reclamation, full depth reclamation, and precast concrete pavement systems) were identified for flexible, and rigid pavements.



Breakdown of Life-Cycle Benefits
for a hypothetical ATCS Application

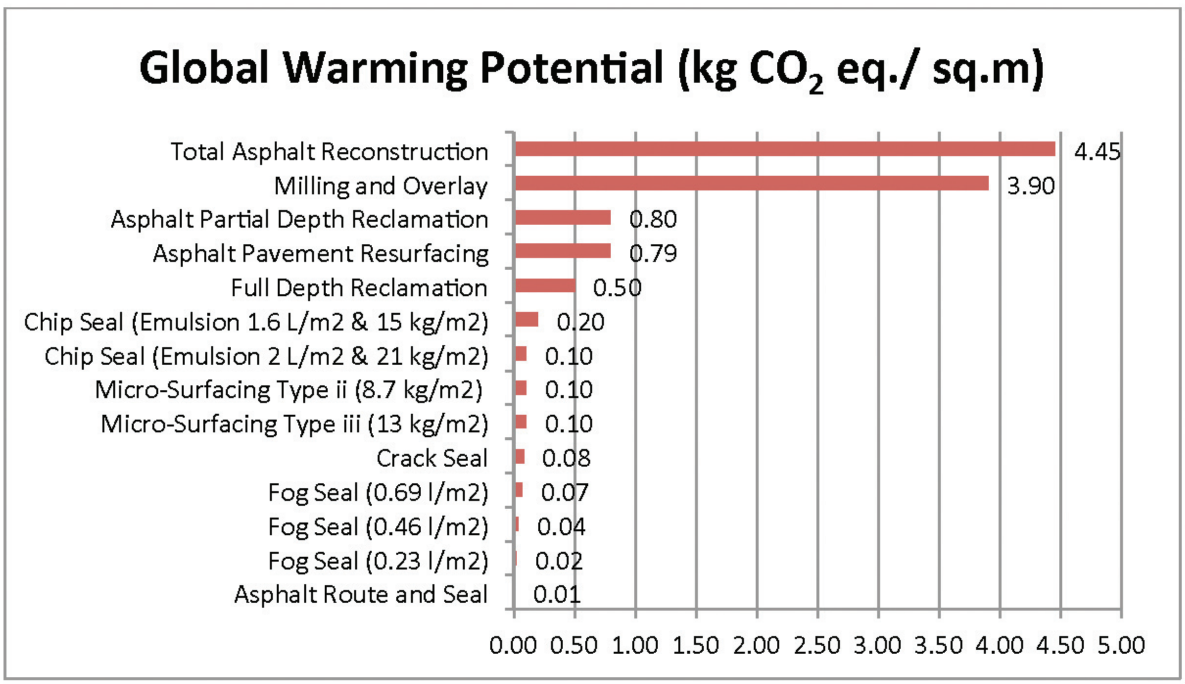


Breakdown of Life-Cycle Benefits
for a hypothetical Ramp Metering Application

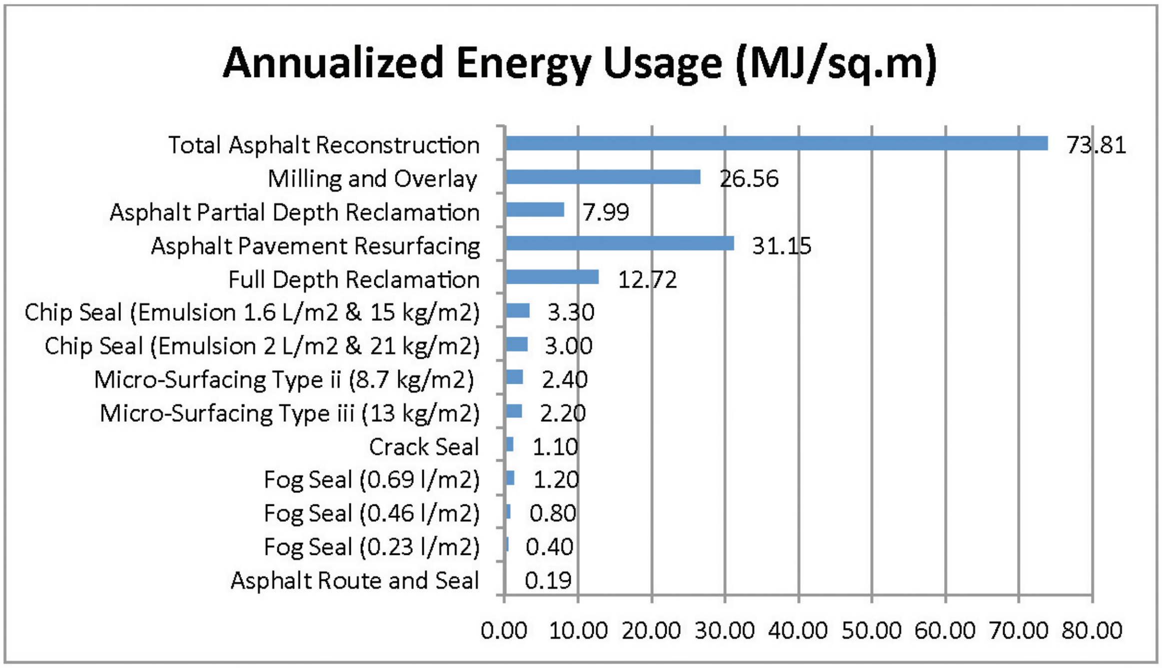
- Travel Time Savings Benefits
- Energy Saving Benefits
- Safety Benefits

Environmental impacts of the most commonly used MRR strategies were calculated in terms of global warming potential (in kg CO2 eq), acidification potential (in moles of H+ eq), eutrophication potential (in kg N eq), ozone depletion potential (in kg CFC-11 eq), and smog potential (in kg O3 eq). Data were obtained from existing life cycle assessment (LCA) studies and calculations were done using LCA software like the Athena Highway Impact Estimator, and GaBi.The treatment processes for flexible and rigid pavements are considerably different due to the structural nature of the pavements. As flexible pavements are much older than rigid pavements, there are more innovative options available for flexible pavement MRR than for rigid pavements. Life cycle assessment results were calculated in two formats: a) annualized impact per square meter of the pavement, and b) impact over the design life of one center kilometer of a pavement. LCA results showed that for flexible pavements, innovative rehabilitation techniques like partial or full depth reclamation have less life cycle environmental impacts than traditional techniques like milling and overlay or total reconstruction. One of the major reasons is that in pavement reclamation techniques the existing asphalt layer is recycled to produce a new stable layer which minimizes the need of raw virgin materials unlike traditional techniques. Again, among maintenance processes, innovative techniques like microsurfacing have lesser resource usage, global warming potential, and energy consumption than traditional processes like chip seal. Minor treatment processes like fog seal, and crack seal have minimum impacts with maximum benefits when the corresponding life extensions are compared. Thus, it was observed that products with lower asphalt content and a lesser heat requirement use less energy and have minimum GHG emissions.

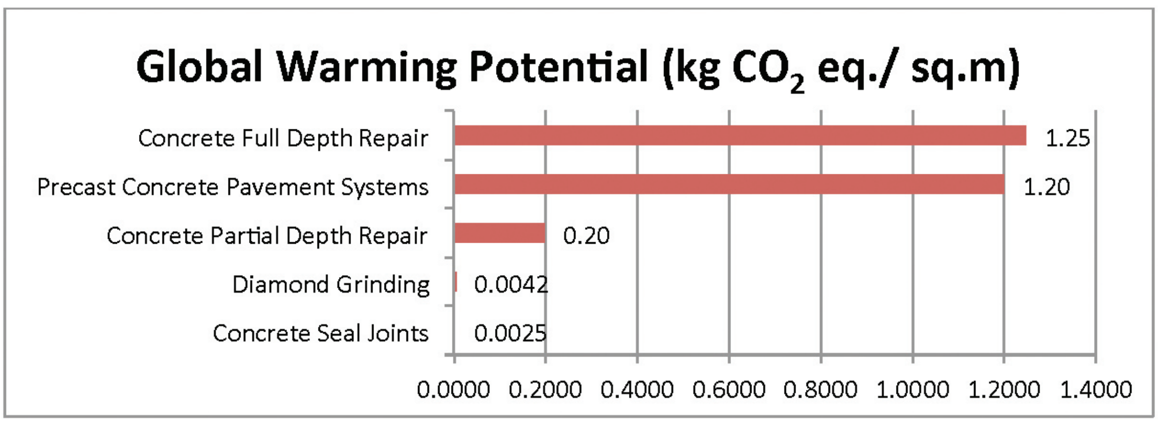
For rigid pavements, all the rehabilitation techniques are comparatively new. The GHG emissions and energy consumption due to materials used, construction equipment, and transportation were found to be similar for both traditional techniques like full depth repair and accelerated techniques like precast concrete pavement systems. Similar to flexible pavements, minor treatment processes like concrete seal joints, diamond grinding, and partial depth repair have much less lifecycle environmental impacts with substantial benefits in terms of life expectancy. Thus, it can be concluded that the DOTs should make maximum utilization of all the treatment processes, and should focus more on the innovative strategies including recycling techniques, to achieve a sustainable arterial maintenance, repair, and rehabilitation plan.



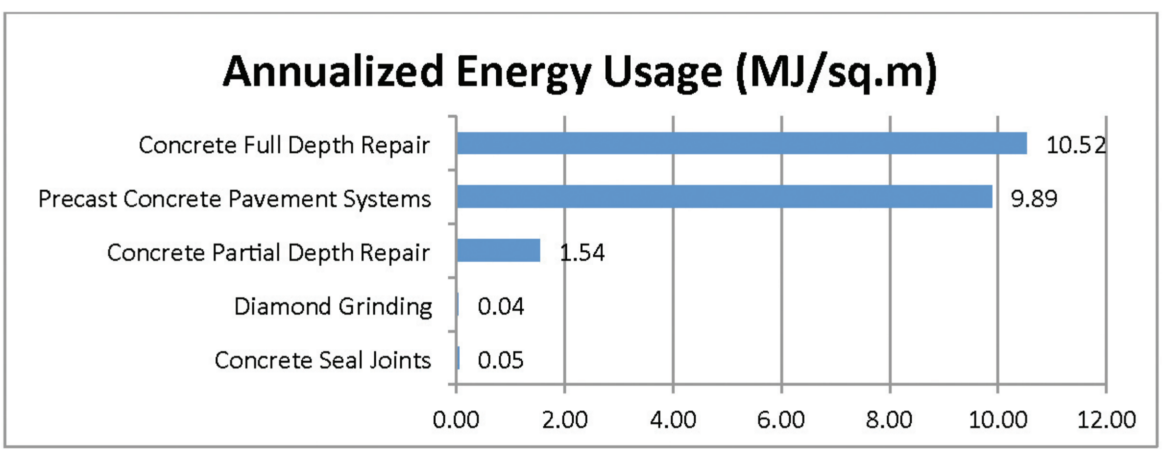
Global Warming Potential for Flexible Pavement MRR Techniques



Annualized Energy Usage for Flexible Pavement MRR Techniques



Global Warming Potential of Rigid Pavement MRR Techniques



Annualized Energy Usage of Rigid Pavement MRR Techniques

Green Cooperative Adaptive Control Systems in the Vicinity of Signalized Intersections

Investigator(s): Hesham Rakha & Raj Kishore Kamalanathsharma
Consortium Partner: Virginia Tech

The research presented in this report provides a comprehensive analysis of using advanced signal timing information as well as information about speed and spacing of surrounding vehicles to optimize vehicle fuel consumption levels. This system was modeled, tested and evaluated in multiple simulation environments. The report also analyzed the previous and concurrent research efforts in the field of advanced eco-driving, using signal timing information. Multiple literatures were reviewed on optimizing fuel consumption at signalized intersections but most of them lacked a comprehensive analysis or even an explicit optimization function that incorporates microscopic fuel consumption models. Most researchers assumed fuel consumption to be tied directly with vehicle acceleration levels and used that as a control to optimize fuel consumption. This claim is not necessarily true and depends on a variety of other parameters. The Algorithm Development chapter described in brief how the algorithm is modeled to include multiple constraints that are based on advanced signal information, vehicular and roadway parameters.

