Program Progress Performance Report
University Transportation Centers
Cover Page TranLIVE

Submitted to: Office of the Assistant Secretary for Research and Technology

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Project Title: TranLIVE (Transportation for Livability by Integrating Vehicles and the Environment

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Recipient Organization: University of Idaho, Office of Sponsored Programs, 875 Perimeter Dr., MS 3020, Moscow, ID 83844-3020

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SEMI-ANNUAL REPORTING CATEGORIES
TranLIVE DTRT12GUTC17
July 1, 2014 to December 31, 2014

1. ACCOMPLISHMENTS:

A. University of Idaho:

i. ***Developing and Testing Eco-Traffic Signal System Applications***

a. Developed a real-time traffic signal system instrumentation using NEMA TS2 SDLC as part of the hardware-in-the-loop simulation environment for connected-vehicle applications for coordinated systems.
b. Documented the impact of corridor signal timing plans, optimized using different objective functions, on the characteristics of traffic operations for vehicle groups with different origin-destination.
c. Provided guidelines on optimizing coordinated corridors to minimize fuel consumptions and emissions.

ii. ***Calibration of Multi-Scale Energy and Emissions Models***

Used vehicle-emission and fuel consumption data for different vehicle types under different speed and acceleration operation, generated using the GT-Suite advanced engine modeling software, to calibrate fuel consumption and emission models in two microscopic simulation models: VISSIM and Integration and one macroscopic model Transyt 7-F.

iii. ***Design Improvements and Performance Validation of a Competitive Hybrid FSAE Vehicle***

The team was awarded the 1st place overall hybrid trophy as well as 2nd place in the design competition, and a close 2nd place in the Teamwork award at the competition. The vehicle's design received the second highest powertrain score and was the only vehicle awarded a perfect score for aesthetics. The team was also awarded two other significant trophies and cash prizes from industry as well. The team received the 1st place Chrysler Innovative Powertrain design as well as the 1st place General Motors Best Engineered Hybrid Systems awards.

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

Final tests were completed in September 2014 and the final report was generated in December 2014.

v. ***Upgrading Biomass Pyrolysis Bio-oil to Renewable Fuels***

The objective of this study was to develop an effective routine for HDO of Douglas-fir (Pseudotsuga menzeseii) pyrolysis bio-oil. The bio-oil was fully characterized by GC-MS, HPLC, and ESI-MS. Phenols, furans, acetic acid, fatty acids and other oxygenates were identified by GC-MS. The bio-oil was fractionated using phase separation by addition of water to obtain a water-insoluble (WIS) and water-soluble (WS) fractions from the bio-oil. These two separate fractions were investigated for their suitability for hydrotreatment. The WIS of bio-oil (pyrolytic lignin rich) was effectively cracked in methanol over a Ni(65%)/SiO2-Al2O3 catalyst to monomeric and dimeric compounds, which was shown by ESI-MS. A further step of HDO (using Ni(65%)/SiO2-Al2O3 or Ni(20%)-NS catalyst) on the cracked oil had successfully deoxygenated the phenolics into cycloalkanes. All the produced alkanes and alcohols can be directly used as drop-in transportation fuels.

vi. ***Direct Drive AC Rim Motor for Responsive Energy Control of Alternative Electric Vehicle***

There are more than 20 student volunteers that have been working on the project. Graduate student completed her thesis.

vii. ***Daily Travel Feedback to Encourage Eco-Routing***

a. Analyzed data. Much of this period was used to analyze the data we collected through our experiment.
b. Wrote a paper for publication in a scholarly journal. The paper was submitted to the transportation research board. It was accepted for presentation. We are currently preparing the paper for submission elsewhere.

viii. ***Eco-driving Modeling Environment***

a. Tested and validated a SimLink interface between the GT-Suite software and the NADS MiniSim Model. The interface will facilitate the integration of the two models to create an Eco-Driving model training tool.
b. Using Windows Presentation Foundation (WPF) an EcoDash was finalized. The model will run along with other system components in real-time with MiniSim.

B. <u>Old Dominion University</u>:

i. ***New Strategies for the Emergency Vehicle Routing to Reduce Response Time Using Vehicle-to-Vehicle Communications***

This research evaluated and tested routing strategies for emergency vehicles (EV) to reduce response times and for improving EV location awareness to background traffic. It was directed at developing strategies using connected-vehicles and connected-infrastructure to exchange locations, speeds, and signal timings to allow EVs to travel efficiently and safely through urban environments. Two concepts were evaluated in this study. The first involved navigating EVs through congestion by sending maneuvering information to background traffic to allow the EV to proceed through congested signalized intersections as quickly as possible. This was achieved by creating a split in the vehicle queue in one lane at a critical location to allow the EV to proceed at its desired speed while minimizing the disruption to the rest of the traffic. The results showed that this strategy can shorten the travel time significantly for EVs through congested signalized intersections. The research findings were presented at the 2013 Transportation Research Board (TRB) Annual Conference and subsequently published in the Transportation Research Record.

The second involved a strategy of evaluating the order of traffic signal preemption. This strategy used shockwave theory to determine the order in which a group of signalized intersections should be preempted based on the vehicle queues on the EV's approach leg. The results showed that this strategy can shorten the travel time for EVs through closely spaced signalized intersections. The research findings were presented at the 2015 TRB Annual Conference.

ii. ***Real-Time Prediction of Queues at Signalized Intersections to Support Eco-driving Applications***

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. 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 were developed where both over-saturated and under-saturated conditions were 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 was 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 was tested on the data obtained from traffic

simulation software VISSIM. It was 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%.

iii. ***Reducing Energy Use and Emissions through Innovative Community Designs: Methodology and Application***

a. A report that covers relevant literature is being written. Key portions of the reviewed literature are contained in research papers presented and published based on the project. This information is being integrated into a draft final report.
b. Regional macroscopic analysis focusing on smart/compact growth. This task includes three topics: 1) using behavioral data to understand smart growth land use scenarios and its impacts on travel decisions; 2) testing regional models with different land use scenarios; 3) assessing the impacts of TOD (Transit Oriented Developments). Several papers on these topics have been prepared, presented at various meeting, and published in journals. These activities will be completed shortly.
c. Intelligent technologies: eco-friendly traveler information. This task includes two topics: 1) how to generate traveler information for supporting instantaneous driving decisions based on behavioral models; and 2) how to generate emissions information for eco-friendly route selection. One relevant paper on this topic was presented at the ITS World Congress 2014 conference (Detroit, Sep 7-11, 2014) and more will be presented at the 2015 TRB annual meeting. Another paper discussing generating emissions information for route selection has been published in the Journal of Intelligent Transportation Systems, Taylor and Francis Publishers.
d. Modeling alternative fuel vehicle data. We used behavioral and sensor driving data to model hierarchies in travel data to understand the role of alternative fuel vehicles. One paper on this topic is forthcoming in Transportation Research, Part C.
e. Microscopic Transportation Systems Analysis. The topics in this task include: 1) understanding driver's instantaneous behaviors; 2) creating regional indices for better understanding how people drive in the area, given different land use and local contextual conditions; 3) examining the role of HOV/eco-lanes as a sustainable option to reducing emissions. These tasks were accomplished.

