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Measurement, Modeling, and Impact Studies of Vehicle Exhaust Emission and Fuel Consumption

- Sample Practices at Texas Southern University

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About Texas Southern University





- A State University Founded in 1927 and Located in Houston, Texas
- The ^{2nd largest} Historically Black Colleges and University (HBCU) in the nation
- One of the Largest Historically Black Colleges and Universities (UBCU)
- Twenty Year's Experiences in Measuring and Modeling Vehicle Emissions Using Portable Emission Measurement System (PEMS)
- With Newly Awarded National Center for Sustainable Transportation (NCST) (\$1.8 Million) by the U.S. Department of Transportation

TSU Transportation and Environmental Programs • Degree Programs



- Ph.D. Programs
 - Environmental Toxicology (with a focus on transportation environmental studies)
 - Urban Planning and Environment Policy (with a concentration in transportation)
- \odot Master Level Graduate Programs
 - Master of Science in Transportation Planning and Management
 - Environmental Toxicology (with a focus on transportation environmental studies)
 - Urban Planning and Environment Policy (with a concentration in transportation)
- \circ Undergraduate programs
 - Civil Engineering, Civil Engineering Technology, Maritime Transportation Management and Security, Aviation Science Management
- Graduate Research Assistant Program
- Summer Undergraduate Research Program (SURP)
- K-12 Programs
 - National Summer Transportation Institute (NSTI)
 - Maritime Summer Transportation Academy
 - O UTC Tier One TranLIVE Summer Transportation Academy (STA)
 - O UTC Tier One Transportation and Environmental Club (TEC) at Minority-serving Elementary School



TSU Innovative Transportation Research Institute (ITRI)

ESTABLISHED – 2000

Co-director: Dr. Fengxiang Qiao (713-313-1915)









Innovative Transportation Research Institute (ITRI)

- TSU Environmental and Sustainable Transportation Related Research Activities are Mainly Conducted at ITRI
- The Innovative Transportation Research Institute (ITRI) at TSU was developed in the fall of 2006 by expanding the former Urban Traffic and Air Quality Lab (UTAQL), which was first established in 2000.
- ITRI Receives Funds from Various Federal and State Level Agencies to Support its Innovative Transportation Research Activities



ITRI Goals

- Develop, Evaluate, Optimize, and Recommend Comprehensive Strategies
 - For mobile source emission reduction, fuel consumption saving, traffic congestion mitigation, urban transportation planning, and ITS development
 - Through the smart utilization of advanced technologies, large scale computer simulation methods, complex modeling systems, and state-of-the-art lab equipment

ITRI Mission Statement



- Conduct Innovative Research and Development
 To seek optimal solutions to various transportation problems
- Develop and Deliver High-quality Education and Training Programs
 - To traffic engineers, transportation planners, transportation managers, air quality specialists, etc.







ITRI Research and Outreach Efforts



- Vehicle Emission Testing and Modeling
- Transportation Impacts on Air Quality
- Transportation Impacts on Public Health
- Transportation Modeling and Simulation
- Transportation Planning and Management
- Intelligent Transportation System (ITS) Technology Applications
- Driving Behavior Studies
- Artificial Intelligence and Soft-computing Applications in Transportation
- Education, Training, and Technology Transfers

Major Funding Sources

- US Department of Transportation (US DOT)
- National Academy of Sciences (NAS) Transportation Research Board (TRB)
- Transportation Research Board National Cooperative Highway Research Program (NCHRP)
- Texas Department of Transportation (TxDOT)
- National Science Foundation (NSF)
- National Institute of Standards and Technologies (NIST)
- Air Force Research Laboratory (AFRL)
- Houston Advanced Research Center (HARC)
- National, Tier One, and Regional University Transportation Centers (UTC)

 National Center for Sustainable Transportation (NCST)
 Tier One Center: Transportation for Livability by Integrating Vehicles and the Environment (TranLIVE)
 Southwest UTC



State-of-the-art Lab Facilities





Portable Emission Measurement Equipment **Driving Simulator**

Mobile Traffic Van

Real-time Traffic Surveillance System through Houston TranStar

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Portable Emission Measurement Equipment - PEMS



- Axion RIS by
 - Clean Air Tech -> 3DATX (Dave Miller)
- \odot Tested Vehicle Emissions and Developed Models since 2003
- Being able to measure emissions and fuel consumption of trucks, cars, buses, vessels, and non-road equipment
- \odot Accuracy certified by EPA
- \odot The TSU unit is to be Upgraded to the newest version soon