The report also analyzes vehicle-specific modeling of Eco-Speed Control (ESC) where the system was calibrated to 30 top-sold automobiles in the US, which are attributed to six different Environmental Protection Agency (EPA) classes. MATLAB-based simulation analysis was done to test the sensitivity of the model with respect to vehicle class, bounding speed-limits and green-time delay for optimization of vehicle trajectories. The Eco-Cooperative Adaptive Cruise Control (ECACC) system was found to be sensitive to these three criteria and fuel savings were measured as absolute and relative values.

Class-based analysis suggested that absolute fuel savings is highest in light-duty trucks and lowest in compact cars, whereas the relative fuel savings is vice-versa. However, the absolute and relative trends matched for other variables such as approach speed and green-time delay. A higher speed-limit caused greater fuel savings and a higher green-time delay caused lesser fuel savings. The green-time delay is defined as the time differential between the actual green time and the time to intersection of the vehicle prior to optimization.

Agent-based modeling of Eco-Speed Control was performed to test the performance of the system on a fully-functional signalized intersection from downtown Blacksburg, Virginia. The traffic signal is a single lane, four legged intersection. The test uses real estimates of approach volumes and signal timings. Approach volumes considered correspond to various fractions of the current evening peak demand up to 175 percent, so as to have a scenario for over-saturated conditions (v/c > 1.0). The intersection was simulated at a microscopic level including specific features such as grade and lane geometry. Reactive agents were used to simulate vehicles that run on ESC logic with respect to changing signal conditions. Two measures of effectiveness were considered – the average fuel consumption and the average travel-time for the 400 meter vicinity of the intersection. The MOEs categorized according to the approach and also the overall intersection MOE. Washington Street is the minor approach and Main Street is the major approach.

The following are the simulation results:

1. Eco-speed control is able to reduce the overall fuel consumption of vehicles by around 30 percent in the vicinity of intersections.
2. The increase in average travel-speed for all the cases was 210 percent.
3. Fuel savings were greater for the major street than the minor street for the test intersection because of the short red-time for the major approach.
4. Lower volumes yielded more fuel savings and higher percentage increase in average travel-speed.
5. The biased minor-street volumes caused the fuel savings for the higher-volume leg to be lower. This is because of the extended time to intersection caused by queuing.
6. Fuel savings and percentage increase in average travel speed were comparable for the major approaches since they had comparable demands.

While these conclusions present interesting inferences regarding the agent-based simulation tool, further enhancements are warranted from this study. This includes simulating multiple intersections and signalized corridors which run on coordinated and uncoordinated signals. The simulation tool presented in this paper presents a comprehensive and novel approach to test eco-driving strategies such as the one used in this paper in a simulation environment owing to its agent-based logic and ability of vehicle agents to react to external stimulants. A model validation is also warranted as a future work when actual field experiments can be done using the proposed eco-speed control approach.

1

Eco-Driving and Eco-Routing

Developing an Eco-Routing Application

Investigator(s): Hesham Rakha & Kyoungho Ahn
Consortium Partner: Virginia Tech

The study develops eco-routing algorithms and investigates and quantifies the system-wide impacts of implementing an eco-routing system considering two large metropolitan networks, namely downtown Cleveland and Columbus, OH. Recently navigation tools and trip planning services have introduced a vehicle routing option that is designed to minimize vehicle fuel consumption and emission levels, known as eco-routing. The eco-routing option selects the most fuel efficient route, which is not necessarily the shortest distance or the fastest travel time route. Consequently, there is a need to develop such systems and test them on large-scale networks considering different levels of system market penetration.

In this study, two eco-routing connected vehicle (CV) algorithms are developed: one based on vehicle sub-populations (ECO-Subpopulation Feedback Assignment or ECO-SFA) and another agent-based system that considers individual drivers (ECO-Individual Feedback Assignment or ECO-IFA). Both approaches initially assign vehicles based on fuel consumption levels for travel at the facility free-flow speed when the network is empty and no information is available. Subsequently, fuel consumption estimates are refined based on experiences of other vehicles within the same class by communicating their experiences to the Cloud. This stochastic, multi-class, dynamic traffic assignment framework was demonstrated to work for both test scenarios (ECO-SFA and ECO-IFA).
The study also quantifies the system-wide impacts of implementing a dynamic eco-routing system, considering various levels of market penetration and levels of congestion in downtown Cleveland and Columbus, Ohio, USA. The study concludes that eco-routing systems can reduce network-wide fuel consumption and emission levels in most cases; the fuel savings over the networks range between 3.3% and 9.3% when compared to typical travel time minimization routing strategies. The study demonstrates that the fuel savings achieved through eco-routing systems are sensitive to the network configuration and level of market penetration of the eco-routing system. The results also demonstrate that an eco-routing system typically reduces vehicle travel distance but not necessarily travel time. The study demonstrates that the configuration of the transportation network is a significant factor in defining the benefits of eco-routing systems. Specifically, eco-routing systems appear to produce larger fuel savings on grid networks compared to freeway corridor networks. The study also demonstrates that different vehicle types produce similar trends with regard to eco-routing strategies. Finally, the system-wide benefits of eco-routing generally increase with an increase in the level of the market penetration of the system.

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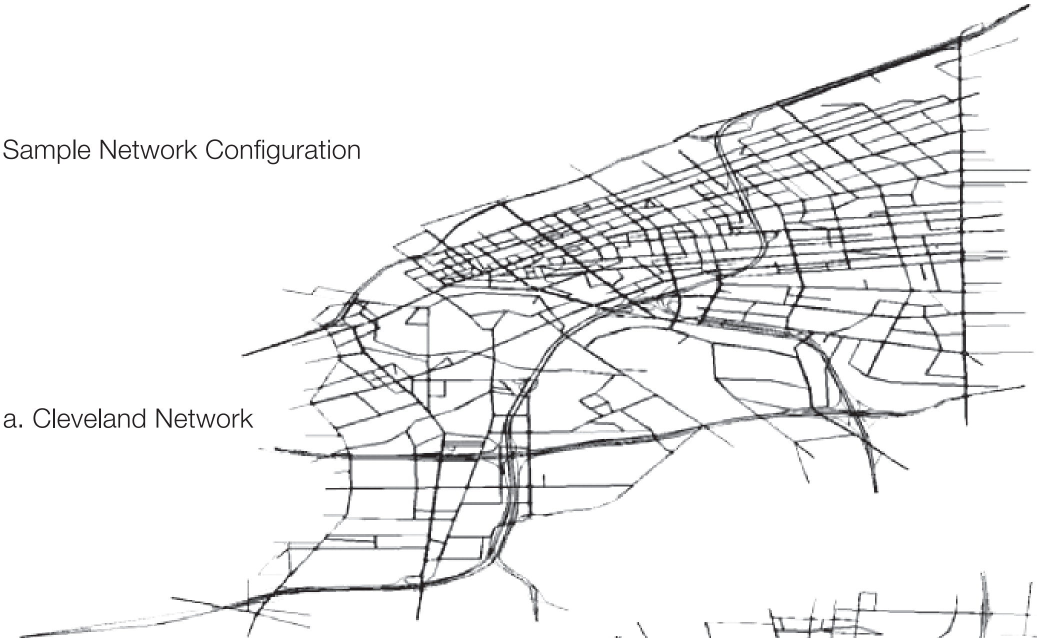
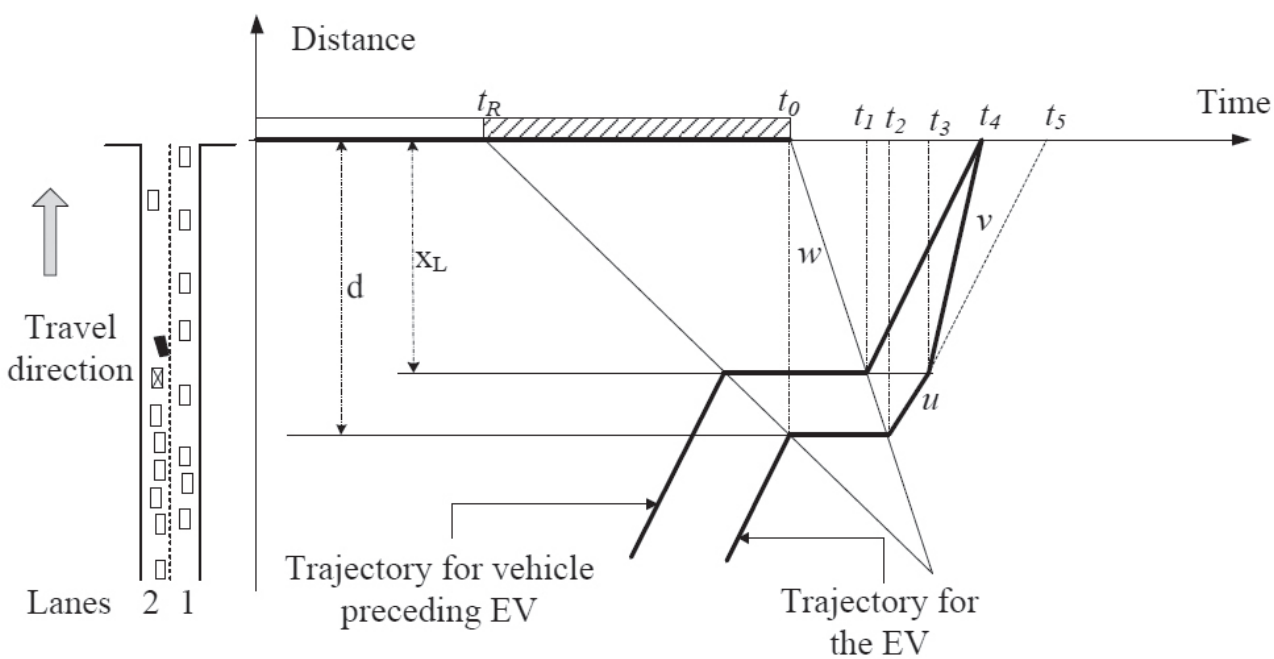
Sample Network Configuration



a. Cleveland Network

b. Columbus Network



Shock wave profile of a single queue at a traffic light and the trajectories of the EV and preceeding vehicle.