iv. ***Optimize Freight Routes and Modes to Minimize Environmental Impacts***

a. The methodology forecasts a reduction in total system truck emissions by only a small percentage (0.61%, 88.8 tons), but this result proved the methods potential contribution to minimizing emissions. The results showed that reducing emissions came at essentially negligible cost to the total system travel time and trucks changing routes did not impact passenger car travel.
b. To extend this research, future work will require refinement of the Vehicle Specific Power calculation. Additional influences, including road grade, rolling resistance, and wind resistance values, should be considered. Implementing these values -- especially grade changes -- may have a great effect on what routes are chosen to reduce emissions. The acceleration value is an aggregate value and would be more accurate when measured from a microscopic model. Regional microscopic models are becoming more viable and the work done in this paper compliments the future of transportation modeling. Large microscopic models will need to utilize dynamic traffic assignment algorithms to determine the distribution of flows and the same methodology can be applied to those models but with a better measure of VSP.

C. Syracuse University:

i. The TranLIVE research projects undertaken by Syracuse University are as follows:–

a. Project 1: *Enhancing TSM&O Strategies through User Cost Analysis and Life Cycle Assessment*; Final report in review.

b. Project 2: *Assessing Social and Environmental Impacts of Work-Zones in Arterial Improvement Projects*; Sudipta Ghorai, research assistant, working with Dr. Salem has completed the project and it is in review for publishing.

c. Project 3: *Assessing Environmental Impacts of Traffic Congestion and Vehicular Emissions on Groundwater and Fresh Water Supplies,* Alex Johnson joined SU as an MS/PhD student in Summer 2014. He has taken over the project which involves measurement of contamination of urban stormwater by motor vehicles. Alex began using the developed methods for anion analysis using ion chromatography. In Summer and Fall 2014, he conducted a number of measurements of anion concentrations in precipitation, in runoff from the OnCenter Green Roof, and in runoff from the adjacent War Memorial Control Roof. These data were presented in a platform talk by Cliff Davidson in October 2014 at the National Conference of the American Association for Aerosol Research (AAAR) in Orlando. Mallory Squier: continued her PhD work on the capture of stormwater runoff from streets, driveways, parking lots, and other impermeable surfaces by green infrastructure. It is difficult to conduct such work at street level, so Mallory has instrumented the Green Roof on the Onondaga County Convention Center (OnCenter) to conduct her experiments. In Fall 2014, Mallory obtained quantitative data from an electromagnetic flowmeter installed just below the roof, along with simultaneous precipitation data for a number of rainstorms. The data are being analyzed prior to model development.

d. Project 4: *A Sustainable Asset Management Framework for Transportation System Management and Operation Systems,* Song He, a graduate student working with Dr. Salem, has completed literature review on best practices in TSM&O systems, life cycle cost analysis, deterioration/ forecasting models, and prospective environmental and social benefits of alternative TSM&O systems. He is currently working on establishing inventory and performing life-cycle cost analysis for TSM&O systems.

e. Project 5: *Improving Sustainability of Work-zones by Implementing Lean Construction Techniques.,* Sharareh Pirzadeh, a graduate student working with Dr. Salem, has she studied how lean construction techniques can be implemented to reduce environmental, economic and social impacts of work zones.

D. Texas Southern University:

i. ***A Systematic Evaluation of the Impacts of Traffic Condition Information on the Reduction of On-road Mobile Emissions***

a. What we have done:

1) Modified the case study by developing the results of emission rates for three different pollutants, namely, CO, NO_x and VOC.
2) Reviewed more literature.
3) Drafted a final report.

b. What we have learned:

The results of the case study showed that the total system travel time was highest for no diversion case. The lowest emission factor occurred around 40% Diversion Rate, which will be a system optimal point. It was observed that CO emission rates were reduced by 58%, NO_x emission rates were reduced by 56.5% and VOC emission rates were reduced by

34.8% for the no diversion and user equilibrium state. The results of this study demonstrate the benefits of using ATIS in terms of total system travel time and total emission levels. It also illustrates the usefulness of the framework developed in this study. Practitioners can use the framework and operating mode ID distribution developed in this study to carry out similar evaluation studies.

ii. ***Education and Outreach Activities***

a. Successfully organized the summer transportation academy at TSU in June, 2014 for two sessions of high school students (minority). This summer academy is a continuation from summer 2012 and 2013. Most of the students are minority students.
b. Support three undergraduate students for summer internship 2014. One of them is sponsored by TSU matching. The other two use UTC funds.
c. Provided scholarships to support graduate students for their studies in transportation. All are U.S. citizens.
d. Supported student travels to present research papers or receive awards in academic conferences such as:
    1) Intelligent Transportation Society Texas Chapter Annual Meeting in Irving, Texas, October 2014.
    2) The National Technical Association (NTA) 86th Annual National Conference. Cleveland, Ohio, September 24-26, 2014.

iii. ***Develop an Integrated Data Management System at the Microscopic, Mesoscopic, and Macroscopic Levels to Assess the Environmental Impacts of Transportation System***

Incorporating with a project from Texas Department of Transportation (TxDOT), vehicle emissions have been tested in junction with the records of pavement roughness information. Necessary correlation analyzed is in processing.

iv. ***Use the Driving Simulator to Synthesize the Related Vehicle Specific Power (VSP) for Emission and Fuel Consumption Estimations***

The VSP from the simulator and from the real world continue to be compared and analyzed.

v. ***Develop Multi-scale Energy and Emission Models for Arterial Traffic Systems***

a. Modeled excess carbon dioxide emissions from traffic congestion in urban areas and analyzed the effects of bus rapid transit policy strategies on CO_2 emissions.
b. Characterized the changes of mobile source air pollution in metropolitan areas using vehicle emission model MOVES.
c. Analyzed effect of driving behaviors on emissions in eco-driving at intersections.

vi. ***Improve the Environment for a Livable Community: Advance the AERIS Program by Developing and Testing Eco-traffic Signal System Control Applications***

a. Impacts of foggy weather conditions on driver behavior at yellow intervals were characterized, and how driver behavior is influenced by the advanced warning message from the Drivers Smart Signal System (DSSS) at high-speed signalized intersection approaches was discussed after driving simulator test.
b. Tested impacts of route choice on vehicle emissions.

vii. ***Developing Short Range Vehicle-to-Infrastructure Communication Systems***

a. Designed smartphone applications and tested in work zone and signalized intersections using driving simulator.
b. Continuously analyzed drivers' driving performance when approaching intersections with sun glare, with stop signs, and when approaching work zones.
c. Results show that, wireless communication has great impacts on driving performance such as vehicle's approaching speed, acceleration rates, braking distance, and braking response time.
d. Drivers' socio-demographic background has great impacts on driving performance, too.

e. Wireless communication has impacts on vehicle emissions in tested cases in work zones and intersections for both field and simulation tests.