Portable Emission Measurement Equipment - PEMS



- Sample Testing Activities
 - \odot Truck Emissions together with EPA, TTI, and Virginia Tech at the Border between U.S. and Mexico
 - \odot Heavy-Duty Vehicle Emissions in Greater Houston Area for TxDOT
 - $\odot\,\text{Truck}$ idling emissions in Houston Area
 - $\odot\,\mbox{Emissions}$ of Vehicles of different Types in Houston and other Texas Areas
- Developing Relevant Models to Characterize the Air Quality and Health Impacts Resulted from
 - $\odot \textsc{Travel}$ activities
 - Roadway geometric designs (weaving design, alignment, left turn...)
 - \circ Pavement Roughness
 - Signal plan (signal coordination, ramp metering, congestion pricing, ...)
 - O Different environmental policies and transportation management strategies 12





- TSU was Newly Awarded as a Member of the National Center for Sustainable Transportation (NCST) in February 2023

 By the United States Department of Transportation (US DOT)
 - With \$1.8 million funding to TSU
- The Only National Center on Preserving the Environment by US DOT
- Lead by University of California at Davis
- Other Member Universities
 - University of California at Riverside
 - University of Southern California
 - \odot California State University Long Beach
 - \odot Georgia Institute of Technology
 - \odot The University of Vermont









• To develop strategies and techniques to reduce energy consumption and enhance air quality in multimodal transportation systems



TSU Students were Preparing Vehicle Emission Testing Using the Portable Emission Measurement System (PEMS) $_{14}$

Sample Studies: Sponsored by TxDOT, US DOT Tier One UTC TranLIVE, and NSF CREST

STATE AND A STATE

Total Length (mi)

30.45

223.49

738.67

74.80

Impacts of Pavement Roughness on Vehicle Emissions

SELECTION OF THE ROADWAY & TEST PLAN

The test covered new pavements, old pavements, and work zones with rougher pavements. It also included high-speed freeways to low-speed local roads, covering a wide range of speed limits.



Site (Location)

Austin

El Paso

Houston

San Antonio

over 1,000 miles in Four Metropolitan Areas in Texas

Sample Studies: Sponsored by TxDOT, US DOT Tier One UTC TranLIVE, and NSF CREST



Impacts of Pavement Roughness on Vehicle Emissions

DATA COLLECTION



Vehicle Information		Engine Information	
Year/age	2004/10 years' old	Displacement (L)	2.5
Make	Subaru	Cylinder Configuration	4
Model	Forester	HP@RPM	165 @ 5,699
Vehicle Weight	3,100 lb	Torque@RPM	225 Nm @ 4,000
Test Weight	3,500 lb	Fuel Delivery	Gas
Mileage at start	10,250 mi	Transmission	Auto

- Emission data were collected by portable emission measurement system (PEMS) and roughness data by ROADROID app
- No tests have been done during the winter or on rainy days
- During testing, periodic checks were done
- To maintain consistency and data precision, one test vehicle with one driver was appointed
- Several rounds of data were collected to obtain statistically meaningful data.

Sample Studies: Sponsored by TxDOT, US DOT Tier One UTC TranLIVE, and NSF CREST

10.0









FC

FEATURE SELECTION & PREDICTOR Predictor Importance Predictor Importance CO HC cIRI(m/km)-



0.15

Predictor Importance

0.2

0.25

0.05

0.1





For CO₂ and FC, VSP has been predicted the most important predictor in comparison to IRI, speed, and acceleration. But for CO, HC, and NO_x , the model has predicted IRI as the most important feature.



- The Random Trees Model showed significant impact of Roughness Index IRI
 - IRI is the first predictor for CO, HC, and NOx and
 - IRI is the second predictor for CO2 and FC, which positively clarify the impact of IRI on the Emission Factor prediction.
 - Average validation errors less than 3.5%

Sample Studies

Impacts of Freeway Weaving Segment Design on Environment and Public Health

- Exhaust Emissions
- In-vehicle Noise
- Drivers' Heart Rate Variability



Exhaust Emissions



In-vehicle Noise





Drivers' Heart Rate Variability





Impact of Different Ramp Metering Strategies on Vehicle Emissions along Freeway Segments

- Estimate emissions while driving along mainline freeways with a series of ramps that are controlled by meters
- The vehicle emissions were estimated based on the instant vehicle speed and acceleration rate through dynamic vehicle operating modes defined by EPA MOVES
- Real time driving speed and acceleration rate were measured from a test vehicle driving along the freeway I-45 in Houston, TX, where five on-ramps were placed with three control mode

 \circ (1) no metering, (2) isolated metering, and (3) integrated metering.



Looking Forward to any Opportunities on Vehicle Emission and Fuel Consumption Measurement and Modeling

TSU Contact

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