National Center for Intermodal Transportation for Economic Competitiveness

NCITEC

Project 2013 ─ 33

Restoration of Gulf Coast Passenger Rail Service for Sustainable and Economically Efficient Intermodal Corridor Integration

Final Report: NCITEC Project 2013 - 33

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RESTORATION OF GULF COAST PASSENGER RAIL SERVICE FOR SUSTAINABLE AND ECONOMICALLY EFFICIENT INTERMODAL CORRIDOR INTEGRATION

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ABSTRACT

Transportation infrastructure network assets are essential to sustain public mobility, economy, society and quality of life. The Amtrak sunset service served the Mississippi Gulf Coast on its route from Miami to Los Angeles through New Orleans. Operated triweekly during nighttime hours, the Amtrak sunset service was first interrupted in 1993 after the worst rail disaster in Amtrak history. Later it was suspended during the 2005 Hurricane Katrina disaster due to destruction of the rail infrastructure. Currently, Amtrak coastal rail is not operational through Alabama and Mississippi, therefore taking away a valuable public transportation mode for the underserved and/or vacationers to casinos and beaches. The overall goal of this project is to evaluate economic impacts of the restoration of passenger rail service and offer intercity rail solutions. The integration of passenger/commuter rail with the auto traffic in major Mississippi Gulf Coast highway and rail corridors can ease auto travel demand on the existing highway corridors, offer economically competitive and safer travel, and reduce CO_2 emissions and air pollution.

The primary objective of this project is to conduct technical feasibility and economic competiveness evaluations of selected passenger and commuter transit alternatives to serve cities and rural communities along the Mississippi Gulf Coast. This project scope includes passenger mobility in the region with emphasis on the needs of Gulf Coast cities, rural communities, and government and private employers. The Mississippi DOT's strategic planning reports indicate: (a) Most of Interstate-10 corridor has average speeds (in both directions) at or below 55 mph. (b) In the Jackson-Hattiesburg-Gulfport Corridor the majority of freight is moved by truck (91 percent) and through traffic (61 percent), which is expected to grow. The high commercial traffic volume increases general congestion on highways and safety risks to other auto commuter traffic. About nine percent of all highway fatalities in 2009 involved large trucks. Fatality rate per 100 million vehicle-mile-traveled is higher for large truck related fatality than other vehicles. Major widening of Mississippi's I-10 and improvement along with other highway corridors are being pursued by the Mississippi DOT but there is lack of initiative to integrate with passenger rail service. Currently, the Amtrak sunset service from Miami to Los Angeles through New Orleans is not operational. It served the Gulf Coast triweekly before it was suspended during 2005 Hurricane Katrina disaster. The results of this project shows possible alternatives to integrate passenger/commuter rail with the auto traffic which can ease auto travel demand on the existing road corridors, offer economically competitive and safer travel, and reduce air pollution.

It is recommended that the developed approach of commuter rail study be applied by transportation agencies to assess other societal benefits, which include reduction in highway congestion and decrease in transportation related emissions of carbon dioxide and other harmful pollutants.

ACKNOWLEDGEMENTS

DISCLAIMER

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1. BACKGROUND AND OVERVIEW

1.1 Introduction

Research Needs for Gulf Coast Passenger Rail Service Revival

This project addresses the NCITEC theme of efficient, safe, secure, and sustainable national intermodal transportation network that can be made resilient to disasters. Traffic congestion on highways significantly impacts air quality degradation, greenhouse gas emissions, and global warming. Transportation sector is second largest contributor of energy related greenhouse gas emissions in the U.S. (Uddin 2012). The integration of passenger/commuter rail with the auto traffic in major Mississippi Gulf Coast highway and rail corridors can ease auto travel demand on the existing road corridors, offers economically competitive and safer travel, and reduces transportation related Carbon Dioxide (CO_2) emissions and air pollution. Transport infrastructure funding crisis is evident on all levels and for all transportation modes. This funding shortfall is a big hurdle in modernizing rail infrastructure, such as hardening of rail bridges for enhancing flood disaster resilience and rail electrification with almost zero emissions.

The Amtrak sunset passenger rail service from Miami to Los Angeles through New Orleans served the Mississippi Gulf Coast triweekly during nighttime hours. The Amtrak sunset service was first interrupted in 1993 after the worst rail disaster in Amtrak history. The Amtrak passenger rail service was suspended during the 2005 Hurricane Katrina disaster due to destruction of the rail infrastructure. Currently, Amtrak coastal rail is not operational through Alabama and Mississippi, therefore taking away a valuable public transportation mode for the underserved communities and/or vacationers to casinos and beaches.

Goals

The overall goal of this project is to evaluate economic impacts of the restoration of passenger rail service and offer intercity rail solutions. The support of all the cities, public, and employers in the corridor will be essential. There is a dire need for the restoration of the passenger rail service on the Gulf Coast to show the return on massive rail infrastructure investment, which is important to secure federal and non-federal funding. The integration of passenger/commuter rail with the auto traffic in major Mississippi Gulf Coast highway and rail corridors can ease auto travel demand on the existing road corridors, offers economically competitive and safer travel, and reduces CO_2 emission and air pollution.

Objectives

The primary objective of this project is a technical and economic competeveness evaluation of selected passenger rail/commuter intercity rail service alternative plans. The scope of this UM study is limited to the Mississippi Gulf Coast. However, the results can be extended to the entire Gulf Coast using the historical demographic and economic data of the region. This approach of economic impact evaluation is valid for enhancement/revival of other passenger rail services, such as Southwest Chief corridor. The project enhances intermodal transportation education by supporting graduate and UG students.

Project Timeline

The project period was from July 1, 2013 to December 31, 2015. Figure 1 shows the approved planned activities and time line, as well as actual completion dates. There were no significant changes in the research approach described in the approved plan.

NCITEC RESEARCH PROJECT PROGRESS SCHEDULE

Project Title: Restoration of Gulf Coast Passenger Rail Service for Sustainable and Economically Efficient Intermodal Corridor Integration

PI: Dr. Waheed Uddin (UM)   PI: Dr. Burak Eksioglu (MSU)   PI: Dr. Patrick Sherry (DU)

Task	Description	Work, %	Month from Notice To Proceed
	(% wirtten above)		Start ... End
	Planned Schudule of Tasks		July 1, 2013 ... December 31, 2015
	Progress / Planned Duration		
1	Review literature, compile passenger and employer data, and synthesize information.	20	20% 20% 20% 20% 20%
2	Create geospatial maps of passenger rail corridor, stations, and transit connectivity sites.	20	20% 20% 20% 20% 20%
3	Collect economic indicator data and projections for cities/counties in the rail corridor region.	20	10% 20% 20% 20% 20% 10%
4	Review rail service plans with stakeholders and evaluate costs, benefits, and economic impacts.	20	40% 20% 20% 20%
5	Travel to present results at NCITEC workshop/conference and selected conference sites.	5	Conference(s) NCITEC Conf 20% 20% * Presentation * Conference 100% TRB-CMTS Conference ITS 3C Conf Alaska Conf
6	Prepare and submit final project report.	10	50% 50%
7	Submit semi-annual progress reports.	5	20% 20% 20% 20% 20%
	Total Work, %	100	◆
	Planned Overall Progress, %		10 20 # 50 70 80 90 100
	Notice To Proceed / Month==> 0		2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
▲	Progress report (semi-annually)		▲ ▲ ▲ ▲ ▲
	Report submitted √		√ √ √ √ √
◆	Final Report		◆
*	Presentation		

(Duration is estimated on the basis that one or more tasks may be performed as parallel activities.)

Figure 1. Research Project Tasks and Timeline

Research Team and Collaborators

Key Investigators and Roles:

Dr. Waheed Uddin (PI), University of Mississippi (UM) cvuddin@olemiss.edu   Professor of
    Civil Engineering and Director, Center for Advanced Infrastructure Technology (CAIT)

Dr. Patrick Sherry (PI), University of Denver psherry@du.edu
    Executive Director of National Center for Intermodal Transportation (NCIT)
    Program Director, Department of Counseling Psychology, University of Denver

Dr. Burak Eksioglu (PI), Associate Professor, Department of Industrial Engineering,
    Clemson University, South Carolina (Formerly, Associate Professor, Department of
    Industrial & Systems Engineering and NCITEC Director, Mississippi State University)
    burak@clemson.edu

Contacts with the following agencies:

Mississippi Department of Transportation, Jackson, Mississippi
    (Divisions of Information Technology, Planning, and Traffic Engineering)
Colorado Department of Transportation, Denver, Colorado

Other UM Researchers:

Other researchers of UM CAIT team include:

Dr. Y.M. Najjar, Professor & Chair of Civil Engineering Department contributed to the
project, 2015.
Muhammad Ahlan (Civil Engineering Graduate MS Student) Fall 2013 & 2014; M.S. degree,
December 2014
Seth Cobb (UG Civil Engineering student, 2013-2014; Graduate M.S. student, 2014-15);
M.S. degree, August 2015
Support from the following CAIT/Civil Engineering students, 2012-2015: three PhD
    students, two M.S. students, seven UG students

Other collaborators or contacts been involved:

- Transit Cooperative Research Program (TCRP) of the National Academies/TRB,
  Washington DC.
    - Dr. Uddin is a member of TRCRP Panel for transit state of good repair project.
      He has already in contact with the other panel members. The panel includes
      representatives from the following public transit agencies and non-governmental
      organizations: Federal Railroad Administration (FRA); transit and metro
      agencies of Washington DC metro, New York, Pennsylvania, California,
      Washington; American Public Transportation Association.
    - Dr. Uddin continued guiding the Graduate M.S. student for using the final version
      of the TCRP transit asset prioritization tool and management software.
      Previously, he guided two CAIT project students for using the TCRP project

research team's transit asset management analytical tool as pilot testing. The project ended in 2014.

- John Robert Smith: Current president and CEO of *Reconnecting America*, Former mayor of Meridian, MS.   www.reconnectingamerica.org

- As Intergraph Registered Research Lab, CAIT Remote Sensing and Transportation Modeling Laboratories received geospatial industry support for education and training of students in geographical information system (GIS) applications for the project research. This Intergraph software grant is a testimony of industry support to the UM researchers and a cooperative feature of this project. Since January 2014 the statewide license has been provided by MARIS through Mississippi Institution of Higher Learning (IHL).

- Dr. Burak Eksioglu, PI, Clemson (formerly with MSU) collaborated with other stakeholders.

- Dr. Patrick Sherry, DU PI, works/collaborates with freight rail and truck fleet operators. He contacted selected logistics organizations for getting rail corridor infrastructure data and stakeholders.

- The following organization and businesses are possible stakeholders and sources of mass transit information and employer stakeholder feedback:
  - Gulf Coast Transit Authority (CTA) providing bus transit services to the City of Biloxi, the City of Gulfport and Harrison County on Mississippi Gulf Coast

  - Oxford-University Transit (OUT) service, Oxford, Mississippi
  - Cities of Gulfport Port and Biloxi; Port Authority of each of these cities
  - Federal Rail Administration - USDOT
  - American Public Transportation Association (APTA)
  - National Association of Railroad Passengers (NARP)
  - CSX Rail and other rail operators; Association of American Railroads

- Dr. Uddin is an appointed member of Board of Directors of the Mississippi Transportation Institute (MTI) since March 2014 and the Gulf Region Intelligent Transportation Society from 2009 to 2013. These are important state transportation organizations to benefit from the key results of the NCITEC projects including the white paper on the revival of Gulf Coast passenger rail service.

- Dr. Uddin and TTI – Texas A&M researchers established contacts in December 2015 to discuss future collaborations for passenger rail corridors in southern states.

Research Methodology

Both technical merits and economic evaluation are imperative to select the most economically efficient and safe rail service alternative. These goals involved several research activities. The CAIT project research team (CAIT 2014) implemented the following research methodology:

1. Create geospatial databases and spatial maps of highway and rail infrastructure networks for Mississippi and buffer maps of the counties on the Gulf Coast.
2. Collect data in the Gulf Coast corridor and surrounding region on demographics, traffic volume demand and peak hour patterns, employers' data on current jobs and future expansion, transit services in the region, and economic indicators of cities on the Gulf Coast region.
3. Develop utility models for passenger travel mode choice in the pilot study area and implement for the entire Gulf Coast communities in the study region.
4. Generate alternatives including rail and other mass transit technologies. This effort is needed to minimize total commute and transport time and maximize ridership in dollar values.
5. Produce spatial visualization of selected possible rail passenger/commuter corridors and estimate number of stations and intermodal facilities for providing transit connectivity and employers' vans/buses to cities and places of work in the selected corridor.
6. Conduct before and after rail service studies of traffic patterns, ridership estimation, and economic development impacts (concessions and jobs created due to revived rail service and integration with other local transport modes such as transit or privately owned short haul transport services).
7. Apply comprehensive Value Engineering (VE) and life cycle assessment (LCA) of capital improvement and operational costs and revenues, fuel cost savings and other quantifiable benefits, increased worker productivity and decreased stress, lesser pollution and associated public health costs, and reduction in CO_2 and Green House Gas (GHG) emissions.
8. Establish the Gulf Coast passenger rail corridor case study and use the results of reductions in agency costs, revenue and economic benefits, and CO_2 emissions to prepare "white paper" for consideration by government transportation agencies, public officials, private transport operators, and all other stakeholders.

The economic competitiveness, safety, security and disaster resilience of passenger transport Infrastructure can be significantly enhanced if owners, operators, and users of all transportation modes understand the importance of operational integration of the passenger travel modes. Integration of passenger rail services with other highway/road travel mode can reduce wastage of millions of hours of travel time of single occupancy vehicle commuters. This leads to cost avoidance of billions of gallons of fuel wastage on congested highway corridors and reduce transportation related emissions of and other harmful pollutants.

1.2 Project Accomplishments

Key outcomes and other achievements are summarized, as follow
1. This project developed geospatial maps using GIS software and imagery analysis software, synthesis of travel data, detailed analysis of costs and benefits, life cycle benefit

and cost results of simulation studies involving several alternatives for passenger rail integration with selected highway corridors on the Mississippi Gulf coast and life cycle economic analysis results of economic and environmental impacts.

2. Life cycle analysis of costs and benefits was used for value engineering studies to show the importance of the intermodal integration approach for enhancing the economic competitiveness, safety, and congestion and emission reduction of passenger transport. Both technical merits and economic evaluation are imperative to select the most economically efficient and safe rail service alternative as a part of the value engineering study.

3. The developed approach is able to assess other societal benefits, which include elimination of wastage of millions of travel time hours by reducing traffic congestion, cost avoidance of billions of gallons of fuel wastage on congested highway corridors, and reduction in transportation related emissions of CO_2 and other harmful pollutants.

4. The intermodal passenger corridor case studies are used to develop a "white paper" considering comments and suggestions by other PIs and folks interested in sustainable mobility topics including an economic development advisor, a public transport and tram executive, a marketing expert, and a former student of Dr. Uddin who is advisor to a city government on the East Coast.

5. The white paper has been enhanced and a cover page added. It has been posted on the CAIT web page and SlideShare, as well as posted on Twitter. The project news and white paper are included in Appendix.

6. The white paper on economic viability of Gulf Coast Rail revival can serve as a "best practice guide" for consideration in similar case studies by government transportation agencies, private transport operators, cities, and other bus transit and rail stakeholders.

7. Training of undergraduate (UG) and graduate students in transportation network analysis and development of geospatial workforce are additional benefits for transportation workforce development.

The project results have been presented at regional and national meetings and published, as summarized in the following section, and disseminated through social media.

Education and Training of Workforce Development
All graduate students and several UG students took Dr. Uddin's "Geospatial Course" in Spring and Fall 2013, May Intersemester 2014 and 2015, and Spring 2015. Three PhD students, two MS graduate students, and several UG students working on the NCITEC projects took a "highway pavements" course taught by Dr. Uddin during Fall 2014. They were taught about transportation infrastructure and life cycle analysis for asset management. One UG senior student worker pursued his M.S. degree under Dr. Uddin's supervision at the University of Mississippi. Project staff used the computer stations and backup equipment installed in the CAIT Transportation

Modeling and Visualization Lab at Ole Miss Jackson Center. This laboratory has now a statewide ITS surveillance monitoring equipment in cooperation with the Mississippi DOT. The student workers used new 2014 versions of GeoMediaPro geospatial software packs which were installed on all CAIT Lab computers.

Dr. Uddin directed the two assigned graduate MS students for data collection and geospatial mapping of multimodal corridors (highways, Mississippi River, and rail lines) for the state of Mississippi and the Gulf Coast counties. New MS student (previously senior UG research assistant) continued working on this project creating geospatial maps and geospatial analysis of intermodal integration benefits using value engineering tools. Three PhD students, supported by their government scholarship, also worked partially on the project. Total 3 PhD students, 2 M.S. students, and seven UG students were partially supported and trained on the project.

1.3 Results Dissemination and Outreach

Dr. Uddin distributed the "white paper" on passenger train revival to public transportation agencies and state legislators in Mississippi, USDOT, road agency contacts in Louisiana and Alabama, and Gulf Coast Mayors Association.

Presentations to External Organizations

All three PIs were involved in outreach activities associated with the project results. The PI and co-PI presented the project highlights and key results to the visiting professors and professionals, at professional meeting, and in other on-site presentations:

January 10-14, 2016, *TRB 95th Annual Meeting*: Dr. Uddin presented PhD research results of Alper Durmus in the first Bridge-DAWG forum on finite element simulation of US-51 highway bridge subjected to floodwater forces (Durmus 2016). Alper Durmus previously worked on NCITEC 2012-25 project for numerical modeling and simulation of extreme flood inundation to assess vulnerability of transportation infrastructure assets (Durmus et al. 2015, Uddin and Altinakar 2015).

January 29-31, 2015, Denver, Colorado: Dr. Sherry interacted with the rail stakeholders who are involved in his center's advisory panel. He will be soliciting stakeholder survey feedback at the OPERATION STIMULUS 2015 conference on January 29-31, 2015, organized by Denver Transportation Club, Colorado.

January 13, 2015, Washington DC: Dr. Sherry invited rail industry executives at the 2015 TRB annual meeting exhibit hall on January 13, 2015 to share the project results of rail-highway integration. Dr. Uddin presented the background on exhaustive commodity flow data analysis and key findings. Positive feedback was provided by the stakeholders and an implementation plan will be pursued by Dr. Sherry for Denver region.

January 10-14, 2015, *TRB 94th Annual Meeting*: Mississippi DOT Research Division was invited and presented a poster on the 2014 AASHTO award of Sweet Sixteen projects won by the MDOT's roundabout project (Dr. Uddin was the project PI).

January 10-14, 2015, *TRB 94th Annual Meeting*: Dr. Uddin presented research results of NCITEC 2012-25 project on numerical modeling and simulation of extreme flood inundation to assess vulnerability of transportation infrastructure assets. These included bridges on I-55 highway, US-51 highway, and rail line (Durmus et al. 2015, Uddin and Altinakar 2015).

October 29-30, 2014: Acey Roberts, Mississippi DOT ITS Engineer and GRITS President, lectured both days about the video panel wall installed in CAIT Laboratory in collaboration with the MDOT. Visiting attendees of the winter workshop of the Gulf Region Intelligent Transportation Society toured the CAIT Transportation Lab on October 30. The workshop was held at the University of Mississippi Campus in Oxford, Oct 29-30, 2014. Dr. Uddin provided brief overview of the Lab facilities, the NCITEC projects, and history of the Lab evolution in cooperation with the Mississippi DOT Traffic Engineering Division as a part of the establishment of a model ITS Lab.

October 24-25, 2014: Dr. Uddin's teaching and research profile was compiled and presented at the annual banquet on 24th October in Austin, Texas to honor 2014 inductees of the University of Texas CAEE Academy of Distinguished Alumni where he received the award.

October 21, 2014: Dr. Uddin attended the annual board meeting as 2014 appointed member and the conference of the Mississippi Transportation Institute (MTI), in Convention Center, Jackson, Mississippi. He briefly interacted with State Senator and Representative who were the workshop speakers, the Mississippi DOT Executive Director, as well as, Chief Engineer, Bridge Engineer, Aviation Engineer, and Research Division engineers.

October 3, 2014: Dr. Lucy P. Priddy visited the Lab. She is Research Civil Engineer with the ERDC Airfields and Pavements Branch in Vicksburg, Mississippi. After welcome remarks by Dr. Uddin, Dr. Priddy reflected on her experience during her University of Mississippi years as one of the first UG RAs who worked on CAIT research projects during 1999-2002.

September 14-17, 2014: Dr. Uddin attended the ITS3C regional conference and presented overview of NCITEC projects and Gulf Coast rail study results. The conference was organized by the Gulf Region Intelligent Transportation Society (GRITS), the Intelligent Transportation Society of Florida (ITSFL) and the Intelligent Transportation Society of Georgia (ITSGA). The joint conference was held September 14-17, 2014 at the Arthur R. Outlaw Convention Center in Mobile, Alabama.

December 12, 2013: After an international conference in São Paulo, Dr. Uddin visited Brazil's Dutra Concession Highway from Rio de Janeiro to São Paulo, Project Office. (This highway passes through a major river floodplain and a portion of the highway was washed away during the flood and landslide recently. Dr. Uddin made a presentation in collaboration with Dr. Rita

Fortes to the highway concession operator staff on the approach of geospatial analysis and flood simulations being pursued in this NCITEC project to protect transport infrastructure from flood disasters.)

October 28, 2013: Visiting EITs from the Mississippi DOT, Ms. Jessica Headrick (Planning Division) and Ms. Catherine Colby Willis (Roadway Design Division) were presented project overview and on-going planimetrics examples of Sardis site. The visit was held at CAIT Transportation Modeling & Visualization Lab in UM Jackson Center. Both EITs worked with CAIT on geospatial and airport laser survey projects before graduating from the University of Mississippi.

Collaboration

The PI collaborated with the following organizations, who provided support to the project team:

- Intergraph for continuing academic license of GeoMedia Pro at no cost to the University of Mississippi for use on CAIT projects (worth $118,000 per year).
- As Intergraph Registered Research Lab, CAIT Remote Sensing and Geospatial Analysis Laboratory and CAIT Transportation Modeling and Visualization Laboratory is receiving geospatial industry support for education and training of students in GIS applications through the project research tasks.

  This Intergraph software grant is a cooperative feature of this project. Since January 2014 the statewide license has been provided by the Mississippi Automated Resource Information System (MARIS). This software and ArcGIS software, provided by the Mississippi Mineral Resource Institute, were used to create planimetrics of roads, rail lines, bridges, and buildings from high resolution aerial imagery and other digital maps.

Dr. Uddin has brain storming sessions with Drs. McCarty and Sharma on their project 2013-31 on field applications for their laboratory research on nanocoated piezoelectric sensors to harness energy from traffic vibrations (Uddin et al. 2015).
Dr. Uddin interacted Dr. Uddin interacted with Dr. Kristen Swain of the UM's Journalism Department. Her Students in the Journalism department at the University of Mississippi often contact Dr. Uddin for their video projects on sustainability related topics for the George Washington University's Planet Forward web site every year. Dr. Uddin discussed with Journalism students the significance of their projects so that sustainable intermodal transportation integration topics can become one of their projects. The following example of Planet Forward video on the use of waste glass for sustainable road applications was produced by a UM journalism student in May 2013. http://infrastructureglobal.com/sustainable-infrastructure-by-recycling-waste-glass-to-enhance-road-safety-and-reduce-emissions-guest-post-22/
Earlier, YouTube videos of other students on life cycle analysis for sustainability projects and rapid rail transit technology were posted on the *Planet Forward* web site.
http://planetforward.org/idea/life-cycle-analysis-of-sustainable-technologies/
http://www.planetforward.org/idea/personal-rapid-transit-system-a-solution-for-cities

Lakyn Birks, a journalism student, interviewed Dr. Uddin on November 18, 2014 on the topic of "Why trees on the University Campus are important to promote sustainability". Ms. Birks posted her (planet forward) sustainability video assignment "Tree Recovery Sustainability video" on YouTube. http://youtu.be/tdZgnMr0WXo   http://youtu.be/Qu48hmwUq20

A YouTube video by Mason Herman (Public Policy/Journalism UG student), "Dr. Uddin Interview on Transportation and Air Quality Mitigation," April 30, 2014. https://youtu.be/wCJQiXaV3gc

The following organizations were cooperative features for this project:
1) Mississippi Department of Transportation (MDOT): Information Technology Division provided Mississippi geospatial database.
2) MDOT Planning Division through contact with Dr. Uddin's former student and EIT for accessing overlapping aerial imagery scenes of the study sites.
3) MDOT Transportation Information Director (Mike Cresap) and MDOT Director of Structures -State Bridge Engineer (Justin Walker) have been especially helpful to provide drawings and photos for the I-55/US-51 highway bridges in northern Mississippi and updated geospatial database of all state maintained highways and bridges of Mississippi. These were very important and useful contributions to this project.

Workshop and Symposium

2015 Critical Infrastructure Symposium, Baltimore, Maryland: Dr. Uddin presented at this symposium sponsored by the Infrastructure Security Partnership (TISP) and the Society of American Military Engineers (SAME), April 20-21, Baltimore, Maryland.

2014 Workshop, University of Mississippi: "Extreme Flood Inundation Mapping and Risk Modeling of Transportation Infrastructure Assets"

The workshop was held on December 5, 2014 and opened to all by email invitations and CAIT web page posting. It was held in NCCHE Conference Room, Brevard 3rd Floor, University of Mississippi Oxford campus. Presentations were made by Dr. Uddin, Dr. Altinakar (jointly with NCCHE researchers Marcus McGrath and Vijay Ramalingam), Alper Durmus, Quang Nguyen, with closing remarks by Dr. Altinakar. Besides the NCCHE staff, all CAIT graduate students attended the workshop.

1.4 Impacts on The Principal Discipline(s), Research Infrastructure, and Workforce

Impacts on Principal Discipline and Institutional Infrastructure
The project improved computing facilities, geospatial laboratory, geospatial software, and transportation corridor/traffic flow simulation capabilities.
- Enhancement of CAIT Transportation Modeling and Visualization Lab, shown in Figure 2(a), at off-campus location of Ole Miss Jackson Center was a major impact of the

project. (An additional eight computer workstations and visualization equipment were procured using project funds and installed in CAIT Transportation Modeling & Visualization Laboratory in UM Jackson Center after approval by the DOT RITA sponsors.) These new computers and 6 old computers from CE Graphics Lab have been functioning fully since Fall 2013 after installation of geospatial software and other programs.

Figure 2(a). UM's CAIT Transportation Modeling & Visualization Lab, JAC 102, Oxford, MS

- The Lab is being used mostly to conduct research, offer geospatial UG and graduate courses, and train students in geospatial visualization and mapping technologies. New 2014 versions of GeoMediaPro geospatial software packs were installed on all CAIT Lab computers after creating full backup up of all project files and folders by project staff. The Lab is being used mostly to conduct research, offer geospatial UG/graduate courses, and train students in geospatial visualization and mapping technologies.

  The CAIT lab expanded recently with new high performance computer equipment, new computer furniture, large video monitor for presentations, and seminar/meeting tables, chairs, and accessories. The geospatial course has been taught in this facility since 2013 and most of the NCITEC project research work is conducted in this lab.

- The UM's CAIT Transportation Modeling & Visualization Lab also houses a model ITS Laboratory, as seen in Figure 2(b). The Mississippi DOT's Intelligent Transportation System (ITS) section has been collaborating for many years with the University of Mississippi to provide traffic video display wall and extend the fiberoptic backbone to the JAC building and the CAIT Transportation Modeling & Visualization Laboratory facility in order to establish a model ITS lab.

  In October 2014 the CAIT Transportation laboratory was provided a video panel wall by the Mississippi DOT ITS section as a part of a model ITS lab to monitor real-time traffic flow on roads and barge under bridges over the Mississippi River. Since Fall 2015 the lab has been used for real-time traffic data collection and teaching UG for research use to monitor flow attributes by UG and graduate students.

Figure 2(b). Model ITS Laboratory (video wall for accessing statewide traffic video network)

- Dr. Uddin's NCITEC project at CAIT supported 3 PhD students, 2 M.S. students, 5 UG Civil Engineering students, and 2 UG non-engineering students.
- New graduate and undergraduate CAIT student workers were trained for geospatial analysis and transportation demand modeling research. The contents of the Transportation and Geospatial course are enhanced using the NCITEC project products.
- It is expected that the research accomplishments will lead to a specialized transportation course and disaster resilient management course, as well as a trained geospatial workforce.

  The contents of geospatial courses CE495 and ENGR597 Section 25, taught by Dr. Uddin, were updated using the NCITEC project work. CE495 was offered in the 2014 May intersemester. These courses were offered again in Spring 2015 and 2015 May intersemester. Beginning Spring 2017 a new section of CE495 will be offered by Dr. Uddin as regular UG technical course every year.

Impacts on Transportation Curriculum
- Research results have been incorporated in the existing CE 495 – Geospatial Visualization course (3 credit hours), CE 481 – Transportation Engineering I course (3 credit hours), CE 570 – Infrastructure Management course (3 credit hours), CE 590 – Airport Planning and Design, and a new course ENGR 692 Section 2 – Numerical Methods and Optimization and Nonlinear Time Series Modeling in the Department of Civil Engineering. These were taught by Dr. Uddin.
- CE 570 course was offered by Dr. Uddin in Fall 2013 and CE 585 – Highway pavement in Fall 2014 to UG seniors and graduate students. The new textbook for CE570 course was 2013 McGraw-Hill book *Public Infrastructure Asset Management* (Uddin, Hudson, Haas). Dr. Uddin offered ENGR 692 Section 2 in Spring 2015 and CE 590 in Fall 2015.

Students Supported and Degrees Completed

The project supported the following graduate and undergraduate students: 3 PhD, 2 M.S., 7 UG.

Graduate students who received project funding and completed degrees: 2 M.S. (2014, 2015)

- Recruited and supported one civil engineering graduate from the University of Mississippi who completed his M.S. thesis in August 2015 using his geospatial analysis and CO_2 prediction results accomplished in passenger train and freight mobility projects.

  Cobb, Seth. (2015). Economic Viability and Societal Benefits of Integrated Multimodal Freight Corridors and Sustainable Passenger Transportation. M.S. Thesis, University of Mississippi, August 2015.

- Supported one international M.S. student who completed his graduating research report by using his geospatial and CO_2 prediction results accomplished in passenger train and freight mobility projects. He implemented the research framework to his own country Indonesia by analyzing traffic related emissions and impacts of the loss of tropical forest cover on CO_2 production.

  Ahlan, Muhammad. (2014). Geospatial Applications for Mobility, Travel Demand, Transport Infrastructure, and Associated Impacts on the Environment. M.S. Graduate Report, University of Mississippi, December 2014.

Impacts on Transportation Workforce Development

The project has a significant impact on transportation workforce development. For example, the project:

- Provided opportunities to UG students, Master's and Doctoral graduate students, other participating specialists for research in transportation management of commodities, supply chain logistics, intermodal network optimization, geospatial visualization, and related disciplines.
- Enhanced intermodal transportation education by supporting graduate and UG students. Led four PhD graduate students, two M.S. students, and five UG students to work on project related assignments at UM. Some of them completed their course projects on project related topics.
- One M.S. student completed his graduating research report by using his geospatial and CO_2 prediction results accomplished in passenger train and freight mobility projects. He implemented the research framework to his own country, Indonesia, by analyzing traffic related emissions and impacts of the loss of tropical forest cover on CO_2 production.
- Improved the performance and modern computer modeling and visualization skills of main stream professionals and members of underrepresented groups (minority students) that will improve their access to or retention in transportation research, teaching, supply chain management, or other related professions.