E. Virginia Tech:

i. ***Develop Mesoscopic Fuel Consumption and CO_2 Emission Models***

Validate the mesoscopic modeling approach by comparing the model results in Task 3 against results obtained from a microscopic approach and field observations for sample networks.

ii. ***Develop Green Cooperative Adaptive Control Systems in the Vicinity of Signalized Intersections***

a. Developed and tested the logic in an agent-based simulation framework.
b. Integrated the software with microscopic traffic simulation software and tested the algorithm.
c. Wrote the project final report.

iii. ***Develop Macroscopic Fuel Consumption and CO_2 Emission Models***

a. Gather field data to characterize drive cycles on typical roadways as a function of the roadway speed limit, level of congestion, type of intersection control (stop, yield or traffic signal).
b. Develop macroscopic models to estimate vehicle fuel consumption levels using the drive cycles constructed in Task 1.
c. Validate the models developed in Task 2 against field observations.
d. Implement the models developed in Task 2 in a planning model framework.
e. Develop the framework developed in Task 4 against the use of a microscopic modeling framework for different networks.

iv. ***Develop Multi-scale Energy and Emission Models***

a. Developed and validated the VT-CPFM model.
b. Developed a framework for modeling diesel engine vehicle fuel consumption levels.
c. Developed a framework for modeling transit vehicle fuel consumption and emission levels.
d. Investigated the potential for use of electrified vehicles to serve traveler needs using naturalistic driving data.
e. Extending VT-CPFM to model vehicle emissions of CO, HC, and NO_x.

F. Multi-institution:

i. ***Developing and Field Implementing a Dynamic Eco-routing System* –Virginia Tech, lead; University of Idaho and Old Dominion University, partners**

a. Develop a simulation environment for testing the eco-routing system.
b. Study the dynamics of driver routing behavior.
c. Develop algorithms to enhance the minimum path search.
d. Conduct simulation/field tests.
e. Write report summarizing the results of the experiments.

ii. ***Smartphone-based Solutions to Monitor and Reduce Fuel Consumption and Co_2 Footprint – Old Dominion University, lead; Virginia Tech and Texas Southern University, partners***

a. An Android App (called GoGreen) was developed and improved upon to collect acceleration, gyroscope, magnetometer, and GPS data from smartphones. The App can also connect to an OBD device on the vehicle if available. Speeds from GPS and OBD are used for model development and testing.
b. GoGreen App was further developed by integrating the VT-CPFM model to estimate fuel consumption which is currently computed based on GPS data.

c. A user interface was developed for the GoGreen App to show the fuel consumption rate graphically in real-time.
d. An SQL database was created and enhanced to store the raw data collected by smartphones. The GoGreen App uploads the data automatically to the database when connected via WiFi.
e. Algorithms have been developed and improved upon to predict the mode of travel based on sensor data from smartphones.
f. Shortest path algorithms have been developed to detemined the eco-friendly shortest paths.

iii. ***Eco-traffic Signal System*** **– University of Idaho, lead; Virginia Tech and Syracuse University, partners**

a. Developed connected-vehicle lab integrating DSRC receivers and road side units.
b. Validated the data exchange mechanics between the DSRC units, road side units, a microprocessor interface, and the traffic controller July.

iv. ***Studying the impact of accelerated construction methods in work zones using micro-simulation, on vehicle emissions and the environment*** **– Syracuse University, lead; Virginia Tech and University of Idaho, partners**

A comprehensive literature review was done on the MRR activities and accelerated construction techniques to get familiar with the construction methods, construction sequencing, contracting requirements and traffic management plans (TMPs) used by various transportation agencies. Available literature on how to develop transportation management plans for work zones was reviewed to understand the factors influencing the decision making process. Popular traffic simulation (e.g. TRANSIMS, CORSIM, PARAMICS, VISSIM, etc.), and emission models (e.g. MOVES, CMEM, VT-MICRO, VT-MESO, INTEGRATION) were identified and the types of outputs they can generate were studied.

2. <u>PRODUCTS</u>:

A. <u>University of Idaho</u>:

i. ***Developing and Testing Eco-Traffic Signal System Applications***

a. Sherief Elbassuoni, "Guidelines for Eco-Traffic Signal System Operations in Small and Medium Size City Environments", Doctoral Student Research in Transportation Operations and Traffic Control, TRB 94th Annual Meeting, Transportation Research Board, National Research Council, Washington, D.C., January 2015, Presentation # P15-7006.
b. Jacob W. Preston, Richard W. Wall, and Ahmed Abdel-Rahim, "Real-Time Traffic Signal System Instrumentation using National Electrical Manufacturers Association TS2 Synchronous Data Link Control Networks", CD-ROM, Proceedings of the TRB 94th Annual Meeting, Transportation Research Board, National Research Council, Washington, D.C., January 2015, Paper # 15-3047.
c. Sherief Elbassuoni and Ahmed Abdel-Rahim, "Eco-Traffic Signal System Operations for Coordinated Corridors", Paper submitted for publication in ASCE Journal of Transportation Engineering.
d. Sherief Elbassuoni, Christopher Davidson, and Ahmed Abdel-Rahim, "Guidelines for Eco-Traffic Signal System Operations for Isolated Actuated Intersections", Paper submitted for publication in ASCE Journal of Transportation Engineering.

ii. ***Calibration of Multi-Scale Energy and Emissions Models***

a. Calibrated fuel consumption and emission models for three traffic engineering software tools: VISSIM, Integration, and Transyt 7-F.

b. Mostafa Asfoor, "Development and Optimization of a Rule-Based Energy Management Strategy for Fuel Economy Improvements in Hybrid Electric Vehicles", Ph.D. Thesis, University of Idaho, June 2014.

iii. ***Design Improvements and Performance Validation of a Competitive Hybrid FSAE Vehicle***

a. M. Asfoor, R. Lilley, and S. Beyerlein (2015 Pending), "Discrete Grid Optimization of a Rule-Based Energy Management Strategy for Formula Hybrid Electric Vehicle," 2015 SAE World Congress, SAE Paper # 15FPL-0416.

b. R. Lilley, M. Asfoor, M. Santora, D. Cordon, E. Odom, and S. Beyerlein (2015 Pending), "Design of the University of Idaho Formula Hybrid Vehicle," 2015 SAE World Congress, SAE Paper # 15MSEL-0007.

c. Final report competed: http://tranliveutc.org/engr/niatt/tranlive/projects/2012/design-improvements-and-performance-validation-of-a-competitive-hybrid-fsae-vehicle.