Improving Travel Times for Emergency Response Vehicles: Traffic Control Strategies Based on Connected Vehicles Technologies

Investigator(s): Craig Jordan & Mecit Cetin   Consortium Partner: Old Dominion University

This research is focused on developing and evaluating new traffic control strategies to enable emergency response vehicles (EVs) to travel throughout transportation networks as quickly as possible while the disruption to the rest of the traffic is kept to a minimum. Providing the best possible route or trajectory for an EV depends on the traffic conditions, the type of roadway, and other relevant factors. For instance, under light traffic on multilane highways, vehicles equipped with Vehicle-to-Vehicle (V2V) communications can be alerted to clear a particular lane to allow the EV to pass by at its desired speed. If the lanes are wide enough or there is a wide shoulder, vehicles can also be directed to move to the shoulder to provide the EV an unobstructed path. However, under congested conditions on roadways with narrow lanes, enabling the EV to traverse the road at high speeds may not be trivial since there is no obvious solution to clear a lane for the EV.

This research evaluates two concepts, the first involved navigating EV through congestion by applying platoon split concept through sending maneuvering information to background traffic on the network. It involves stopping traffic on one lane at a critical point to allow the EV to change lanes so that it can travel unimpeded through the intersection. The second concept involved a strategy of evaluating the order of traffic signal preemption. This strategy is designed to assist EV before they reach congested signalized intersections by preempting the downstream traffic signals using a specific order that will allow downstream vehicle queues to discharge prior to the arrival of an EV. The evaluation of both strategies was performed in a microscopic traffic simulator, which provides flexibility in testing environments and duplication of traffic patterns for strategy comparison. The proposed strategies are evaluated in microscopic simulation software (e.g., VISSIM).

The application of the platoon split concept was illustrated for two scenarios. The scenarios investigated splitting the vehicle queue on one lane at a critical location so that an EV could proceed at its desired speed while the disruption to background traffic was minimized. The formulations were developed based on the shock wave theory of traffic flow to predict the queuing behavior at signalized intersections.

The proposed method was simulated in VISSIM for evaluation.The results from applying platoon split concept indicated that this strategy can shorten the trip times significantly for EV for the one intersection and two intersection scenarios. The simulation results showed time saving percentages approached the theoretical maximum values (ranging from 16% to 34% depending on the relative speeds of the EV and other vehicles) as the distance from the EV (when in the queue) to the intersection (d) is increased at 100% market penetration rate. Considerable travel time savings are expected when market penetration rates are as low as 20%.

The application of the signal preemption concept was illustrated for three scenarios. The scenarios investigated preempting the traffic signals all-at-once, sequentially, and determined by queue length. The formulations were developed based on the shock wave theory of traffic flow to predict the queuing behavior at signalized intersections. The proposed methods were simulated in VISSIM for evaluation.

The results of the second strategy indicated that queue length determined preemption order can shorten the trip times for EV over the other proposed strategies. The simulation results showed EV travel time savings of approximately 2 seconds over the all-at-once strategy and 88 seconds over the sequential strategy. In addition, the delay incurred by background traffic is significantly lower for the queue length determined preemption order strategy than the all-at-once strategy.

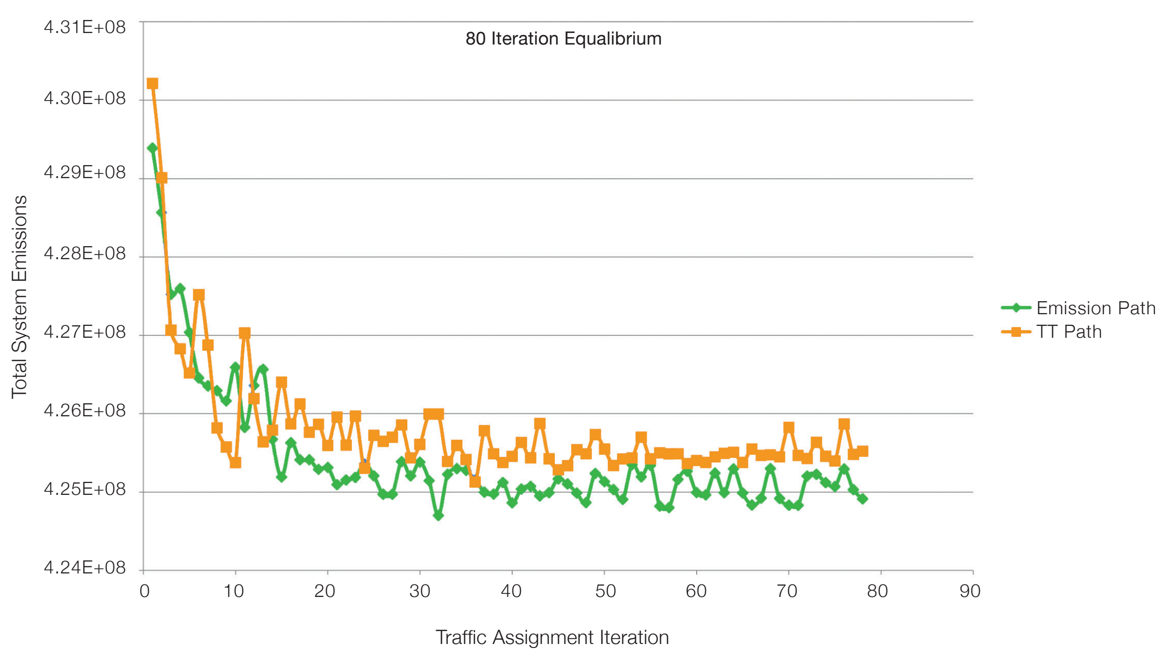
Optimizing Freight Routes and Modes to Minimize Environmental Impacts: Integrating Truck Emissions Cost in Traffic Assignment

Investigator(s): R. Michael Robinson & Peter Foytik Consortium Partner: Old Dominion University

Adverse impacts of greenhouse gasses (GHG) and the imperative for reducing the production are well established. The transportation sector accounts for 28% of all U.S. GHG production. Heavy-duty vehicles (e.g., large freight trucks) account for nearly 1/5 of the U.S. total and this fraction is growing.Most current efforts emphasize one of four areas: (1) engineering solutions to improve fuel economy or reduce emissions, (2) shifts to other transport modes, (3) improved logistics management to reduce the movement of partially full or empty containers, and (4) reduced travel costs for individual trucks. A small fraction of studies have assessed modifications to route choice considerations as a means of improving fuel economy of individual vehicles. These studies suggest the potential gains are very small.

In this study, the potential gains of emissions-based route choice are assessed by testing a simplified measure of emissions within a regional macroscopic travel demand model. The emissions measure is updated and utilized as part of the path cost in a Frank-Wolfe algorithm. This measure of emissions is not intended to be a more accurate measure of emissions but a relative measure that can be used to reflect paths of potentially less emissions based on the updated congestion results of the traffic assignment. Results are checked with the U.S. Environmental Protection Agency Motor Vehicle Emissions Simulator (MOVES) as a way to verify potential emissions reduction.

A simplified emissions calculation was developed based on a binning method using the information from the input tables in MOVES and an aggregate measure of vehicle specific power (VSP). This calculation was executed within the traffic assignment Frank-Wolfe iterations, providing an up to date value of emissions per segment. With an updated emission value per segment the path cost equation was amended to include emissions as an added cost to congested travel time. Using the emissions plus travel time path cost, the model was run and tested with truck volume to see if it would converge. Results showed that emissions values were too large to allow good convergence, but reducing the size of emissions by dividing the emission values by a flat static value could be used in the model with results that would converge. The total truck emissions, as calculated in the traffic assignment, were recorded for a scenario where trucks used a path cost of emission plus travel time and passenger cars used path costs of travel time only. They were also recorded for a scenario where both trucks and passenger cars used a path cost of travel time only. Results from both scenarios were run with the MOVES emissions model and compared. The methodology described was able to reduce total system truck emissions by a small percentage (0.61%, 88.8 tons). The study results showed that the proposed methodology can contribute to reducing emissions.



Comparison of Total System Emissions per traffic assignment iteration for the scenario where trucks use emission in path cost and cars use travel time (TT) and the scenario where trucks and cars use travel time only for path costs.

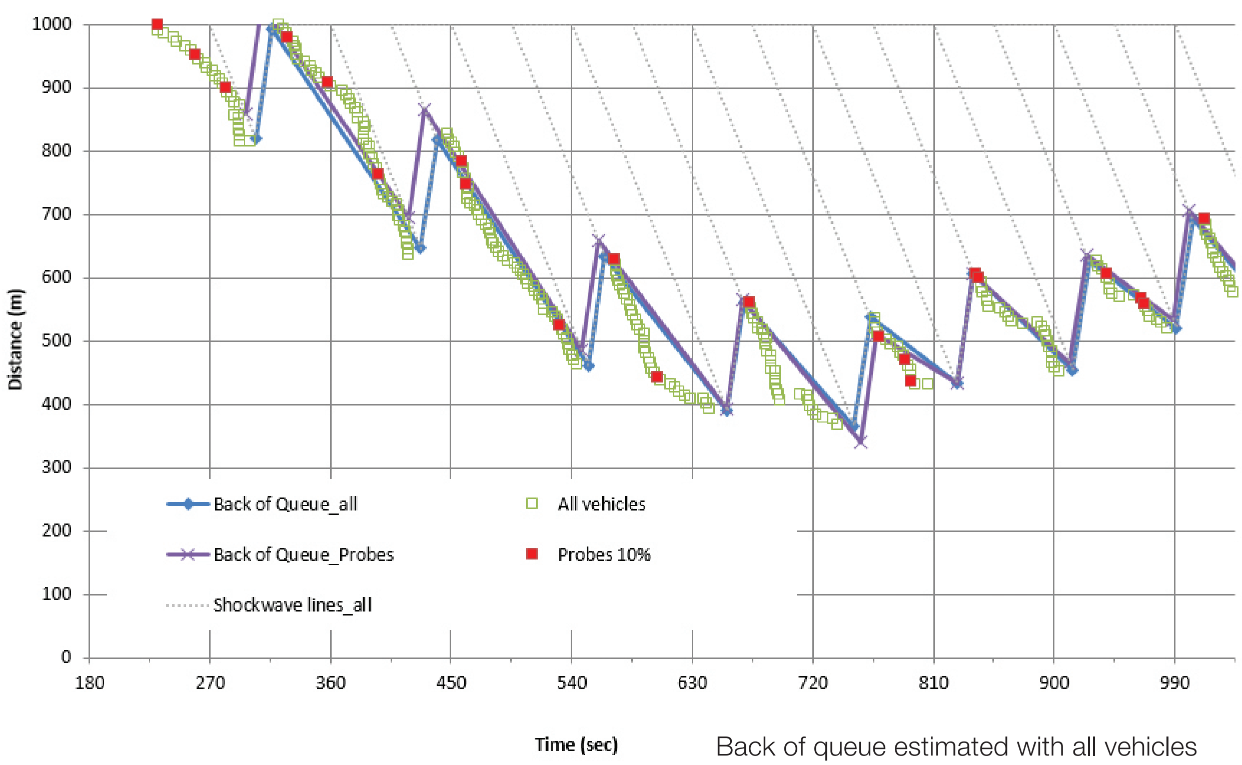
2
Eco-Traffic Signal Systems

Real-Time Prediction of Queues at Signalized Intersections to Support Eco-Driving Applications

Investigator(s): Mecit Cetin & Ozhan Unal   Consortium Partner: Old Dominion University

For signalized intersections, queue length is one of the most important performance measures. Knowing the evolution of queue lengths over time and space allows quantifying system performance and improving signal operations, and supports eco-driving and eco-signals applications. Previously, researchers estimated the average queue length at traffic signals based on loop detector data and signal timing information. This study is focused on estimating queue lengths using the information provided by probe vehicles. As more vehicles become equipped with location tracking and communications systems, they will provide new opportunities to observe the transportation networks more effectively. The United States Department of Transportation's Connected Vehicle program is a significant effort to make the vision of seamless vehicle-to-vehicle and vehicle-to-infrastructure communication a reality. Within this vision, vehicles will be aware of their own locations in the transportation systems and will exchange useful information with other vehicles as well as with the infrastructure. By tracking the positions of these "probe" vehicles along roadway segments a wealth of information is generated to precisely characterize traffic flow dynamics. This in turn allows the system operators to improve system efficiency by taking relevant control actions (e.g., retiming traffic signals, responding faster to incidents).