- Involved the Student Chapter of the Institute of Transportation Engineers (ITE) and both graduate and undergraduate transportation students in project activities. A major goal to support undergraduate students is to motivate them to pursue graduate studies in transportation systems and professional careers in transportation engineering discipline.
- Developed and disseminated new educational/training materials and provide exposure to transportation, science and technology for practitioners, public works professionals, teachers, young people, media, supply chain stakeholders, and general public. This has been accomplished through geospatial workforce training in the teaching lab, classroom, tweets, YouTube videos, and SlideShare presentations.
- Enhanced information resources and electronic means through CAIT web pages, news interviews by journalism students,
  YouTube video and SlideShare production, blog posts, tweets, and scientific papers.
  (Over 12,000 SlideShare views of three posts presentations on Gulf Coast Rail and over 6,000 views of project related YouTube videos.)

Impacts on Underrepresented Groups and General Public
- Improved the performance and modern computer modeling and visualization skills of main stream professionals and members of underrepresented groups (minority students) that will improve their access to or retention in transportation research, teaching, supply chain management, or other related professions.
- Developed and disseminated new educational/training materials and provide exposure to transportation, science and technology for practitioners, public works professionals, teachers, young people, media, transport and transit infrastructure stakeholders, and general public. This has been accomplished through geospatial workforce training in teaching lab, classroom, tweets, YouTube videos, and SlideShare presentations, as listed in preceding section and the following section.

1.5 Website(s) or other Internet site(s)

Web Site, Social Media and Online Postings

UM CAIT web page: http://www.olemiss.edu/projects/cait/ncitec/

The NCITEC project tab on the University of Mississippi CAIT web site, linked to Mississippi State web site, provides useful background of NCITEC goals, university partners, and UM project summaries.

Dr. Uddin has been following rail industry, sustainable transportation and urban planning professionals through the YouTube videos, SlideShare, and Twitter social media.

Dr. Uddin prepared and posted SlideShare presentations that include background on the passenger train restoration on the Gulf Coast and project updates on supply chain, flood simulation, and highway-waterway freight intermodal integration.

Blog: http://infrastructureglobal.com/ Dr. Uddin's blog about infrastructure and natural disasters.

SlideShare: Over 16,000 SlideShare views of 8 NCITEC projects related posts. Figure 3(a). http://slidesha.re/1CiiDn https://www.slideshare.net/waheeduddin/uddin-caitncitecprojects11-oct2013slsh

The following SlideShare post on the Gulf Coast Rail White Paper had over 12,600 views and 138 tweets. http://www.slideshare.net/waheeduddin/mississippi-gulf-coast-rail-revival-ncitec-white-paper-background-cait

Twitter: https://twitter.com/drwaheeduddin   Started in January 2012; several lists and "Global Infrastructure" timeline created; over 46,500 tweets; and August 2016 Summary of 497 tweets, over 104,100 Tweet impressions, 2,634 Profile visits. Figure 3(b).

Twitter: https://twitter.com/disasterglobal   Started in 2012 on topics of protection from natural disasters and resilience management of infrastructure assets; over 4,100 tweets.

Twitter: https://twitter.com/InfrastructureG   Started in January 2014 to focus on built infrastructure and transportation assets; several lists on specific categories such as sustainable transportation; over 1,100 tweets.

YouTube Videos: Over 9,000 views of NCITEC projects related YouTube videos were reported. http://youtu.be/8JjM2QEexFE   https://youtu.be/8JjM2QEexFE
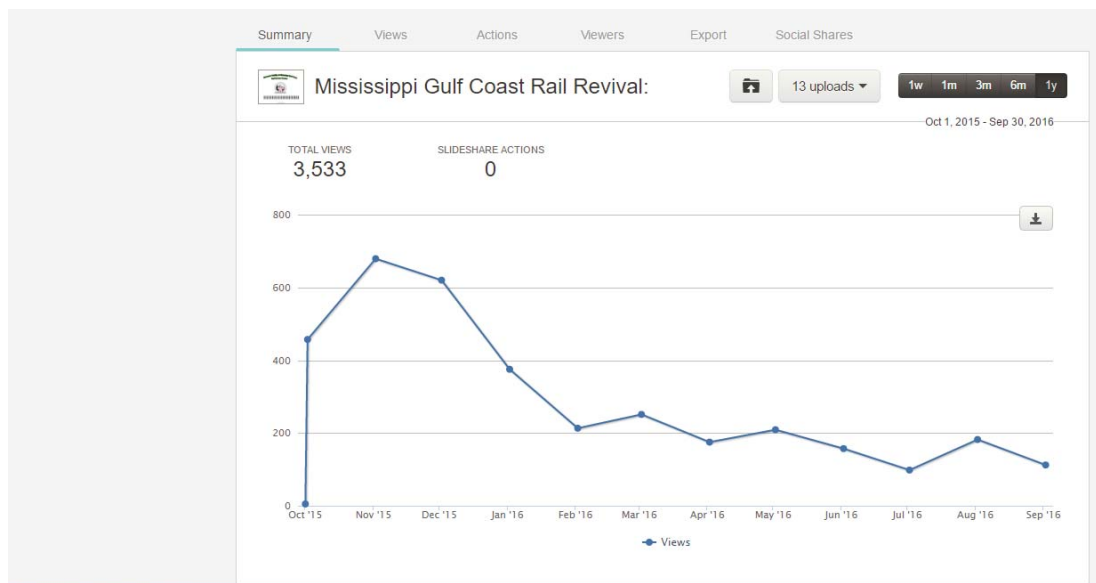

Figure 3(a). Screenshot of SlideShare Analytics for the Most Viewed Post, One Year 2016
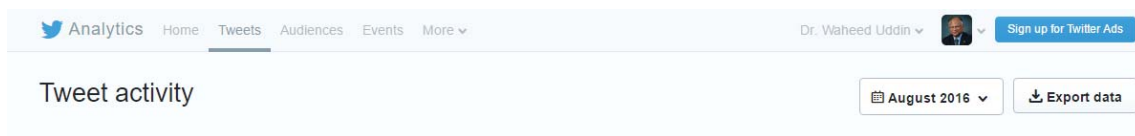
Figure 3(b). Screenshot of Twitter Analytics, August 2016

2.   SUSTAINABLE PASSENGER TRANSPORTATION ON THE GULF COAST

2.1 Background on Discontinued Amtrak Passenger Rail Service on the Gulf Coast

Historical Overview

The Amtrak sunset service from Miami to Los Angeles through New Orleans served the Mississippi Gulf Coast triweekly nighttime. The Amtrak sunset service serving the Gulf Coast was first interrupted in 1993 after the worst rail disaster in Amtrak history. The catastrophic rail bridge damage occurred on September 22, 1993 by the collision of a barge near Mobile, AL resulting in the destruction of rail cars and loss of 47 lives (LA Times 1993). This nightly service carried approximately 53,000 passengers annually or just over 1,000 passengers per week (Uddin 2014). Figure 4(a) shows the suspended line as a dashed line between New Orleans and Jacksonville (CityLab 2013).
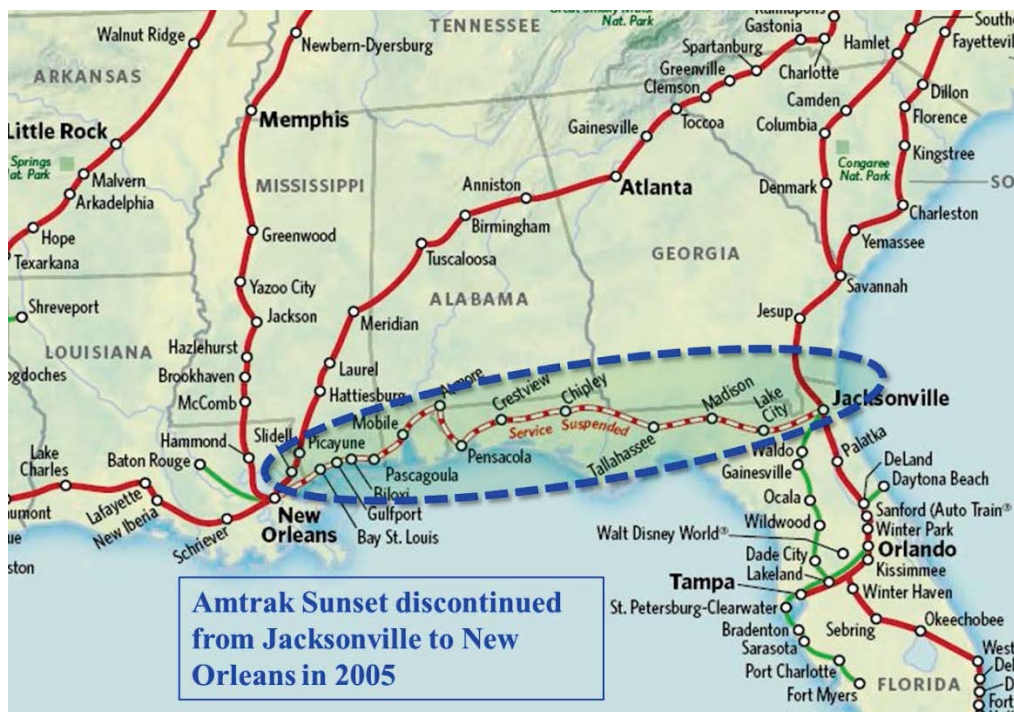
Figure 4(a). Amtrak Network with Suspended Sunset Line (after CityLab 2013)

The Amtrak Sunset service probably did not serve regular commuters similar to the daily commuter rail services operated between NY-NJ/DC, Detroit-Chicago, and counties around Chicago. Figure 4(b) shows the top busiest Amtrak stations' map (BTS 2010). The Amtrak Gulf Coast passenger rail service was suspended after 2005 Hurricane Katrina. Figure 5 shows counties affected by Katrina and damage to coastal infrastructure (FEMA 2015) as the CSX track used by Amtrak was destroyed. Currently, Amtrak coastal rail is not operational through Alabama and Mississippi, therefore taking away a valuable public transportation mode that could be expanded for the underserved and/or vacationers to casinos and beaches.

Figure 4(b). Amtrak National Rail Network (top left), Gulf Coast Corridor (top right), Map of the Top 25 Busiest Amtrak Stations (bottom)
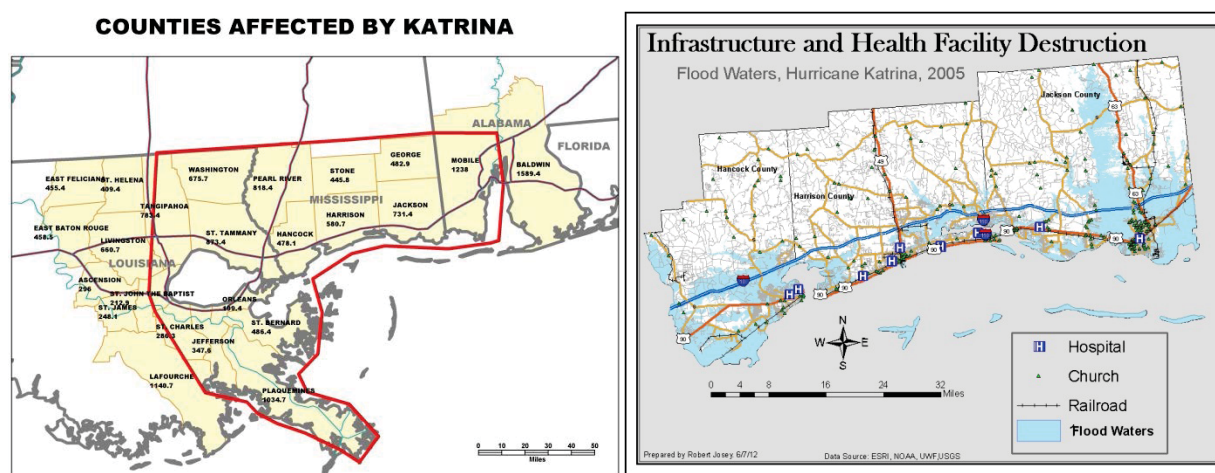
https://www.fema.gov/pdf/hazard/flood/recoverydata/ms_overview.pdf April 22, 2015
http://rej7gisblog.blogspot.com/2012/06/applications-in-gis-hurricane-lab.html March 2, 2013

Figure 5. Gulf Coast Counties Affected by Hurricane Katrina, 2005

Review of Gulf Coast Passenger Rail Restoration

Cobb (2015) reviewed the status of passenger rail service on the Gulf Coast, which is summarized in this section. Restoring the Amtrak Sunset line would complete the transcontinental sunset route, but to do so would require a very large amount of taxpayer dollars (Florida 2015). The idea is a great one to rail enthusiasts, union workers, and train travelers, but not for those who will be paying for it. According to the 2014 Performance Report from Amtrak, the existing sunset line lost more than $350 per passenger (Amtrak 2014). The Sunset Gulf Coast line was one of the "least efficient routes" according to the Florida Department of State, and generated $29.3 million in losses in 2004 before Katrina (FDOS 2010). According to Randal O'Toole (Florida 2015), "No Amtrak long-distance train covers its operating costs. None even come close."

The Federal Rail Administration (FRA) is working with the state and city agencies to develop high speed rail corridors on the east coast, Midwest, and west coast (Figure 6).

Source: http://www.wired.com/autopia/2010/02/high-speed-rail-grants/
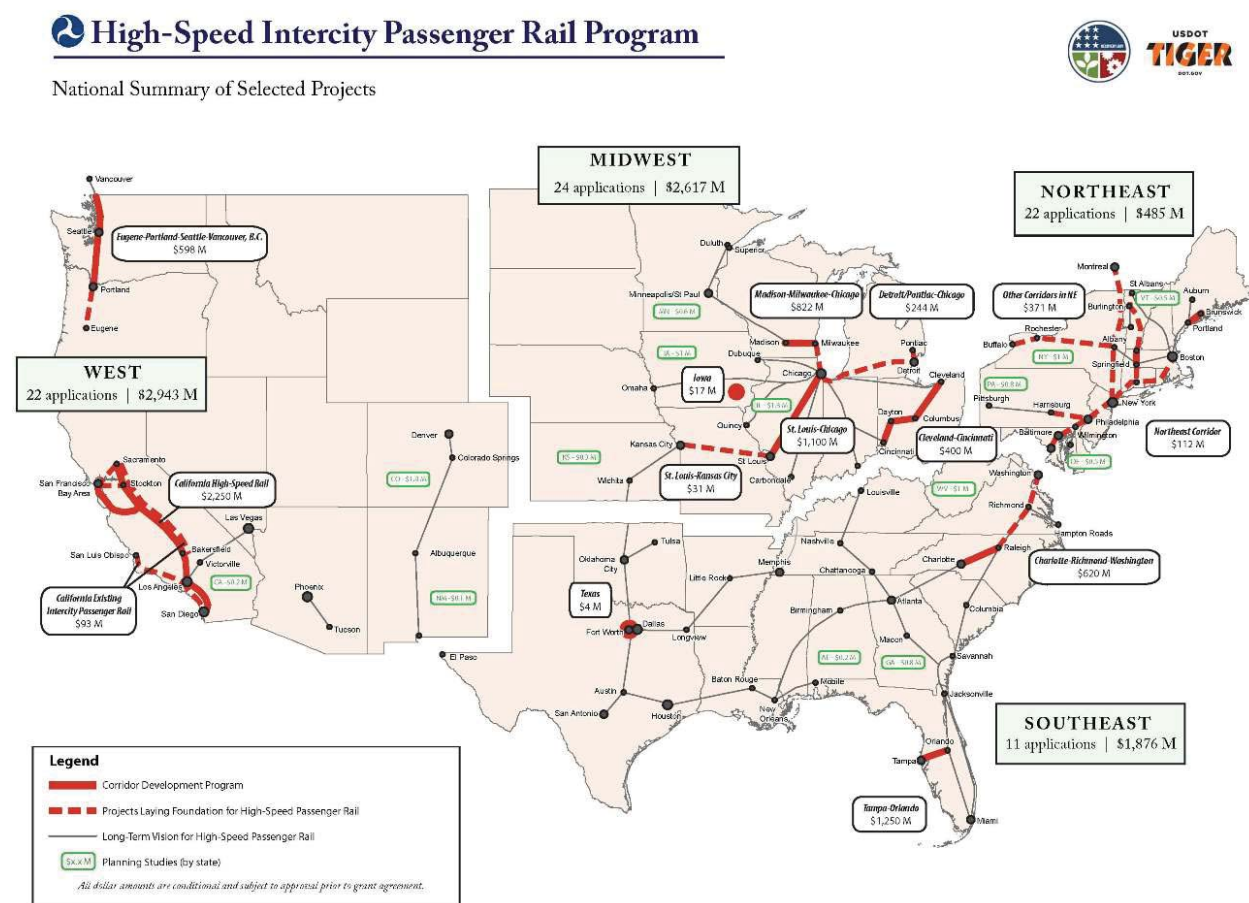
Figure 6. High Speed Rail Corridors

According to a 2009 report by Transportation Nation and Amtrak data (TN 2012): as required by the 2008 Passenger Rail Investment and Improvement Act (PRIAA), Amtrak proposed three options:

1) Restore the triweekly nighttime service.
2) Extend the well-known City of New Orleans route from Chicago to New Orleans and turning it east to Orlando, Florida.
3) Launch a new daily service.

However, no firm action has been taken for further studies on the revival of Gulf Coast passenger rail. The coalition of city mayors on the Gulf Coast and local leaders have teamed up to lobby their representatives in Congress for the federal funding process to revive the passenger rail service on the Gulf Coast. (http://www.reconnectingamerica.org/) Because of these issues with the revival of long-distance Amtrak lines, this study proposed a shorter distance commuter rail service using existing freight rail lines that run along the Mississippi Gulf Coast.

Post-Katrina Demographics and Economic Recovery
Hurricane Katrina landed on 29th August of 2005 and destructed the Gulf Coast becoming one of the worst coastal storms to ever hit the United States and completely destroying the existing infrastructure and businesses (Figure 7). Its worst toll was in Mississippi where 238 people lost their lives (TWP 2015).
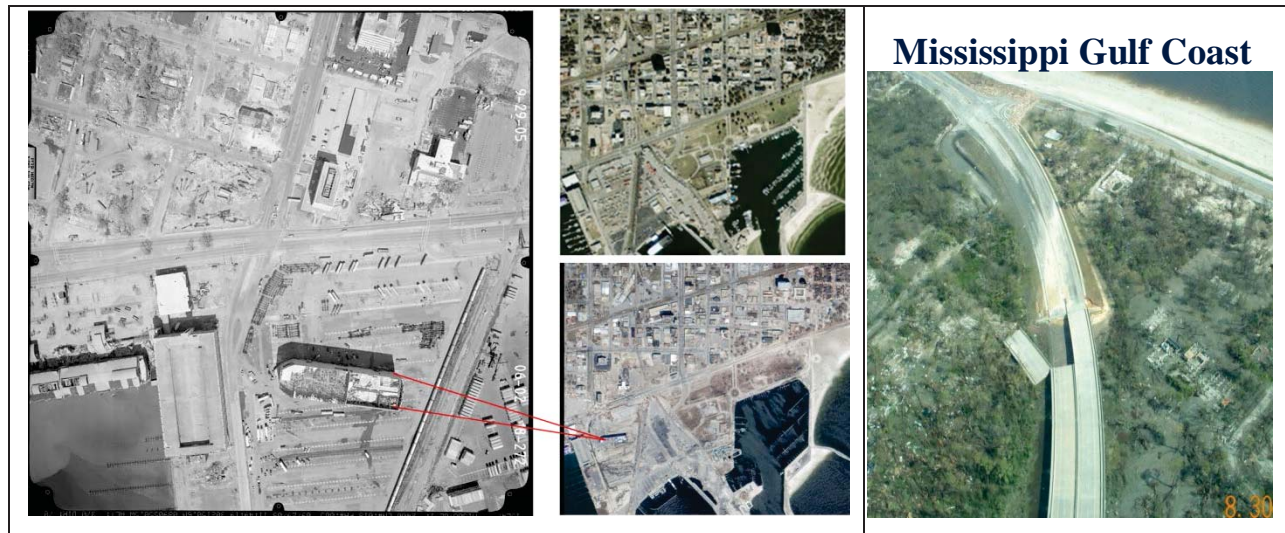
(Photos Credit: Mississippi DOT Highway Division and Bridge Division)

Figure 7. Hurricane Katrina Destruction of Transport Infrastructure on Mississippi Gulf Coast

The Washington Post examined the impacts of Katrina after 10 years, as shown in the following excerpts (TWP 2015):

"The storm hit the mouth of the Pearl River, bringing with it winds of more than 150 mph, great walls of waves and 28-foot storm surges, hurling its warm breath counterclockwise. Anything east of where the storm landed was virtually wiped out. Whole towns were obliterated…. Although much of the nation focused on the damage to New Orleans caused by levee failures, the immense destruction to Mississippi was caused by a direct hit from nature….The storm, which sent hurricane-force winds 200 miles inland, left more than 100,000 people homeless, put thousands more out of work — the unemployment rate soared to nearly 25 percent after the storm — and caused at least $25 billion in damage, state officials said…… Katrina's scars are still visible from Highway 90, which hugs the Mississippi Gulf Coast, crosses the Pearl River and cuts through the seaside cities of Bay St. Louis, Long Beach, Pass Christian, Gulfport, Biloxi, Ocean Springs, Gautier and Pascagoula. The wind and water may be gone, but Katrina's reach remains."

Figure 7 shows examples of some of the destruction that occurred to the transportation infrastructure by Hurricane Katrina. Hurricane Katrina also demolished the Mississippi Gulf Coast economy causing an 11.7% drop in employment (approximately 23% drop for the Gulfport-Biloxi area alone) and causing catastrophic damage to 1,264 of 2,678 businesses along the Mississippi Coast (BLS 2006). Nearly a decade later and the Mississippi Gulf Coast is still trying to rebuild and even improve much of the infrastructure and tourist attractions throughout the coast. Ten years later, significant rebuilding has occurred along Highway 90 and in according to the Washington Post report (TWP 2015), as follows: "Harbors have been rebuilt to better withstand future storms. Beaches and barrier islands once washed away have been restored. Last year, casino revenue topped $1.5 billion, beating the pre-Katrina haul."

The USA Today newspaper (USA 2011) reports that even with the impact of Katrina in 2005, the Mississippi Gulf Coast is experiencing population growth. Jackson County's population increased 6.3% from 2000 to 2010 and Hancock County experienced a 2.2% increase over this same period. Harrison County experienced a slight drop, at 1.3%, but was on the rise until Hurricane Katrina in 2005. It is a good sign for economic recovery to see population growth in the Mississippi Gulf Coast counties even after the occurrence of such a devastating disaster. Many feel that the expanding casino market of the Mississippi Gulf Coast aided in this recovery (Norado 2008).

Being an important container port facility on the Gulf, Gulfport has numerous freight industries and related services, which employ a large number of people besides the port and government agencies. As illustration of traffic demand and modal choice modeling, the following vital demographic and economic data is presented for the City of Gulfport (http://www.gulfport-ms.gov/):

- According to the 2010 census, the city's resident population was 69,220 people, compared to 2.98 million population of the state.

- The city had 31,602 housing units at an average density of 555.4/sq mi (214.4/km²) and an average of 2.57 persons lived in each occupied housing unit.
- Mean travel time to work (for workers of age 16+ during 2006-2010) was 21.4 minutes.
- Retail sale per capita in 2007 was $23,796, more than double the average for the state.
- Sales tax revenue is 20% of total revenue collected by the city.

As the population continues to grow along the Mississippi Gulf Coast, and as it continues to rebuild its infrastructure, new problems are being introduced to the major Gulf Coast cities. Some of these problems include (Uddin 2015):
- High traffic congestion during peak hour periods.
- Increased volume of commercial traffic, which pose safety risks to personal automobile traffic.
- High levels of vehicle emissions.
- Lack of public transportation options.

The Mississippi DOT's strategic planning reports (MDOT 2011) indicate: (a) Most of Interstate-10 corridor has average speeds (in both directions) at or below 55 mph. (b) In the Jackson-Hattiesburg-Gulfport Corridor the majority of freight is moved by truck (91 percent) and through traffic (61 percent), which is expected to grow. The high commercial traffic volume increases general congestion on highways and safety risks to other auto commuter traffic. The strategic multimodal transportation plan (MDOT 2011) shows capacity expansion and improvement involving Mississippi's congested I-10 and other connected highway corridors on the Gulf Coast. Can it solve the traffic congestion in these highway corridors, especially around major cities? The past experience in other states does not support this approach. For example, the expansion of additional lanes on I-10 corridor in Houston area over the past decades has demonstrated that it cannot ease auto/truck traffic congestion in the long term due to the induced traffic patterns. However, apparently there is lack of initiative to promote passenger rail infrastructure and integrate intercity commuter rail service on the Gulf Coast as shown in the FRA plans for intercity rail (Figure 7).

Much of this high traffic congestion becomes an issue during emergency evacuation events, such as Hurricane Katrina, which is a major issue in short notice scenarios. One solution to some of these problems is to implement some alternative form of passenger transportation to not only help with emergency evacuation, but to also focus on the passenger mobility needs of the Mississippi Gulf Coast cities, communities, and employers. The passenger rail service is not given serious consideration in the intermodal transport integration in Mississippi and most states as the emphasis is on multimodal planning without any real integration of some of the competing modes.

This study investigated the opportunity and benefits of utilizing alternative forms of public transportation, but its primary focus was on the revival of a passenger rail service to the Mississippi Gulf Coast area.

2.2 Synthesis of Travel Demand, Congestion, and Safety Data for U.S. and Mississippi

Application of Geospatial Analysis and Visualization

Geospatial analysis is an important tool to support decision making by organizing the data that have spatial identification. The data are organized by geospatial analysis through decision support systems (DSS), which process, analyze, and deliver the information, generally by using computers. Spatial identification refers the data to the physical location by using the geographical coordinate system (Uddin et al. 2013). Geographic information system (GIS) and geospatial analysis can be used to integrate the data from various types of infrastructure based on the spatial information. As shown in Figure 8, GIS can be utilized to integrate transportation databases, public transit bus databases, water supply pipeline databases, solid waste management databases, and domestic waste water databases into a georeferenced location based database (Uddin 2011a, Uddin et al. 2013).

Figure 8. GIS Decision Support System for Infrastructure Assets

The applications of geospatial analysis include but are not limited to:
- Data visualization
- Infrastructure assets management
- Disaster impact assessment

Geospatial visualization can be used for geographic and non-geographic database management. The non-geographic data include traffic data, transportation safety, emissions data,

demographics, socio-economic levels, industries, and housing. In regard to geographic database management, Geospatial visualization is effective for remote sensing data, road network maps, and land use vector maps (Uddin 2011b). Figure 9 shows the survey results of state transportation agencies related to their applications of geospatial tools. The top three applications are: geomatics/surveying, project planning, and asset management (NCHRP 2013). This project extensively used geospatial analysis and mapping applications using both geographical data of infrastructure features and non-geographic attributes.
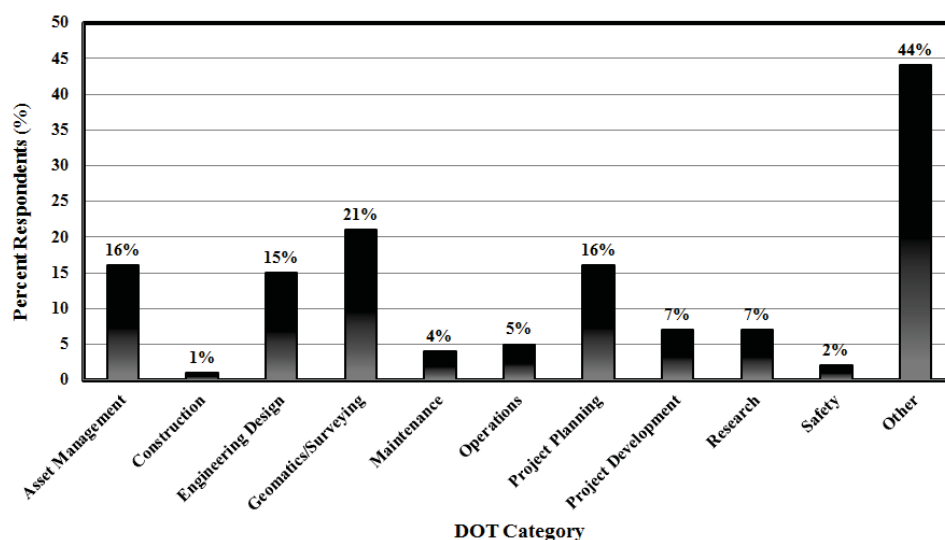

Figure 9. DOT Responses for Geospatial Applications

Review and Synthesis of Highway Transportation Travel Data

This section is largely based on the research conducted by Ahlan (2014) as apart of this project and M.S. graduate report (Ahlan 2014). Some mobility statistics are summarized, as follows:

- American public traveled 4,230 billion miles on U.S. highways in 2011, while 575 billion passenger miles traveled were on air, 54.3 billion were on transit, and 6.6 billion were on rail. In addition, most U.S. people's mobility depends on highway mode, specifically personal vehicles.

- The majority of highways passengers, 83.1 percent, drove personal vehicles in 2009. On the other hand, 11.5 percent of highway users biked or walked, 1.9 percent used transit, and 1.7 percent went by bus (BTS 2014a). As a result, an American traveled on average 36.1 miles per day.

- Travel demand is contributed by the trip purposes and the number of available vehicles per household. In 2009, 42.5 percent of total person trips per household were for family or personal business, 27.5 percent for social or recreational, 18.7 percent for work, and 9.6 percent for school. In regard to vehicles-availability, 22.7 percent of households in the U.S. had three or more vehicles in 2009, 36.3 percent had two vehicles, 32.3 percent had one vehicle, and 8.7 percent had no vehicle (ORNL 2009).

Travel demand indicators include Vehicle Miles Traveled (VMT), number of trips, vehicle count, distance to work, public transit use, number of persons of walking, and number of persons of biking. Annual VMT data are used in the U.S. to quantify travel demand by the number of vehicles on the road multiplied by miles traveled by each vehicle (FHWA 2012, WSDOT 2005). The annual VMT is calculated using a method proposed by the Federal Highway Agency (FHWA) for most roads, while other method can be used by the State Highway Agencies (SHA) to calculate VMT for local and rural minor roads. For the FHWA method, VMT is calculated using the average annual daily traffic (AADT) that were collected with automatic traffic recorders for continuous counts and other devices for short period counts. For local and rural minor roads, SHA can use the same method or other methods, for example demographic survey based VMT estimation method (IDOT 2002).