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

Final report completed: http://tranliveutc.org/engr/niatt/tranlive/projects/2013/a-high-speed-trapezoid-image-sensor-design-for-continuous-traffic-monitoring.

v. ***Upgrading Biomass Pyrolysis Bio-oil to Renewable Fuels –***

a. Yinglei Han, Armando McDonald, David McIlroy (2014) "Upgrading wood pyrolysis oil by hydrogenation using nanocatalysts to green transportation fuels" 2014 International Union of Forest Research Organizations World Congress, Salt Lake City UT, October 6-10th.

b. Alexis Fouetio Kengne (2014) "Surface Chemistry of Hierarchical Nanosprings for Sensing and Catalysis" Ph.D dissertation, University of Idaho, Moscow ID, December.

c. Yinglei Han (2014) "Upgrading of Pyrolysis Bio-oil to Renewable Fuels by Hydrodeoxygenation", M.S. thesis, University of Idaho, Moscow ID, December.

vi. ***Direct Drive AC Rim Motor for Responsive Energy Control of Alternative Electric Vehicle***

a. Veach, Giselle S. (2014), "Development, theory, and design of the image motor for automotive applications," Master of Science thesis, University of Idaho, August 2014.

b. Two papers pending review for conferences.

vii. ***Daily Travel Feedback to Encourage Eco-Routing***

Chang, K. Lowry, M., Seely, B., and Cook, R. (2015). "Using a Responsive Interactive Program to Enhance Daily Travel Feedback" Presented at the 94th Annual Transportation Research Board, Washington, D.C. January 11-15, 2015.

viii. ***Eco-driving Modeling Environment***

Prototype for a MiniSim EcoDash display providing fuel consumption and emission data for users.

B. <u>Old Dominion University</u>:

i. ***New Strategies for the Emergency Vehicle Routing to Reduce Response Time Using Vehicle-to-Vehicle Communications***

a. Jordan, C. and M. Cetin, "Signal Preemption Strategy for Emergency Vehicles Using Vehicle to Infrastructure Communication," 94th Annual meeting of the TRB, Washington, D.C. January 11-15, 2015, paper # 15-5723.

b. Final report completed: http://tranliveutc.org/engr/niatt/tranlive/projects/2012/emergency-vehicle-routing.

ii. ***Real-time Prediction of Queues at Signalized Intersections to Support Eco-driving Applications***
   a. S. Rompis, F. Habtemichael, and M. Cetin, "Calibrating Simulation Models for Traffic During Incidents Using Shock Wave Speeds Estimated from Field Data" Presented at the 94th Annual meeting of the Transportation Research Board, Washington, D.C., January 11-15, 2015.
   b. Final report completed - http://tranliveutc.org/engr/niatt/tranlive/projects/2012/real-time-prediction-of-queues.

iii. ***Reducing Energy Use and Emissions through Innovative Community Designs: Methodology and Application***
   a. Liu J., X. Wang, A. Khattak, Providing Real-Time Driving Volatility Information, Presented at ITS World Congress 2014 conference (Detroit, Sept 7-11)
   b. A. Khattak, J. Liu, X. Wang, Supporting instantaneous driving decisions through vehicle trajectory data, to be presented at TRB 2015 annual meeting, Washington DC.
   c. Liu J., A. Khattak, X. Wang, The Role of Alternative Fuel Vehicles: Using Behavioral and Sensor Data to Model Hierarchies in Travel, forthcoming in Transportation Research-part C.
   d. Liu J., A. Khattak, X. Wang, Creating Indices for How People Drive in a Region: A Comparative Study of Driving Performance, to be presented at TRB 2015 annual meeting, Washington DC.
   e. Bandeira J., P. Fernandes, T. Fontes, S. Pereira, A. Khattak, & M. Coelho, Assessment of eco-traffic assignment strategies in an urban corridor. Submitted for review in transportation journal.
   f. Bandeira J., S. Pereira, T. Fontes, P. Fernandes, A. Khattak, M. Coelho, An Eco-Traffic Management Tool, Computer-based Modelling and Optimization in Transportation, Advances in Intelligent Systems and Computing, Volume 262, 2014, pp 41-56.
   g. Son S., A. Khattak, Geographical Travel Time Reliability: A Comparative Study of Transit-oriented Development Commuters and Auto-oriented Development Commuters, to be submitted for review in transportation journal.
   h. Son S., A. Khattak Activity Sequencing Behavior from a Regional Perspective: A Comparative Study of Transit-oriented Development Residents and Auto-oriented Development Residents, to be submitted for review in transportation journal.

iv. ***Optimize Freight Routes and Modes to Minimize Environmental Impacts***
   a. Foytik, P. and Robinson, R.M. "Integrating Truck Emissions Cost in Traffic Assignment," TRB paper # 15-4936, Presented at the 94th Annual Transportation Research Board, Washington, D.C., January 11-15, 2015.
   b. Final report completed - http://tranliveutc.org/engr/niatt/tranlive/projects/2012/optimize-freight-routes-and-modes.

C. <u>Syracuse University</u>:

i. Dr. Sam Salem and Sudipta Ghorai presented a paper on "Environmental Life-Cycle Assessment of Pavement Maintenance, Repair and Rehabilitation Activities" in a poster session at the TRB 94th Annual Meeting January, 2015 in Washington, DC.

ii. Dr. Cliff Davidson is PI on a new grant to host a workshop at NSF in Arlington, Virginia on sustainability in engineering education, which includes all aspects of engineering including transportation engineering. The workshop was organized during the spring and early summer 2014, and was held in August 2014. The purpose of the workshop was to explore the possibility of establishing a web platform as a repository for engineering education materials

on sustainability, which will include materials on transportation engineering from courses around the U.S. The workshop was attended by around 60 engineering professors with interests in sustainability, including several with interests in sustainable transportation systems. The workshop summary is being written, and will be available in Spring 2015.

iii. Dr. Sam Salem and Sudipta Ghorai published a conference paper titled "Using Traffic Micro-Simulation to Assess the Benefits of Accelerated Pavement Construction for Reducing Traffic Emissions" in International Conference on Civil and Architectural Engineering. Bangkok, Thailand in December, 2014

iv. Dr. Sam Salem, Jeff Chen, Dr. Baris Salman, and Dr. Ahmed Abdel-Rahim published a conference paper titled "Life-Cycle Benefits & Cost Analysis Framework of Adaptive Traffic Control System Deployment", presented in the International Conference on Architecture and Civil Engineering in Dubai, UAE

v. Dr. Sam Salem, Jeff Chen, Dr. Baris Salman, and Dr. Ahmed Abdel-Rahim submitted a conference paper titled "Life-Cycle Benefits & Cost Analysis Framework of Ramp Metering System Deployment" presented at the Transportation for Sustainability Conference in Washington D.C., which is organized by Transportation Research Board.