In this study, the time and space coordinates of those probe vehicles going through signalized intersections are utilized to predict the back of the queue profile. For a single intersection, prediction models are developed where both over-saturated and under-saturated conditions are considered. The shockwave theory (i.e., the Lighthill-Whitham-Richards theory) is used to estimate the evolution of the back of the queue over time and space from the event data generated when probe vehicles join the back of the queue. An analytical formulation is developed for determining the critical points required to create time-space diagrams to characterize the queue dynamics. These critical points are used to estimate the queue lengths. The formulation is tested on the data obtained from traffic simulation software VISSIM. It is found that the shockwave-based formulation is effective in estimating queue dynamics at signalized intersections for under- and over-saturated conditions even with a relatively low percentage of probes (e.g., 10-20%) in the system. For example, under the oversaturated conditions simulated, the error is less than ±10% in more 90% of the cycles when the market penetration of probe vehicles is 15%. The table and Figure below show sample results when the intersection is oversaturated.



Back of queue estimated with all vehicles and 10% probes (input volume 1150 vph).

Connected Vehicles Cyber Security

Security And Survivability Of Real-Time Communication Architecture For Connected-Vehicle Eco-Traffic Signal System Applications

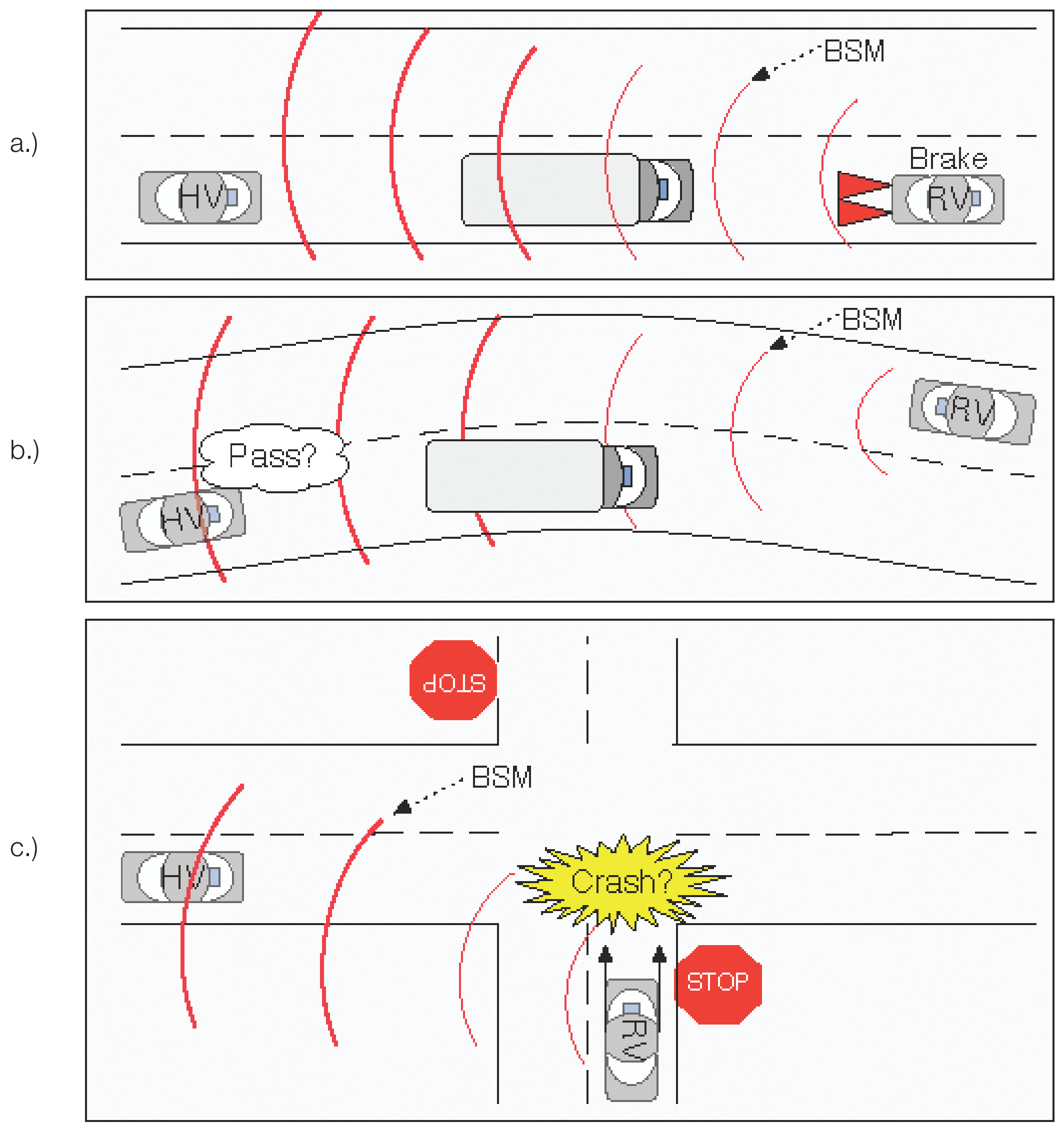
Investigator(s): Axel Krings, Ahmed Serageldin, Ahmed Abdel-Rahim, and Michael Dixon
Consortium Partner: University of Idaho

Connected vehicle safety applications are designed to increase situational awareness and reduce or eliminate crashes through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmission that supports: driver advisories, driver warnings, and vehicle and/or infrastructure controls. These technologies may potentially address up to 82 percent of crash scenarios with unimpaired drivers, preventing tens of thousands of automobile crashes every year. Dedicated short-range communications (DSRC) provides the critical communications link for V2V and V2I crash avoidance and safety applications that can save lives by warning drivers of an impending dangerous condition or event in time to take corrective or evasive actions. It is obvious that such critical safety applications are directly affected by any degradation of communication reliability. Such degradation may be the result of adverse effects on the signals implementing communication, but it may also be the result of malicious act. Given the fact that surface transportation is a critical infrastructure, that it is a safety critical application, and that any fault of benign or malicious nature could have far-reaching consequences, the security and survivability of connected vehicle communication infrastructure including DSRC networks are of paramount importance. The objectives of this work are to increase reliability and survivability of DSRC Safety Applications, considering benign faults and malicious attacks. This is to be done without introducing mechanisms deviating for the existing standards. The main focus of the research is on the effects of malicious act. However, any mechanisms that increase the resilience against attacks will also benefit the reliability under normal operation.

By exchanging vehicle-based data such as position, speed, and location, V2V communications aid in the assessment of threats and hazards with a 360 degree awareness of the position of other vehicles and the threat or hazard they present; calculate risk; issue driver advisories or warnings. Although V2V communications uses diverse message types, the most important message for safety applications is the Basic Safety Message (BSM) as defined in the SAE J2735 Message Set Dictionary Standard. Due to the nature of wireless communication, however, BSMs used in V2V communication and control infrastructures are vulnerable to malicious acts ranging from jamming to direct physical manipulation. This report presents the findings from our investigation into the reliability of DSRC Safety Applications in the presence of malicious act. Several malicious scenarios were considered, including different jamming types, possibly in conjunction with humanly induced actions that cause hazards, e.g., the attacker causing a hazard while jamming a BSM to prevent communication between vehicles affected by the hazard.

This research demonstrates how message dissimilarity and channel redundancy can be used to overcome the effects of malicious act. While the degree of redundancy is general, i.e., not fixed, specific redundancy levels are demonstrated and analyzed. The dual and triple-redundant schemes presented in this report enable channels with higher power ratings to communicate critical BSM safety application data with a higher-level of resilience to jamming attacks. Based on our research, we describe a new safety application communications architecture that does not deviate from and, therefore, can be efficiently incorporated into existing standards.

Selected crash scenarios analyzed as part of the study



4 Bio and Alternative Fuels

Pyrolysis Bio-Oil Upgrading to Renewable Fuels

Investigator(s): Armando McDonald, David McIlroy, Yinglei Han, and Blaise-Alexis Kengne
Consortium Partner: University of Idaho

This study aims to upgrade wood biomass pyrolysis bio-oil into transportation fuels by catalytic hydrodeoxygenation (HDO). Catalysts with high activity and selectivity are thereby highly desired in the upgrading process. Nickel (Ni) and ruthenium (Ru) supported on conventional silica gel and alumina gel supports along with novel silica nanosprings (NS) supports were successfully synthesized and studied as catalysts for bio-oil HDO. The catalytic behaviors of all the catalysts were first tested on model compounds, phenol and guaiacol, for pyrolysis bio-oil. The Ni-NS was shown to deoxygenate phenol to hydrocarbons (mainly cylcohexane) at 300oC and 400 psi H2 pressure and performed better than conventional supported Ni catalysts. The Ru-NS performed better than the Ni-NS catalysts as well as conventional supported Ru catalysts. The Ru-NS catalysts were shown to be stable without loss of activity even after five subsequent phenol HDO treatments. To upgrade pyrolysis bio-oil, first the bio-oil needs to be fractionated into water soluble (WS) and water insoluble (WIS) fractions. The WS fraction can be successfully HDO treated to hydrocarbons and alcohols. The WIS bio-oil fraction requires a two-step process to minimize coke formation on the catalyst which is (i) hydrocracking the oligomeric bio-oil components to monomers and dimers using a commercial catalyst at 400 psi H2 pressure and 200oC and (ii) then a HDO treatment of the hydrocracked bio-oil to hydrocarbons at 300oC. Results from bio-oil catalytic hydrogenation revealed that mainly furans, ketones, and aldehydes in water soluble bio-oil were reduced to their corresponding alcohol. Furthermore, the organic bio-oil fraction was successfully hydrocracked into small aromatic and aliphatic compounds which can easily be upgraded to hydrocarbons.