FHWA divides the rural area as basic rural, developed rural and urban boundary rural (FHWA 2004). The basic rural areas are the dispersed counties or regions with major population centers less than 5,000. The transportation in basic rural generally is localized rural transportations that connect the farm to the market. The developed rural areas are the spread counties or regions with one or more population centers of 5,000 or more and can include a metropolitan area with 50,000 or more in population. Transportation in developed rural areas is more varied than in basic rural areas, including commuting and intercity travel. The urban boundary rural is located just next to the border of large urban areas. Transportation in urban boundary rural areas is varied with high level of commuting and other trip purposes (FHWA 2004).

Figure 10 shows the spatial map of VMT in the U.S. by state for 2010. The VMT of 48 states and Washington DC are shown on the spatial map, while the VMT of Alaska and Hawaii are shown as the texts. Figure 11 shows a plot of the ten states that had the highest number of VMT in each of these states. The highlights of these data include:

- Total VMT in the U.S.A. in 2010 was 2,967 billion.
- There were 15 states that had VMT more than 70 billion in 2010, 7 states had VMT between 50 and 70 billion, 10 states had VMT between 30 and 50 billion, and 10 states that had VMT between 10 and 30 billion in 2010.
- In addition, Washington D.C. and 8 states including Hawaii and Alaska had VMT less than 10 billion.
- The top ten states listed from the largest number of 2010 VMT to the smallest (Figure 11) were as follows: California (322.8 billion), Texas (234.0 billion), Florida (195.8 billion), New York (131.3 billion), Ohio (111.8 billion), Georgia (111.7 billion), Illinois (105.8 billion), North Carolina (102.4 billion), Pennsylvania (100.3 billion), and Michigan (97.6 billion).
- Total 2010 VMT in Mississippi was 39.8 billion.

2010 Annual Vehicle Miles Traveled
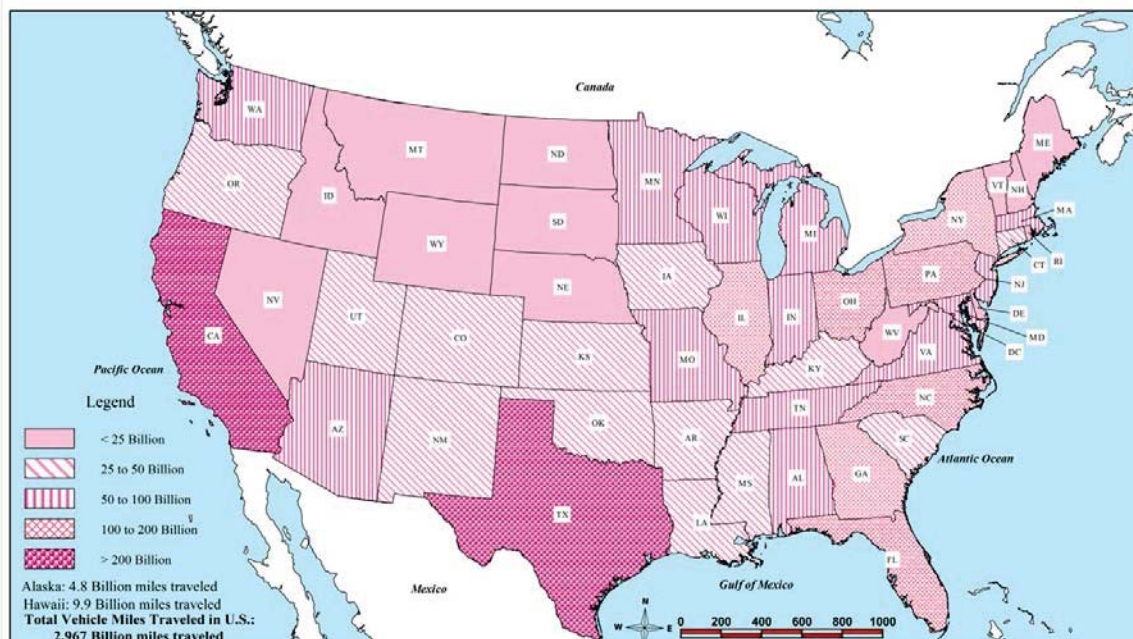
Figure 10. Spatial Map of 2010 VMT by State

Total 2010 VMT in USA: 2,967 billion

Total 2010 VMT in Mississippi: 39,841 million
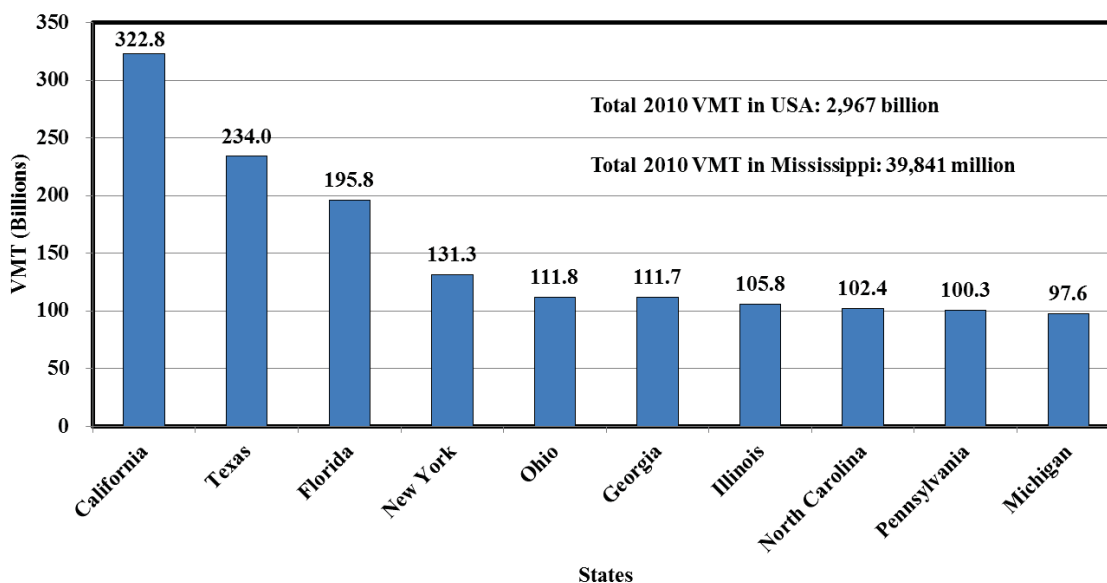
Source: "Statistics." FHWA. Web. Accessed on November , 20, 2013.
http://www.fhwa.dot.gov/policyinformation/statistics/2010/.

Figure 11. Top Ten VMT by States in the U.S., 2010

The Government uses VMT data for travel demand analysis and budgeting as well. Numbers of VMT values are used to consider the amount of fund allocated for the roadway infrastructure maintenance.

Figure 12 shows the ten counties that had the highest number of VMT in Mississippi in 2010. Total VMT in Mississippi in 2010 was 39,841 million. The top ten counties in Mississippi listed from the largest number of 2010 VMT to the smallest were as follows: Hinds (3,774 million), Harrison (2,271 million), Rankin (1,976 million), Jackson (1,681 million), DeSoto (1,632 million), Lauderdale (1,296 million), Lee (1,281 million), Madison (1,051 million), Jones (939 million), and Forrest (808 million).
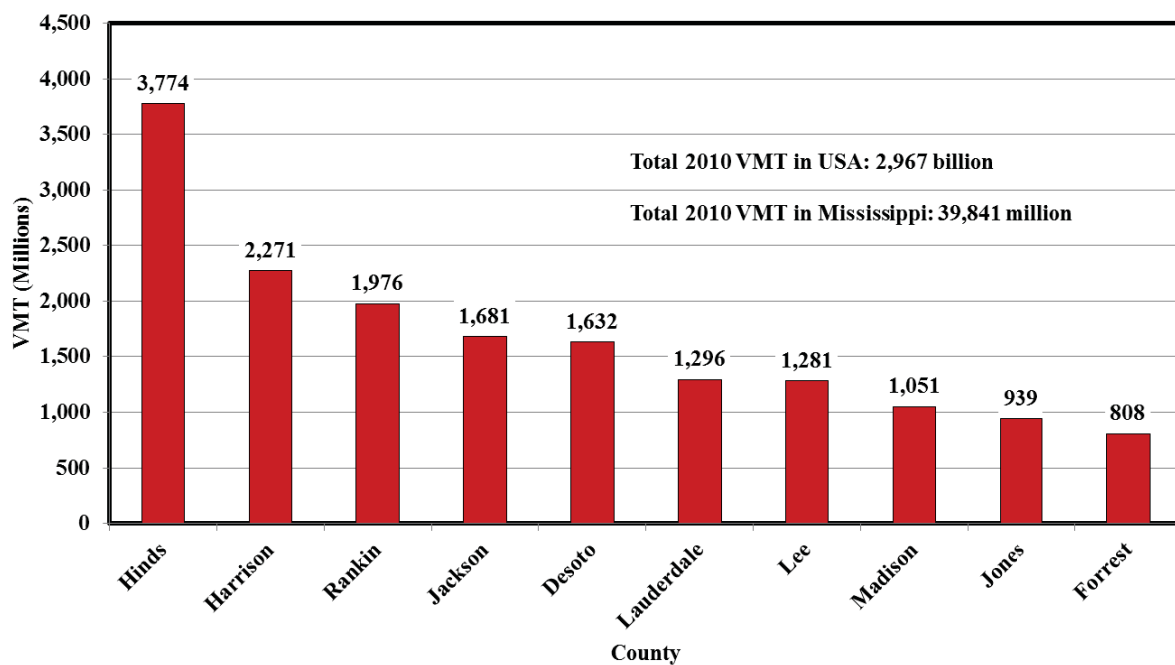
Source: "2005 VMT by County." Docstoc. Web. Accessed on November 20, 2013.
http://www.docstoc.com/docs/7875673/2005-VMT-by-County-(XLS).

Figure 12. Top Ten VMT by Counties in Mississippi, 2010

Total VMT in Mississippi in 2010 was 1.3 percent of total VMT in the U.S. The U.S. VMT in the rural area was 33.2 percent of total U.S. VMT in 2010, while Mississippi VMT in the rural area was 59 percent in the same year. As a result, majority of VMT in the U.S. took place in urban areas, while majority VMT in Mississippi was in rural areas.

The top ten states in the U.S. with the highest VMT had a larger percentage of VMT in urban than in rural in 2010. California had 82 percent of total VMT in urban; Texas had 71 percent of total VMT in urban; Florida had 82 percent of total VMT in urban; and New York had 75 percent of total VMT in urban. In addition, Ohio had 68 percent of total VMT in urban; Georgia had 67 percent of total VMT in urban; and Illinois had 75 percent of total VMT in urban. North Carolina had 61 percent of total VMT in urban; Pennsylvania had 64 percent of total VMT in urban; Michigan had 67 percent of total VMT in urban.

Highway traffic in the urban areas is more than the traffic in the rural areas because the population in urban areas is larger than the population in the rural areas. On the other hand, the trip distance in the rural areas is longer than the trip distance in the urban areas because the rural areas consist of the spread regions.

In rural areas, the arterials serve about half of the vehicle miles of travel, while this percentage is regularly higher in urban areas. The next largest percentages of VMT are in collector roads. Urban area collectors have 5 to 15 percent of total VMT, while rural area collectors have about 20 to 30 percent of total VMT. Local roads in rural areas normally account for very low density, while the local roads in urban areas serve larger proportions of travel than their rural counterparts.

As a result, travel demands in the United States mostly were reflected by the urban areas, while majority travel demands in Mississippi were reflected by the rural areas. The country-wide travel demand density was larger than the rural areas travel demand density. The average trip distance in the United States is shorter than the average trip distance in rural areas because of the spreading regions. Finally, the country-wide and rural mobility concentrations on the various functional class highways are different. Comparing the country-wide and rural travel demand is important to propose the proper transportation mode service for the people, decide the highway infrastructure maintenance funding, and to manage the roadway infrastructure.

Construction of more highway infrastructure and expansion of existing lane miles is not the solution of the traffic congestion problem in the U.S. The long term solution to this problem requires the use of alternative travel modes for both passenger and freight transportation. Cobb (2015) presents a breakdown of the miles of infrastructure by transportation mode in the U.S. in 2011 as reported by the FHWA (2015a). There are approximately four million miles of road in the U.S., only 138,518 of rail infrastructure, and just over 13,000 miles of inland waterways (FHWA 2015). As the population continues to increase, congestion on the nation's National Highway System (NHS) will continue to outgrow the current highway infrastructure leading to even worse conditions on roadways.

Review of Highway Congestion
Highway congestion occurs when traffic volume demand approaches or exceeds the capacity of the highway system and level of service degrades. The FHWA states that roughly half of the congestion that occurs in the U.S. is "recurring," meaning there are simply more vehicles than roadway available (FHWA 2015b). In 2011, the FHWA reported the following statistics about the current NHS (FHWA 2015c):
- Over 164,000 miles in the National Highway System
- 3 trillion vehicle miles travelled in 2009
- 246 million registered vehicles

- 210 million licensed drivers (685 drivers per 1,000 population)
- 392 billion person-trips
- 172 billion gallons of fuel consumed

These numbers are expected to increase significantly in all categories over the next 30 years. The increase of these items will lead to increased congestion on the NHS, as construction of new highway capacity will be unable to keep pace. Figures 13(a) and 13(b) (FHWA 2015d) show the peak period congestion on the NHS in 2011 and a projection for 2040.

Figure 13(a). Peak-Period Congestion on the NHS, 2011 (FHWA 2015d)

Figure13(b). Peak-Period Congestion on the NHS, 2040 (FHWA 2015d)

Figure 14 shows major causes of travel delays as reported by SHRP-2 report (SHRP-2 2005). Variability in travel time is dependent on many sources; primarily: lack of capacity, traffic incidents, and weather. About 65% time congestion occurs due to the lack of capacity resulting in bottlenecks and traffic incidents .
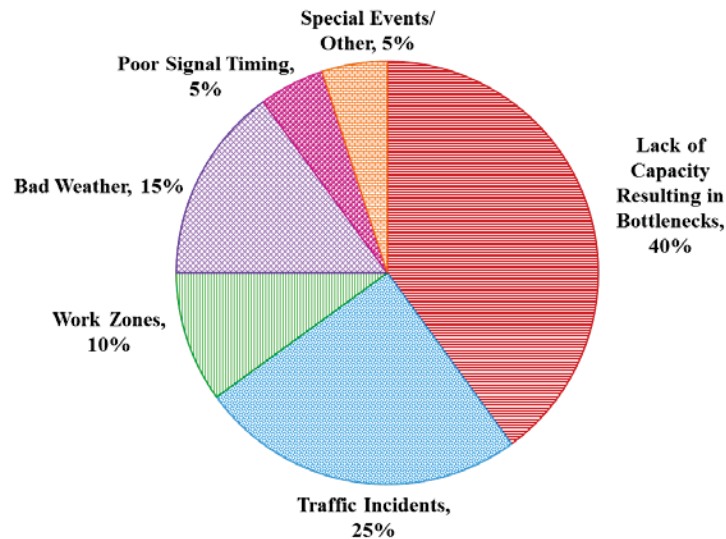

Figure 14. Causes of Travel Delays

Adapted from (Guide to Incorporating Reliability Performance Measures into the Transport Planning and Programming Processes. SHRP-2 Report, 2005. Print)

Traffic congestion has been growing in cities of all sizes in the United States from 1982 to 2005 in term of hours of delay per traveler (FHWA 2014a). The following statistics indicate the congestion crisis, especially in urban areas:

- Moreover, there was a significant increase of annual hours of delay per auto commuter in the ten most congested urban areas in the U.S.A. from 1982 to 2011 (BTS 2014b).
    o The highest delay increase of 49 hours in Washington DC-VA-MD.
    o Then a 37 hours delay increase in San Francisco.
    o A 34-hours delay increase in Denver-Aurora.
    o Both Orlando and Baton Rouge had 32-hours delay increases.
    o The delay in Baton Rouge, LA increased 32 hours.
    o The delay in Bridgeport-Stanford CT-NY increased 29 hours.
    o The delay in Honolulu, HI increased 26 hours.
    o The delay in Columbia, SC increased 25 hours.
    o The delay in Worcester, MA-CT and Cape Coral, FL increased 20 hours each.
- Furthermore, three most populated cities in the U.S.A. were included in the 10 most traffic congested cities in the world based on the annual average delay time on road systems in 2012 (FORBES 2012).

- o Los Angele, California: 59 hours of annual averaged delay.
- o Honolulu, Hawaii: 50 hours of annual averaged delay.
- o San Francisco, California: 49 hours of annual averaged delay.

Figure 15 shows how all commuters in the U.S. got to work in 2012 (BTS 2015a). Over 75% of the commuters in the U.S. went by personal automobile and another 10% carpooled in personal automobile, while only 5% opted to use public transportation. Figure 16 shows the proportion of day trips taken by mode, and 83.1% of those trips were taken by a personal automobile, while only 1.9% of those trips were taken by some type of public transportation (BTS 2015b). These two figures show how underutilized public transportation has been.
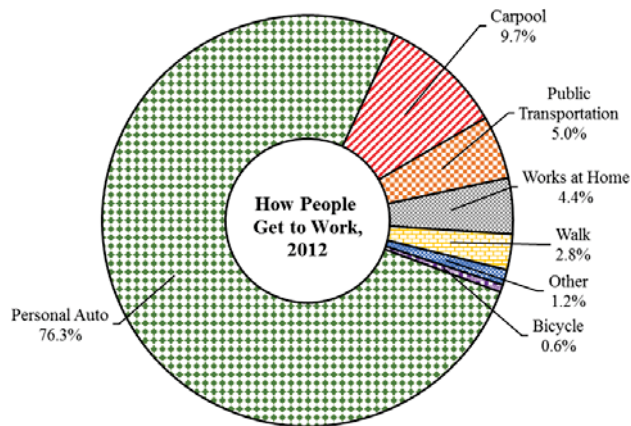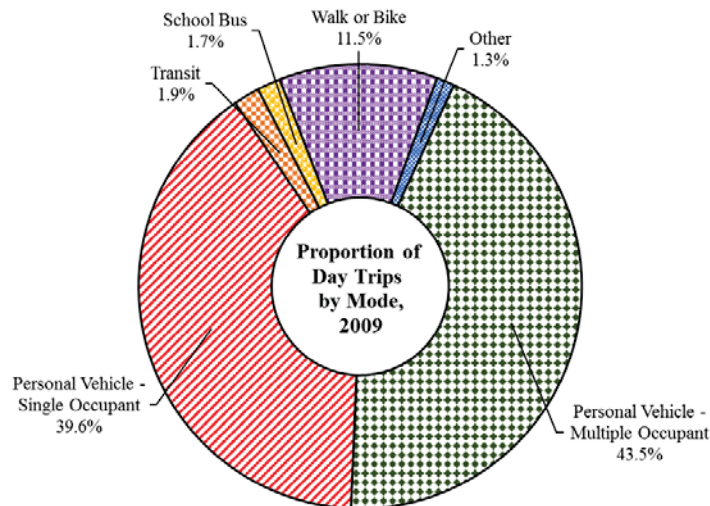

Figure 15. How People Get to Work, 2012

Figure 16. Proportion of Day Trips by Mode, 2009

Figure 17 shows alternative modes to solve congestion and mobility problems in cities and urban areas where personal autos have been used traditionally. It displays number of people that can be transported per hour by various different transportation modes. Mixed auto traffic is the least

efficient at 2 people per hour and commuter rail is the most efficient at 80-100 people per hour. Except the last two rail options on separate dedicated rail lines, all other modes take space on a shared road and highway based on the size of transport, BRT occupying the most space.
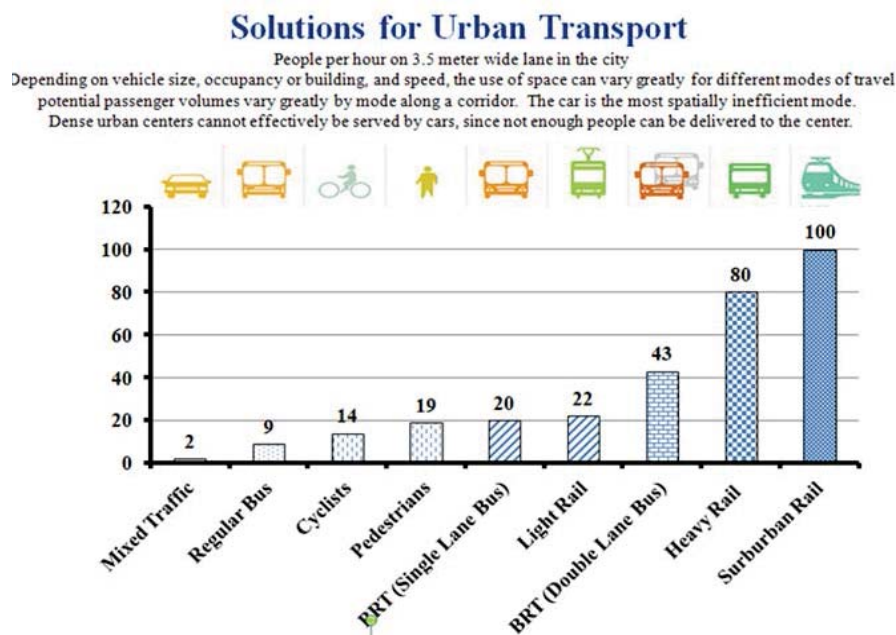
Figure 17. Efficiency and lane occupancy of different urban mobility modes

Developing a sustainable transportation system requires efforts to reduce the use of single occupancy vehicles and the number of personal automobiles from the highway. Because of this, there is an increased emphasis on public transit, multimodal, and non-motorized transportation alternativess. Public transportation including commuter rail can play a key role in reducing congestion, and confronting environmental challenges of undesirable vehicle emissions from the burning of fossil fuel.

To solve the highway traffic congestion problems and reduce transportation-associated emissions the following contributing factors must be evaluated: highway network capacity, travel demand, current traffic volume and delay, and transport alternatives. The transportation infrastructure inventory, mobility and travel demand, and alternative strategies can be visualized in spatial maps and analyzed using geospatial analysis GIS decision support systems.

Review of Highway Safety Data
This section is based on review and synthesis of safety data by Ahlan (2014). Transportation safety is crucial for sustainable infrastructure development. According to a study, there are significant societal costs of traffic accidents compared to other typical road user and non-user costs (Uddin 2007). The U.S. transportation safety historical data is reviewed in this section to

find the trend of the number of fatalities, the percentage of fatalities by highway mode, and the fatality risk for selected highway modes. According to the national transportation statistics, the annual number of fatalities that happened in U.S. transportation system has decreased in early this decade 2010 compared to early 2000s (BTS 2014c), although the number of fatality in the latest year 2015 increased compared to the previous year 2011. The majority of the fatalities relate to highway travel mode (Figure 18).
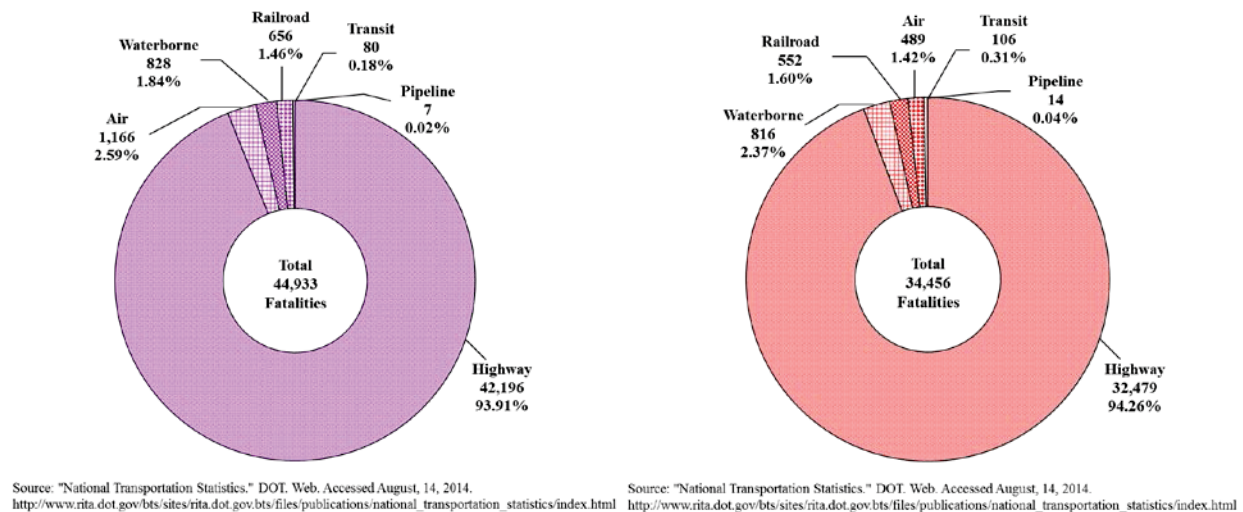

Figure 18. Fatalities by Travel Mode in the U.S., 2001 (left) and 2011 (right)

Figure 18(left) shows the percentage of 44,933 total fatalities by travel mode in the U.S. in 2001. Most of the fatalities, 93.91 percent, were related to accidents on highways. Additionally, 2.59 percent of total transportation based fatalities were related to air transportation; 1.84 percent of the fatalities were related to waterborne transportation; 1.46 percent of the fatalities were related to the railroad; 0.18 percent of the fatalities were related to transit; and 0.02 percent of the fatalities were related to pipeline.

According to Figure 18(left), there were 42,196 highways related fatalities in the U.S. in 2001; 1,166 fatalities were related to air transportation; 828 fatalities were related to waterborne transportation; 656 fatalities were related to the railroad; 80 fatalities were related to transit; and 7 fatalities were related to pipeline. Total transportation-based fatalities in the U.S.A. in 2001 were 44,933.

According to Figure 18(right), total transportation related fatalities of 34,456 in 2011 decreased 23.3 percent compared to 2001. Highway transportation-related fatalities of 32,479 in 2011 also decreased 23 percent compared to 2001. Highway related fatality, which was 94.26 percent of total transportation related fatalities, still became the largest portion of the total transportation-based fatalities in the U.S. in 2011. Waterborne transportation-related fatalities decreased 1.4 percent; railroad-related fatalities decreased 15.8 percent; air transportation-related fatalities decreased 58 percent; transit-related fatalities increased 32 percent; and pipeline-related fatalities

increased 100 percent from 2001 to 2011. Air mode decreased from the second position in 2001 to the fourth largest contributor of the total transportation related fatalities in 2011. Table 1 shows historical trend of transportation fatalities by mode.

Table 1. Percentage of Total Fatalities by Travel Mode in USA, 1990 - 2011

1	2	3	4	5	6	7	8
Travel Mode	1990	1995	2000	2005	2009	2010	2011
Highway	94.1%	93.8%	94.5%	95.3%	94.3%	94.4%	94.3%
Waterborne	2.2%	2.3%	2.0%	1.8%	2.3%	2.2%	2.4%
Air	1.8%	2.2%	1.7%	1.3%	1.5%	1.4%	1.4%
Railroad	1.5%	1.5%	1.4%	1.4%	1.5%	1.7%	1.6%
Transit	0.3%	0.2%	0.2%	0.1%	0.3%	0.3%	0.3%
Total fatalities	47,379	44,602	44,376	45,645	35,920	34,968	34,458

Source: "National Transportation Statistics." DOT. Web. Accessed August, 14, 2014.
http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html
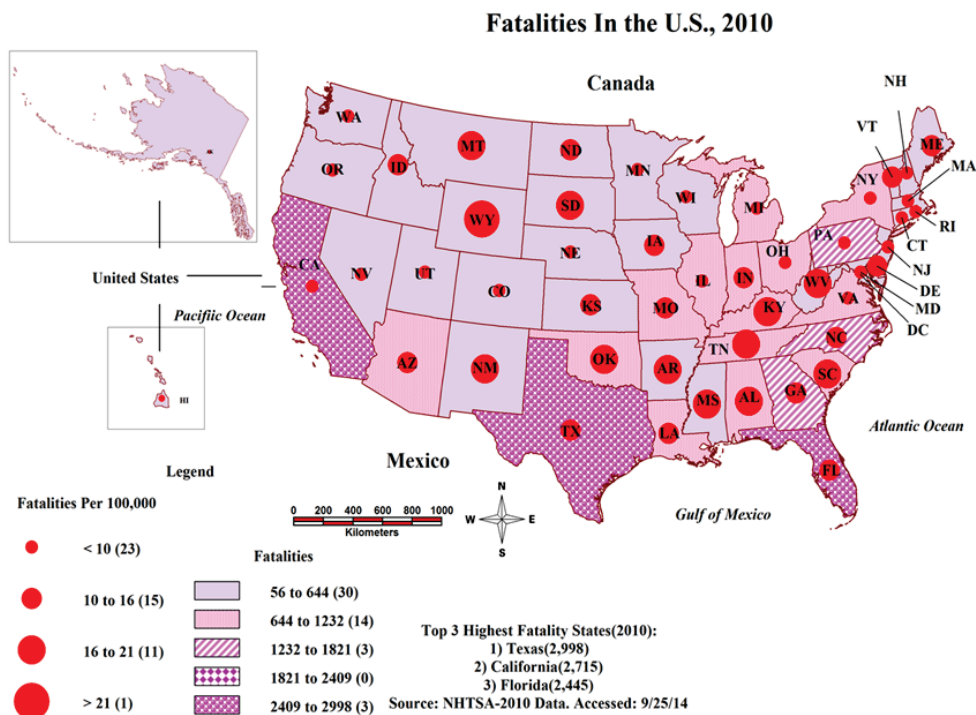
Figure 19. Spatial Map of Highway Fatalities in the U.S.A., 2010

Figure 19 shows a spatial map of highway fatalities in 2010. The total fatalities are low in rural states compared to states with more urban areas. However, rural states of Wyoming, Montana, West Virginia, and Mississippi are the most dangerous states considering the number of fatalities per 100,000 population. In 2003 the highway fatality rate in Mississippi was 31 per 100,000

population (Uddin 2007). In 2011, Mississippi and Montana had the third largest highway fatality rate of 21 per 100,000 million populations compared to other states in the U.S. Wyoming had the largest fatality rate of 24 per 100,000 million populations in the U.S. (BTS 2013).

The majority of fatalities on highway transportation systems relate to passenger car occupants. Figure 20 shows percentage of total highway fatalities by highway mode in the U.S. in 2011. Passenger car occupant fatalities of 12,014 contributed 37 percent of total highway fatalities; truck occupant fatalities of 9,942 contributed 30.6 percent; motorcyclist fatalities of 4,630 contributed 14.3 percent; and pedestrian fatalities of 4,457 contributed 13.7 percent of total highway fatalities. In addition, pedalcyclist fatalities of 682 contributed 2.1 percent of total highway fatalities; bus occupant fatalities of 55 contributed 0.2 percent; and the other highway modes of 699 contributed 2.2 percent of total highway fatalities. Total highway fatalities in the U.S. in 2011 were 32,479.