vi. Dr. Sam Salem, Sharareh Pirzadeh, Sudipta Ghorai, and Dr. Ahmed Abdel-Rahim published a conference paper titled "Improving Sustainability of Work-zones by Implementing Lean Construction Techniques", presented at the International Conference on Architecture and Civil Engineering in Dubai, UAE.

vii. Dr. Cliff Davidson and Mallory Squier published a conference paper titled "Stormwater mass balance on a large extensive green roof in Syracuse, NY", presented at the International Conference on Sustainable Infrastructure, American Society of Civil Engineers, Long Beach, CA, November 6-8, 2014.

viii. Dr. Cliff Davidson and Miriam Heller published a conference paper titled "Introducing sustainability into the engineering curriculum", presented at the International Conference on Sustainable Infrastructure, American Society of Civil Engineers, Long Beach, CA, November 6-8, 2014.

ix. Dr. Cliff Davidson and Dr. Shahzeen Z. Attari published a conference paper titled "Metrics of sustainability in human development: How well do people understand the impacts of their activities?", presented at the Workshop on Measurement Science for Sustainable Construction and Manufacturing, National Institute of Standards and Technology and American Society of Civil Engineers, Reston, VA, June 12-13, 2014.

D. <u>Texas Southern University</u>:

i. ***A Systematic Evaluation of the Impacts of Traffic Condition Information on the Reduction of On-road Mobile Emissions –*** Nothing to report

ii. ***Education and Outreach Activities -*** A series of education programs are in production, covering all range of students (K-12 and college). These include the summer transportation academy for high school students and the transportation club for primary school students.

iii. ***Develop an Integrated Data Management System at the Microscopic, Mesoscopic, and Macroscopic Levels to Assess the Environmental Impacts of the Transportation System***
Wu Ying, Mehdi Azimi, Fengxiang Qiao, Po-Hsien Kuo, Pengfei Liu, and Lei Yu. Pilot Test of Vehicular Emissions under Different Pavement Types in Houston. Accepted for publication in the proceedings of the 28th Annual Conference of the International Chinese Transportation Professionals Association (ICTPA), May 14-16, 2015, Los Angeles.

iv. ***Use the Driving Simulator to Synthesize the Related Vehicle Specific Power (VSP) for Emission and Fuel Consumption Estimations***

a. Ziyue Li, Lei Yu, Fengxiang Qiao, Jinghui Wang (2015). Feasibility Study of Using Driving Simulator to Develop Operating Mode Distributions for Emission Analysis. Presented at Transportation Research Board Annual Meeting, Transportation Research Board of the National Academies, Washington, DC, January 11-15, 2015.
b. Li, Q. and F. Qiao. (2014). How Drivers' Smart Advisory System Improves Driving Performance? A Simulator Imitation of Wireless Warning on Traffic Signal under Sun Glare. LAMBERT Academic Publishing. ISBN-13: 978-3-659-57193-0.
c. Johora Munni, Fengxiang Qiao, Qing Li, Lei Yu, and Po-Hsien Kuo. (2015). Driving Behavior and Emission Analysis at Yellow Intervals with Advanced Warning Message under Foggy Weather Condition: A Simulator Test. Accepted by the Transportation Research Forum for the 56th Annual Forum to be held March 12-14, 2015 in Atlanta, GA.
d. You, B., F. Qiao, Q., and L. Yu. (2015). Implications of Left Turn Smartphone Warning Messages in Work Zone Termination Areas through Driving Simulator Tests. Accepted for publication in the proceedings of the 28th Annual Conference of the International Chinese Transportation Professionals Association (ICTPA), May 14-16, 2015, Los Angeles.
e. Qiao, F., Q. Li, and L. Yu. (2014). Testing Impacts of Work Zone X2V Communication System on Safety and Air Quality in Driving Simulator. Proceedings of the 2014 Intelligent Transportation Society (ITS) World Conference, Detroit, September 7-11, 2014.

v. ***Develop Multi-scale Energy and Emission Models for Arterial Traffic Systems***

a. Fengxiang Qiao, Ling Liu, Wen Long, and Lei Yu. (2015). Modeling Excess Carbon Dioxide Emissions from Traffic Congestion in Urban Areas. World Soft Computing Conference WSC18 Proceeding in the Springer Book Series "Advances in Intelligent Systems and Computing" 2015. In Print.
b. Fengxiang Qiao, Ling Liu and Lei Yu. (2015). Quantifying Changes of Mobile Source Air Pollution in Metropolitan Areas Using Vehicle Emission Model MOVES. Journal of Environmental Science and Engineering. David Publishing Company. In Print.

vi. ***Improve the Environment for a Livable Community: Advance the AERIS Program by Developing and Testing Eco-traffic Signal System Control Applications***

Chelse Hoover, Lei Yu, Fengxiang Qiao, and Mehdi Azimi. (2015). Emission Implications of Alternative Origin-Destination Routes: Case Study in Houston, Texas. TRB 15-2511. Presented at Transportation Research Board Annual Meeting, Washington, DC, January 11-15, 2015.

vii. ***Developing Short Range Vehicle-to-Infrastructure Communication Systems***

a. Qi Zhao, Sicong Zhu, Lei Yu, Fengxiang Qiao (2015). Experimental Development and Testing of Smartphone Eco-driving App. TRB 15-3211. Presented at Transportation Research Board Annual Meeting, Washington, DC, January 11-15, 2015.
b. Rahman, R., F. Qiao, Q. Li, L. Yu, and P.-H. Kuo (2015). Smart Phone Based Forward Collision Warning Message in Work Zones to Enhance Safety and Reduce Emissions. Accepted for Publication in the Journal of Transportation Research Record, Transportation Research Board of National Academy of Sciences.
c. Li, Q., F. Qiao, and L. Yu. (2015). Update Flow Dispersion Model to Incorporate Impacts of V2I Advanced Warning Message. Accepted for publication in the proceedings of the 28th Annual Conference of the International Chinese Transportation Professionals Association (ICTPA), May 14-16, 2015, Los Angeles.
d. Li, Q., F. Qiao, X. Wang, and L. Yu. (2015). Measures of Performance when Drivers Approaching STOP Sign Intersections with the Presence of Drivers Smart Advisory System. Accepted for publication in the proceedings of the 28th Annual Conference of the International Chinese Transportation Professionals Association (ICTPA), May 14-16, 2015, Los Angeles.

e. Li, Q., F. Qiao, and L. Yu (2014). Calibration of Traffic Flow Dispersion Model with Vehicle to Infrastructure Communication System in Effect. Publication in the Proceedings of the National Technical Association (NTA) 86th Annual National Conference. Cleveland, Ohio, September 24-26, 2014.