Yinglei Han and Armando McDonald

In Situ Transesterification of Microalgal Oil to Produce Algal Biodiesel

Investigator(s): B. Brian He and Zheting Bi   Consortium Partner: University of Idaho

Research on processing microalgae into algal biofuels is a needed step for commercialization. This study aimed at exploring a one-step processing technology that combines lipid extraction and transesterification in a single step or in situ transesterification. Specifically, the effects of process parameters on the process efficiency were investigated using whole microalgae as the feedstock. With the model microalga Schizochytrium limacinum, experiments were performed on the effects of lipid to methanol molar ratio (sRatio; 1:50, 1:75 and 1:100), operating temperature (170°C, 210°C, 250°C, and 290°C), reaction time (30, 60, 90, and 120 minutes), and initial pressure of CO2 (0 psig and 200 psig of CO2) based on a factorial experimental design. All experiments were carried out in a batch reactor system with precise temperature control. The content of microalgal methyl esters, the targeted product in the mixture after reaction, was analyzed by a gas chromatography-mass spectrometry (GC-MS). The product yield and the product selectivity were used as the indicators for process efficiency.

The Batch Reactor System

Reactor Assembly

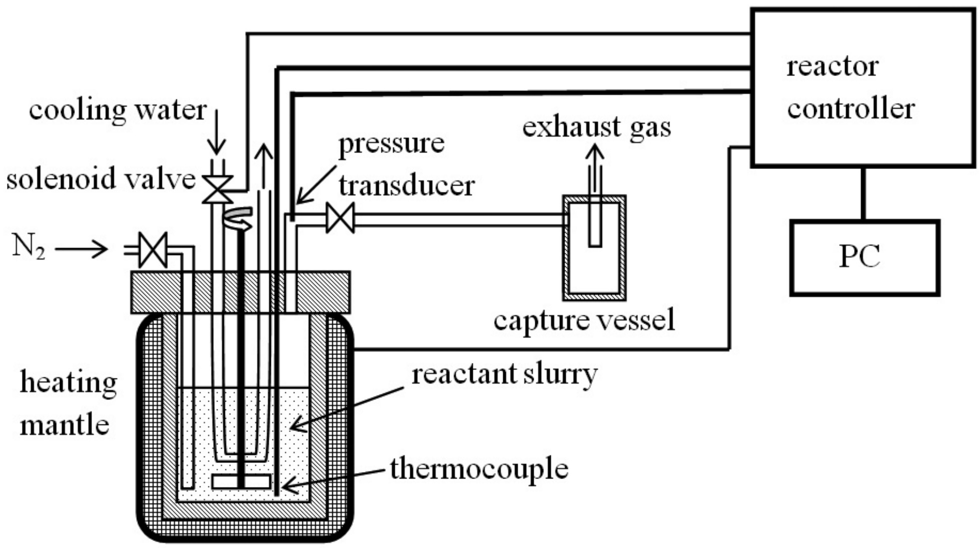
The Chamber

The conditions for optimum product yield and/or product selectivity were inconclusive. Preliminary statistical analysis on the experimental data did not show an optimum point; instead, multiple points of higher yield and/or selectivity can be found under the interactive effect of the process parameters. It was found that the operating temperature and the reaction time are the most influential process parameters in the in situ transesterification of the microalga in sub-/supercritical methanol with no catalyst application. The effects on the process efficiency were collectively contributed by the combinations of these two process parameters.

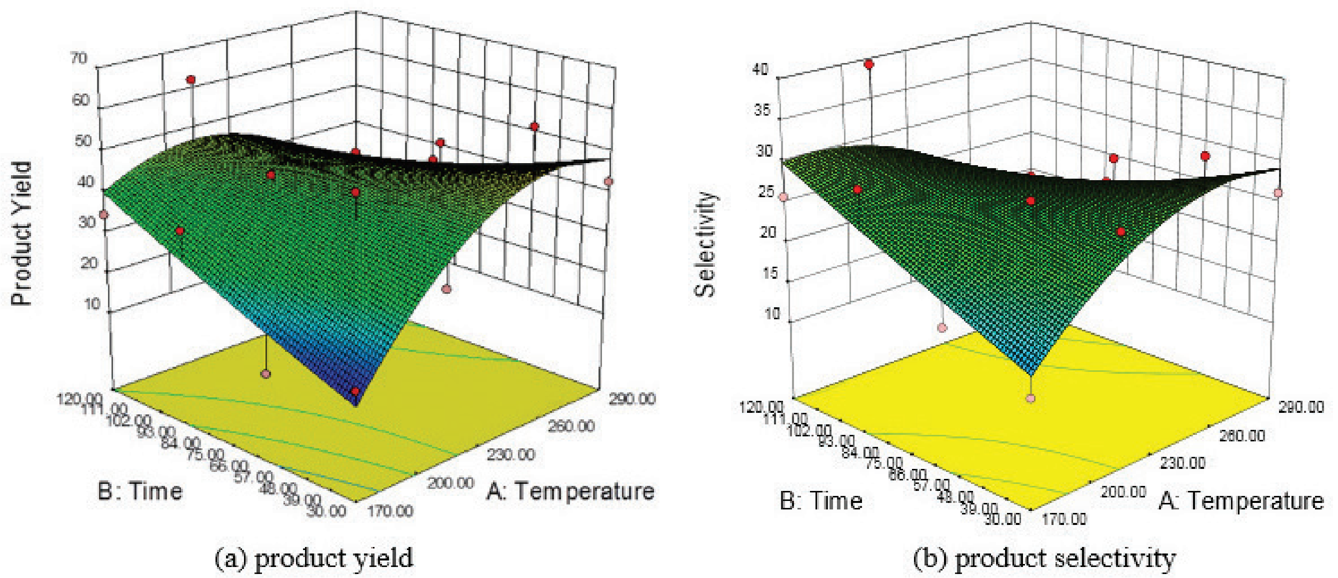
To obtain satisfactory product yields and/or selectivities, the temperature and time combinations are either lower operating temperature (210°C) and longer reaction time (120 minutes) or higher operating temperature (290°C) and short reaction time (30 minutes). The decision on choosing the optimum conditions for practical applications, therefore, depends also on other parameters such as the productivity (short reaction time) or the requirement for utility availability, such as high temperature media for heating. The final decision should be made ultimately by optimizing the system based on the overall capital and operational costs.

A product yield of 68.7% was achieved after 60 minutes at 210°C with a selectivity of 35%. A similar product yield of 68.6% but higher selectivity of 46.8% was obtained after 30 minutes at 250°C.

The lipid-to-methanol molar ratio (sRatio) is an important parameter for lipid extraction, but its effects on product yield were found insignificant between the levels of sRatio due to the higher ratios tested in this study. The addition of carbon dioxide (CO2) as a co-solvent showed a noticeable influence on the processing in preliminary investigations; however, further investigation did not reveal significant effects on the overall in situ transesterification process. This is likely because not all operating conditions reached the supercritical pressure of CO2 (7.4 MPa or 1,073 psig), thus resulting in an insignificant effect from the subcritical CO2.



Reactor Schematic Diagram



Surface response analysis of the product yield and selectivity of microalgal esters via in situ transesterification with sRatio 1:75.

5 Other Associated Research

Exploring Image-Based Classification to Detect Vehicle Make and Model

Investigator(s): Jeffrey Flora, Mahbubul Alam, Amr Yousef, Khan Iftekharuddin
Consortium Partner: Old Dominion University

The goal of this work is to improve the understanding of the impact of carbon emissions caused by vehicular traffic on highway systems. In order to achieve this goal, this work obtains a novel pipeline for vehicle segmentation, tracking and classification by leveraging techniques in computer vision and machine learning using the existing Virginia Department of Transportation (VDOT) infrastructure on networked traffic cameras. This vehicle segmentation and classification data can be used to obtain a real-time estimation of carbon emissions. The VDOT traffic video is analyzed for vehicle detection and segmentation using an adaptive Gaussian mixture model algorithm. The segmented vehicles are tracked using speeded up reduced feature (SURF) methods. The morphological properties and histogram of oriented features are derived from the detected and segmented vehicles. Finally, vehicle classification is performed using a multiclass support vector machine classifier. The resulting classification scheme offers an average classification rate of 85% under good quality segmentation.

This work constitutes the first step in estimating carbon emission for highway traffic. In the subsequent steps, we need to extract additional vehicle information (e.g., type, model), speed, and other relevant parameters and use this information for EPA's Motor Vehicle Emissions Simulator (MOVES) or similar tool to estimate the carbon emission. We also need to work on more challenging weather conditions as well as nighttime scenarios to make this tool applicable to real life application.

A Study on the Impact of Parameter Uncertainty on the Emission-Based Ranking of Transportation Projects

Investigator(s): Umama Ahmed and ManWo Ng
Consortium Partner: Old Dominion University

With the growing concern with air quality levels and, hence, the livability of urban regions in the nation, it has become increasingly common to incorporate vehicular emission considerations in the ranking of transportation projects. Network assignment methods have proven invaluable in the characterization of system level emissions. The estimation of these regional air quality impacts has been typically based on the assumption of determinism. That is, model parameters in network assignment methods are typically assumed to be known with complete certainty. In this research, the assumption of determinism is relaxed and the impact of trip table/demand uncertainty and road capacity uncertainty is examined. In addition to emissions as the project selection criterion, the classical total system travel time measure is also considered. Based on extensive simulations, our results indicate that the impact of uncertainty is limited. However, at the same time, it is to be emphasized that the findings in this study are preliminary in nature and might not necessarily generalize to other settings than the ones considered in this report.

Progress in Catalytic Ignition Fabrication, Modeling and Infrastructure: Part 1 Catalytic Ignition Studies

Investigator(s): Judi Steciak, Steve Beyerlein, Ralph Budwig, Dan Cordon, and David McIlroy
Consortium Partner: University of Idaho

Platinum has been recognized as a viable combustion catalyst for use in transportation engines operating at fuel-lean conditions. Its change in electrical resistance with temperature has been used to measure light-off temperatures and rates of heat generation for various fuel-oxygen mixtures at the University of Idaho. In an attempt to maximize the surface area for these reactions to occur, platinum-coated nanosprings have been manufactured. A reliable method of determining an effective temperature-dependent temperature coefficient of resistance (□(T)) for the nanosprings assembly has been developed and verified using pure platinum. Measured values of □(T) for platinum were matched against literature data at 373 and 1100 K. A linear fit was assumed for the gap between these temperatures; measurements made with platinum at intermediate temperatures were in good agreement. Using the same methodology, □(T) for the nanosprings assembly will be determined, which will allow for further research of the nanosprings in catalytic combustion.

Progress was made in measuring the temperature coefficient of thermal resistance. Thermal shielding improved results at high temperatures. Convective mixing was implemented to improve low temperature results. The temperature coefficient of thermal resistance is needed to measure the catalyst temperature at which surface reactions initiate.

A separate report was prepared on the development of a multi-zone engine model simulated using MATLAB software.

Progress in Catalytic Ignition Fabrication, Modeling and Infrastructure: Part 2 Development of a Multi-Zone Engine Model Simulated Using Matlab Software

Investigator(s): Jeremy Cuddihy and Steve Beyerlein Consortium Partner: University of Idaho

A mathematical model was developed for the purpose of providing students with data acquisition and engine modeling experience at the University of Idaho. In developing the model, multiple heat transfer and emissions models were researched and compared before being implemented in the final model. It was decided that empirical methods would be used to predict engine performance facets due to their simplicity, and would be later modified, or adjusted, to fit the test results.