Highway Fatalities in Mississippi in 2011: 630 (1.9 % of U.S. Highway Fatalities)

Source:
[1] "National Transportation Statistics." DOT. Web. Accessed August, 14, 2014.
http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html
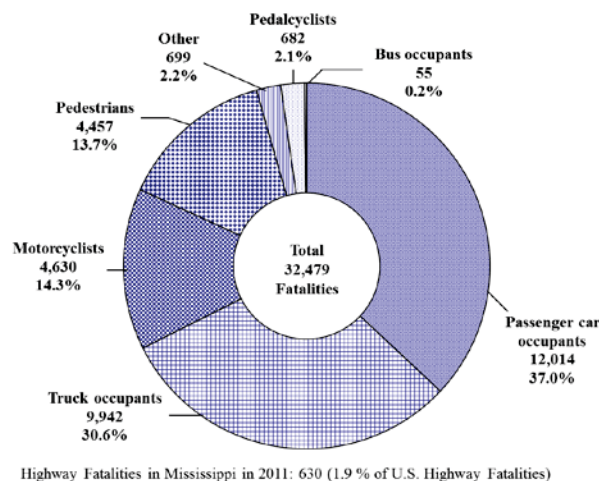[2] "State of Mississippi FY – 2014 Highway Safety Plan." State of Mississippi. 2011.

Figure 20. Highway Fatalities by Highway Travel Mode in the U.S.A., 2011

Figure 21 shows the percentage of total highway fatalities by highway mode in Mississippi in 2011. Total highway fatalities in Mississippi in 2011 were 630, which was 1.9 percent of total U.S. highway fatalities. Passenger car, truck, and bus occupant fatalities of 518 contributed to 82.2 percent of total highway fatalities; motorcyclist fatalities of 58 contributed to 9.2 percent; pedestrian fatalities of 47 contributed to 7.5 percent; pedalcyclist fatalities of 7 contributed to 1.1 percent of total highway fatalities. U.S. motorcyclists, pedestrians, and pedalcyclist fatalities of 30.1 percent were higher than Mississippi motorcyclists, pedestrians, and pedalcyclist fatalities of 17.8 percent.

Although the number of fatality for motorcyclists, pedalcyclists, and pedestrians were lower than the number of fatality for passenger car occupants, the fatality risk for motorcyclists,

pedalcyclists, and pedestrians were higher than the one for the passenger car occupants. Figure 22 shows the highway fatality rate as the percentage of total users of each mode in 2002 and 2012. The fatality rate of motorcyclists and pedalcyclists of 1.6 percent in 2012 was higher than the fatality rates of pedestrians and passenger cars as percentage of total users of each mode.

Highway Fatalities in USA in 2011: 32,479

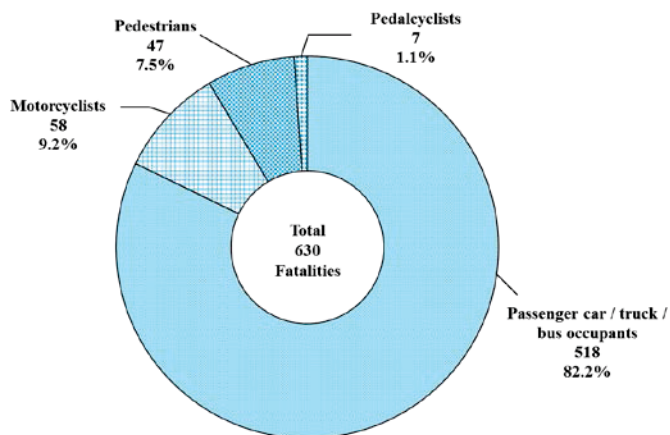Source: "State of Mississippi FY – 2014 Highway Safety Plan." State of Mississippi. 2011.

Figure 21. Highway Fatalities by Highway Travel Mode in Mississippi, 2011
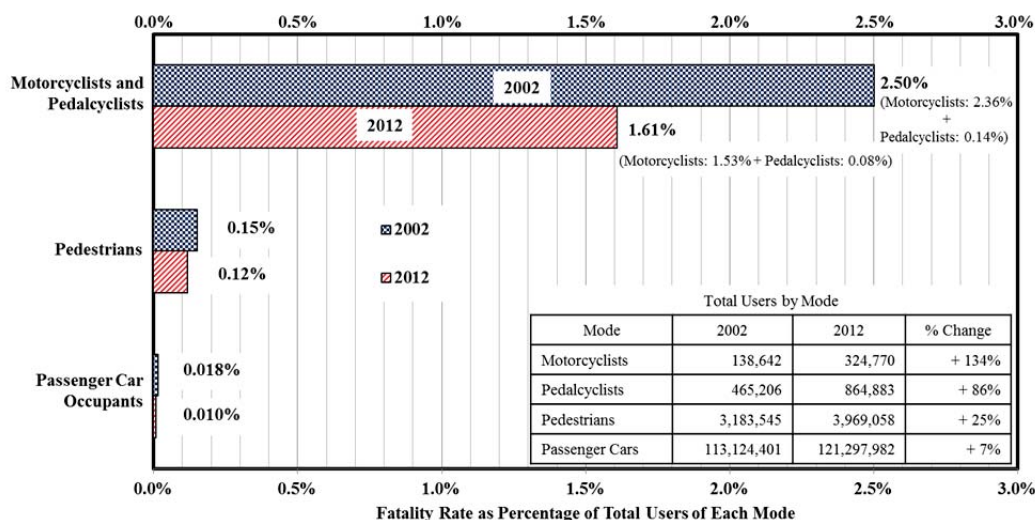
Source:
[1] "National Transportation Statistics." DOT. Web. Accessed August, 14, 2014.
    http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html
[2] "Principal Means of Transportation to Work." DOT. Web. Accessed September, 5, 2014.
    http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_41.html

Figure 22. Highway Fatality Rate as Percentage of Total Users of Each Mode, 2002-2012

The motorcyclists and pedalcyclists fatality rate in 2012 decreased 36 percent compared to 2002. Fatality rate of pedestrians was 0.12 percent in 2012. The fatality rate of pedestrians in 2012 decreased 20 percent compared to 2002. Figure 23 shows that total pedestrian deaths are increasing. Fatality rate of passenger car occupants was 0.01 percent in 2012, a reduction of 44.4

percent compared to 2002. Thanks to public campaign and DOTs vision zero fatality programs, drunk driving fatalities decreased during 1982-2012. Figure 24 shows that the fatality rate of truck occupants increased during 1980-2012 compared to passenger car occupants (BTS 2014c).
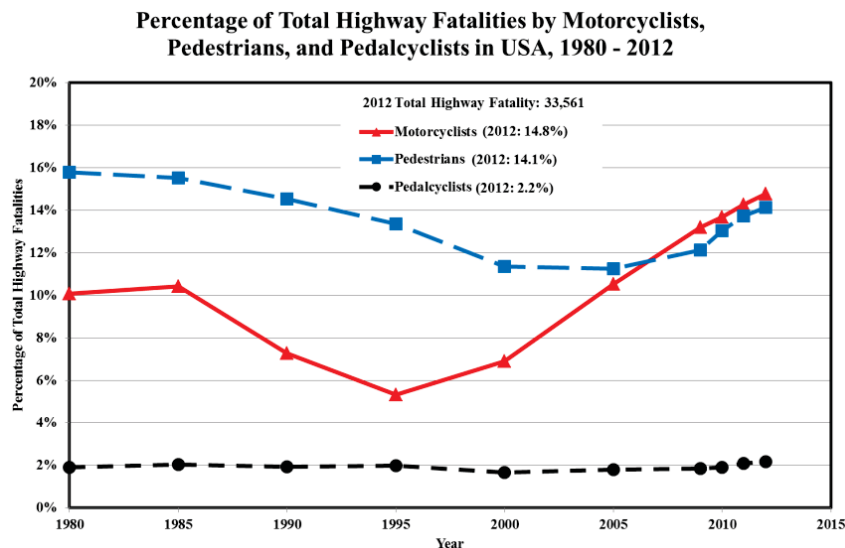
Figure 23. Trends of Highway Fatalities of Bikes and Pedestrians
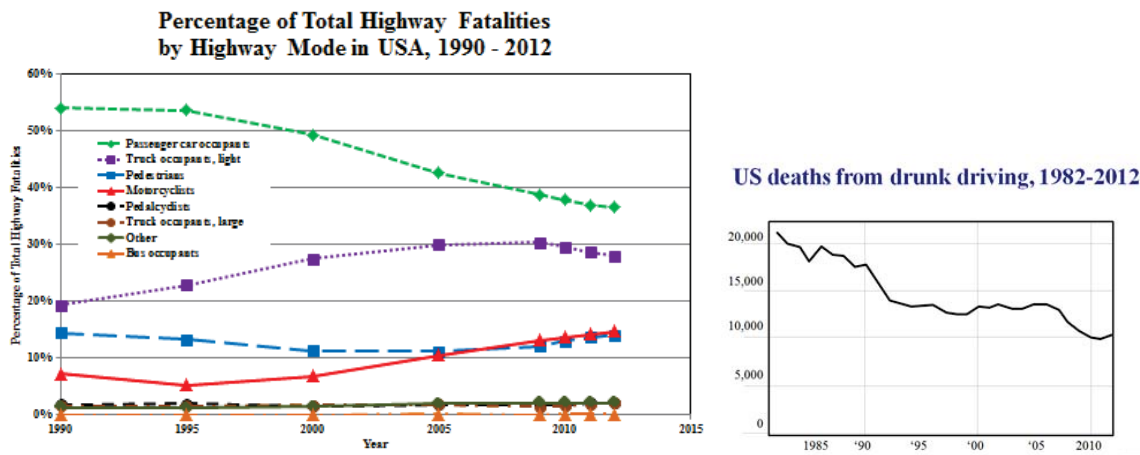
Figure 24. Trends of Highway Fatalities: by Mode (left) and from Drunk Driving (right)

The majority of U.S. highway-related fatalities, which were 56 percent, took place in rural areas in 2009, although only 23 percent of the U.S. population lived in rural areas. Crashes on rural roads were likely to be severe because many rural collectors and local roads do not have paved shoulders, clear zones, and divided directions of travel. In addition, there were higher average vehicle speeds on rural roads. Lower safety belt usage was also indicated in the rural areas. Finally, medical facilities were likely to be at greater distances (FHWA 2011).

In an average year between 2000 and 2009, about half of all motorcyclist fatalities occurred in single-vehicle incidents; 47 percent of the passenger car occupant fatalities occurred in single

vehicle crashes, and 66 percent of the light truck occupant fatalities occurred in single vehicle crashes. In addition, 75 percent of truck occupant fatalities occurred in single vehicle crashes. The single-vehicle crashes happened when a vehicle hit an animal or debris in the roadway or a fixed object at the side of the road, overturned without a prior collision, or caught fire (Savage 2013).

The bicycle and pedestrian are one of the alternative transportation modes proposed in the world nowadays because these modes do not contribute to emissions. In addition, using these modes can decrease the vehicle numbers and the congestion on the highway. However, the transportation infrastructures for the pedalcyclists and pedestrians should fulfill the safety requirements. In addition, the bicycle and motorcycle users are growing; this mode does not take large space as on the highway as passenger vehicles. However, the safety risk for cycle and motorcycle mode is alarming due to the large motorcycle mode fatality numbers (Figure 22). In 2015, the fatality rate of this two-wheeler mode was higher than the previous years (BTS 2016).

Transportation related fatalities in the United States decreased from 2001 to 2011. However, the fatality numbers were still large. Passenger car and truck occupants were the main contributors to the highway fatalities. Although the highway related fatalities in Mississippi was 1.9 percent of total highway related fatalities in the United States, the Mississippi had the third largest highway fatality rate in the U.S.A. The fatality risk for motorcyclists, pedalcyclists, and pedestrians were higher than the one for passenger car occupants. Future introduction of autonomous vehicles on a mass scale will bring more unknowns in the crash and fatality trend.

The trends of congestion and highway fatality rate indicate that the following considerations should be taken on state and federal levels.
- Implementation of seat belt law and other laws dealing with driver behavior.
- Improved traffic management and emergency response through real-time intelligent transportation systems (ITS).
- Increased use of bus transit and shared vehicles instead of single owner vehicles to reduce AADT.
- Reduction of highway travel demand by diverting traffic to alternative modes such as commuter rail using shared track with freight rail, light rail, and monorail.

2.3 Evaluation of Commuter Needs and Travel Demand Modeling for the Gulf Coast

Travel Demand in Gulf Coast Counties and I-10/US90 Corridors
Figure 25 shows a spatial map of VMT by county for Mississippi in 2010. There were 11 counties that had VMT more than 700 million in 2010; 10 counties had VMT between 500 and 700 million; and 23 counties had VMT between 300 to 500 million. In addition, 36 counties had VMT between 100 and 300 million and 2 counties had VMT less than 100 million. Total VMT

in Mississippi in 2010 was 39,841 million**.** People in Mississippi that drove alone to work in 2010 were 84.1 percent of total population. The Mississippi highway infrastructure map show that the most populated counties in Mississippi are well connected with the National Highway System. As a result, this is realistic that the population spread in Mississippi are likely similar to the VMT dispersion. The following key observations are based on Figure 25:

- Large VMT numbers were found for the counties that have large population as well. Total 2010 VMT in Hinds, Rankin, and Madison, which are among the top populated counties in Mississippi, were 6,802 million. VMT of these counties was 17 percent of total VMT in Mississippi.
- In addition, the 2010 VMT in Mississippi Gulf Coast counties, which consist of large population counties as well, was 4,613. The VMT of Mississippi Gulf Coast counties were 11.5 percent of total VMT in Mississippi.
- The VMT in Pearl River, Lamar, Forrest, Jones, and Lauderdale counties, all of which are along I-59 and rail route, were 4,236.5 in 2010 (10.6 percent of total Mississippi VMT).
- As a result, these 11 large populated counties, which are spread around the City of Jackson, in Mississippi Gulf Coast, and along I-59 and rail route, contributed to 39.1 percent of total VMT in all 82 Mississippi counties.
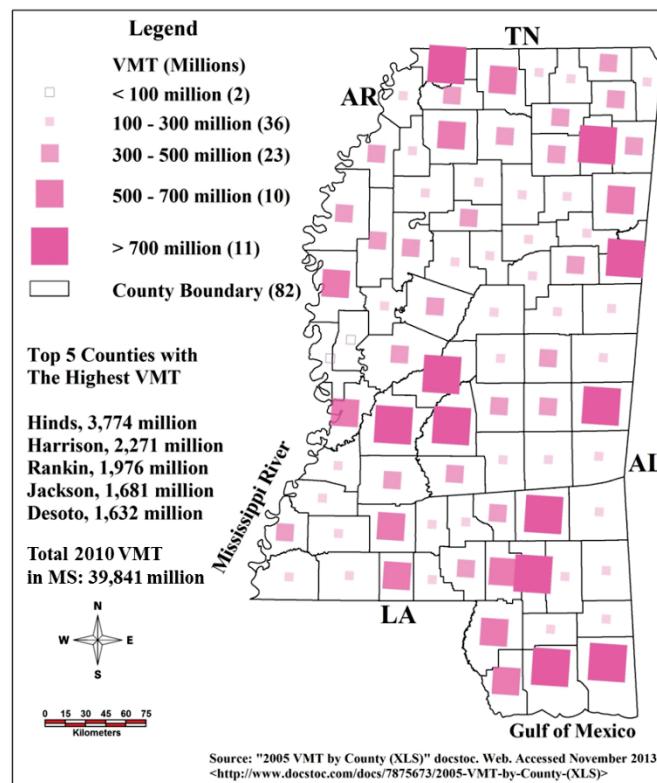

Figure 25. Spatial Map of VMT in Mississippi by County, 2010

Traffic Congestion and Travel Time Data

There are several indicators of congestion: travel time, level of service, speed, and delay. Several studies proposed the reliability of the highway system for the most proper congestion indicator, for example commuter in a dense urban area may accept that a 20 mile freeway trip takes 40 minutes during the peak period, so long as this predicted travel time is reliable and is not 20 minutes one day and 3 hours the next.

Highway congestion permanently is caused when traffic demand nears or surpasses the capacity of the highway system. In addition, there are several impermanent causes of the congestions, as follows:

- First, bottlenecks, which are the points where the roadway narrows or regular traffic demands affect traffic to backup. Bottlenecks are the largest congestion source.
- Second, traffic incidents, such as crashes, stuck vehicles, debris on the road. Traffic incidents cause about 25 percent of congestion problems.
- Third, work zones, which are associated with new road construction, rehabilitation, reconstruction, and maintenance activities. The congestion caused by these actions can be prevented by proper management.
- Fourth, bad weather. The potential for increased congestion due to bad weather can be informed to the travelers in order to address this uncontrolled congestion source.
- Fifth, poor traffic signal timing, which can occur because the time allocation for a road does not match the associated transportation volume. Poor traffic signal is a source of congestion on major and minor roads.
- Finally, special events like football game day in a university town, which is irregular cause of congestion (FHWA 2014a).

Travel time to work shows the efficiency of the transportation system. Travel time to work effects the capability of the community to go to work as well as life in the adequate housing location. Travel time to work is also a component of a community's economic competitiveness, which not only generates value added and keeping it in the area, but also has good access to the market (Sustainable 2014, EU 2014). The travel time data was obtained from American Community Survey (ACS). Respondents answer questions about commuting, including how long it takes to travel to work (Census 2011).

The spatial map in Figure 26 shows the average travel time to work in Mississippi by County from 2006 to 2010. Interstate, U.S. highways, and rail road systems are shown as well in the figure. The map shows that:

- The top five counties in Mississippi listed from the largest number of average travel time to work to the smallest were as follows: Franklin (42.8 minutes), Benton (36.5 minutes), Walthall (36.3 minutes), Marion (35.7 minutes), and Simpson (35.2 minutes).
- Five counties had average travel time to work between 35 and 45 minutes.

- 29 counties had average travel time to work between 25 and 35 minutes; and 48 counties had average travel time between 15 and 25 minutes.
- According to Figure 26, the high travel time was found in the locations which are near the high populated counties and passed by the U.S. highway only, not Interstate. The high travel time were found at the counties that passed by US-98, US-84, US-49, and US 72. This fact indicates that, first, the high travel time occurs due to the large number of commuters and relatively intermediate capacity of the highway. Second, the travel time is more due to the long travel distance made by the commuters traveling from the rural to urban. On the other hand, many low travel times were found in the counties that had low population, for example along the Mississippi river. It indicates that most populations in such counties tend to work inside or near their county and do not travel to the urban areas to work.
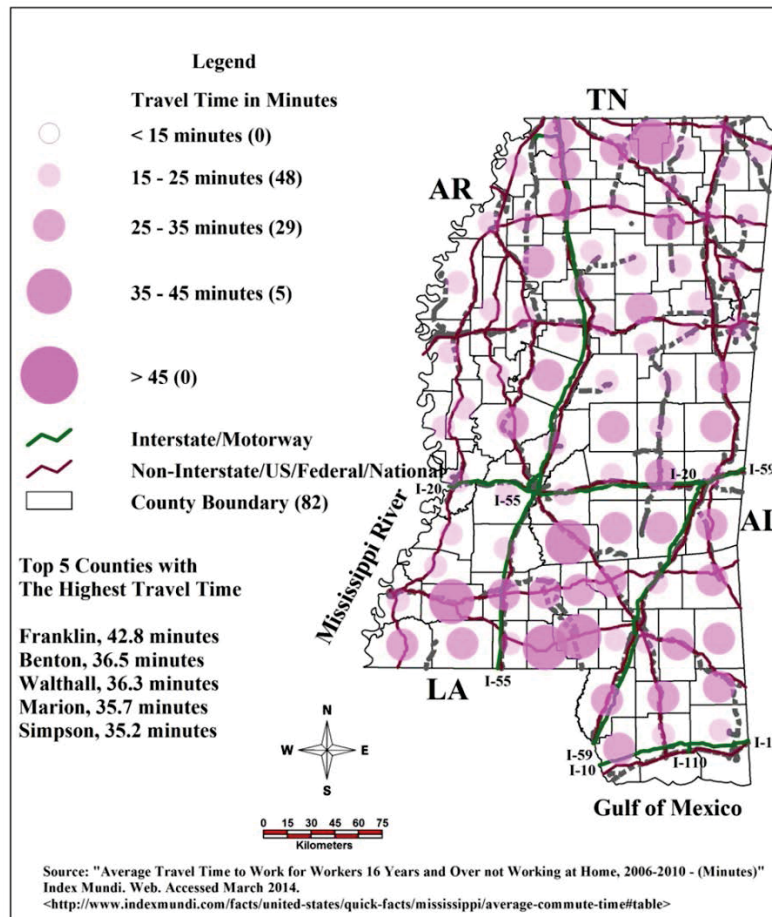
Figure 26. Average Travel Time to Work in Mississippi by County, 2006 – 2010

There are several ways to address the congestion problem: improving service on existing roads, value pricing, adding road capacity, work zone management, travel demand management, and traveler information (FHWA 2014b). In regard to traveler information, Mississippi Department of Transportation provides traffic and closure road information through the map (MDOT 2014).

The map shows the construction or maintenance location, closed roads, incident alerts, weather related alerts, and rest areas.

Demographics and Analysis of Commuter and Travel Time Data in Gulf Coast Counties
As discussed in the preceding section, population is a major factor in generating number of trips made by commuters. Figure 27 is a spatial map of Mississippi that shows county names of all 82 counties. The top ten counties in Mississippi listed from the largest area to the smallest are as follows: Yazoo (922.95 square miles), Bolivar (876.57 square miles), Hinds (869.74 square miles), Pearl River (810.86 square miles), Wayne (810.75 square miles), Copiah (777.24 square miles), Rankin (775.49 square miles), Kemper (766.18 square miles), Monroe (765.09 square miles), and Holmes (756.7 square miles) (Index Mundi 2014a). City of Jackson in Hinds County is the capital city of Mississippi.
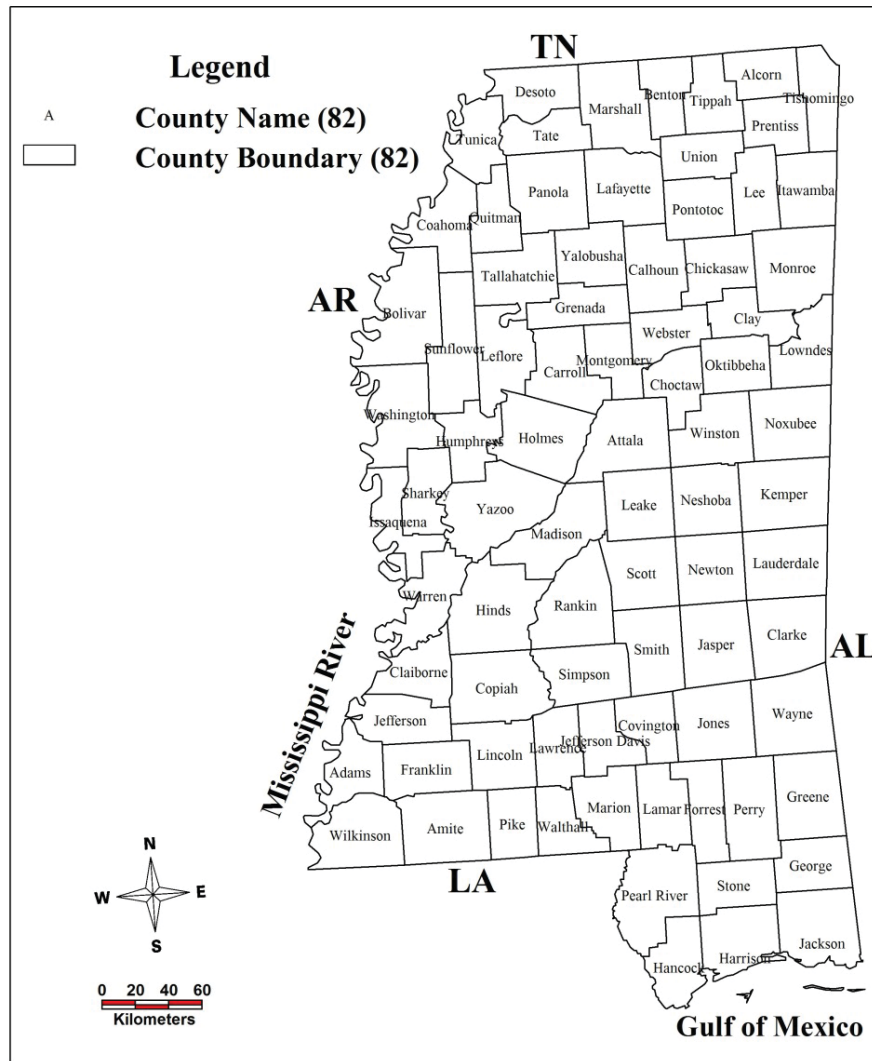
Figure 27. Map of Mississippi Counties

Total population of Mississippi in 2010 was 2,967,297, which was 0.96 percent of total U.S. population. Figure 28 displays the population by county. The top ten counties in Mississippi listed from the largest population to the smallest were as follows: Hinds (245,285), Harrison (187,105), DeSoto (161,252), Rankin (141,617), Jackson (139,668), Madison (95,203), Lee (82,910), Lauderdale (80,261), Forrest (74,934), and Jones (67,761). There was one county that had a population of more than 200,000 in 2010; 4 counties had a population between 100,000 to 200,000; 9 counties had a population between 50,000 to 100,000. There were 25 counties that had a population between 25,000 to 50,000 and 43 county had a population of less than 25,000.

The total population in Hinds, Rankin, and Madison counties in 2010 were 482,105, where is 16.2 percent of total Mississippi population. The population in Pearl River, Lamar, Forrest, Jones, and Lauderdale counties, all of which are along I-59 and rail route, were 334,448 in 2010 (11.2 percent of total Mississippi population). As a result, these 11 large populated counties, which are spread around the City of Jackson, in Mississippi Gulf Coast, and along I-59 and rail route, contributed to 39.8 percent of total population in all 82 Mississippi counties. Military and federal installations together with the tourism and casino industries are the backbone of the Mississippi Gulf Coast economy. The combined population of Mississippi Gulf Coast counties in 2010 was 370,702, which was 12.4 percent of total Mississippi population.
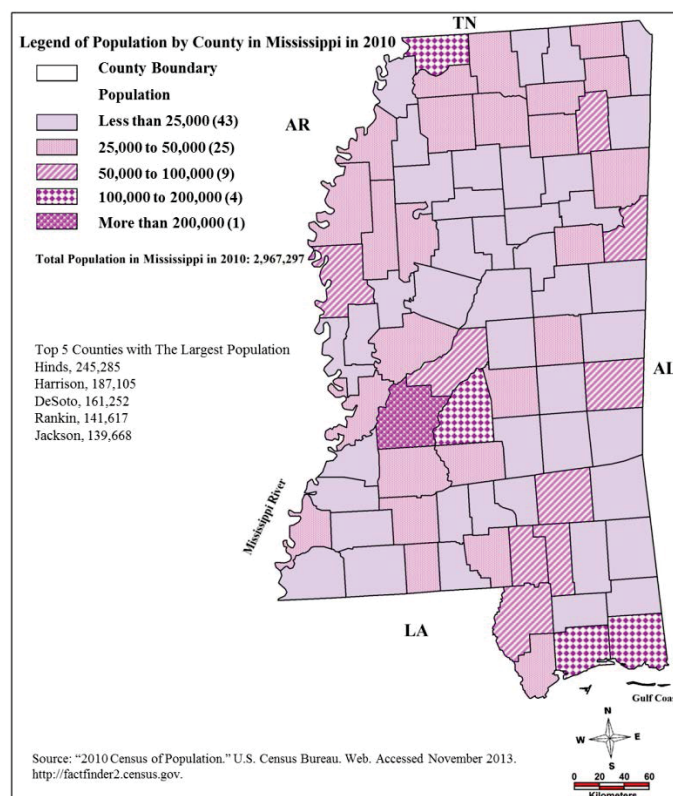
Figure 28. Spatial Map of Population in Mississippi by County, 2010

With respect to the population density, the top ten counties in Mississippi listed from the largest population density to the smallest in 2010 were as follows: DeSoto (338.7 people per square mile), Harrison (326 people per square mile), Hinds (282 people per square mile), Jackson (193.2 people per square mile), Lee (184.3 people per square mile), Rankin (182.6 people per square mile), Forrest (160.7 people per square mile), Madison (133.2 people per square mile), Lowndes (118.3 people per square mile), and Lauderdale (114.1 people per square mile). Population density in Mississippi in 2010 was 63.2 people per square mile, while population density in the U.S.A. in 2010 was 87.4 people per square mile (Index Mundi 2014b). The most populated Mississippi counties mostly are in the surroundings of the City of Jackson, which are Hinds, Rankin, and Madison, in the Mississippi Gulf Coast, and counties along I-59, which are Pearl River, Lamar, Forrest, Jones, and Lauderdale.

Ahlan (2014) conduced a comprehensive socioeconomic and demographics study, as follows. The total number of commuters in a county includes in-commuters and out-commuters. In-commuters in a county involve people that live and work in the county and people that live outside the county but work in that county. Out-commuters in a county are people that live in the county but work outside that county. In-commuters and out-commuters data were available by Mississippi Department of Employment Security (MDES), which are based on the U.S. census data (MDES 2014). Changes in the public's socioeconomic and demographic scenes are associated with the changes in commuting patterns. Figure 29 shows number of in-commuters in Mississippi by county in 2012.

In-commuters include the commuters that live and work in the county and the commuters that live outside the county but work in the county. The top five counties in Mississippi listed from the largest number of in-commuters to the smallest were as follows: Hinds (103,426), Harrison (86,439), Desoto (77,171), Rankin (66,405), and Jackson (59,668). There was one county that had in-commuters less than 1,000; 48 counties had 1,000 to 10,000 in-commuters; 28 counties had 10,000 to 50,000 in-commuters; 4 counties had 50,000 to 100,000 in-commuters; and one county had in-commuters more than 100,000.