E. Virginia Tech:

i. ***Develop Mesoscopic Fuel Consumption and CO_2 Emission Models***

Wang J., Rakha H. and Yu L. (2015), "Operating Mode Distribution Characteristics of Different Freeway Weaving Configurations and their Effects on Vehicular Emissions," Presented at the 94th Transportation Research Board Annual Meeting, Washington DC, January 11-15, CD-ROM [Paper # 15-1429].

ii. ***Develop Macroscopic Fuel Consumption and CO2 Emission Models –*** Nothing to report

iii. ***Develop Green Cooperative Adaptive Control Systems in the Vicinity of Signalized Intersections***

a. Kamalanathsharma R. and Rakha H. (In press), "Leveraging Connected Vehicle Technology and Telematics to Enhance Vehicle Fuel Efficiency in the Vicinity of Signalized Intersections," *Journal of ITS: Technology, Planning, and Operations*.
b. Kamalanathsharma Kamalanathsharma R. and Rakha H. (2014), Agent-Based Simulation of Eco-Speed Controlled Vehicles at Signalized Intersections," Transportation Research Record: Journal of the Transportation Research Board, Issue 2427, pp. 1-12.
c. Kamalanathsharma R., Rakha H. and Yang H. (2015), "Network-wide Impacts of Vehicle Eco-Speed Control in the Vicinity of Traffic Signalized Intersections," Presented at the 94th Transportation Research Board Annual Meeting, Washington DC, January 11-15, CD-ROM [Paper # 15-4290].
d. Final report competed: http://tranliveutc.org/engr/niatt/tranlive/projects/2012/develop-green-cooperative-adaptive-control-systems-in-the-vicinity-of-signalized-intersections.

iv. ***Develop Multi-scale Energy and Emission Models***

a. Edwardes W. and Rakha H. (2014), "Virginia Tech Comprehensive Power-Based Fuel Consumption Model: Modeling Diesel and Hybrid Buses," Transportation Research Record: Journal of the Transportation Research Board, Issue 2428, pp. 1-9.
b. Elmoselhy S., Faris W. and Rakha H. (2014), "Experimentally validated analytical modeling of diesel exhaust HC emission rate," *The Journal of Mechanical Science and Technology*.
c. Faris, W.F., Rakha, H.A. and Elmoselhy (2014), "Impact of Intelligent Transportation Systems on Vehicle Fuel Consumption and Emission Modelling: An Overview," SAE Transactions: International Journal of Materials and Manufacturing, 7 (1), pp. 129-146.
d. Faris, W.F., Rakha, H.A. and Elmoselhy (2014), "Analytical Model of Diesel Engines Exhaust NOx Emission Rate," International Journal of Vehicle Systems Modelling and Testing, vol. 9, no. 3/4, pp. 264-280.

F. Multi-institution:

i. ***Developing and Field Implementing a Dynamic Eco-routing System* –Virginia Tech, lead; University of Idaho and Old Dominion University, partners**

a. Ahn K. and Rakha H. (2014), "Eco-Lanes Applications: Preliminary Testing and Evaluation," Transportation Research Record: Journal of the Transportation Research Board, Issue 2427, pp. 41-53.
b. Wang J. and Rakha H. (2015), "Impact of Dynamic Route Information on Day-to-Day Driver Route Choice Behavior," Presented at the 94th Transportation Research Board Annual Meeting, Washington DC, January 11-15, CD-ROM [Paper # 15-4918].

ii. ***Smartphone-based Solutions to Monitor and Reduce Fuel Consumption and Co2 Footprint – Old Dominion University, lead; Virginia Tech and Texas Southern University, partners***

a. The following papers were presented or will be presented:
   1) Ustun, A. Alasaadi, T. Nadeem, M. Cetin, "Detecting Vehicle Stops from Smartphone Accelerometer Data", the 21st ITS World Congress, Detroit, MI, Sept 7-11, 2014.
   2) Jahangiri A. and Rakha H. (2015), "Distributed Learning: An Application to Transportation Mode Identification," Presented at the 94th Transportation Research Board Annual Meeting, Washington DC, January 11-15, CD-ROM [Paper # 15-0826].
   3) I. Makohon, Z. Li, M. Sosonkina, Y. Shen, M.Cetin, M. Ng, D.T. Nguyen, "JAVA Based Visualization and Animation for Teaching Dijkstra Shortest Path Algorithm in Transportation Networks", to be presented at the MODSIM '2015 conference, Virginia Beach Convention & Visitor Bureau, VA Beach, VA, March 31-April 2, 2015.
   4) Z. Li, I. Makohon, M. Sosonkina, Y. Shen, D.T. Nguyen, "Visualization and Animation for Teaching Frank-Wolfe Transportation Network Equilibrium", to be presented at the MODSIM '2015 conference, Virginia Beach Convention & Visitor Bureau, VA Beach, VA, March 31-April 2, 2015.

b. Journal paper under review:
   Drs. Nguyen/Ng and Paul Johnson (CEE Ph.D Student) submitted a paper " A New Large-Scale Network Partitioning Algorithm and Its Application to Transportation Networks (TRC-D-13-00556R1) " for possible publication to Transportation Research Part C, and are now addressing the reviewers' comments.

c. The following presentations were done:
   1) M. Cetin and T. Nadeem "Mining Motion Sensor Data from Smartphones for Estimating Vehicle Motion" NSF Drive Sense 2014 Workshop,Norfolk, VA, Oct 30-31, 2014.
   2) Jahangiri and H. Rakha "Transportation Mode Recognition using Smartphone Sensor Data" NSF Drive Sense 2014 Workshop,Norfolk, VA, Oct 30-31, 2014.
   3) D.T. Nguyen, M. Ng "Domain Decomposition, Parallel Computing and Traffic Assignment", invited presentation (P15-6590; 9:00am-9:20am; January 11-2015) at the TRB'2015 Annual Meeting (Workshop on Parallel Computing in Traffic Simulation and Assignment: Moving from Innovations to Practice), Washington, D.C. , January 11-15, 2015.

      Contributions by ODU Graduate Students/Faculty
      CEE Department: G. Bakhtyar (Ph.D), P. Johnson (Ph.D), Assoc. Professor M. Cetin
      MSVE Department: I. Makohon (M.S.), S. Allen (M.S.), N. Pham (Ph.D)
      MAE Department: V. Nguyen (Ph.D)

iii. ***Eco-traffic Signal System – University of Idaho, lead; Virginia Tech and Syracuse University, partners***

Developed a connected vehicle traffic signal system lab in which data are exchanged between the vehicle, the road side unit, and the traffic controller that will facilitate field deployment.

iv. ***Studying the impact of accelerated construction methods in work zones using micro-simulation, on vehicle emissions and the environment*** **– Syracuse University, lead; Virginia Tech and University of Idaho, partners**

Ghorai, S., and Salem, O. (2014). "Using Traffic Micro-Simulation to Assess the Benefits of Accelerated Pavement Construction for Reducing Traffic Emissions" *International Conference on Civil and Architectural Engineering. Bangkok, Thailand.*

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

A. University of Idaho:

UI has been working with the Idaho Transportation Department, Decagon Devices, Inc., Harbrick, AutonomouStuff, LLC., and Econolite Controls holding various meetings to collaborate on projects and holding training meetings.