In an attempt to improve the accuracy of the MATLAB (Matrix Laboratory) model, specific heats were modeled as a function of temperature, friction effects were modeled as a function of engine speed (RPM), valve opening and closing was included, and emissions predictions were included based on a two-zone approach. Although the model is in the process of being validated, preliminary comparisons with engine manufacturer's data has shown promising results.

A High-Speed Trapezoid Image Sensor Design for Continuous Traffic Monitoring at Signalized Intersection Approaches

Investigator(s): Suat Ay Consortium Partner: University of Idaho

The goal of this project is to monitor traffic flow continuously with an innovative camera system composed of a custom designed image sensor integrated circuit (IC) containing trapezoid pixel array and camera system that is capable of intelligent future extractions. The new trapezoid CMOS image sensor IC was designed, fabricated, and tested. New feature extraction algorithms for moving object monitoring was developed and implemented in field programmable gate array (FPGA) platform. A camera system composing of FPGA platform to run the algorithms and control the trapezoid imager was developed.

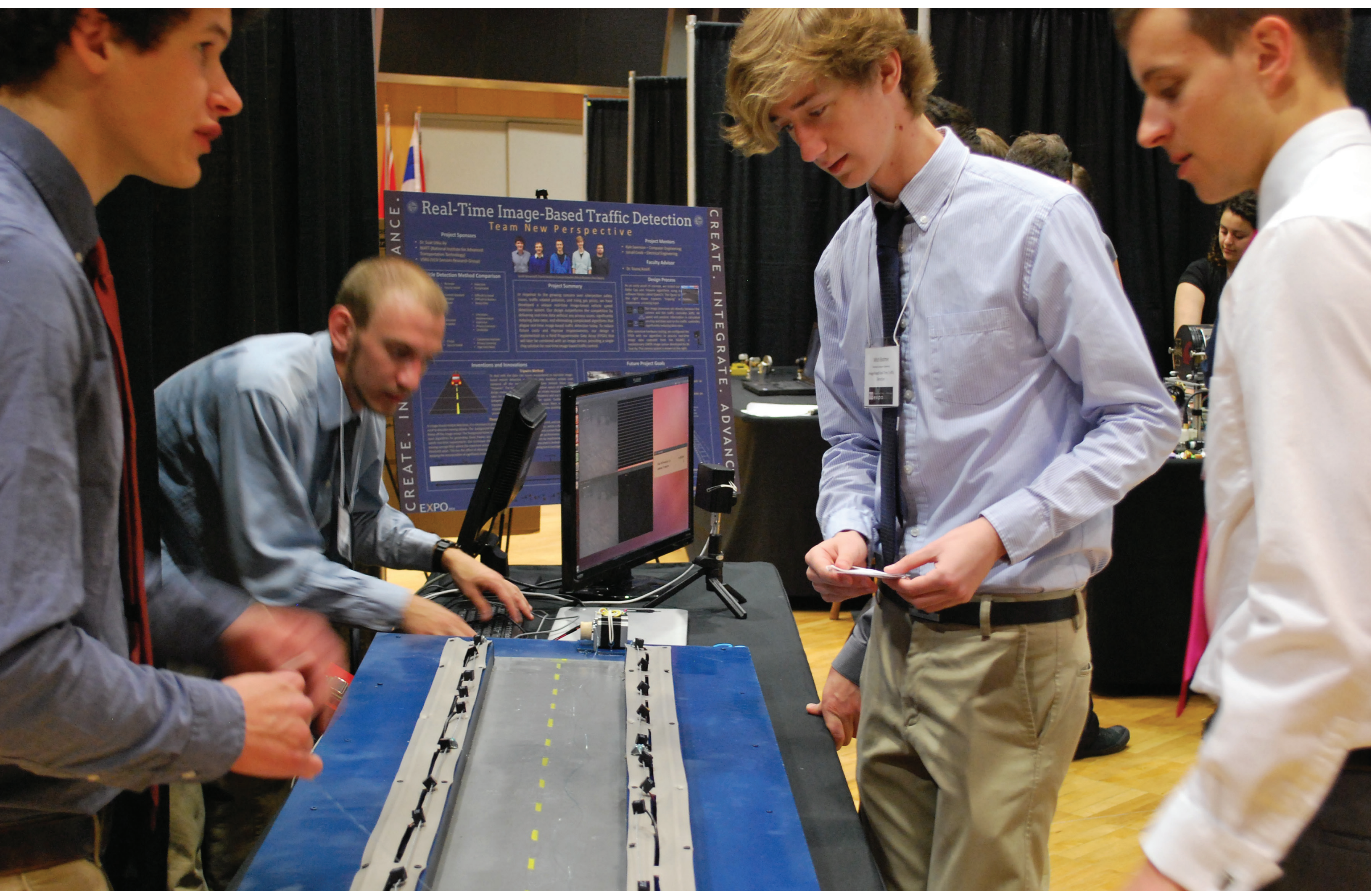
Undergraduate Research

A High-Speed Trapezoid Image Sensor Design for Continuous Traffic Monitoring

Consortium Partner: University of Idaho

In response to the need for real-time traffic control, less congestion, and reduced emissions, a team of University of Idaho engineering students developed a unique vehicle speed detection system using a low-power image sensor.

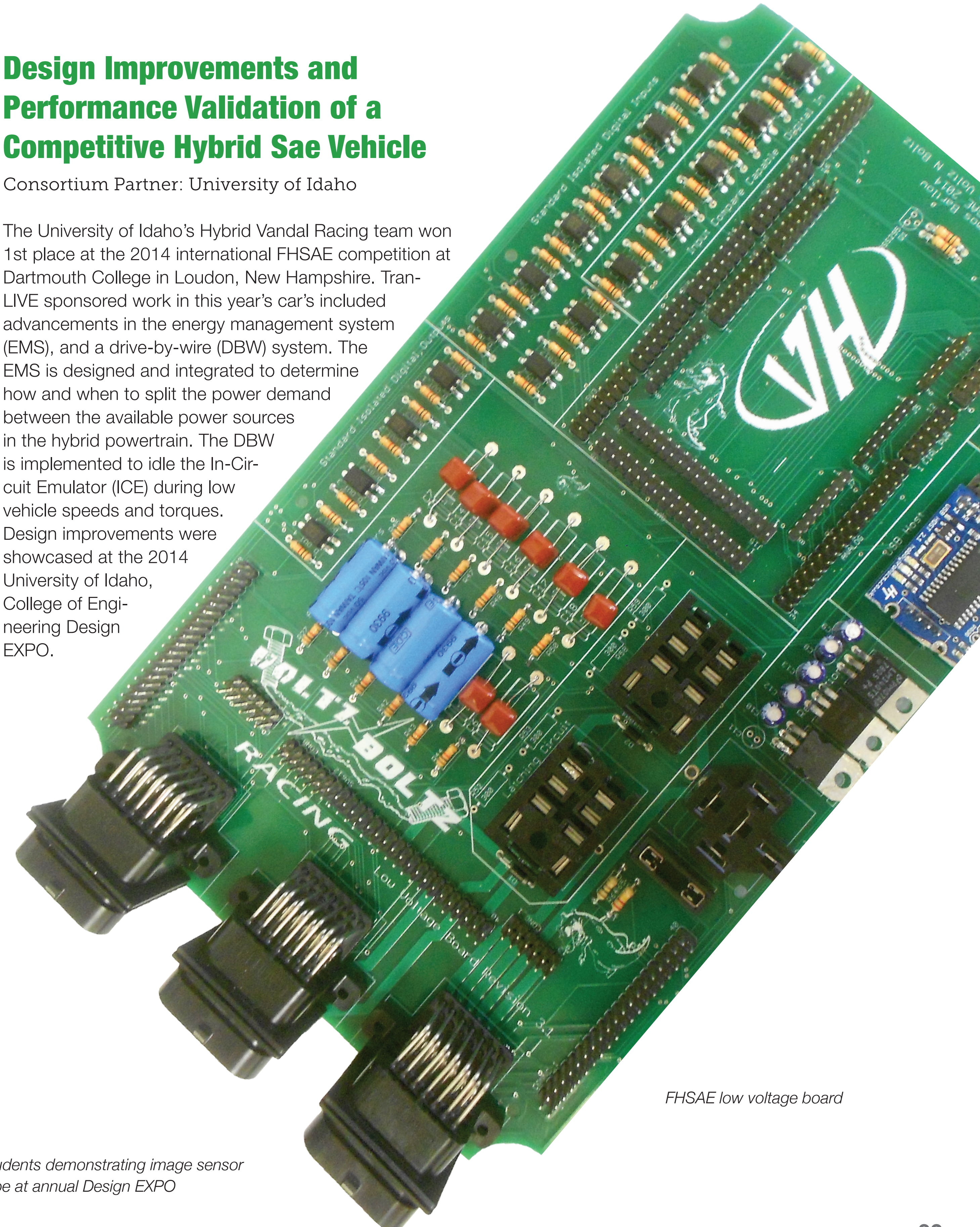
Computer Science students Paul Bailey and Carson Stauffer and Electrical & Computer Engineering students Mitch Bodmer, Jacob Grinestaff and Francis Sziebert presented a prototype of their design and explained the algorithms for their trapezoid imager at the annual 2014 University of Idaho, College of Engineering Design EXPO.



Design Improvements and Performance Validation of a Competitive Hybrid Sae Vehicle

Consortium Partner: University of Idaho

The University of Idaho's Hybrid Vandal Racing team won 1st place at the 2014 international FHSAE competition at Dartmouth College in Loudon, New Hampshire. TranLIVE sponsored work in this year's car's included advancements in the energy management system (EMS), and a drive-by-wire (DBW) system. The EMS is designed and integrated to determine how and when to split the power demand between the available power sources in the hybrid powertrain. The DBW is implemented to idle the In-Circuit Emulator (ICE) during low vehicle speeds and torques. Design improvements were showcased at the 2014 University of Idaho, College of Engineering Design EXPO.