The in-commuter spatial map (Figure 29) shows a relatively same pattern with the population spatial data in Mississippi. The top populated counties show large number of in-commuters. The number of in-commuters in Hinds, Madison, and Rankin were 214,782, which were 18 percent of total in-commuters in Mississippi. Similarly, the in-commuters in Mississippi Gulf Coast, which were among the top populated counties, were 164,108 or 13.7 percent of total in-commuters in Mississippi. The in-commuters in Pearl River, Lamar, Forrest, Jones, and Lauderdale counties, all of which are along I-59 and rail route, were 138,285 (11.6 percent of total in-commuters in Mississippi). As a result, these 11 counties that have a large number of in-

commuter, which are spread around the City of Jackson, in Mississippi Gulf Coast, and along I-59 and rail route, contributed to 43.3 percent of total in-commuters in all 82 Mississippi counties.
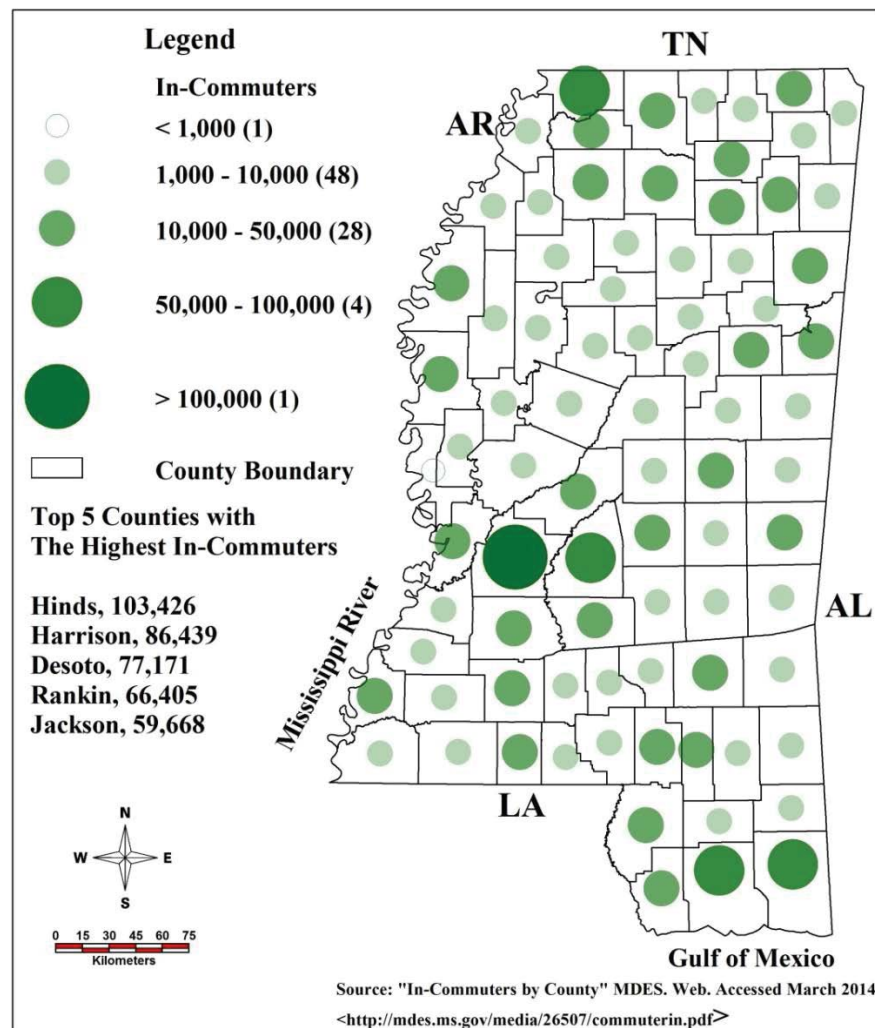
Figure 29. Spatial map of In-Commuters in Mississippi by County, 2012

Figure 30 shows number of out-commuters in Mississippi by county in 2012. Out-commuters in a county mean the commuters that live in the county but work outside the county. The top five counties in Mississippi listed from the largest number of out-commuters to the smallest were as follows: Rankin (32,075), Hinds (28,242), Madison (22,234), Jackson (16,072), and Lamar (14,397). There were 7 counties that had out-commuters less than 1,000; 70 counties had 1,000 to 10,000 out-commuters; and 5 counties had 10,000 to 50,000 out-commuters.

The out-commuter spatial map shows relatively same patterns with the population spatial data in Mississippi. The top populated counties show large number of out-commuters. The number of out-commuters in Hinds, Madison, and Rankin were 82,551, which were 25.3 percent of total out-commuters in Mississippi. Similarly, the out-commuters in Mississippi Gulf Coast, which

were among the top populated counties, were 31,077 or 9.5 percent of total out-commuters in Mississippi. The out-commuters in Pearl River, Lamar, Forrest, Jones, and Lauderdale counties, all of which are along I-59 and rail route, were 33,927 (10.4 percent of total out-commuters in Mississippi). As a result, these 11 counties that have a large number of out-commuter, which are spread around the Jackson city, in Mississippi Gulf Coast, and along I-59 and rail route, contributed to 45.2 percent of total in-commuters in all 82 Mississippi counties.

Hinds, Madison, and Rankin had higher out-commuters percentage of 25 percent of total Mississippi number compared to these counties in-commuters percentage that were 18 percent of total Mississippi figure. Consequently, although Hinds, Madison, and Rankin absorb large number of workers from outside each county, the large amount of these counties resident also work outside of each county.
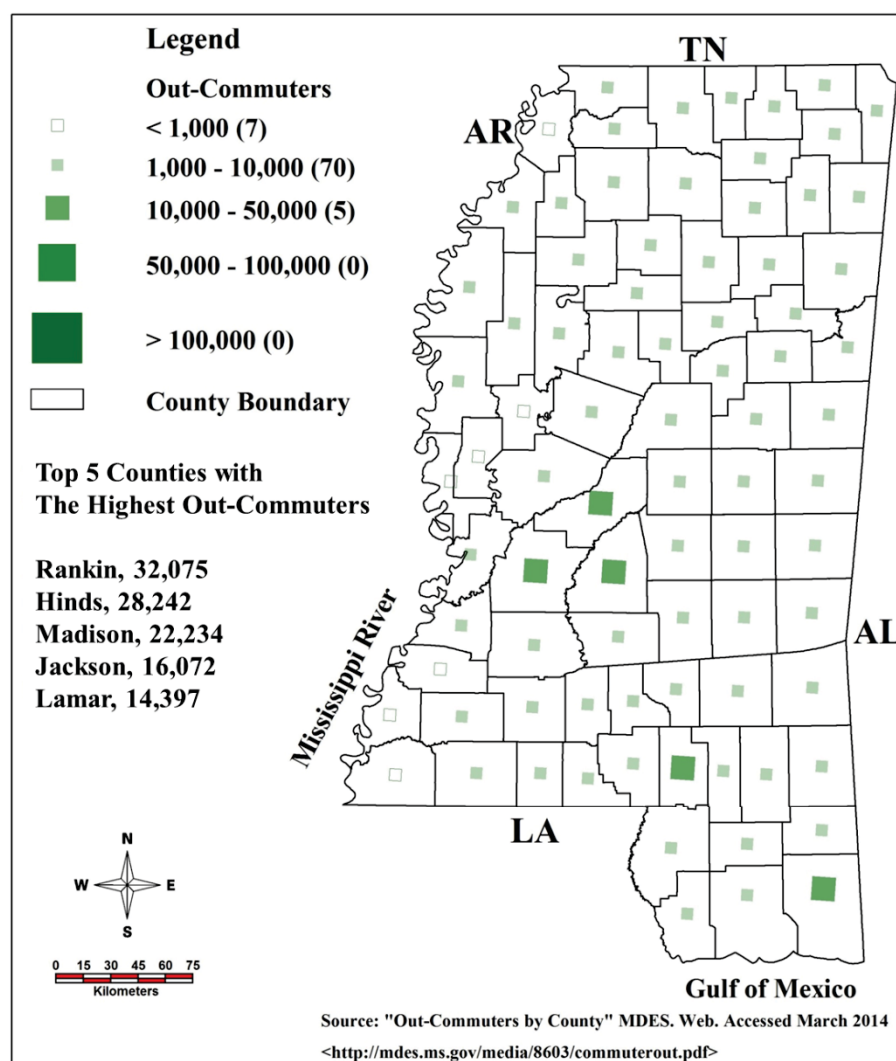
Figure 30. Spatial map of Out-Commuters in Mississippi by County, 2012

Table 2 shows number of employments and establishments by county in Mississippi in 2012 (MDES 2014).

Table 2. Number of Establishments and Employments by County in Mississippi, 2012

A	B	C	D	E
	Avg Monthly Employment		Establishments	
County	Number	Percent of Total Mississippi	Number	Percent of Total Mississippi
Hinds	115,514	11.3	5,271	9.4
Harrison	76,649	7.5	3,791	6.8
Rankin	55,204	5.4	3,237	5.8
Lee	49,974	4.9	2,184	3.9
DeSoto	47,206	4.6	2,279	4.1
Jackson	47,047	4.6	2,037	3.6
Madison	46,409	4.5	2,792	5.0
Forrest	35,846	3.5	1,659	3.0
Lauderdale	32,699	3.2	1,774	3.2
Jones	28,024	2.7	1,210	2.2
Lowndes	24,476	2.4	1,414	2.5
Lafayette	18,619	1.8	1,046	1.9
Warren	18,375	1.8	1,029	1.8
Oktibbeha	18,112	1.8	830	1.5
Lamar	17,537	1.7	1,212	2.2
Washington	17,207	1.7	1,195	2.1
Pike	14,295	1.4	939	1.7
Leflore	13,779	1.3	748	1.3
Alcorn	12,923	1.3	746	1.3
Neshoba	12,633	1.2	501	0.9
Scott	12,323	1.2	478	0.9
Bolivar	11,765	1.2	773	1.4
Tunica	11,292	1.1	264	0.5
Hancock	11,230	1.1	735	1.3
Pontotoc	11,165	1.1	447	0.8
Lincoln	10,850	1.1	751	1.3
Adams	10,656	1.0	821	1.5
Panola	10,650	1.0	602	1.1
Pearl River	9,772	1.0	767	1.4
Union	9,625	0.9	463	0.8
Grenada	9,497	0.9	511	0.9

Table 2. Number of Establishments and Employments by County in Mississippi, 2012

(Continue)

A	B	C	D	E
	Avg Monthly Employment		Establishments	
County	Number	Percent of Total Mississippi	Number	Percent of Total Mississippi
Smith	2,689	0.3	165	0.3
Walthall	2,574	0.3	220	0.4
Montgomery	2,538	0.2	217	0.4
Lawrence	2,483	0.2	170	0.3
Noxubee	2,400	0.2	216	0.4
Wilkinson	2,057	0.2	147	0.3
Webster	2,029	0.2	162	0.3
Perry	1,992	0.2	146	0.3
Greene	1,956	0.2	123	0.2
Choctaw	1,826	0.2	128	0.2
Jefferson Davis	1,626	0.2	141	0.3
Franklin	1,603	0.2	121	0.2
Amite	1,571	0.2	182	0.3
Benton	1,281	0.1	74	0.1
Jefferson	1,276	0.1	78	0.1
Sharkey	1,216	0.1	152	0.3
Quitman	1,214	0.1	135	0.2
Carroll	1,147	0.1	111	0.2
Issaquena	236	0.0	32	0.1
Total	1,022,490	100.0	55,941	100.0

The top ten counties in Mississippi listed from the largest number of average monthly employment to the smallest were as follows: Hinds (115,514), Harrison (76,649), Rankin (55,204), Lee (49,974), DeSoto (47,206), Jackson (47,047), Madison (46,409), Forrest (35,846), Lauderdale (32,699), and Jones (28,024). Total employments in Mississippi in 2012 were 1,022,490.

The county that had a large number of employments also had a high number of establishments or businesses. There were 5,271 establishments in Hinds, 3,791 establishments in Harrison, 3,237 establishments in Rankin, 2,184 establishments in Lee, 2,279 establishments in DeSoto, 2,037 establishments in Jackson, 2,792 establishments in Madison, 1,659 establishments in Forrest, 1,774 in establishments Lauderdale, and establishments 1,210 in Jones. Total establishments in Mississippi in 2012 were 55,941.

Travel Demand and Congestion in Gulf Coast Counties and I-10/US90 Corridors

The travel demand and commuter data was collected from the U.S. Census Bureau web site for major cities of the Mississippi Gulf Coast (Census 2012). Figure 31 shows the distribution of commuters in Gulfport by travel mode where 80 percent commuters travel by auto mode in mostly in a single occupancy vehicle. Figure 32 is a donut pie chart that displays Gulfport employment by industry. This chart shows that there are 28,803 civilian employed residents in Gulfport, MS. The surrounding pie chart displays what percentage of the residents work in which industry in Gulfport, MS. For example 20% of the civilian labor force in Gulfport are in the education, healthcare, and social assistance industry.
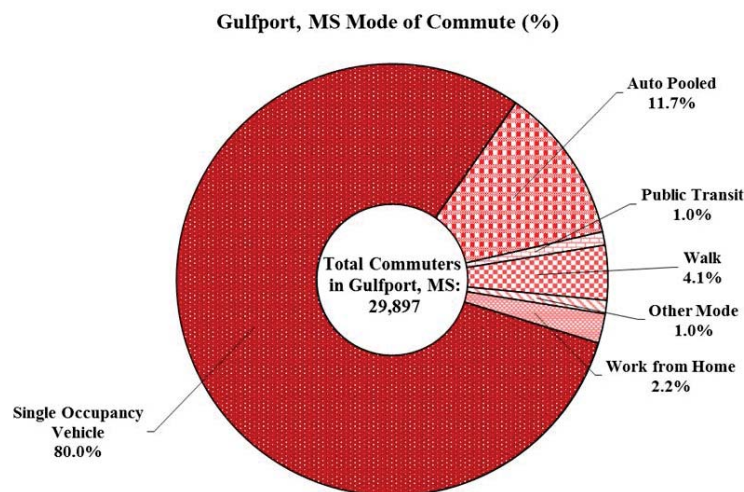
Figure 31. The total number of commuters and their travel modes in Gulfport, MS

Figure 32. The total number of commuters and their travel modes in Gulfport, MS

These five major Gulf Coast cities all showed similar trends in commuter behavior for 2012. Table 3 shows the commuter data for five of the largest cities along the Mississippi Gulf Coast (Cobb 2015).
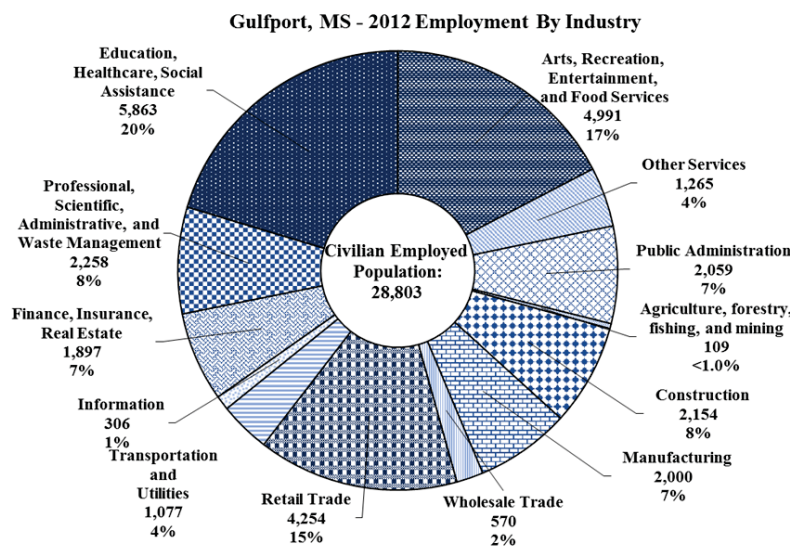
Table 3. Commuter Data for Major Mississippi Gulf Coast Cities, 2012

City	County	Avg. Commute Time (min)	Total Commuters	% Single Auto	% Pooled Auto	% Transit	% Walk	% Other	% Home
Bay St. Louis	Hancock	21.4	4,338	77.1	17.5	0.0	0.5	2.4	2.5
Gulfport	Harrison	21.0	29,897	80.0	11.7	1.0	4.1	1.0	2.2
Biloxi	Harrison	18.8	22,870	76.5	10.0	0.7	9.3	1.8	1.7
Ocean Springs	Jackson	22.9	8,190	82.0	12.2	0.0	1.8	2.0	2.0
Pascagoula	Jackson	17.3	9,346	78.5	14.6	0.1	3.6	1.7	1.7

The list provides two cities from Jackson County, two cities from Harrison County, and one city from Hancock County. Gulfport and Biloxi are where most of the commuters are located on the coast, but Pascagoula and Ocean Springs are cities where the population is currently on the rise. For each of the five cities the average commute time is around 20 minutes. There are approximately 75,000 residents that commute to work in just these five cities. Each city reported that between 75% and 85% of the population went by single automobile to work and between 10% and 20% carpooled. Gulfport, Biloxi, and Pascagoula had 1.0% or less that opted to use public transportation. Based on these statistics there is significant opportunity for the implementation of some new form of public transit that would be attractive to Gulf Coast commuters.

With a large number of commuters there is a high amount of vehicle miles traveled accumulated in the coastal counties. The VMT by county on the Mississippi Gulf Coast in 2010 is summarized as follows (Ahlan 2014, Cobb 2015): Harrison County, which is the most populated and most developed of the three coastal counties, showed the highest VMT at just over 2 billion miles. Jackson County which is experiencing significant growth, was second at 1.68 billion miles, and Hancock was third at 6.6 million. This high amount of auto traffic besides through auto and truck traffic are the leading cause of traffic congestion on the Gulf Coast Highway I-10 and US-90 corridors.

The MDOT strategic planning study identified severe congestion in this corridor, as follows (MDOT 2011): (a) Most of Interstate-10 corridor has average speeds (in both directions) at or below 55 mph. (b) In the Jackson-Hattiesburg-Gulfport Corridor the majority of freight is moved by truck (91 percent) and through traffic (61 percent), which is expected to grow. with average travel speed of 55 miles per hour during peak hours. The high commercial traffic volume increases general congestion on highways and safety risks to other auto commuter traffic.

Study of Person Trips and Travel Demand on I-90 and US-90 Corridors
The U.S. Census Bureau collected data of the Mississippi Gulf Coast by county, which are as follows: population, number of households, number of vehicles available per household, number of commuters, average travel time to work, and means of transportation to work (Census 2011). Some of the census data for the Mississippi Gulf Coast counties are shown in Table 4. Other census data for the Mississippi Gulf Coast counties are shown in Figure 33 to 35.

Table 4. Census Data for Mississippi Gulf Coast Counties

A	B	C	D	E
County	2010 Population	2010 – 2012 Number of Households	2012 Number of Commuters	Average Travel Time to Work, min
Hancock	43,929	18,131	23,570	28.8
Harrison	187,105	74,711	95,875	22.3
Jackson	139,668	50,625	75,740	24.6
Total or Average	370,702	143,467	195,185	25.2
	Total	Total	Total	Average

Number of commuters is the addition of in-commuters and out-commuters. In-commuters in a county include people that live and work in the county and people that live outside the county but work in that county. Out-commuters in a county are people that live in the county but work outside that county. In-commuters and out-commuters data were set by Mississippi Department of Employment Security based on the U.S. census raw data (MDES 2014).

Figure 33(a) shows the household size by vehicles available in Hancock County from 2010 to 2012. There were 37.7 percent of total households in Hancock County that had 2 vehicles available; 35.1 percent of total households had 1 vehicle available; 18.8 percent of total households had 3 vehicles available; 4.8 percent of total households had 4 or more vehicles available; 3.6 percent of total households had no vehicle available. Total households in Hancock County Mississippi from 2010 to 2012 were 18,131.

Figure 33(b) shows the household size by vehicles available in Harrison County in 2012. There were 38.4 percent of total households in Harrison County that had 1 vehicle available; 37.4 percent of total households had 2 vehicles available; 11.9 percent of total households had 3 vehicles available; 7.4 percent of total households had 4 or more vehicles available; and 4.9 percent of total households had no vehicle available. Total households in Harrison County Mississippi in 2012 were 74,711.

Figure 33(c) shows household size by vehicles available in Jackson County in 2012. There were 41.5 percent of total households in Jackson County that had 2 vehicles available; 29.6 percent of total households had 1 vehicle available; 18.1 percent of total households had 3 vehicles

available; 6.3 percent of total households had 4 or more vehicles available; and 4.5 percent of total households had no vehicle available. Total households in Jackson County Mississippi in 2012 were 50,625.
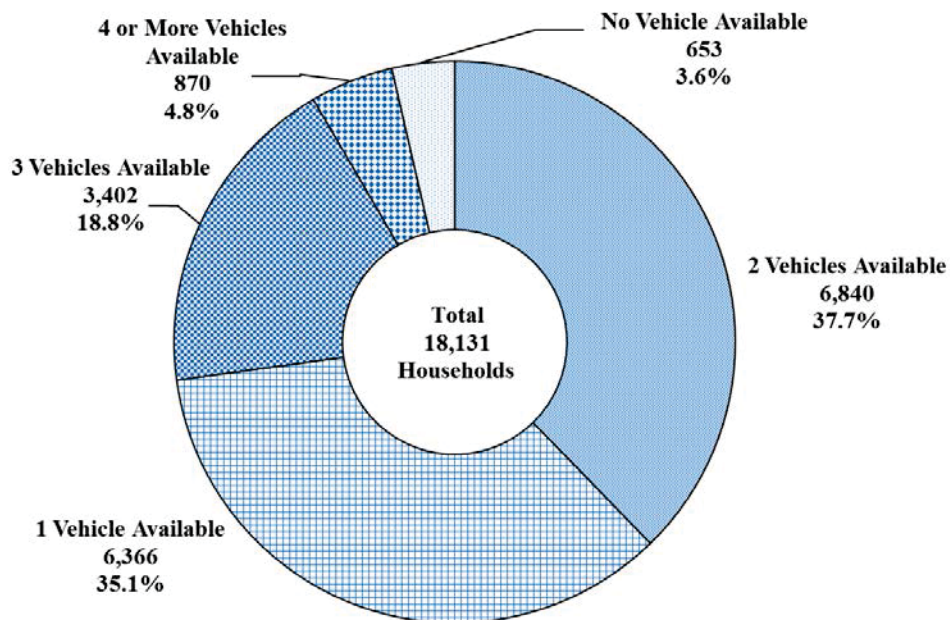
Source: "Household Size by Vehicles Available." US Census Bureau. Web. Accessed April, 4, 2014.
http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

Figure 33(a). Household Size by Vehicles Available in Hancock County, 2010 – 2012
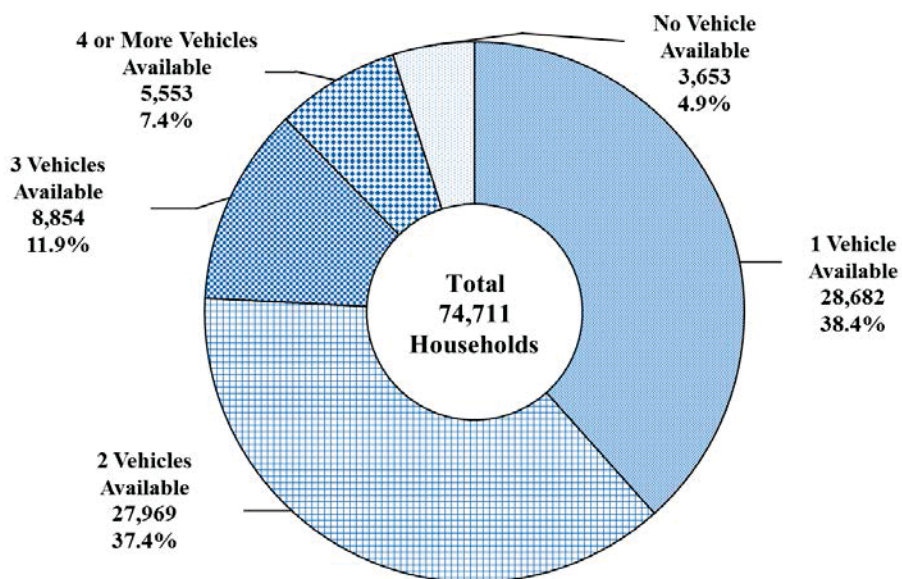
Source: "Household Size by Vehicles Available." US Census Bureau. Web. Accessed April, 4, 2014.
http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

Figure 33(b). Household Size by Vehicles Available in Harrison County, 2012
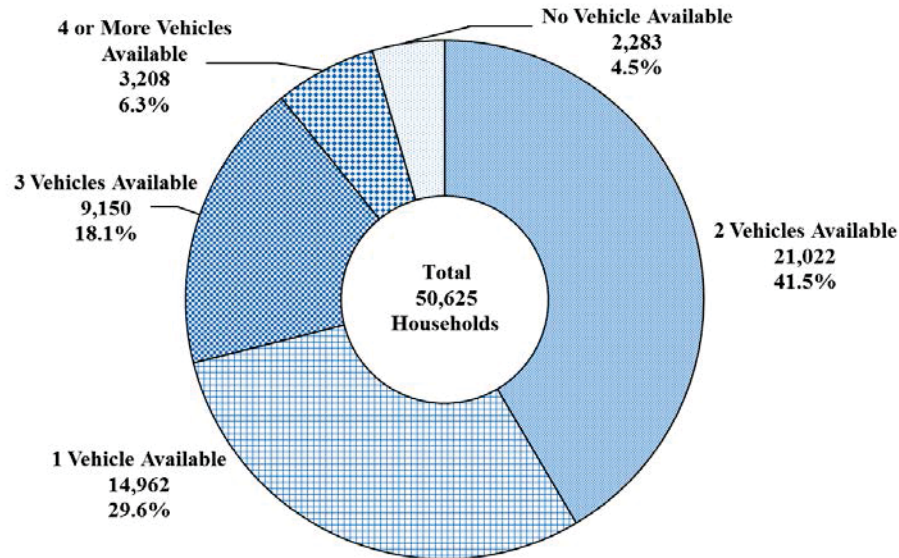
Source: "Household Size by Vehicles Available." US Census Bureau. Web. Accessed April, 4, 2014.
http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

Figure 33(c). Household Size by Vehicles Available in Jackson County, 2012
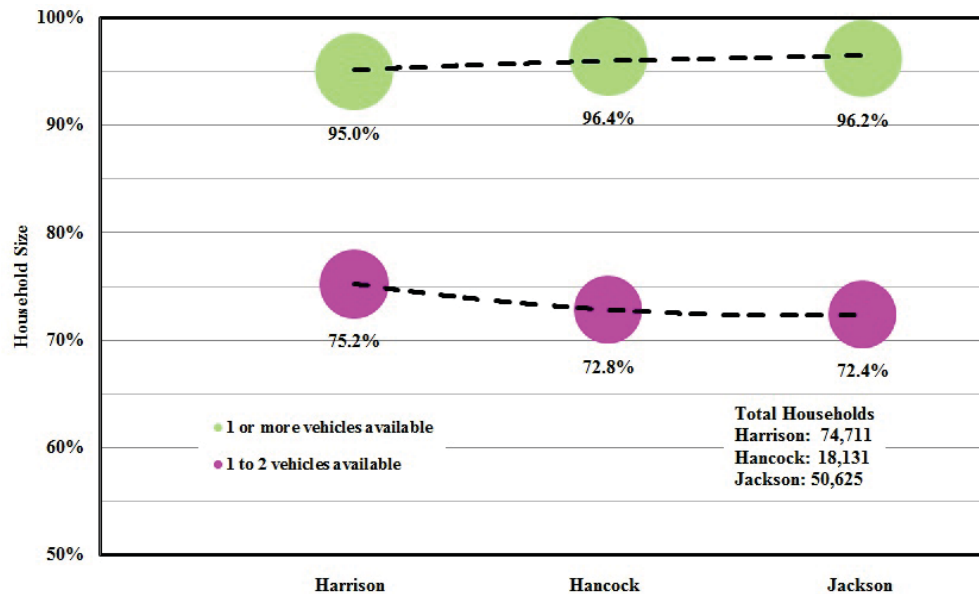
Source: "Household Size by Vehicles Available." US Census Bureau. Web. Accessed April, 4, 2014.
http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_B08201&prodType=table

Figure 34. Household Sizes by Vehicles Available in Mississippi Gulf Coast, 2010 – 2012

Figure 34 shows the household sizes by 1 and 1 to 2 vehicles available by county in Mississippi Gulf Coast Counties from 2010 to 2012. The household size that had more than 2 vehicles available can be obtained by subtracting the household size that had 1 to 2 vehicles available from the household size that had 1 or more vehicles available. There were 19.8 percent of total households in Harrison County that had more than 2 vehicles available; 23.6 percent of total

households in Hancock County had more than 2 vehicles available; and 23.8 percent of total households in Jackson County had more than 2 vehicles available.

Figure 35 shows percentage of means of transportation to work by selected characteristics in Mississippi Gulf Coast counties from 2010 to 2012. Workers that drove alone were 82.1 percent in Hancock County, 81.69 percent in Jackson County, and 81.42 percent in Harrison County. Workers who used car pooled were 13.23 percent in Hancock County, 13.26 percent in Jackson County, and 10.56 percent in Harrison County. Workers that used public transportation were 0.02 percent in Hancock County, 0.32 percent in Jackson County, and 0.89 percent in Harrison County.
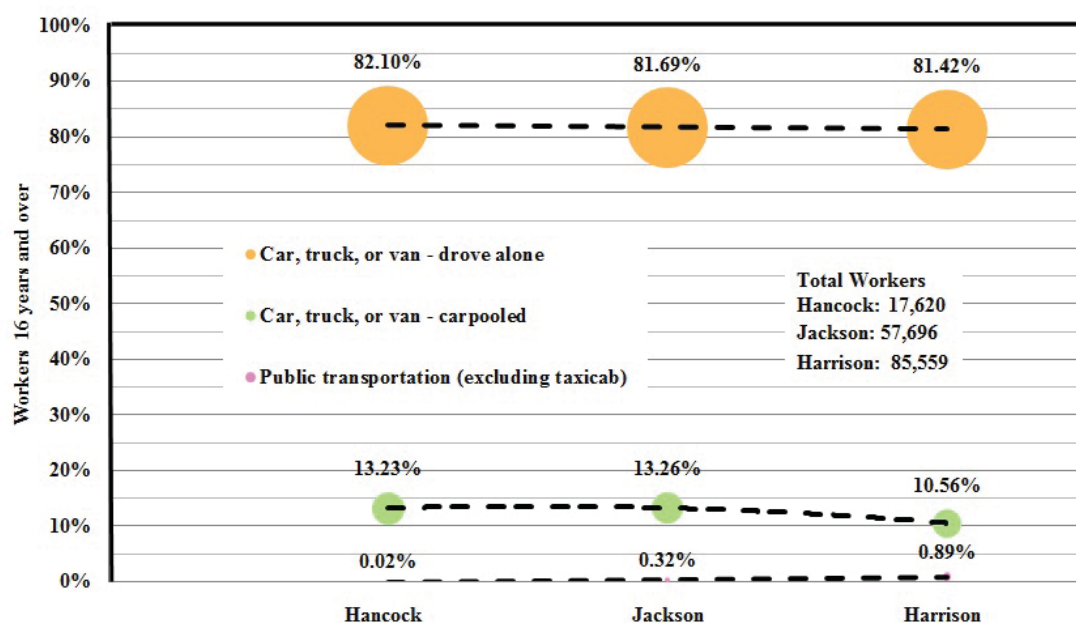
Source: "Means of Transportation to Work by Selected Characteristics." US Census Bureau. Web. Accessed April, 16, 2014. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_3YR_S0802&prodType=table

Figure 35. Means of Transportation to Work in Mississippi Gulf Coast Counties, 2010 – 2012

Figure 35 shows the means of transportation to work for those employed ages 16 and over. This ensures that the entire employed population is eligible to drive. It can be seen that in all three coastal counties approximately 82% of the commuters drive alone in their personal automobile to work. About 10% to 14% of the commuters carpool in a personal automobile, and less than 1% of the commuters opt to take public transportation in each of the three counties.

Estimating Passenger Traffic Volume from Person Trip Data
These are the step-by-step processes used to calculate passenger mobility in Mississippi Gulf Coast counties.
- Collect Average Annual Daily Traffic (AADT) data

- Calculate commuter person trips per day by county
- Calculate vehicle trips for the different transportation modes

Daily traffic volume number, represented by AADT, is collected on different stations of a highway or road. One method of calculating AADT is AASHTO method, which firstly computes average monthly days of the week and then averages the data to yield the AADT (FHWA 2013).