B. Old Dominion University:

Dr. Khattak worked collaboratively with foreign collaborators at University of Aveiro, Portugal (J. Bandeira, T. Almeida, & M. Coelho) on research papers that are related to the TranLIVE theme and were submitted for review in refereed journals.

C. Syracuse University:

Nothing to report

D. Texas Southern University:

i. Dr. Xumei Chen from Beijing Jiaotong University in China and Dr. Yi Qi, TSU, were awarded a project "Dynamic Model on Emission Control and Estimation at Multimodal Signalized Intersections with Traveler Information System" by the National Science Foundation of China (grant #71373018) based on some results from "A Systematic Evaluation of the Impacts of Traffic Condition Information on the Reduction of On-road Mobile Emissions" project.

ii. Two Ph.D. international exchange students are visiting TSU-one from Australia and one from China. They are exchanging research ideas and activities with TSU graduate and undergraduate students.

iii. Exchanged ideas and potential collaborative work with researchers at the University of Texas, El Paso.

ii. Professor Haibo Zou from Chang-an University, and Professor Liqing Wei from Chongqing Jiaotong University (both from China) worked as visiting scholars at TSU.

iii. Conducted collaborative research with National Science Foundation (NSF) CREST center on complex network, especially its subcenter on wireless communications at TSU.

iv. Texas Department of Transportation (TxDOT) project vehicle emissions have been tested in junction with the records of pavement roughness information.

E. Virginia Tech:

i. ***Develop Mesoscopic Fuel Consumption and CO_2 Emission Models –*** Nothing to report

ii. ***Develop Macroscopic Fuel Consumption and CO_2 Emission Models*** – Nothing to report

iii. ***Develop Green Cooperative Adaptive Control Systems in the Vicinity of Signalized Intersections -*** Nothing to report

iv. ***Develop Multi-scale Energy and Emission Models***
The research team collaborated with researchers from the International Islamic University of Malaysia (IIUM).

F. Multi-institution:

i. ***Developing and Field Implementing a Dynamic Eco-routing System* –Virginia Tech, lead; University of Idaho and Old Dominion University, partners –** Nothing to report

ii. ***Smartphone-based Solutions to Monitor and Reduce Fuel Consumption and Co2 Footprint – Old Dominion University, lead; Virginia Tech and Texas Southern University, partners –*** Nothing to report

iii. ***Eco-traffic Signal System – University of Idaho, lead; Virginia Tech and Syracuse University, partners –*** Harbrick, AutonomouStuff, LLC – Moscow, Idaho

iv. ***Studying the impact of accelerated construction methods in work zones using micro-simulation, on vehicle emissions and the environment*** – **Syracuse University, lead; Virginia Tech and University of Idaho, partners** – Nothing to report.

4. <u>IMPACT</u>:

A. <u>University of Idaho</u>:

i. ***Developing and Testing Eco-Traffic Signal System Applications***

a. Education:
   1) One Bachelor of Science in Civil Engineering student graduated and joined the transportation engineering graduate program at the University of Idaho.
   2) Two undergraduate Civil Engineering students joined as undergraduate research intern.

b. Research:
   1) Guidelines for actuated control parameters to minimize fuel consumption and vehicle emissions for fully actuated signaled intersections operating on isolated or free mode of operation.
   2) Guidelines for optimizing coordinated corridors to minimize fuel consumptions and emissions.
   3) Architecture for a hardware-in-the-loop simulation environment for connected-vehicle applications for corridor operations integrating.

c. Tech Transfer: Publication of results at various meetings and conferences.

ii. ***Calibration of Multi-Scale Energy and Emissions Models***

a. Education:
   1) One Ph.D. student in Mechanical Engineering graduated.
   2) One undergraduate electrical engineering student continued working as undergraduate research intern.

b. Research: Calibrated fuel consumption and emission models for three traffic engineering software tools: VISSIM, Integration, and Transyt 7-F.

iii. ***Design Improvements and Performance Validation of a Competitive Hybrid FSAE Vehicle***

a. Education: It provides an opportunity for young engineers to investigate, design, and experiment with hybrid automotive technologies. This exposes them to a vital and ever more important part of transportation technology. Having this experience gives team members an advantage when entering industry. Experience with hybrid technology is in ever increasing demand from auto companies.

b. Technology Advancement: Graduate students conducted the majority of the research that supports the design work. Mostafa Asfoor, Jeremy Cuddihy, Rory Lilley, John Teske, and Phil Peterson each have or are currently conducting research specifically based upon the Formula Hybrid Program. “A User-Friendly, Two-Zone Heat Release Model for Predicting Spark-Ignition Engine Performance and Emissions” created by Jeremy Cuddihy was used to create the engine model used to predict the Brake Specific Fuel Consumption map.

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

Dynamic traffic monitoring has potential benefits for national economy and environment by reducing fuel consumption of city vehicles and reducing CO_2 emission.

v. ***Upgrading Biomass Pyrolysis Bio-oil to Renewable Fuels***

a. We have developed novel catalysts to convert woody biomass pyrolysis bio-oil into drop in fuels.

b. This project has supported the training of two graduate students in the area of catalyst development and catalytic conversion of biomass into fuels.
c. We have participated in technology transfer forums by presenting our research at technical and scientific meetings.

vi. ***Direct Drive AC Rim Motor for Responsive Energy Control of Alternative Electric Vehicle***
Nothing to report

vii. ***Daily Travel Feedback to Encourage Eco-Routing***
Tech transfer will continue through conference presentations and journal publications.

viii. ***Eco-driving Modeling Environment***
a. Research: An Eco-Driving modeling environment that integrates the NADS MiniSim driver simulator model and the GT-Suite advanced engine modeling tool
b. Education: One computer science undergraduate student

B. Old Dominion University:

i. ***New Strategies for the Emergency Vehicle Routing to Reduce Response Time Using Vehicle-to-Vehicle Communications***
This research was presented at the 92nd and the 94th TRB annual conferences. A related paper was published in the Transportation Research Record. This research also contributed to education with Craig Jordan's MS thesis based on this project. The results of this project can be incorporated into designing future emergency vehicle routing systems under the vehicle-to-vehicle communications infrastructure.

ii. ***Real-time Prediction of Queues at Signalized Intersections to Support Eco-driving Applications***
This research was presented at the 93rd and the 94th TRB annual conferences. This research also contributed to education with two PhD students at ODU currently expanding on this work for their dissertations. The results of this project can be incorporated into designing future traffic signal optimization as well as eco-signals applications under the vehicle-to-vehicle communications.