FHSAE low voltage board

Left: Students demonstrating image sensor prototype at annual Design EXPO

Education

Operation, Analysis, and Design of Signalized Intersections: A Module for the Introductory Course in Transportation Engineering

Investigator(s): Michael Kyte and Maria Tribelhorn
Consortium Partner: University of Idaho

This report presents materials that can be used as the basis for a module on signalized intersections in the introductory course in transportation engineering. The materials were developed based on studies of the work of students who took this introductory course, including analysis of examination results, homework assignments, and interviews with students to identify concepts that were particularly difficult for them. Existing textbooks commonly used in the introductory course were reviewed to identify how concepts and topics related to signalized intersections were treated. Standard guidebooks used by transportation professionals were reviewed to identify concepts that would be appropriate to include in a new curriculum. The following guidelines were used to develop these materials:

1. Understanding the basic operation of a traffic controller is an important foundation for a realistic understanding of how a signalized intersection works, linking the user of the intersection to the detection system, the controller, and the signal displays.
2. Focusing on the automobile user and pretimed operation allows the student to learn about fundamental principles of a signalized intersection, while laying the foundation for future courses that address other users (pedestrians, bicycle riders, public transit operators) and more advanced traffic control schemes such as actuated control, coordinated signal systems, and adaptive control.
3. Queuing models are presented as a way of learning about the fundamentals of traffic flow at a signalized intersection. A graphical approach is taken so that students can see how flow profile diagrams, cumulative vehicle diagrams, and queue accumulation polygons are powerful representations of the operation and performance of a signalized intersection.
4. Only those equations that students can apply with some degree of understanding are presented. For example, the uniform delay equation is developed and used as a means of representing intersection performance. However, the second and third terms of the Highway Capacity Manual delay equation are not included, as students will have no basis for understanding the foundation of these terms.
5. Learning objectives are clearly stated at the beginning of each section so that the student knows what is to come. At the end of each section, the learning objectives are reiterated along with a set of concepts that students should understand once they complete the work in the section.
6. Over 70 figures are included in the module. We believe that graphically illustrating basic concepts is an important way for students to learn, particularly for queuing model concepts, controller timing processes, and the development of the change and clearance timing intervals.

Sustainable Transportation: Technology, Engineering, and Science - Summer Camp Instructor's Guide

Investigator(s): Michael Lowry, Jonathan Petersen, Kristen LaPaglia, and Bradford Tower
Consortium Partner: University of Idaho

This instructor's guide, developed as part of this project, is intended for a ten day summer camp focused on sustainable transportation. There are three units. The first three days are part of the Vehicle Technology unit. Topics covered during this unit include vehicle dynamics, engine design, and emissions and pollutants. The next four days are part of the Traffic Engineering and Operations unit. Topics covered during these days include vehicle detection, coordinated intersections, traffic safety, and geometric highway design. The final three days are part of the Transportation Science and Planning unit. Topics covered during these days include traffic forecasting, bicycle and pedestrian planning, and public transportation.

The daily schedule for the summer camp is split into three sections. The first section is called "Overview and Introduction." The second section is called "Topic Discussion and Example." The third section is called "Activity." The Overview and Introduction, as well as the Topic Discussion and Example are intended to be completed in a classroom and each are designed to be presented as 90 minute lectures. The Activity is intended to be done either in a classroom or as a fieldtrip and should last approximately three hours.

Each section is intended to engage students in a fun and interesting way while still presenting transportation engineering concepts and fundamentals. During each activity, students are required to perform basic calculations, intended to advance their mathematical skills. Throughout the camp, students need to have calculators, pencils, clipboards, and the handouts associated with each section. The materials contained in the instructor's guide were first implemented during the summer of 2013 as part of a STEM Access Upward Bound TRIO project. The STEM Access Upward Bound TRIO project prepares high school students for college and post-secondary careers in science, technology, engineering, and math (STEM). The project serves students from low-income, first college generation backgrounds. Students work actively every summer on different STEM research projects to investigate a topic in depth through inquiry. STEM professionals support the research process through hands-on interaction at various field sites and job settings.

The first implementation of this curriculum was used to teach 21 students who were primarily from the Lewiston, Idaho, Clarkston, Washington, and Coeur d'Alene, Idaho area. The students ranged in age from 14 to 18 years old, with grade levels ranging from entering their freshman year of high school to entering their senior year of high school.

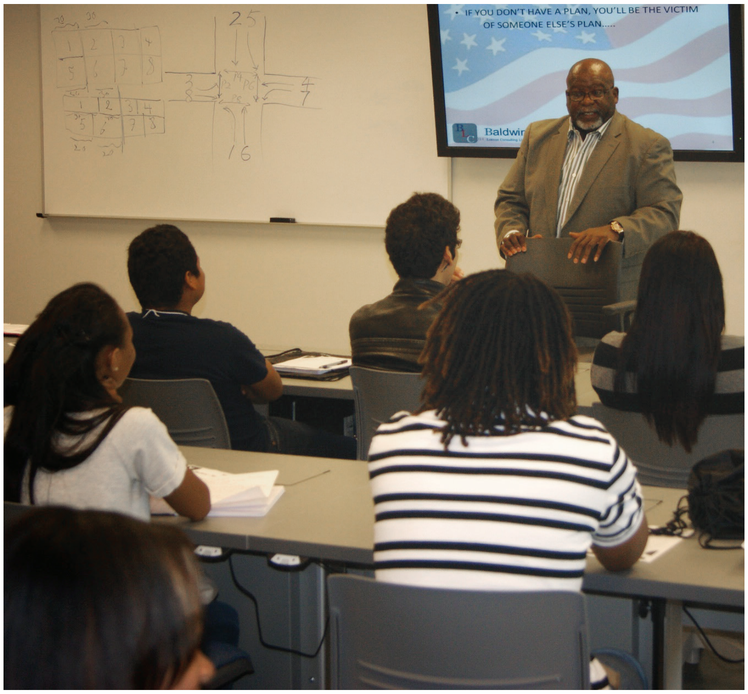
After the curriculum was presented, all of the students attending the camp spent ten days in Washington, DC, where they met with congressmen, learned about transportation policy, and experienced the traffic of a large city.

Summer Camp students and staff in Washington, DC with US Representative Raul Labrador from Idaho

2014 Summer Transportation Academy

Investigator(s): Yi Qi, Mehdi Azimi and Fengxiang Qiao
Consortium Partner: Texas Southern University

Since 2010, Texas Southern University (TSU) has hosted a Summer Maritime Transportation Academy (SMA). Beginning in 2012, the SMA included one day each session for the TSU TranLIVE program, aiming on educating high school juniors and seniors on the awareness of vehicle emissions and their environmental impacts. The dates of the 2014 summer program sessions were: Session I – June 9-13, 2014 and Session II – June 16-20, 2014. This non-residential program was held on the campus Monday – Friday, from 8:30 am – 4:30 pm, with one day specially focusing on vehicle and environmental issues. The speakers were (1) Dr. Yi Qi – Chair of Department of Transportation Studies at TSU on Traffic Congestion and Vehicle Emissions; (2) Dr. Mehdi Azimi – TSU Post-Doctoral Research Associate on Transportation Conformity Analyses; and (3) Dr. Fengxiang Qiao - Associate Professor in Innovative Transportation Research Institute of TSU on the Quantitative Analyses of Vehicle Emissions. Besides academic educations, students were also trained about professional skills (e.g., communications and leadership), and have gained practical knowledge from field trips.



Leadership Training Course

Session I participants represented a cross body of students from the Greater Houston Area. There were 15 students representing the following high schools: Austin HS, Carver HS, Chavez HS, Manvel HS, DeBakey HS, Girls and Boys Prep Academy, Cypress Wood HS, and Westbury Christian Academy.

Session II participants were recruited through the Project GRAD Staff at each of the Project GRAD high school campuses: Yates HS, Wheatley HS, Davis HS, and Reagan HS. Twenty Project GRAD students participated in the SMA.

The program evaluations revealed that students found some benefit in these summer academic activities. Fifty seven (57) percent of students strongly agreed that the program increased their interest in transportation and environmental related fields, and twenty- nine (29) percent strongly agreed that they would apply to TSU in the future.

Dr. Yi Qi explaining the concept of Traveler Information Systems to Mitigate Congestions

Communications Training Course

Workforce Development and Outreach

Formula Hybrid SAE Racecar

Investigator(s): Steve Beyerlein, Edwin Odom:
Year 1 - Dylan Rinker, Herb Hess;
Year 2 – Rory Lilley, Mostafa Asfoor,
Michael Santora, and Dan Cordon
Consortium Partner: University of Idaho

Year 1

User-friendly tools are needed for undergraduates to learn about component sizing, powertrain integration, and control strategies for student competitions involving hybrid vehicles. A TK Solver tool was developed at the University of Idaho for this purpose. The model simulates each of the dynamic events in the Formula Hybrid Society of Automotive Engineers (FHSAE) competition, predicting average speed, acceleration, and fuel consumption for different track segments. Model inputs included manufacturer's data along with bench tests of electrical and IC engine components and roll-down data. This vehicle performance model was used to design the 2014 vehicle's hybrid architecture, determine the energy allocation, and to select the batteries. Model predictions have been validated in full vehicle tests under simulated race conditions. The TK Solver tool has proven effective in making decisions about sizing gasoline and electric power components, establishing an optimal coupling connection between the electric motor and the gasoline engine, selecting and configuring the battery pack, tuning the gasoline engine, and making recommendations for energy management under different driving conditions. The resulting vehicle is being readied to compete in the 2014 FHSAE competition.

The Formula Hybrid SAE Vehicle testing at the 2014 Loudon, New Hampshire competition

Year 2

Over the last five years the Vandal Hybrid Racing team at the University of Idaho has developed a compact, lightweight, and mass centralized vehicle design with a rule-based energy management system. Major areas of innovation included an upright, spindle, and braking system that dramatically reduced rolling resistance, a close fitting frame design made possible by locating major components (engine, battery box, electric motor, and gas tank) close to the ground and to the center of gravity. The vehicle also incorporates a trailing link suspension, and realization of a rule-based energy management system that oversees operation of a Lynch electric motor as well as a YZ250F engine that is housed in a custom crankcase. The battery pack can initially store 2 MJ of energy in a single 50 lb. lithium polymer battery pack underneath the cockpit. The gas tank of the vehicle holds 33 MJ of energy in a 1.5 inch wide, 1.01 gallon tank immediately behind the cockpit. The resulting vehicle weighs 550 lbs. without the driver, achieves a top speed of 55 mph on the 75 meter acceleration track, and exhibits a hybrid fuel economy on the endurance course of 29 mpg. This is achieved by the implementation of a supervisory controller that turns on and off the electric motor as well as regulates the internal combustion engine in response to vehicle's speed and the battery pack's state of charge. Vehicle serviceability is greatly enhanced by reconfiguration of the low voltage system to be more accessible during track side operations. The vehicle won the 2014 FHSAE competition in Loudon, New Hampshire. It is currently undergoing comprehensive performance testing that will inform the design and operation of a next generation vehicle.

Formula Hybrid Team Wins International Championship

University of Idaho's Vandal Formula Hybrid Racing Team returned from New Hampshire Motor Speedway winners of the 2014 international Formula Hybrid Competition.

The Vandal racing team – also known as Voltz N' Boltz – drove home with the competition's top prizes. The team earned the Chrysler Innovation Award, which recognizes innovative design and implementation, and the General Motors Best-Engineered Hybrid first place award, which is given to teams that demonstrate achievements in three categories: introducing new technologies and/or a remarkable implementation of existing technologies, making a positive difference and extraordinary vehicle balance. In addition, the team placed second in the Skip Barber Teamwork Award, which is given to teams displaying the best overall collaborative teamwork skills.

General Motors representatives encouraged all members of the Voltz N' Boltz to leave resumes and the Chrysler representatives personally invited every member of team for a site visit and job interview at their headquarters.

The University of Idaho Formula Hybrid Team is composed of an interdisciplinary team of students including members of the mechanical engineering department: Jordan Anderson, Jonathan Andring, Derek Arrotta, Adam Bunch, Ignacio Lopez, Nathan Peterson, Bryan Tianiacos, Gillette Zenner and graduate mentors Mostafa Asfoor, Matt Kologi and Rory Lilley; Amos Bartlow from electrical and computer engineering; David Arnett from computer science; and Artemio Ambriz of the virtual technology & design department.