Data of AADT for the Interstate and U.S. highways in Mississippi Gulf Coast counties were collected through the Mississippi Department of Transportation Traffic Count Application which is available in the internet. The AADT data in this application is available from 2004 to 2012 for most sections. The traffic was continuously counted for 2 days at most of the sites. The 2 days counts were modified to AADT using day-of-week and season factors (MDOT 2014).

The AADT of Interstate and U.S. highways by county in the Mississippi Gulf Coast in 2012 were synthesized and tabulated as shown in Ahlan's Graduate Report appendix (Ahlan 2014). The AADT of Louisiana on the west border of Mississippi and the AADT of Alabama on the east border of Mississippi are shown as well in the table for comparison purposes. The Louisiana AADT was obtained from the Louisiana Department of Transportation and the Alabama AADT was collected from the Alabama Department of Transportation (LADOTD 2014, ALDOT 2014). These are AADT data are shown in Figure 36.

The numbers of commuter person trips per day were calculated by multiplying the number of commuters with two trips per commuter, which are going to work and going home trips. There are 47,140 commuter person trips per day in Hancock County, 191,750 commuter person trips per day in Harrison County, and 151,480 commuter person trips in Jackson County. Total commuter person trips in Mississippi Gulf Coast counties are 390,370.

The numbers of vehicle trips by transportation modes were calculated by multiplying the number of person trips with the associated mode shares. Table 5 shows the estimated number of vehicle trips by county in Mississippi Gulf Coast counties.

Figure 36 shows vehicle trips and average AADT by county in the Mississippi Gulf Coast in 2012. Vehicle trips in Hancock were 44,013; vehicle trips in Harrison were 180,004; and vehicle trips in Jackson were 140,976. Total vehicle trips in Mississippi Gulf Coast counties were 364,993.

Average AADT from I-10 and US-90 in Hancock County were 55,361; average AADT from I-10, I-110, US-49, and US-90 in Harrison County were 163,770; and average AADT from I-10 and US-90 in Jackson County were 72,847. Total combined AADT for all highways in Mississippi Gulf Coast counties in 2012 were 291,979.

Table 5. Analysis of Person Trips and Vehicle Trips in Mississippi Gulf Coast Counties

| A	B	C	D1	D2	D3	D4	D5
County	2012 Commu-ters	Commu-ter Person Trips	Person Trips by Auto Single Vehicle	Person Trips by Auto Pooled (2 / Auto Pooled)	Person Trips by Public Transit (20 / Bus)	Person Trips by Others (1 / Veh)	Total Vehicle Trips
		2 x B	1. 82.10% 2. 81.42% 3. 81.69%	1. 13.23% 2. 10.56% 3. 13.26%	1. 0.02% 2. 0.89% 3. 0.32%	1. 4.65% 2. 7.13% 3. 4.73%	D1 + D2 + D3 + D4
Hancock	23,570	47,140	38,702	3,118	0	2,192	44,013
Harrison	95,875	191,750	156,123	10,124	85	13,672	180,004
Jackson	75,740	151,480	123,744	10,043	24	7,165	140,976
Total	195,185	390,370	318,569	23,286	110	23,029	364,993
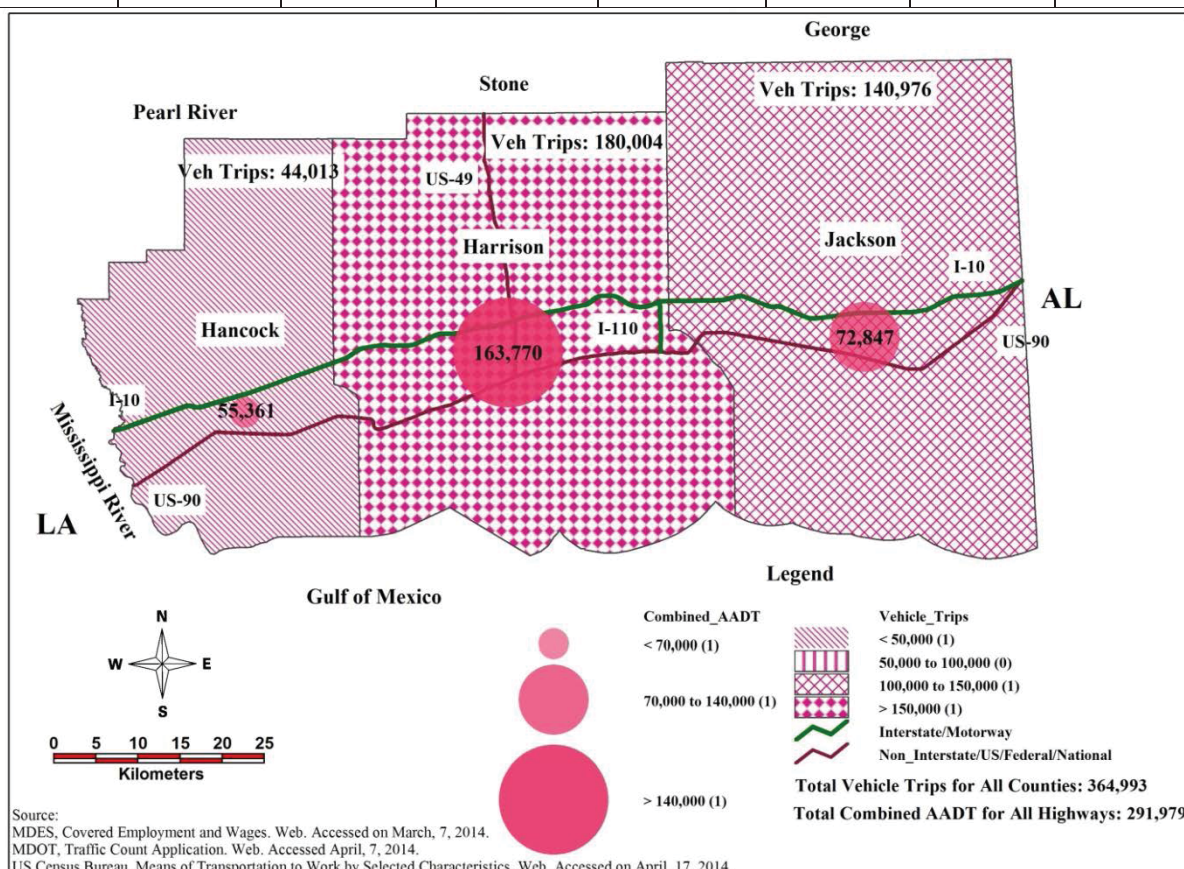
Figure 36. Spatial Map of Average AADT of Major Highways and Vehicle Trips in Each County in Mississippi Gulf Coast Counties, 2012

Interstate 10 creates the principal east-west connection from Santa Monica and Greater Los Angeles in the west to Jacksonville in the east. Interstate 10 serves many cities in the southern tier of the United States, including Los Angeles, Phoenix, El Paso, San Antonio, Houston, New Orleans, Gulfport, Biloxi, and Jacksonville. Interstate 10 is one of the three coast-to-coast Interstates in the United States. In addition, U.S. 90 connects the area from Jacksonville, Florida to Van Horn, Texas.

The traffic in Mississippi Gulf Coast counties is the combination of the through traffic on Gulf Coast highways and in-county traffic. The number of through traffic on Mississippi Gulf Coast highways was estimated by using the average AADT on Interstate 10 and U.S. 90. The number of in-county traffic was estimated with the vehicle trips.

AADT from I-10 and US-90 from Louisiana west of the Mississippi border was 46,247, while the average AADT from I-10 and US-90 in Hancock County were larger, which was 55,361. Similarly, average AADT from I-10 and US-90 from Alabama east of the Mississippi border was 49,690, while the average AADT from I-10 and US-90 in Jackson County was larger, which was 72,847. The difference of number of average AADT between Hancock County and the easter border of Louisiana and the difference of number of average AADT between Jackson County and the west border of Alabama indicate the large trips made in these Mississippi Gulf Coast counties. In addition, the total vehicle trips of 364,993 generated in Mississippi Gulf Coast counties also indicate the large trips made within these coastal counties.

A reasonable assumption for potential passenger traffic to be diverted to an alternative mode of passenger transportation on the Mississippi Gulf Coast is 10% of the single automobiles and pooled automobiles. Based on this assumption, there are potentially 34,185 vehicle trips that could be diverted from the highways onto alternative passenger transportation and mass transit technology. It is also assumed that passengers would opt for alternative transportation because of the cheaper transportation cost, reduced commuting time, and less stress on the auto drivers. . This assumption is modest and based on the review of other larger urban areas. Next, a utility function was used to calculate the more accurate number of potential auto drivers and passengers who will commuter via an alternative mass transit such as commuter rail.

Utility Function to Estimate Passenger Traffic Volume for Alternative Travel Mode
As discussed in the preceding section that according to the 2012 Census data for Mississippi, about 82% of auto traffic is reported in the Gulf Coast counties and 11-13% person-trips by car/van pool (Census 2012). Transit bus trip share per county was 0.02% in Hancock, 0.89% in Harrison, and 0.32% in Jackson County. The existing Coastal Transit Authority (CTA) operates its fleet of 29 buses mostly in Harrison County. An in-depth analysis of Mississippi data for in-bound and out-bound commuter trips in 2012 has been discussed above for the Gulf Coast counties of Jackson, Harrison, and Hancock. The person trip data was then processed to estimate

vehicle trips in each county (Table 5 and Figures 36). Key results are presented combined for all three counties as follow:

- Daily total person trips: 390,370
- Daily total auto vehicle trips: 364,993
- Daily total trips diverted to rail: 34,185 (estimated)

For a commuter rail transit alternative daily trip estimate by commuter rail transit is confirmed by using a utility function. Utility functions for auto and commuter rail transit modes were evaluated based on reference (NHI 2014) and using the following Equations 1 and 2. Additionally, out of pocket costs of 100 cents or $1 for auto trip and 500 cents or $5 for commuter rail trip, and other assumptions were made.

Auto Utility Equation:

$$U_A = -0.025(IVT) -0.050(OVT) - 0.0024(COST) \qquad \text{Eq. 1}$$

Rail Transit Utility Equation:

$$U_R = -0.025(IVT) -0.050(OVT) – 0.10(WAIT) – 0.20(XFER) - 0.0024(COST) \qquad \text{Eq. 2}$$

Where:

IVT= in-vehicle time in minutes (20 minutes for auto & 30 minutes for commuter rail)
OVT = out of vehicle time in minutes (4 minutes for auto & 8 minutes for rail)
COST = out of pocket cost in cents
　　　　(100 cents or $1 for auto trip and 500 cents or $5 for computer rail)
WAIT = wait time (time spent at rail station waiting for train), 10 minutes
XFER = number of transfers equal to zero for commuter rail

Using the above two equations, U_A is equal to -0.94 and U_R is equal to -3.15. The following Equation 3 was used to find proportions of auto trips and commuter rail transit trips.

$$P_A = \frac{e^{(U_A)}}{e^{(U_A)} + e^{(U_R)}} \qquad \text{Eq. 3}$$

$$P_R = \frac{e^{(U_R)}}{e^{(U_A)} + e^{(U_R)}} \qquad \text{Eq. 4}$$

Where:

U_A and U_R = defined above in respective utility equation; U_A= - 0.94 and U_R = - 3.15
P_A = probability of individual choosing auto (Eq. 3) = 0.9 for auto
P_R = probability of individual choosing a commuter rail transit (Eq. 4) = 0.1

Therefore, it is estimated that 10% auto riders are willing to use a commuter rail transit instead of auto travel. In other words, around 34,000 auto trips in these Gulf Coast counties can potentially be diverted to the commuter rail service at competitive fare costs and no driving stress. This modal choice estimate is very close to the earlier estimate based on detailed person-trip analysis.

2.4 Sustainable Passenger Transportation Alternatives

Review of Alternative Public Transportation Services in Other Urban Areas
The review of alternative public transportation services for mass mobility in other urban areas in the United States indicated the following key lessons to consider in this study:
- The expansion of additional lanes on I-10 corridor in the Houston area over the past decades has demonstrated that it cannot ease auto/truck traffic congestion in the long term due to the induced traffic patterns.
- The highly developed multimodal corridors for passenger traffic in other states suffer from low ridership of passenger rail service. Examples include the Bay Area Rapid Transit (BART) of San Francisco in northern California.
- Poor transport connectivity at rail stations to arrive at the final destination in a reasonable amount of time is a major reason of not choosing BART when a taxi or shuttle van can take a passenger in less time to the downtown destination in San Francisco.
- High commuter ridership is evident in the Washington metro area and Virginia Commuter rail because of good connectivity on rail stations with transit buses combined with high parking fees in downtown Washington DC.

An average commuter makes the decision of modal choice by comparing the out-of-pocket costs and travel time to destination. Therefore, for any mass transit solution to succeed, it will be important to provide good transit shuttle connectivity at rail stations and participation of employers in the vicinity. It should also be more attractive in terms of cost and travel time compared to regional aviation alternatives.

Candidate Multimodal Alternatives
Following a detailed review of the bus and rail transit technologies, being used in several U.S. cities, the following alternative modes were considered:
- Trams and street rail cars (on existing highways)
- Bus Rapid Transit (BRT) on dedicated lanes on existing highways
- Light Rail Transit (LRT) on existing highways using median space
- Commuter Rail (with joint share agreement using existing freight rail)
- Monorail (on dedicated elevated track infrastructure)
- Metro Rail line (on dedicated track infrastructure on surface and underground)

Figure 37 shows examples of these mass transit alternatives. Dr. Uddin has traveled widely and experienced traveling by these modes in the U.S. and abroad in many countries including Canada, Mexico, Brazil, UK, Portugal, Italy, Turkey, Singapore, Malaysia, Thailand, and New Zealand (Infra 2012).
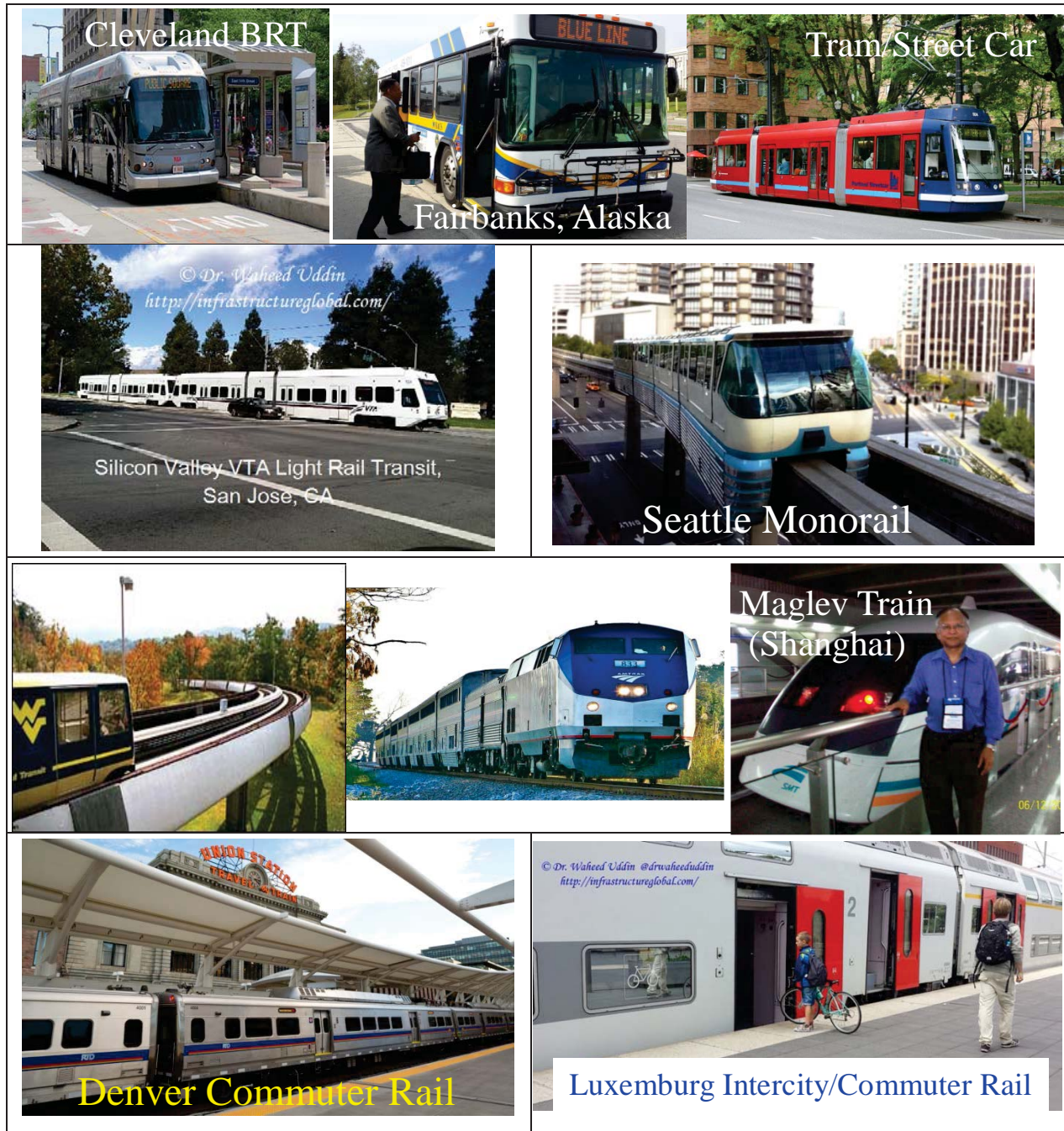

Figure 37. Examples of mass transit alternative modes

The study revealed the following alternative modes are not feasible: transit busses, trams, street rail cars, and high-cost LRT. They are not feasible for the rural area on the Mississippi Gulf coast due to lane occupancy and rail track intrusion that degrades highway traffic capacity, as well as adds safety risks from mixed multimodal traffic on highways. Metro rail line is a high cost alternative and cannot be justified for the relatively less amount of trips and low traffic volume estimated for the Gulf coast corridors. Consequently, these modes are not technically feasible or economically viable from value engineering perspectives of functional and safety requirements.

The following modal choices were selected as candidate alternatives for value engineering analysis of life cycle costs and benefits:
- Commuter rail operating along US-90 along the coast from East to West (E-W)
- BRT along US-90
- Monorail along I-10 and US-90 corridors

The first two modal choices of commuter train and BRT are being operated in many cities and urban areas. Monorail has been in operation in Seattle and Las Vegas.

A challenge in the introduction of any public transit service is to motivate commuters to shift from single occupancy vehicle (SOV) mode to the transit. Some of the highly developed multimodal corridors for passenger traffic in other states suffer from low ridership of passenger rail service. Examples include the BART in San Francisco and other LRT infrastructure of Silicon Valley in northern California. A major reason of not choosing BART is competition with auto choice when a taxi or shuttle van can take a passenger in less time to the downtown destination in San Francisco. Similarly the LRT still competes with SOV mode on high quality highways in Silicon Valley.

Therefore, state agencies, cities and coastal businesses need to find ways to integrate passenger and commuter rail with the auto traffic, which can ease auto travel demand on the existing road corridors, offer economically competitive and safer travel, and reduce air pollution.

The key to select an economically viable and safe strategy will be support of cities and public, as well as good transit connectivity and employers' incentives to use the rail service. An economically successful rail service simply cannot depend only on holiday travelers and tourists by using the old Sunset rail model of tri-weekly night service.

Additionally, the passenger rail must gear towards serving the daily commuters along the Gulf Coast communities by providing a regional commuter rail service. This may require Public-Private-Partnership funding mechanisms for successful launch and operation.

3. TECHNICAL FEASIBILITY AND ECONOMIC VIABILITY OF RAIL TRANSIT

3.1 Spatial Mapping of Routes for Passenger Rail Transit Alternatives on the Gulf Coast

This study used MDOT's geospatial database of the State of Mississippi (MDOT 2013) and related geospatial analysis tools of Geo Media Pro desktop software (Intergraph 2013) extensively to create relevant spatial maps of the proposed alignments for candidate rail transit alternatives.

Spatial Map of Mississippi Gulf Coast Infrastructure

Because of the no future plans to revive the long-distance Amtrak Sunset line, this study is primarily focused on a shorter distance commuter rail service using existing freight rail lines that run along the Gulf Coast. Figure 38 shows the existing cities and transportation infrastructure along the Mississippi Gulf Coast on a Google Earth image (Google Earth 2013). The existing highway infrastructure is shown in yellow with arrows showing the directions the highways extend. The existing freight rail lines are shown with a green dashed line. These include a CSX line that runs east/west along the Gulf Coast and a KCS line that runs north/south from Gulfport through Hattiesburg, MS into Jackson, MS. These two lines are used to propose short distance commuter rail services for the Mississippi Gulf Coast which will be compared other alternative modes of passenger transportation (BRT, LRT, Monorail).

Figure 38. Google Earth Image of Transportation Infrastructure on Mississippi Gulf Coast

Figure 39 is a spatial map of Southern Mississippi and neighboring states of Alabama and Louisiana. The buffers of all highways in the study region were made for spatial analysis of their lengths and exported to the spreadsheet for data processing of person trip and travel demand.

Figure 39. Spatial Map of Highway Buffers in Southern Mississippi

Spatial Map of Commuter Rail Routes

Figure 40 shows a spatial map of the existing infrastructure along the Gulf Coast including interstates, highways, minor roads, and railways. This map was generated by creating buffers of Highways I-10 and US-90 along the coast in East-West direction and a buffer of US-49 in North-South direction.

Figure 41 shows the proposed commuter rail routes highlighted with the bright green dashed line. Additional notes are provided on the figure showing where the line will run to and the distance each rail line will travel beyond the Mississippi border. Cities can be seen with the red dot and casinos are shown with a green diamond.

Initially, the alignment of East-West commuter rail line was proposed for longer than 200 mile stretch East from Florida to Louisiana. Later on it was decided to analyze only the 200 mile length between Mobile, Alabama (AL) and New Orleans, Louisiana (LA) in the West of Gulfport.

The spatial map in Figure 41 also shows a second commuter rail alignment from Gulfport on the coast to Hattiesburg in the North sharing the existing freight rail corridor. Both lines are expected to serve mainly the users in the three Mississippi counties and connect locations of major cities, beaches, and casinos.

Figure 40. Spatial Map of the Existing Transportation Infrastructure Assets along the Gulf Coast

Figure 41. Spatial Map of Proposed Commuter Rail Lines

Spatial Map of Monorail Route

Another alternative proposed is one primarily suited for increasing tourism and gaming in the area. That alternative is monorail. Monorail operates on an exclusive right-of-way and operates as a "rapid transit" system on elevated track structure (Monorails 2014). The Disney World theme park in Orlando, Florida had the first monorail installed in the United States. City of Seattle in Washington State was the first city to install and it has been operating monorail service for many years. City of Las Vegas in Nevada has recently established its monorail service to

connect the airport for easy access to and from hotels and casinos. Monorail infrastructure and services have been initiated in Brazil as a part of 2016 Summer Olympics in Rio de Janeiro, Sao Paulo, and other cities for commuters and tourists (Infra 2012). It does not hinder traffic flow on roads and highways because it is operated on an elevated track.

Monorails have been shown to be one of the safest forms of transportation. Because it operates on dedicated elevated tracks, it is not affected by road traffic congestion and the possibility for collision with automobiles, trucks, and pedestrians is eliminated. Also, because monorails do not operate on a rail system as they operate on a concrete fixed guideway, derailment is highly unlikely to occur. Besides high infrastructure costs, one issue with monorail is elevated trackways, which pose some access issues and danger in the event of a needed evacuation.

Figure 42 shows the proposed route of the monorail line on the Gulf Coast. It is a shorter route length of 30 km. The line can be seen as the magenta dashed line running from Long Beach, MS, to Biloxi, MS. There is no existing infrastructure for this line, so the line will need to be designed and constructed. The primary purpose of the monorail will be slightly different than that of the commuter rail. The commuter rail line is focused more on bring in commuters and tourists from outside the Mississippi Gulf Coast. The monorail will be focused more on tourists and casino patrons that are staying in the gaming area of the coast. The 30-km short route is intended to provide transportation among the different casinos and tourist attractions along the Gulf Coast.

BRT Route

The BRT alternative is considered on 60 km stretch of US-90 Highway route. It is public transit alternative with a high capacity and lower capital infrastructure cost that can help to improve urban mobility. BRT is a permanent, integrated system that uses buses or specialized vehicles on roadways or dedicated lanes to quickly and efficiently transport passengers to their destinations, while still offering flexibility to meet travel demand (BRT 2015). It can help to provide better mobility to Gulfport Part and increase tourism and gaming in the area.

There are many pros and cons of BRT systems. Some of the pros of implementing BRT include flexibility in routes, lower capital and operating costs, and having the ability to serve a larger geographical area. There are many cons to this mode of transportation as well. Some of these include poor quality of service in congested areas, flexibility in routes lead to perception of unreliability and disorganization, lower ridership, and possible traffic disruption. Many feel that BRT is a temporary solution until some sort of rail transit can be implemented (MAPC 2015). BRT was included in this study to provide a highway transit alternative to compare with the other alternative modes. The proposed route for BRT in this study will run from Bay St. Louis, MS, to Pascagoula, MS, reaching all of the major cities along the Mississippi Gulf Coast. This proposed route stretches 60 km on US-90 Highway. Its main limitation is the degradation of the

traffic capacity and Level of Service (LOS) along its route as it occupies the outside lane and makes frequent stops at designated BRT stations.

Figure 42. Spatial Map of Proposed Monorail Corridor
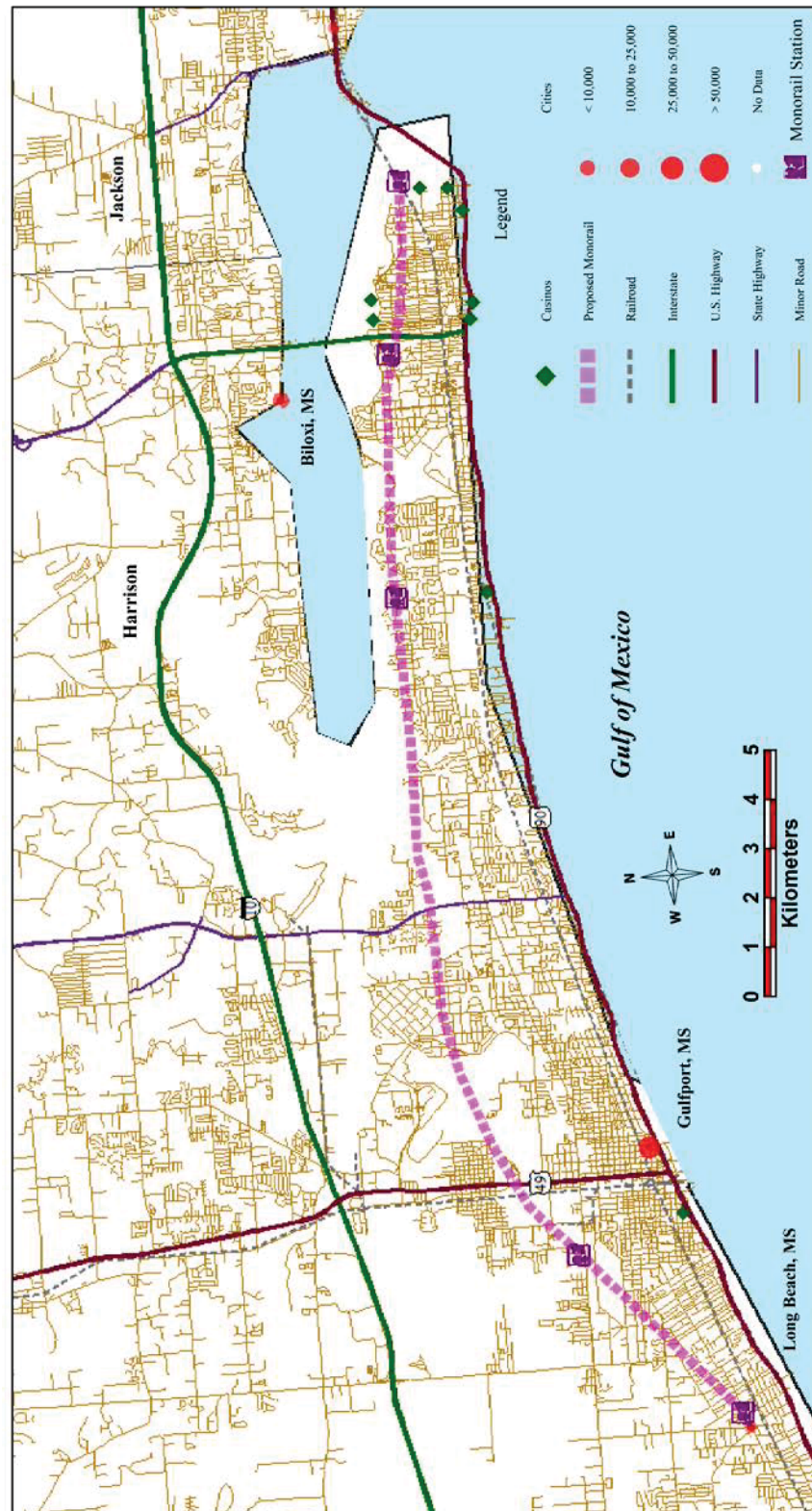
3.2 Analysis of Revenue Sources and Policy Issues for the Mississippi Gulf Coast

Before life cycle assessment (LCA) of costs and benefits can be conducted for the passenger transportation alternatives on the Gulf Coast, web research was performed to determine revenue sources and on the commuter needs of the Mississippi Gulf Coast. This was necessary to determine what the major sources of revenue are for the Mississippi Gulf Coast counties and cities, and which sources can increase from the opening of an alternative mode of transportation. It also helps determine the impacts of commuter travel demand and benefits of introducing an alternative mode of passenger transportation to the area. Finally, comments are provided on traditional and innovative revenue mechanisms and related policy issues based on a prior NCITEC project (Uddin et al. 2016).