C. Syracuse University:

i. The results presented in the final report of the project "Assessing Environmental Impacts of Work Zones in Arterial Improvement Projects" are expected to assist decision makers and construction officials in highway agencies in selecting environmentally sustainable maintenance, repair and rehabilitation solutions.

ii. The literature search conducted by project participants in all TranLIVE projects resulted in development of a comprehensive database and assisted students in generating a deeper understanding with regards to various aspects involved in sustainability of transportation systems. The literature review efforts were particularly beneficial for graduate students in acquiring knowledge on their respective TranLIVE project components and in improving their problem solving skills. Participating in TranLIVE projects taught them to critically analyze the existing information in a scientific manner and to develop the most feasible methodology to address the research needs. In addition, students excelled in defining the scope of their projects, selecting the right model to conduct their analyses, filtering out the less important factors and comparing their results against other published work.

iii. The conferences attended by the project participants allowed them to showcase their ongoing research and obtain useful feedback from transportation experts.

D. Texas Southern University:

i. ***A Systematic Evaluation of the Impacts of Traffic Condition Information on the Reduction of On-road Mobile Emissions***

This project will provide transportation planners or environmental analysts with qualitative assessments of the impacts on air quality of different types of traffic condition information. It will also help the traffic engineer to appropriately deploy the most effective traveler information systems to achieve more environmental benefits. In addition, since very few studies have been performed to directly investigate the impacts of the traveler information on on-road mobile emissions, the proposed research will fill this gap and will help the researchers and practitioners to better understand the related issues in the future. Furthermore, the operating mode ID distributions developed by this study can be used as input to run MOVES and obtain the emission level of any pollutants. The results of this study will facilitate the evaluation of transportation operation and demand management strategies with respect to their impacts on air quality. Finally, the results of project can be incorporated into some teaching curriculums, such as the class TMGT 885 "Quantitative Assessment of Transportation Environmental Impact" at TSU.

ii. ***Education and Outreach Activities***

a. The education program helps to promote interests of K-12 and college students in STEM programs, especially in transportation and environment related areas. The developed curricula and experiences can be easily further expanded and applied to other schools.
b. The education program has brought awareness to students, teachers, community organizers, organizations and families about the impact of transportation on the environment. In addition, these groups have come to understand that their personal decisions regarding transportation impact the quality of their environment.

iii. ***Develop an Integrated Data Management System at the Microscopic, Mesoscopic, and Macroscopic Levels to Assess the Environmental Impacts of Transportation System***

Once the emission and activity database is fully developed, researchers, students at different levels (graduate students, undergraduate students, K-12 students) from different geographic areas (within or outside the consortium, within or outside the country) can utilize this database easily for various transportation and environment related research and education purposes through web access.

iv. ***Use the Driving Simulator to Synthesize the Related Vehicle Specific Power (VSP) for Emission and Fuel Consumption Estimations***

The test procedure provides good material for the development of a lab test for graduate students in courses such as Quantitative Analyses of Vehicle Emissions.

v. Develop Multi-scale Energy and Emission Models for Arterial Traffic Systems

The developed models provide very good examples for undergraduate and graduate level courses. The developed techniques can be expanded for direct use by industry and government.

vi. ***Improve the Environment for a Livable Community: Advance the AERIS Program by Developing and Testing Eco-traffic Signal System Control Applications***

a. Results from the emission analysis demonstrate that the DSSS helps to reduce emission rates at yellow intervals when approaching an intersection. While the DSSS message in foggy weather condition cannot fully recover drivers' behaviors to normal weather condition, it can somehow reduce the risk of safety such as running red lights and sharp decelerations, and may also reduce emissions.
b. The findings can be a good reference in developing optimal strategies for eco-traffic signal system control at intersections and in dynamic traffic assignment.

vii. ***Developing Short Range Vehicle-to-Infrastructure Communication Systems***
The developed system can help to not only enhance safety, but also reduce vehicle emissions. With more tests, it can be widely used in research, industry and for education purposes.

E. Virginia Tech:

i. ***Develop Mesoscopic Fuel Consumption and CO_2 Emission Models***
   a. Education: The funding of a graduate student assistantship.
   b. Research: Development of mesoscopic fuel consumption models for light duty cars and buses.

ii. ***Develop Macroscopic Fuel Consumption and CO_2 Emission Models***
   a. Education: The funding of a graduate student assistantship.
   b. Research: Development of macroscopic fuel consumption models for light duty cars and buses.

iii. ***Develop Green Cooperative Adaptive Control Systems in the Vicinity of Signalized Intersections***
   a. Education: The funding of a graduate student assistantship.
   b. Research: Development of an eco-cruise control in the vicinity of traffic signalized intersections and the development of a cloud-based testing environment.
   c. Technology Transfer: Publication of results at various conferences.

iv. ***Develop Multi-scale Energy and Emission Models***
   a. Education: The funding of a graduate student assistantship.
   b. Research: Development of fuel consumption models for light duty cars and buses.
   c. Technology Transfer: Publication of results at various conferences.

F. Multi-institution:

i. ***Developing and Field Implementing a Dynamic Eco-routing System* –Virginia Tech, lead; University of Idaho and Old Dominion University, partners**
   a. Education: The funding of a graduate student assistantship.
   b. Research: Development of eco-routing prototype.

ii. ***Smartphone-based Solutions to Monitor and Reduce Fuel Consumption and Co2 Footprint – Old Dominion University, lead; Virginia Tech and Texas Southern University, partners* -** The results of the research are being disseminated though journal publications and presentations at international conferences.

iii. ***Eco-traffic Signal System – University of Idaho, lead; Virginia Tech and Syracuse University, partners***
   a. Education: One M.Sc. computer science student working on the project
   b. Research: A connected vehicle traffic signal system lab in which data are exchanged between the vehicle, the road side unit, and the traffic controller that will facilitate field deployment.

iv. ***Studying the impact of accelerated construction methods in work zones using micro-simulation, on vehicle emissions and the environment* – Syracuse University, lead; Virginia Tech and University of Idaho, partners** – Nothing to report

5. CHANGES/PROBLEMS

A. University of Idaho:
Nothing to report

B. Old Dominion University:
Nothing to report

C. Syracuse University:
Nothing to report

D. Texas Southern University:
Nothing to report

E. Virginia Tech:
Nothing to report

F. Multi-institution:
Nothing to report

6. SPECIAL REPORTING REQUIREMENTS

Financials will be sent by the University of Idaho's Office of Sponsored Programs as needed.

Completed by:
University of Idaho: Ahmed Abdel-Rahim
Old Dominion University: Mecit Cetin
Syracuse University: O. Sam Salem
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