The team's faculty and staff advisors include: Professors Dan Cordon, Edwin Odom, Steve Beyerlein, Mike Santora, Herb Hess and machine shop manager Russ Porter.

Webinar Transportation Sustainability: What Intelligent Transportation Systems Offer?

Investigator(s): Hesham A. Rakha
Consortium Partner: Virginia Tech

The Office of the Assistant Secretary for Research and Technology Dr. Hesham A. Rakha for a professional webinar titled: Transportation Sustainability: What can Intelligent Transportation Systems Offer? Dr. Rakha's presentation was held live Wednesday, September 17, 2014 at 1:00pm – 2:00pm EST at the U.S. Department of Transportation's West Building Conference Center Rooms 8-9-10. An archive of the webinar is available at: mediasite.yorkcast.com/webcast/Play/6d7ad-385336a445582ca61cd25bcb3f31d

Vandal Formula Hybrid Racing Team celebrating their win

TranLIVE Student Awards

2013 TranLIVE Student of the Year William "Andy" Edwardes

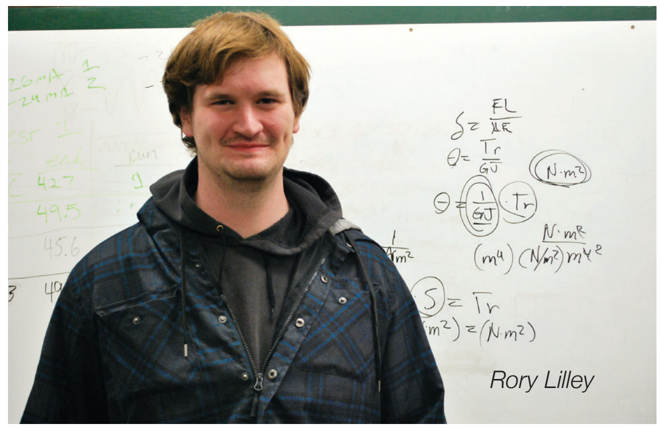
William "Andy" Edwardes of Virginia Tech was awarded the 2013 TranLIVE Student of the Year. Andy worked on two graduate degrees simultaneously, in transportation engineering and in operations research. Andy also worked with the Blacksburg, Virginia bus system (BT) to make it more fuel efficient through improved routing and scheduling, bus assignment and a real-time dispatch support system, and with the deployment of a microscopic fuel consumption model adapted for diesel buses. Among his many extra-curricular activities Andy served as the Alumni Relations Officer for the Alliance of Transportation Engineering Students, an organization working promote the dissemination of knowledge and information related to transportation infrastructure and systems issues, problems and solutions to civil and environmental engineering students at Virginia Tech University.

Andy received the award at the Council of University Transportation Centers (CUTC) annual banquet in Washington D.C., January 11, 2014.

Andy receiving the 2013 TranLIVE Student-of-the-Year award at the CUTC banquet

2014 TranLIVE Student of the Year Rory Lilley

TranLIVE selected Rory Lilley the 2014 TranLIVE Student of the Year. As a Mechanical Engineering master's student at the University of Idaho, Rory has served as an effective leader/organizer/technical consultant to our undergraduate Formula Hybrid SAE team. This project has been sponsored by TranLIVE as an educational outreach since the inception of the TranLIVE center and by the Idaho Engineering Works in the senior design program. Rory worked his way up through the student ranks, as an undergraduate team member, as a senior design student, as a UTC intern, and as a UTC graduate student. Currently, he is an excellent role model in terms of his dedication to hard work, his recruiting of new inter-disciplinary talent to the team, his ability to organize training sessions/design experiences that capture and retain important vehicle design knowledge, his rapport with faculty advisors, his familiarity with manufacturing equipment in our machine shop, his ability to deploy testing equipment in our small engines laboratory, his ability to accurately simulate engine/powertrain systems, and his high standards in the authorship of project reports/technical papers. The impact of his efforts, coaching, and all-around vehicle knowledge can be seen in the FHSAE team success at the 2014 International Formula Hybrid Competition. This included 1st place overall, the Chrysler Innovation Award, and the GM Hybrid Electric Design Award. Rory has been an integral part of the UI FHSAE legacy for many years and his efforts continue to pay it forward to future vehicle platform teams as well as engine design/engine testing research projects. Contributions in both areas are closely aligned with DOT UTC mobility, sustainability, and human resource missions.



Rory Lilley

Rory will receive the award at the annual Council of University Transportation Centers (CUTC) banquet in Washington D.C., January 10, 2015.

Status of TranLIVE Projects

Projects Begun in 2014

Old Dominion University, Texas
Southern University & Virginia Tech

Smartphone-based Solutions to Monitor and Reduce Fuel Consumption and Co2 Footprint
ODU Lead - M. Cetin, T. Nadeem, R.M. Robinson, M. Ng
TSU - F. Qiao
VT - H. Rakha

Syracuse University,
University Of Idaho & Virginia Tech

Studying the impact of accelerated construction methods in work zones using micro-simulation, on vehicle emissions and the environment
SU Lead - O. Salem & C. Davidson
UI - A. Abdel-Rahim
VT - H. Rakha

Syracuse University

A Sustainable Asset Management Framework for Transportation System Management and Operation Systems
O. Salem

University Of Idaho & Virginia Tech

Field Implementation and Testing of Eco-Traffic Signal System Applications
UI Lead - A. Abdel-Rahim & A. Krings,
VT - H. Rakha & K. Ahn

Virginia Tech, Old Dominion University
& University Of Idaho

Developing and Field Implementing a Dynamic Eco-Routing System
VT Lead - H. Rakha & K. Ahn
ODU - M. Cetin & T. Nadeem
UI - A. Abdel-Rahim

Virginia Tech

Develop Mesoscopic Fuel Consumption and CO2 Emission Models for Use in Eco-routing Systems
H. Rakha

Develop Macroscopic Fuel Consumption and CO2 Emission Models
H. Rakha

Projects Continuing from 2013 & 2012

Old Dominion University

2012

Reducing Energy Use and Emissions through Innovative Technologies and Community Designs: Methodology and Application in Virginia
A. Khattak, M. Cetin, & R.M. Robinson

Syracuse University

2012

Contamination of Urban Surface Water by Vehicle Emissions
C. Davidson, D. Chandler, &
O. Salem

Texas Southern University

2013

Developing Short Range Vehicle-to-Infrastructure Communication Systems
F. Qiao & L. Yu

2012

A Systematic Evaluation of the Impacts of Traffic Condition Information on the Reduction of On-Road Mobile Emissions
Y. Qi & L. Yu

Develop an Integrated Data Management System at the Microscopic, Mesoscopic, and Macroscopic Levels to Assess the Environmental Impacts of Transportation Systems
F. Qiao & L. Yu

Develop Multi-scale Energy and Emission Models for Arterial Traffic Systems
L. Yu & F. Qiao

Improve the Environment for a Livable Community: Advance the AERIS Program by Developing and Testing Eco-traffic Signal System Control Applications
L. Yu & F. Qiao

Use the Driving Simulator to Synthesize the Related Vehicle Specific Power (VSP) for Emission and Fuel Consumption Estimations
F. Qiao & L. Yu

University Of Idaho

2013

Daily Travel Feedback to Encourage Eco-routing
M. Lowry & M. Dixon

Direct Drive AC Rim Motor for Responsive Energy Control of Alternative Electric Vehicle
H. Hess, S. Beyerlein & E. Odom

Eco-driving Modeling Environment
A. Abdel-Rahim

Upgrading Biomass Pyrolysis Bio-oil to Renewable Fuels
A. McDonald & D. McIlroy

2012

Calibration of Multi-scale Energy and Emission Models
A. Abdel-Rahim

Improve the Environment for a Livable Community: Advance the AERIS Program by Developing and Testing Eco-Traffic Signal System Applications
A. Abdel-Rahim & M. Dixon

Virginia Tech

2012

Develop Multi-Scale Energy and Emission Models
H. Rakha, K. Ahn, D. Nelson & L. Marr

Projects Completed Final Reports In Review

Syracuse University

Enhancing TSM&O Strategies through User Cost Analysis and Life Cycle Assessment
O. Salem

Assessing the Environmental Impacts of Work Zones in Arterial Improvement Projects
O. Salem

University of Idaho

A High-speed Trapezoid Image Sensor Design for Continuous Traffic Monitoring at Signalized intersection Approaches
S. Ay

Formula Hybrid SAE (Year 2)
R. Lilley, M. Asfoor, S. Beyerlein, E. Odom, D. Cordon & M. Santora

Projects Completed

Old Dominion University

A Study on the Impact of Parameter Uncertainty on the Emission-based Ranking of Transportation Projects
U. Ahmed & M. Ng

Exploring Image-based Classification to Detect Vehicle Make and Model
J. Flora, M. Alam, A. Yousef, & K. Iftekharuddin

Improving Travel Times for Emergency Response Vehicles: Traffic Control Strategies Based on Connected Vehicles Technologies
C. Jordan & M. Cetin

Optimizing Freight Routes and Modes to Minimize Environmental Impacts: Integrating Truck Emissions Cost in Traffic Assignment
R.M. Robinson & P. Foytik

Real-time prediction of queues at signalized intersections to support eco-driving applications
M. Cetin & O. Unal

University Of Idaho

Formula Hybrid SAE (Year 1)
D. Rinker, S. Beyerlein, E. Odom, & H. Hess

In situ Transesterification of Microalgal Oil to Produce Algal Biodiesel (Stage 2)
B. He & Z. Bi

Operation, Analysis, and Design of Signalized Intersections: A Module for the Introductory Course in Transportation Engineering
M. Kyte & M. Tribelhorn

Progress in Catalytic Ignition Fabrication, Modeling and Infrastructure: (Part 1) Catalytic Ignition Studies
J. Steciak, S. Beyerlein, R. Budwig, D. Cordon, & D. McIlroy

Progress in Catalytic Ignition Fabrication, Modeling and Infrastructure: (Part 2) Development of a Multi-Zone Engine Model Simulated using MATLAB Software
J. Cuddihy & S. Beyerlein

Pyrolysis Bio-Oil Upgrading to Renewable Fuels
A. McDonald, D. McIlroy, Y. Han, & B. Kengne

Security and Survivability of Real-Time Communication Architecture for Connected-Vehicle Eco-Traffic Signal System Applications
A. Krings, A. Serageldin, A. Abdel-Rahim, & M. Dixon

Sustainable Transportation: Technology, Engineering, and Science - Summer Camp Instructor's Guide
J. Petersen, M. Lowry, K. LaPaglia, & B. Tower

Virginia Tech

Developing Eco-adaptive Cruise Control Systems
H. Rakha & K. Ahn

Developing an Eco-Routing Application
H. Rakha & K. Ahn

Green Cooperative Adaptive Control Systems in the Vicinity of Signalized Intersections
H. Rakha & R.K. Kamalanathsharma

Transportation for Livability by Integrating Vehicles and the Environment (TranLIVE)

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