Study of Revenue Sources

Figure 43 shows a spatial map of 2010 population of Mississippi by county with overlay of I-10, I-20, I-55, and I-59 highways. Figure 44 is a spatial map of 2007 retail trade in the form of sales of establishment with payroll (Census 2007). The map shows that Harrison County on the coast is in the top five retail trade counties in Mississippi. As discussed in later in this section, the tourism and casino gaming industry is booming on the coastal cities and generating decent revenues.
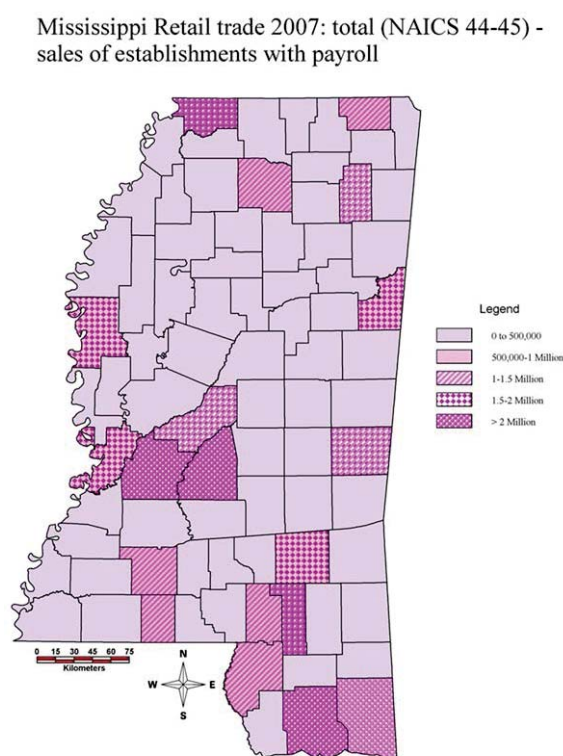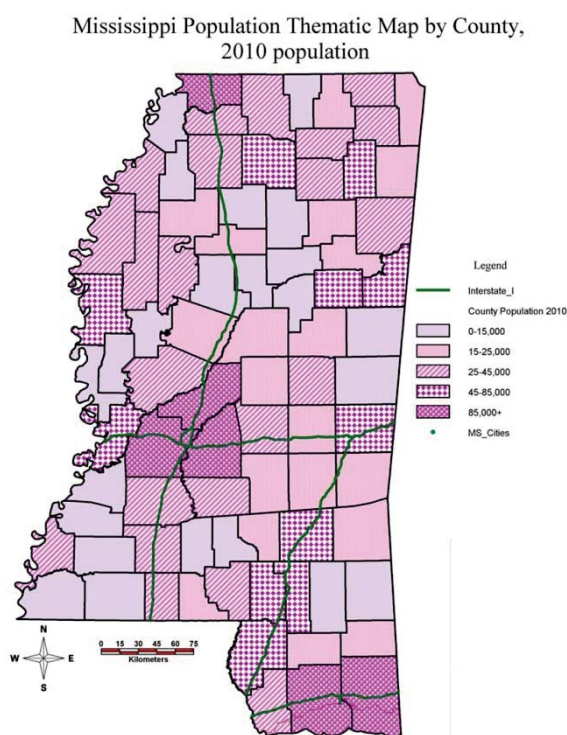

Figure 43. Mississippi Population, 2010   Figure 44. Map of 2007 Mississippi Trade Economy

Before starting the LCA of cost and benefits for each alternative, a study of the revenue and the revenue sources was completed for each of the Mississippi Gulf Coast counties and cities. County and city data were both used so that the study could be provided for the whole Mississippi Gulf Coast area and not only the major urban area. The counties that make up the Mississippi Gulf Coast include Hancock County which is to the west bordering Louisiana, Jackson County to the east bordering Alabama, and Harrison County which is located in the center of the Mississippi Gulf Coast. Some of the major cities that were chosen for the revenue study were Gulfport, Biloxi, Pascagoula, and Bay St. Louis. The purpose of conducting these revenue studies is to determine how opening a new mode a public transportation can affect revenue for the area.

Figure 45 shows a trend of the total revenue for the Gulf Coast counties in Mississippi (OSA. 2013). From 2004 to 2010 Harrison County was the largest in terms of total revenue, possibly due to it being the location of most of the gaming industry along the coast. But in 2011 it was surpassed by Jackson County, which has had a sharp increase in total revenue since 2008. Hancock County has consistently been the lowest in terms of total revenue of the three counties, but has seen a steady increase, which peaked in 2011, then suddenly dropped in 2012. It seems that many cities are being developed in Jackson County, such as Pascagoula and Ocean Springs, and more residents are moving there causing the total revenue to increase for the county. Overall, each county seems to be trending upward over the observation period, which begins at about the time Katrina hit.
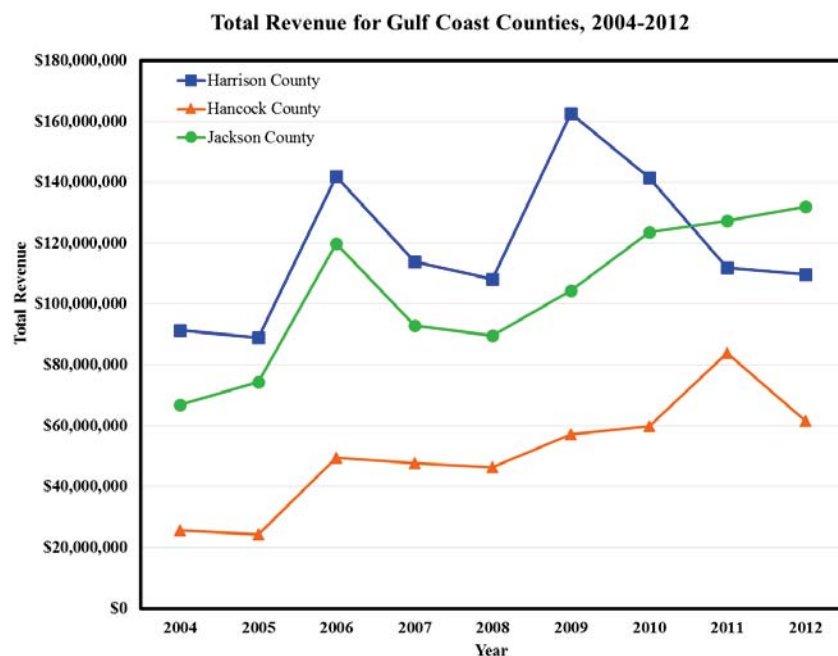
Figure 15. Total Revenue for Gulf Coast Counties, 2004-2012

Figure 46 shows similar data as Figure 45 but instead it focuses on three major cities along the Mississippi Gulf Coast but with limited data available the observation period is much shorter. This trend shows total revenue post Katrina from 2007 till 2012 for Gulfport, Biloxi, and Bay St. Louis. These are the three major gaming cities along the Mississippi Gulf Coast. Gulfport which is the most highly populated city on the Gulf Coast showed the highest total revenue for the entire observation period which peaked in 2009 and showed a steady decline until 2012 (Gulfport 2012). Biloxi has remained relatively constant over the six year period with a slight dip in 2008 and 2009, and peaking in 2010 at just under $120 million (Biloxi 2013). Bay St. Louis is the smallest of the gaming cities and the lowest in total revenue due to its lower population (Bay 2012). Its total revenue peaked in 2009 and just over $50 million and has steadily declined since.
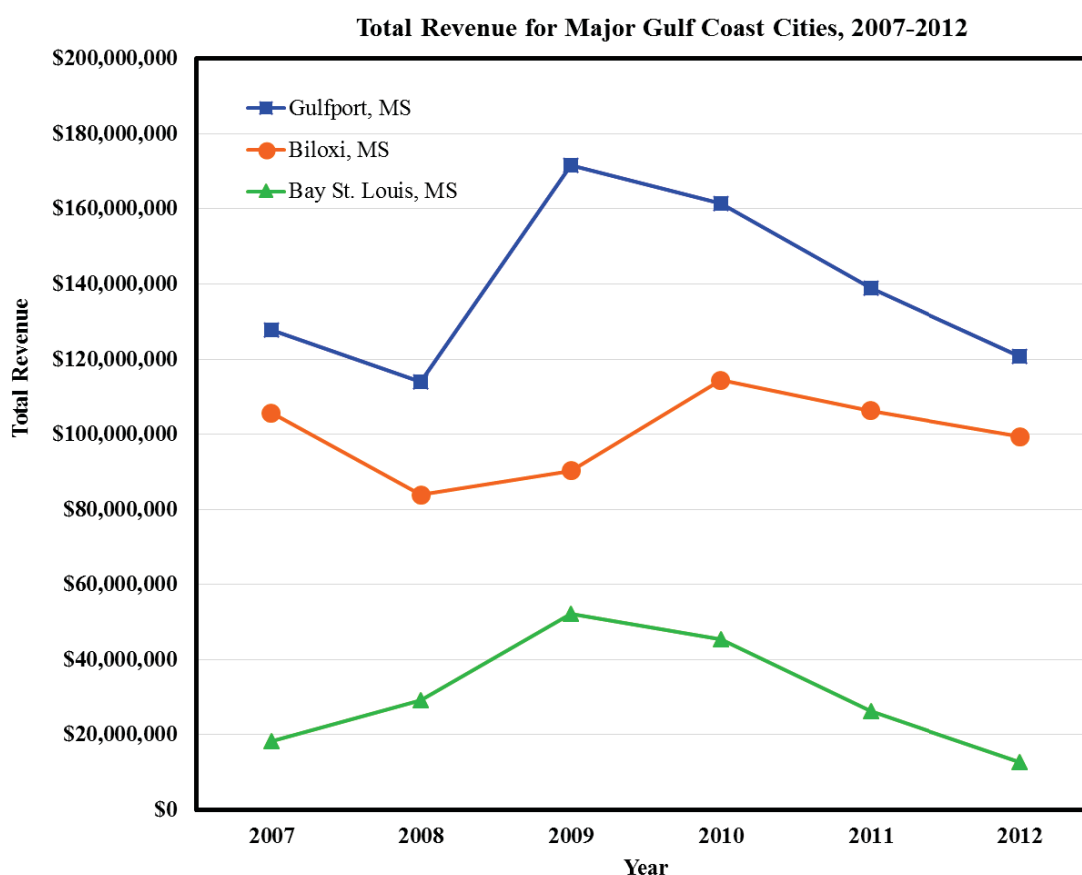
Figure 46. Total Revenue for Major Gulf Coast Cities, 2007-2012

One area in which revenue would be expected to increase from the introduction of a new mode of passenger transportation would be sales tax revenue. Figure 47 shows gross sales tax trends for each of the three Gulf Coast counties and four of the major cities which lie along the Gulf Coast (DOR 2012). The county which draws the highest gross sales tax revenue was Hancock County which is where two of the largest gaming cities are located in Biloxi and Gulfport.

Hancock County sales tax revenue experienced a 1.71% increase in gross sales tax revenue over the 10 year period. All of the cities and counties experienced increases in gross sales tax from 2003 to 2013 with the exception of Biloxi, MS. Biloxi experienced a slight 0.31% decrease in gross sales tax revenue over the observation period. Biloxi experienced a low of around $50 million in 2006, and very slowly began to rebound through 2013 but not enough to provide an upward trend for the city of the ten year period.
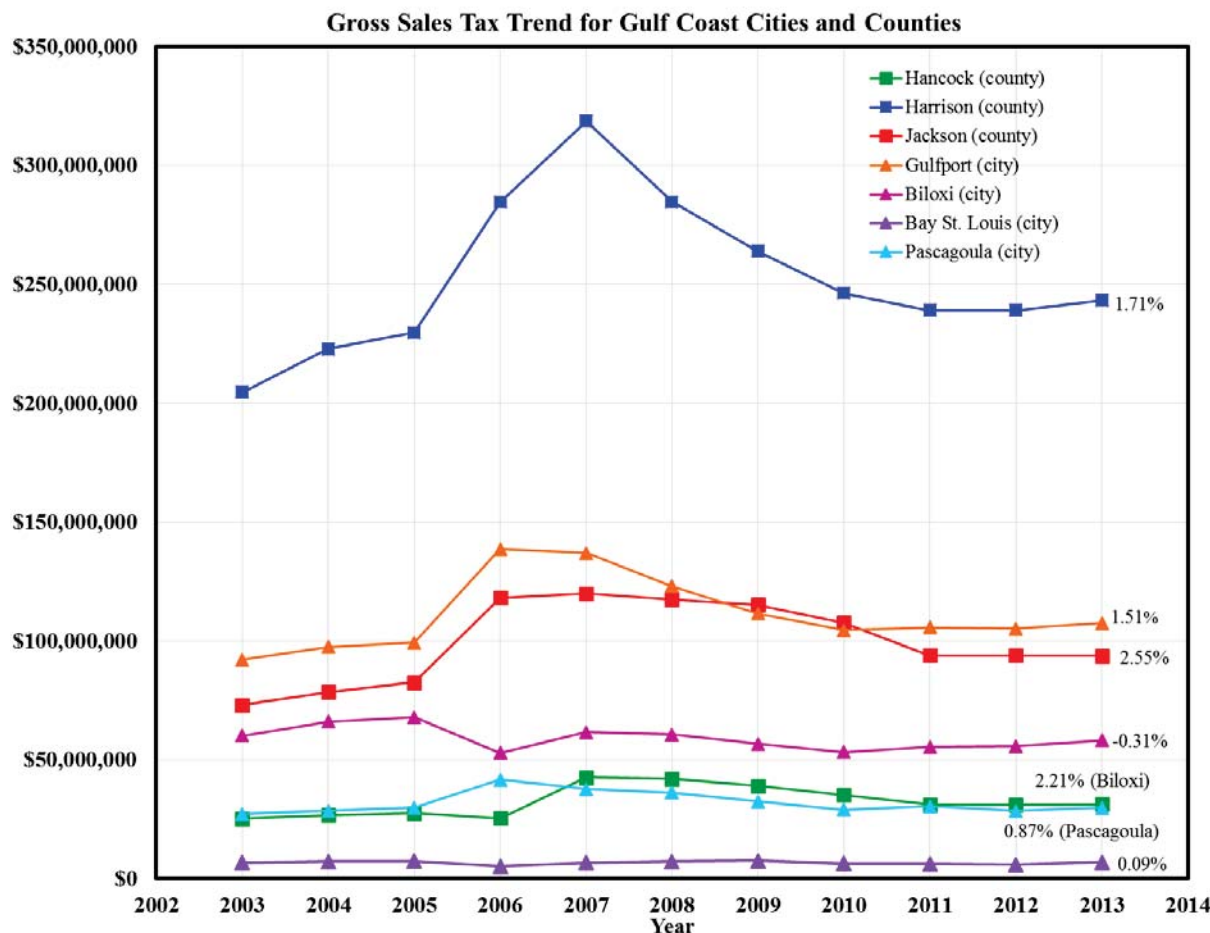
Figure 47. Gross Sales Tax Trend for Mississippi Gulf Coast Cities and Counties (% increase or decrease shown on right side of each curve)

Figure 48 provides a categorical breakdown of the sources of sales tax revenue for the Gulf Coast (DOR 2012). This figure includes revenues for the counties as well as for the major cities along the Mississippi Gulf Coast. The two categories that would most likely see an increase with new passenger transit bringing more people to the area are "Food and Beverage" and "Apparel and General Merchandise" which happen to be the two largest sources of sales tax revenue accounting for 40% of the total sales tax revenue on the Gulf Coast.
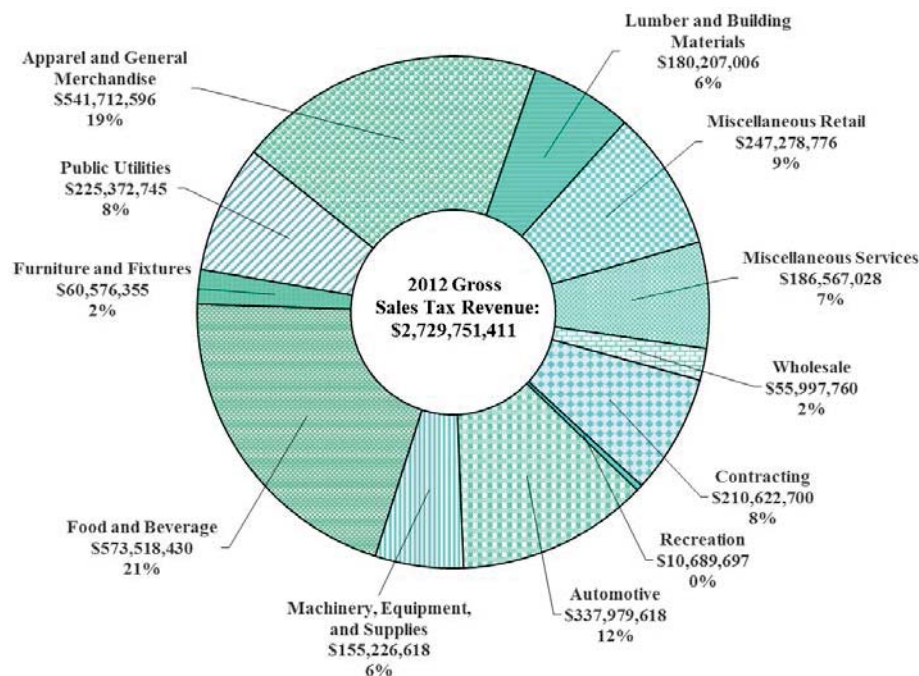
Figure 48. Gross Sales Tax Revenue for Mississippi Gulf Coast, 2012
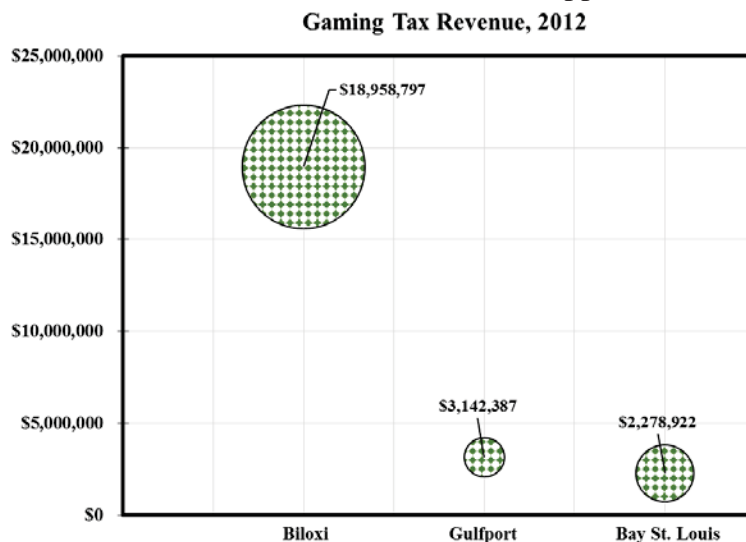
Figure 49. Gaming Tax Revenue for the Mississippi Gulf Coast Cities, 2012

The Mississippi Gulf Coast is one of the largest gaming destinations in the entire U.S. The gaming industry is a huge contributor to the rebounding of the economy on the coast post Hurricane Katrina. Figure 49 shows a plot of the gaming tax revenue generated in 2012 for each of the cities along the coast in which casinos are located (DOR 2012). The size of the bubbles in the plot represents the number of casinos located in that city. Biloxi is home to nine casinos, Gulfport has one casino, and Bay St. Louis has two casinos. With a large volume of casinos Biloxi is the largest city in terms of gaming tax revenue at just under $19 million in 2012.

Gulfport is second city with one casino, but it is a very large and popular casino that generated just over $3 million in gaming tax revenue. Bay St. Louis was third city with just over $2 million in gaming tax revenue.

With the Mississippi Gulf Coast being one of the largest gaming destinations in the country, tourists come from all around the U.S. to gamble on the Gulf. Figure 50 shows where the casino patrons for coastal casinos in Mississippi came from in 2013 (MGC 2013). Of just under 15 million patrons, Mississippi accounted for 32%. Alabama, Louisiana, and Florida, the states that closely border the Mississippi Gulf Coast, accounted for 50% of the total patrons. This presents an opportunity for opening a commuter rail line from Mobile to New Orleans to safely bring more casino patrons and tourists to the Mississippi Gulf Coast.
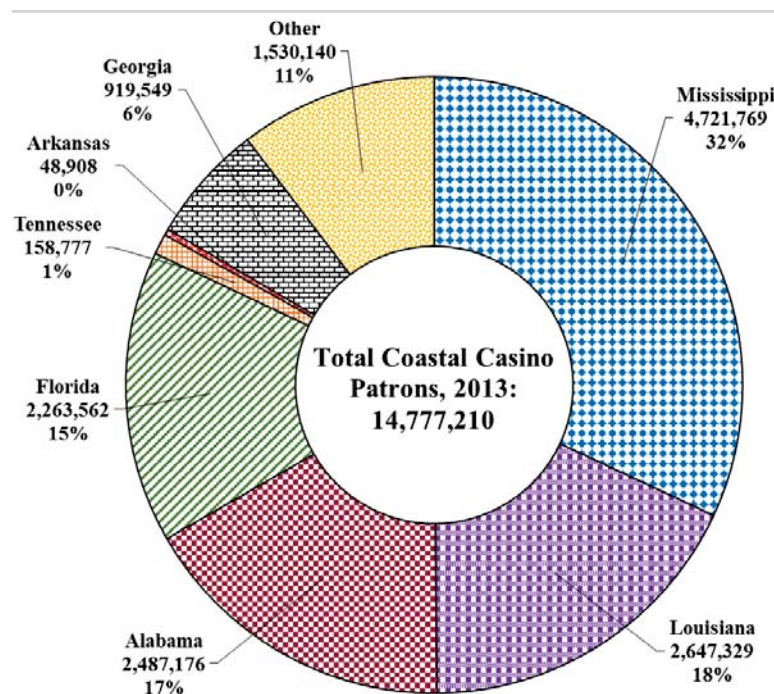
Figure 50. Total Coastal Casino Patrons by State, 2013

Review of Revenue Mechanism and Policy Issues
The following excerpts are from the final report of NCITEC Project 2012-27, detailed discussion of infrastructure revenue generation and funding scenarios (Uddin et al. 2016). The revenue sources for infrastructure funding in practice or being assessed to expand the funding include:
1) Federal fuel tax, collected at gas stations (revenue collection mechanism already in place)
2) State fuel tax, collected by dozens of states in addition to federal tax (revenue collection mechanism already in place)
3) Federal non-fuel taxes on tire, sales taxes on truck tag and trailer, annual taxes on heavy truck use (revenue collection mechanism already in place)

4) Other auto tag registration and license plate tax by state and counties (revenue collection mechanism already in place)

5) Tolls by states and cities on designated roads and bridges, tag registration and license plate tax (revenue collection mechanism already in place)

6) Property taxes collected by cities and counties and in some cases used on local roads and streets (revenue collection mechanism already in place)

7) State and municipal bonds in practice for public schools and other infrastructures (revenue collection mechanism already in place)

8) Fees based on road and highway travel miles as pilots studies by some states (revenue collection not in place and may be costly as discussed later)

9) Traffic congestion based road user fee.

10) Fuel tax for inland waterways, which is currently at 29 cents per gallon and already higher than the truck diesel fuel tax of 24.4 cents per gallon. Additional excise or service tax for the use of waterway infrastructure can bring more revenue for maintenance.

11) The harbor and port excise and service tax on ships in addition to the diesel fuel tax can generate more revenue for maintenance and operation of infrastructure.

The above revenue collection and funding mechanisms have been based on traditional auto/truck traffic and waterborne transport operated on gasoline and diesel. The revenue will vary based on the vehicle fuel efficiency and range of miles driven depending upon the fuel cost. There is a growing demand of electric vehicles (EV), pedal-cycles, and pedestrian traffic sharing highways and roads. These new travel modes do not consume gasoline or diesel. Moreover, these revenue generation practices are primarily limited to highway mode only and do not present a comprehensive approach for integrated multimodal transport network. These issues should be considered while formulating user fee and tax alternatives. The guiding principles must consider (Uddin et al. 2016):

- Equity based on both fossil fuel types and EVs
- Space shared on highways and roads
- Additional user fee on auto-share customers and non-car owners
- Commercial use versus work and other travel purposes
- Damage to pavements (freight trucks not paying enough and cause more damage)
- User fee on barges and ships traveling on waterways and marine highways
- Excise taxes for ports/harbors serving barges, ships, rail, trucks
- Waiver of a part of the federal business income tax for privately owned transportation infrastructure instead of paying "user fee" charge
- Investment opportunities for infrastructure banks to attract pension and retirement funds
- Reasonable cost of user fee collection, preferably through the existing mechanisms
- Interoperability to other jurisdictions and states

The cost of user fee collection can be reduced if a sliding scale of annual miles driven is formulated based on the ownership, different ranges of miles driven annually, and a separate fee for taxi/vehicle sharing model. Inventory of vehicle fleets in the U.S. shows that 36% cars are in rental business and 19% cars are for commercial use (ORNL 2012). On the other hand, 50% of large trucks are for commercial use and only 9% are in rental business. It is rational to charge a higher user fee or fuel tax in proportion to the commercial and rental use of vehicles. A life cycle assessment approach for costs and benefits can help to analyze the long term impacts of a road user fee and or/infrastructure tax structure for any of the current travel models and the future of autonomous vehicle (AV) technologies that may lead to less auto ownership and more car ridership sharing.

The above discussion is mostly geared to generate revenue for highway and road infrastructure funding. The experience with revenue and expense data shows that most Amtrak rail services and state/city commuter rail services are operated with substantial government subsidy. For the proposed commuter rail lines, it is possible to attain breakeven within eight years if it is operated efficiently with strong support of area employers and good bus/shuttle connectivity, combined with additional revenue from concessions at rail stations. For obtaining operating efficiency, a public-private-partnership model is a viable operation where private rail companies are given opportunity to participate. Some of these policy issues are discussed in a white paper on infrastructure bank, which is included in the final report for the NCITEC 2012-27 project (Uddin et al. 2016).

3.3 Value Engineering Study of Sustainable Passenger Transportation Alternatives

Life Cycle Assessment Methodology Used
Based on the revenue source and commuter studies there is opportunity for the introduction of an alternative mode of passenger transportation along the Mississippi Gulf Coast. Transit modes were considered that will be able to connect the entire Mississippi Gulf Coast and make it easier for commuters to move between the major cities on the coast. The following passenger transportation alternatives were analyzed to determine their economic viability and the societal benefits they would provide:
- Commuter Rail running 200 km East-West from New Orleans, LA to Mobile, AL
- Commuter Rail running 110 km North-South from Gulfport, MS to Hattiesburg, MS
- Bus Rapid Transit (BRT) extending 60 km from Bay St. Louis, MS to Pascagoula, MS
- Monorail extending 30 km from Long Beach, MS to Biloxi, MS

For each of the passenger transportation alternatives mentioned, a present worth life-cycle cost (LCC) and benefit analysis (Uddin and Torres-Verdin 1998) was performed for up to a 50-year period. This is an important part of Value Engineering (VE) analysis where it is ensured that there is no compromise on function and safety (Uddin 2013). The LCA was completed by

bringing all costs and benefits that would accrue over the 50-year to a present worth (PW) dollar value. This was completed by using the following equations (Uddin 2013, Uddin et al. 2013):

$$\text{Uniform Series PW Factor} = \frac{(1 + i)^n - 1}{i(1 + i)^n} \qquad \text{Eq. 5}$$

$$\text{Single Payment PW Factor} = \frac{1}{(1 + i)^n} \qquad \text{Eq. 6}$$

$$\text{Uniform Series Compount Amount PW Factor} = \frac{(1 + i)^n - 1}{i} \qquad \text{Eq. 7}$$

Where,

       i = Discount rate (5% used in this study)
       n = Analysis period (50 years used in this study)

These equations are used for discounting costs and benefits to present worth (Uddin et al. 2013). Equation 5 is multiplied by annual cost or annual benefit to get discounted PW value for a given i and n. Equation 6 is multiplied by a single future cost or benefit to get discounted PW value for a given i and given year, as well as it is used calculate PW value of the salvage. Equation 7 is multiplied by a uniform series to calculate a single value at the time of the last future payment.

Inflation was ignored in the above LCA methodology. For each of the transit modes, analyzed in this study, the costs and benefits were broken down, as follows:

    Costs:
- Infrastructure Capital Costs
- Annual Operating Costs
- Annual Maintenance Costs
- Major Overhaul (every 5 years)
- Vehicle Replacement

    Benefits:
- Direct Revenue – Fares, Advertising, Concessions, and Shuttle (if applicable)
- Gaming Revenue Increase
- Sales Revenue Increase
- Savings from Reduced Fuel Consumption
- Economic Development – Jobs created, businesses created, and visitors added

Note that savings due to travel time reduction is not considered in the life cycle assessment. Benefit calculation was based by comparing an alternative with the base scenario (no transit alternative). The data for these costs and benefits were determined using multiple sources. Most of the data were national averages for different mode types received from the National Transit Database (NTD) maintained by the USDOT's Federal Transit Administration (FTA 2014). It reports: "In the United States, transit ridership has grown by more than 20 percent in the last decade." The NTD provides records of the financial, operating and asset condition of transit systems. The in database was searched to find transit systems which were similar to that being constructed or implemented and averages of those costs or benefits were used in this study. The indirect economic benefits like sales tax revenue were assumed to have zero growth in this study. Additionally, reduction in harmful air pollutants and CO_2 emissions were calculated.

Commuter Rail Life Cycle Assessment
The following data and assumptions were used in calculating the initial capital costs for years 1, 5, 10, 20, and 50 for the proposed commuter rail routes (DMJM 2003, FTA 2014, OHDOT 2010).

- Assumed $1 million per km for CSX/KCS line upgrades and usage rights
- $2 million per locomotive
- $1.5 million per passenger car
- $1 million per train station built
- $1 million for maintenance yard
- 15% of total infrastructure capital cost for design and administration

Annual operating costs ($6.4 million per year), annual maintenance costs ($2.6 million per year), and major overhaul every five years ($1.2 million every 5 years) were also considered in the cost calculations. These amounts were determined based on NTD averages for similar rail transit systems.

The benefits were calculated using assumptions and data gathered from the revenue source and commuter studies. As discussed in preceding sections, it was determined by person-trip analysis and utility function that 34,185 commuters could possibly divert from personal automobile to alternative passenger transportation modes. The East-West line was assumed to have a slightly larger ridership due to the urban areas that it reaches. It was assumed that the East-West rail would have a ridership of 20,000 riders per day. The North-South line does not extend to as many urban areas that the East-West line extends to; therefore, it was assumed that it would carry half of the ridership of the East-West line at 10,000 riders per day for North-South line. It must also be noted that the commuters taking the rail would ride the rail twice a day to get to their destination and to return from their destination.

The ridership for each of the rail routes was used to calculate direct revenues. Direct revenues were calculated from only rider fairs, advertising, concessions, etc. Following is a summary of revenue calculations:

- The average ticket price for commuter according to the NTD is approximately $5.00 per trip (FTA 2014).
- Revenues from concession stand at five stations and park and ride shuttle services were also accounted for in direct revenue.
- For gaming revenue it was assumed that each route would provide a 10% increase in casino patrons and gaming revenue for the Gulf Coast area.
- The North-South rail line is assumed to provide a 2.5% increase in sales tax revenue and the East-West rail line was assumed to provide a 5% increase in sales tax revenue.
- The East-West commuter rail line is expected to create 350 jobs in the area directly related to the operations and maintenance of the rail line and it's expected to bring 50 new businesses to the Mississippi Gulf Coast.
- The North-South line would create 75 new rail related jobs and bring 25 new businesses.
- Fuel savings from diverting 20,000 riders to E-W rail and 10,000 riders to N-S rail from highways were also considered.

Table 6 provides the full LCC and benefit analysis breakdown and the breakeven years for both commuter rail alternatives.

Table 6. Commuter Rail Life-Cycle Cost and Benefit Analysis Breakdown

Rail Alternative	Commuter Rail E-W		Commuter Rail N-S	
CL Length; Track	200 km; CSX rail track		110 km; ; KCS rail track	
Rail Infrastructure	6 train stocks; 10 stations		4 train stocks; 3 stations	
Initial Infrastructure Cost	$335.2 Million		$226.9 Million	
Riders per Day	20,000		10,000	
Present Worth Cost-Benefit Analysis	Cost	Benefit	Cost	Benefit
1-Year Present Worth Analysis, $ Million	344	344	230	247.1
5-Year Present Worth Analysis, $ Million	375	1,489	247	1,030
10-Year Present Worth Analysis, $ Million	407	2,656	263	2,110
20-Year Present Worth Analysis, $ Million	450	4,287	286	2,907
50-Year Present Worth Analysis, $ Million	504	6,279	313	5,049
Breakeven Year (considering all revenue sources, fuel saving, and economic benefits)	Year 1		Year 1	
Benefit/Cost Ratio	1.0		1.1	
Breakeven Year (considering only direct revenues)	Within 6 years		Within 8 years	

When considering all benefits including direct revenue, gaming revenue increases, sales tax revenue increases, fuel savings, and economic development, both rail lines were found to breakeven in year one. The initial infrastructure cost for the East-West commuter rail line is $335.2 million and $226.9 million for the North-South line (Cobb 2015). For a more conservative analysis, when only considering direct revenue, which is revenue from only rider fairs, advertising, concessions, etc., the East-West line would breakeven at 6 years and the North/South line would breakeven at 8 years. This is still an excellent return. The fact that the existing infrastructure for the rail lines is already in place makes this a logical option for relieving some of the traffic congestion on the major highway corridors along the Mississippi Gulf Coast.

Monorail Life Cycle Assessment
The following data and assumptions were used in calculating the initial capital costs for years 1, 5, 10, 20, and 50 for the proposed monorail route (FTA 2014, LV Monorail 2013) Transit 2010).
- Assumed $24 million per km for infrastructure capital costs based on national averages
- $140 million for fleet of monorail vehicles
- $6 million per station
- $15 million for maintenance yard
- 15% of total infrastructure capital cost for design and administration

Annual operating costs ($24.6 million per year), annual maintenance costs ($67.4million per year), and major overhaul every five years ($68 million every 5 years) were also considered in the cost calculations. These amounts were determined based on averages (FTA 2014) for similar monorail transit systems in Settle and Las Vegas.

Based on the commuter study and ridership averages around the U.S., it was assumed that 14,000 of the 34,185 commuters would ride the monorail daily. Following is a summary of revenue calculations:
- The fare for the monorail was assumed to be $5.00 per trip.
- Direct revenue for the monorail would also include concession stand revenue at each of the five stations, advertising, and shuttle fair from parking lots to the monorail systems.
- Because the monorail is much more focused on the gaming community, a 10% increase in gaming revenue for the Gulf Coast was assumed.
- Sales tax revenue was expected to grow 5% by implementing the monorail system.
- The monorail system is assumed to create 400 jobs from the operation and maintenance of the system itself and 50 jobs from businesses brought to the area.
- Fuel savings from diverting 14,000 riders from highways were also considered.

The monorail full LCC and benefit analysis breakdown is presented in Table 7.

Table 7. Monorail Life-Cycle Cost Analysis Breakdown

Rail Alternative	Monorail E-W	
CL Length; Track	30 km; Elevated dual track	
Rail Infrastructure	4 train stocks; 5 stations	
Initial Infrastructure Cost	$1,524 Million	
Riders per Day	14,000	
Present Worth Cost-Benefit Analysis	Cost	Benefit
1-Year Present Worth Analysis, $ Million	1,616	302
5-Year Present Worth Analysis, $ Million	1,976	1,306
10-Year Present Worth Analysis, $ Million	2,329	2,330
20-Year Present Worth Analysis, $ Million	2,824	3,760
50-Year Present Worth Analysis, $ Million	3,428	5,508
Breakeven Year	10 Years	
(considering all revenue sources, fuel saving, and economic benefits)		
Benefit/Cost Ratio	1.0	
Breakeven Year (considering only direct revenues)	*Over 50 years*	

When considering all direct revenues, gaming revenue increase, sales tax revenue increase, fuel savings, and economic development the monorail is expected to breakeven at ten years, showing a benefit/cost ratio of 1.0 at year ten. The initial infrastructure was found to be $1.5 billion, which is extremely high compared to the commuter rail alternatives. When performing the LCC and benefit anaysis using only direct revenues for benefits the monorail system will not breakeven in the 50-year observation period. This shows that monorail is not an economically feasible option for the Mississippi Gulf Coast at this time. Similarly, the Light Rail Transit has very high capital costs because it requires its own dedicated infrastructure. This option was not included in the study.

BRT Life Cycle Assessment
The following data and assumptions were used in calculating the initial capital costs for years 1, 5, 10, 20, and 50 for the proposed BRT route (FTA 2014).

- $15.3 million initial infrastructure cost includes video surveillance equipment and:
  - assumed $150,000 per km to dedicate a lane to BRT route)
  - $60,000 per bus
  - $50,000 per bus station
  - $200,000 for maintenance yard
- 15% of infrastructure capital cost for design and administration

Annual operating costs ($3.7million per year), annual maintenance costs $2.9million per year), and major overhaul every five years $1.0 million every 5 years) were also considered in the cost calculations. These amounts were determined based on NTD averages (FTA 2014) for similar systems.

Because the BRT alternative does not have the appeal to riders as the other modes, a lower ridership was assumed for calculating the benefits. For the calculations, 15% of the available commuters to be diverted were assumed to take BRT, which are 5,100 riders per day. Other data follows:

- The fare for using BRT is the cheapest of the alternatives at $2.00 per trip, which is based on the NTD average.
- Advertising and bus station concessions were also accounted for in the benefit.
- BRT was assumed to increase gaming revenue along the Mississippi Gulf Coast by 0.05% and sales tax revenue by 0.05%.
- It was also assumed that the BRT system would develop 110 jobs and create 5 jobs from the development of new businesses.

Table 8 shows the complete LCC and benefit analysis breakdown for the BRT system.

Table 8. BRT Life-Cycle Cost Analysis Breakdown

Rail Alternative	BRT E-W	
CL Length; Track	60 km; Dedicated highway lane	
Rail Infrastructure	50 bus stocks; 30 stations	
Initial Infrastructure Cost	$15.3 Million	
Riders per Day	5,100	
Present Worth Cost-Benefit Analysis	Cost	Benefit
1-Year Present Worth Analysis, $ Million	21.6	20.0
5-Year Present Worth Analysis, $ Million	45.2	95.9
10-Year Present Worth Analysis, $ Million	63.6	154.3
20-Year Present Worth Analysis, $ Million	99.8	219.6
50-Year Present Worth Analysis, $ Million	139.1	364.7
Breakeven Year	Year 2	
(considering all revenue sources, fuel saving, and economic benefits)		
Benefit/Cost Ratio	1.4	
Breakeven Year (considering only direct revenues)	Year 50	

Based on the benefits which include direct revenue, gaming revenue increase, sales tax revenue increase, fuel savings, and economic development and the costs that accrue over the life of the system, BRT is expected to breakeven in the second year of operation. BRT was found to have a

significant lower initial infrastructure capital cost compared to the other proposed modes. Although it shows that it will breakeven at year two, when considering only direct benefits generated by BRT, it will breakeven at the 50-year life cycle.

VE and LCA Results and Discussion

Figure 51 presents the cost data on a level playing field and shows the cost per kilometer for each passenger transportation alternative. Monorail has the highest per kilometer cost at $13.55 million. The East/West commuter rail is second at $2.39 million, followed by the North/South commuter rail at $2.17 million. The lowest per kilometer cost is the BRT at $670,000 per kilometer.

10-Year Present Worth Life-Cycle Cost per km ($ Millions)
10-Year Present Worth Life Cycle Cost per km ($ Million)
$16.00
$14.00
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
$13.55
$2.39
$0.67
$2.17
Monorail
E-W Commuter Rail
Bus Rapid Transit
N-S Commuter Rail
Length
30 km
200 km
60 km
110 km
Daily Ridership
14,000
20,000
10,200
10,000
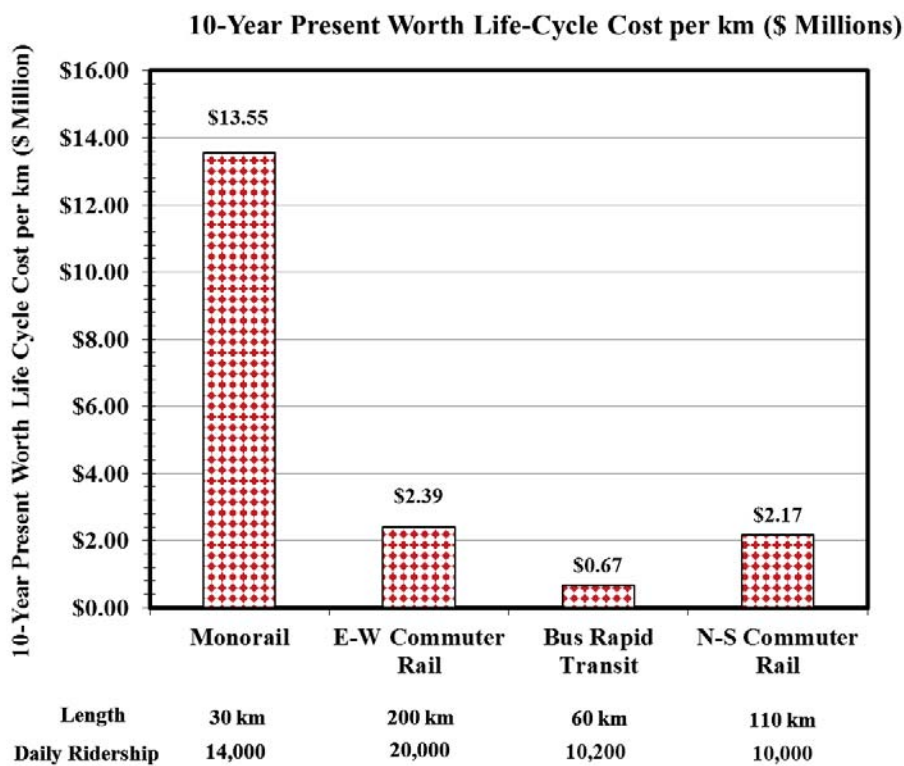
Figure 512. 10-Year Present Worth Life-Cycle Cost per km

The direct benefits can be seen for each of the alternatives a little more clearly in Figure 52. The direct benefits have been normalized for 20,000 passengers. For some of the alternatives there are expected to be a higher number of riders which skew the benefits and make some modes look more beneficial than others, but by normalizing the benefits they can be analyzed on an even level. The direct benefits for the commuter rail alternatives and the monorail are all approximately on the same level at just under $600 million. The BRT benefits are significantly lower in comparison with the other modes, at approximately $350 million.

Figure 52. Normalized Direct Benefits for Gulf Coast Commuter Alternatives, 10-Year Present Worth Analysis

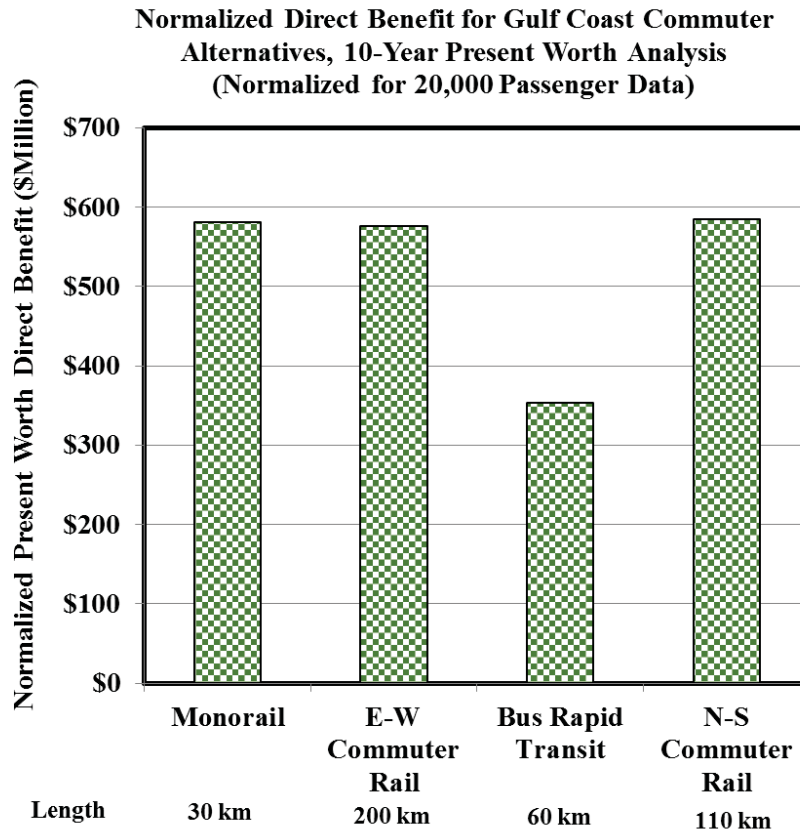Figures 53 and 54 show the results of the comprehensive VE analysis based life cycle assessment of costs and benefits for each of the proposed passenger transportation alternatives. Figure 53 shows the total present worth benefit/cost (B/C) analysis for each of the modes and at what year they will reach their breakeven year. Both commuter rail alternatives breakeven at year one, BRT is just below breaking even at year two. Monorail has the slowest return, breaking even at year ten.

Figure 54 shows similar data as Figure 53 showing the present worth benefit cost analysis results but using only the direct revenue rather than the total benefits. The BRT is expected to finally breakeven at year fifty, while the monorail does not break even in the entire 50-year analysis period.

The East-West commuter shows the quickest return on investment reaching a B/C ratio of 1.0 at year six. It is closely followed by the North-South commuter rail which breaks even at year eight. The commuter rail alternatives are clearly the top choice and distance themselves from the other alternatives when analyzing with only the direct benefits.

Total Present Worth Benefit/Cost Analysis (50 years)

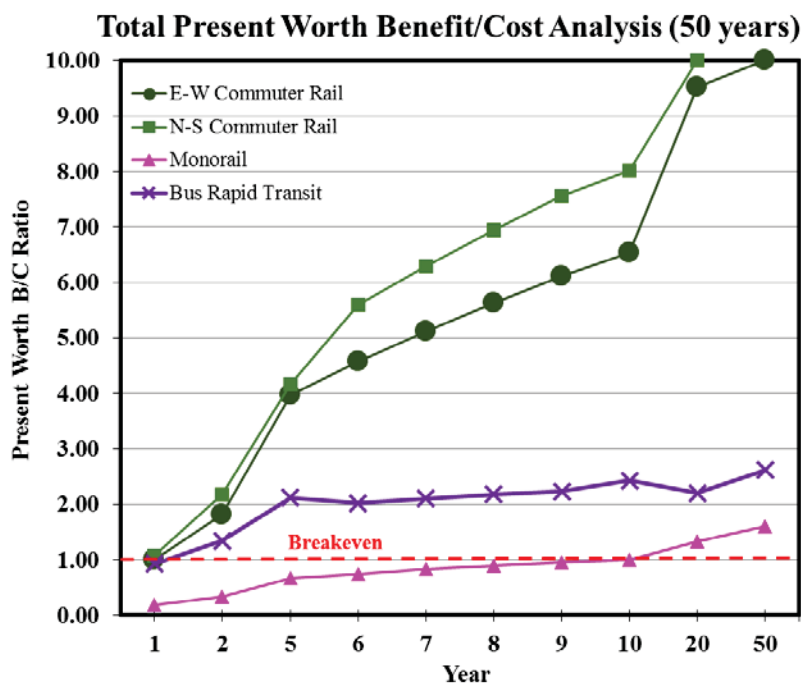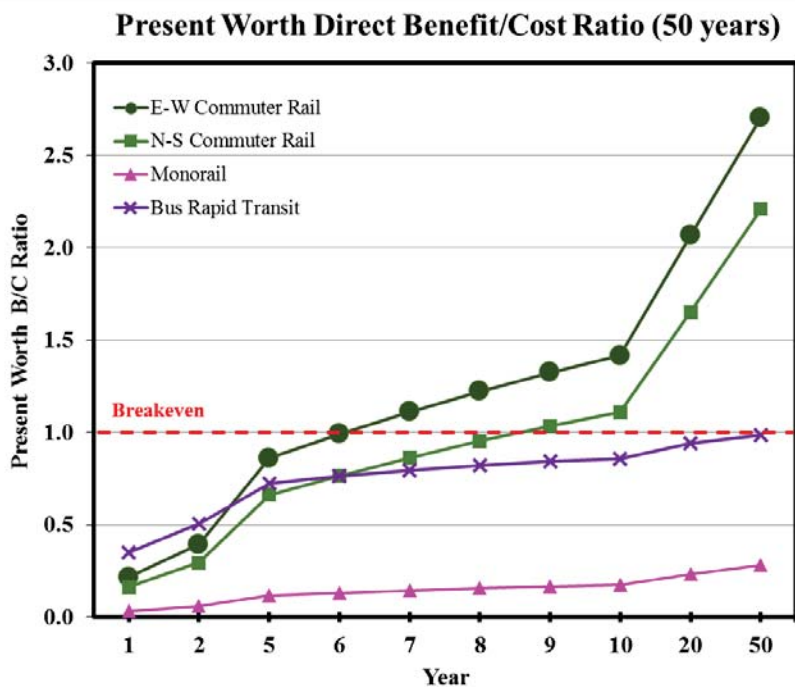
Figure 533. Total Present Worth Benefit/Cost Analysis (50 Year)

Present Worth Direct Benefit/Cost Ratio (50 years)

Monorail needs heavy government subsidy to operate if only direct revenues are considered in the benefit cost analysis.

Figure 54. Direct Present Worth Benefit/Cost Ratio (50 Years)

Based on the final VE analysis and LCA results, although the BRT provides the lowest initial capital cost, the low benefit pushes back the breakeven year to 50th year. Also, since BRT will operate on the highways which are already facing congestion issues, it only worsens the current congestion issue being faced on the Mississippi Gulf Coast. Monorail's extremely high initial infrastructure capital costs eliminate it as being an economically viable option. The same is said for the LRT option. The VE analysis results show that the commuter rail alternatives both provide high rates of return if properly utilized by commuters (Uddin et al 2015). Revival of commuter rail service could make an immediate impact on reducing highway congestion along the coast, as well as growing the economy of coastal cities.

Reduction in CO_2 Emissions Using the Commuter Rail Alternative

Using the daily auto trip estimates diverted to the commuter train and CO_2 emission models (Equation 10 in the next section), the reduction in CO_2 emissions were calculated compared to the base scenarios of no change in highway traffic. The reductions in CO_2 emissions are 2,397 tons per year for E-W train and 1,253 tons per year for N-S train. These and other additional benefits are shown in Table 9.

Table 9. Reduction in CO_2 Emissions and Other Benefits of Commuter Rail Service

Rail Alternative	Commuter Rail E-W	Commuter Rail N-S
CL Length; Track	200 km; CSX rail track	110 km; ; KCS rail track
Initial Infrastructure Cost	$335.2 Million	$226.9 Million
Riders per Day	20,000	10,000
Breakeven Year (only direct revenues)	6 Years	Within 8 Years
CO_2 Emission Reduction *	**2,397 Tons per Year**	**1,253 Tons per Year**
Added Sales Tax Revenue Assumed	Annual 5%	Annual 2.5%
Annual 10% Added Casino Patrons & Visitors/Tourists:	1.48 Million (boost to state economy)	
Total Jobs created from commuter rails:	500 (added economic benefits)	

 * (due to less number cars and SOVs on highways)

Additional Societal Benefits of Using the Commuter Rail Alternative

As discussed by Cobbs (2015), there are many additional benefits beyond the monetary benefits analyzed in the life cycle analysis that can be gained by opting to use the proposed commuter rail lines. Each of the commuter rail lines provides their own benefits for the Mississippi Gulf Coast (CAIT 2015). The Mississippi Gulf Coast will always be vulnerable to natural disasters such as hurricanes, and those who live along the coast must always be prepared. The North-South commuter rail line will always provide a quick evacuation alternative in the event of the need to evacuate the coast. The commuter rail line can run quickly, without any stops and hold many residents and would be a reliable means of removing residents from a dangerous area. By

utilizing this mode for evacuation, this will free up the highway infrastructures for emergency responders and emergency vehicles.

The East-West "Casino Train" commuter rail line will provide many more benefits then just increasing revenues for the gaming community (CAIT 2015). It will help act as a means to bring more tourism to the Mississippi Gulf Coast. Also, for those that choose to come to the large gaming community from surrounding cities to enjoy themselves, it will provide those who have too much to drink a way home. This commuter line will provide safe, reliable transportation and help eliminate drunk drivers who are leaving casinos and bars. This will help reduce crashes and incidents on the highways and also help with the reduction of traffic congestion in the area.

Additional future considerations for providing safe, user-friendly, and environmentally sustainable commuter rail transit services are:

- Intelligent Transportation Systems (ITS) for safe travel with enhanced security
- Free on-board Wi-Fi for travelers
- Piezo electric sensor system for harvesting of lost energy from the vibrations produced by train-rail corridor operations.

Modeling Revenue and Socio-Economic Indicators

As a part of Dr. Najjar's graduate course, Cobbs (2015) investigated the use of the Artificial Neural Network (ANN) methodology to model socio-economic indicators that were used to estimate benefits in the above scenarios. The ANN model was developed to predict future sales tax revenue to the Gulfport, MS area based on societal and economic indicators. Figure 55 shows the Excel interface of the ANN predictor. Using this modeling tool, the sales tax revenue can be predicted based on the proposed commuter rail impacts on the public and the economy.

Gulfport, MS
Sales Tax Revenue
Predictor
By: Seth Cobb
ENGR 691 - Section 23

Input Parameters			Applicable Range	
Month	8	Applicable	12	1
Year	2011	Applicable	2014	2008
Gaming Revenue	$13,863,358	Applicable	$18,146,500	$6,702,821
Employed Population	154,971	Applicable	160,145	145,587
Casino Patrons	4,046,481	Applicable	4,236,577	3,250,176
Gross Sales	$185,000,000	Applicable	$189,696,675	$115,032,651

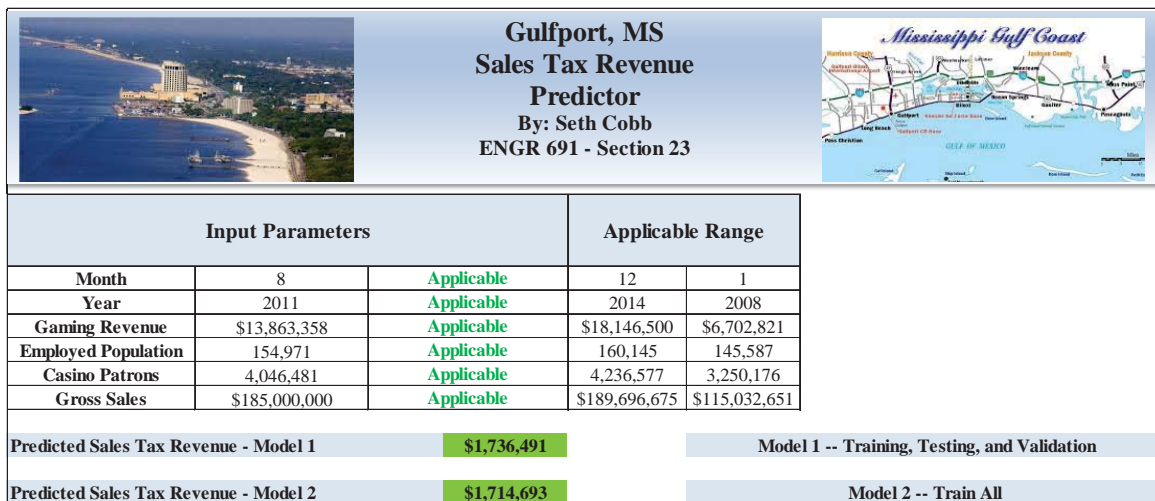| Predicted Sales Tax Revenue - Model 1	$1,736,491	Model 1 -- Training, Testing, and Validation
Predicted Sales Tax Revenue - Model 2	$1,714,693	Model 2 -- Train All

Figure 55. Excel User Interface

Regression modeling was also used and the results of the regression equation were compared against the ANN model results to determine the more suitable model for this data. A significant increase in ANN model accuracy can be seen as the R^2 value increased from 0.1890 in the regression equation to 0.6006 in the ANN model. Due to the low accuracy measures of the regression model based on higher absolute error it was found that ANN modeling provides a more accurate model for predicting future sales tax revenue for the Gulfport, MS area.

Upon completion of the interface, sensitivity analysis for each of the variables was completed. This is done by selecting a data set closest to the average value of each of the variables. This data set is then placed in the interface. Each variable is changed throughout its range while all other variables are kept stationary, showing the effect that the variable being changed has on the output. The month variable showed to have a significant impact on sales tax revenue. Although this is the case, there seems to be a lag in the data. It is expected to have December to have the highest sales tax revenue due to the holiday season but January shows the highest. This is possibly due to a lag in data being provided in financial reports. December data is more than likely being shown in the January financial report. The year shows an increase in sales tax revenue as it increase which is expected due to inflation and population growth. Both time variables were found to be significant to the model. Gaming revenue and casino patrons had significant impacts on the sales tax revenue prediction. Also, the gross sales variable can be removed from the model due to it having no impact trend on the output variable in the sensitivity analysis. It should be noted that each year the prediction is made the model must be retrained to include the previous year. So if the model is predicting for 2016, it must be retrained including the 2015 data as an input to provide an accurate prediction. Further elaboration is not pursued.

3.4 Environmental Impacts and Reduction in CO_2 Emissions

Transportation Emission Related Public Health Impact
Transportation related emissions generate numerous air pollutants and adversely impact the atmospheric air equilibrium. Lead and sulfur, which are the principal air pollutants, are no longer the main contributors to the transportation related emissions due to the development of cleaner unleaded fuel, improvements in vehicle technologies, and the emission control regulation applied in the U.S. and Europe. However, the other principal air pollutants, which are particulate matter (PM), ground level Ozone (O_3), Nitrogen dioxide (NO_2), and carbon monoxide (CO) exist in many urban areas in the U.S. and several megacities in the world (Uddin and Boriboonsomsin 2005, Uddin 2006). Transportation sources also contribute the greenhouse gas emissions by producing CO_2, methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbon (HFC).

Figure 56 shows the air pollutant impacts on public health (EEA 2014). The air pollutants can adversely impact many human's organ systems from head to the productive systems. PM contributes to almost all of the health problems shown in the figure.
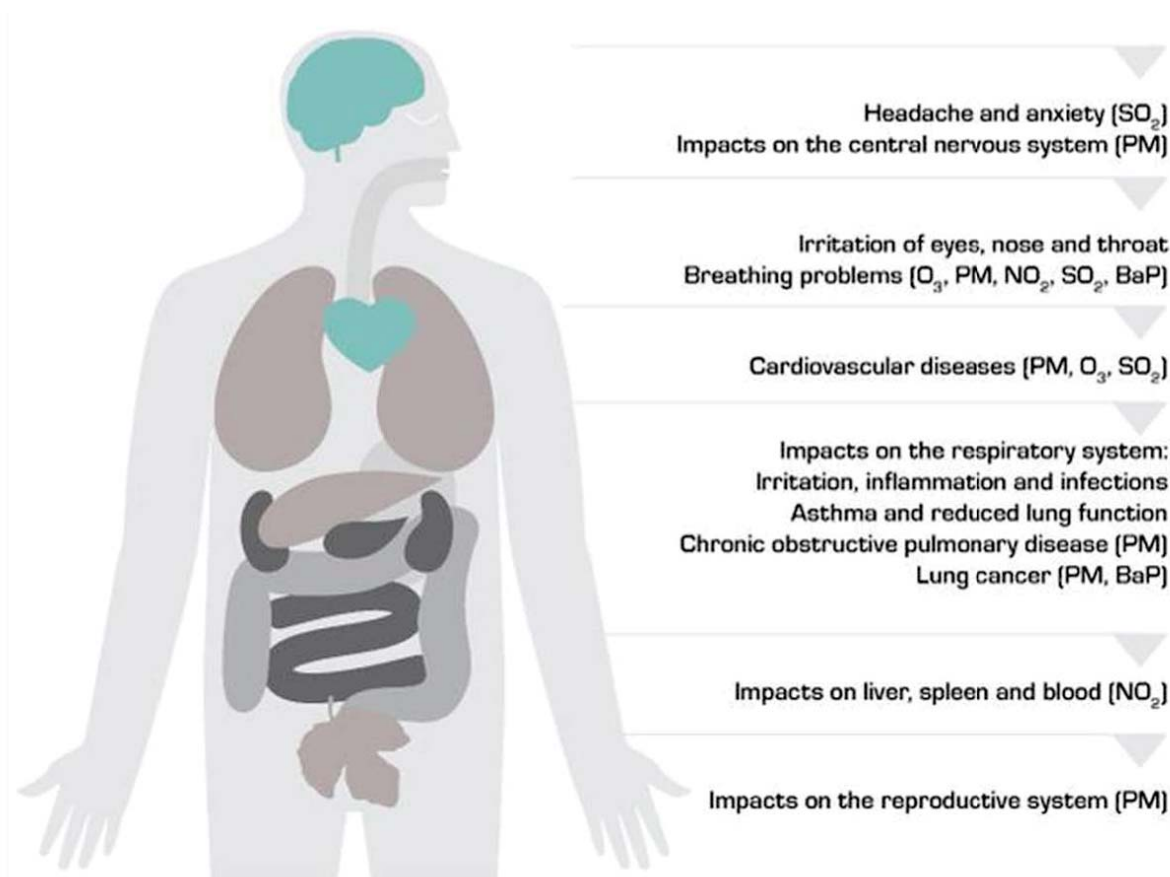
Source: European Environment Agency. "How Does Air Pollution Impact Human Health?" https://twitter.com/EUEnvironment/status/535350479161929729. 2014. Accessed on November, 20, 2014.

Figure 56. Air Pollutant Impacts on Health (EEA 2014)

Scientific evidence specifies that Ozone not only affects the people suffering from asthma, but also the general people. People's lung function can drastically reduce by contacting to Ozone for 6 to 7 hours, even at relatively low concentrations. The studies indicate the positive association between Ozone levels and hospital admissions for respiratory disease in several U.S. cities. In addition, the study indicated that Ozone can cause long-lasting structural damage in the lungs of the animal subjects that contact to high levels of Ozone for several months. Ozone is also responsible for the damages forest ecosystems in the eastern U.S. and California and the agricultural harvest loss.

Nitrogen dioxide is one type of highly reactive gases named nitrogen oxides (NOx). NOx is produced by burning fuel at high temperatures. The principal sources of nitrogen dioxide are motor vehicle and stationary sources, for example electric utilities. Nitrogen dioxide is the main contributor in the atmospheric reactions creating ground-level Ozone.

In regard to the impact of NO_2 to the health, it can aggravate the lungs and decrease the resistance to respiratory infections, for example influenza. Nitrogen dioxide can cause serious respiratory illness in children when they frequently exposed to nitrogen dioxide which has higher concentration than at the normal condition.

Carbon monoxide forms due to un-complete burning process of the carbon in fuels. Carbon monoxide is poisonous gas that does not have color and odor. Highway vehicle machine contributes about 60 percent of total carbon monoxide emissions in the U.S. Moreover, the automobile machine can contribute up to 95 percent of total carbon monoxide in cities. High levels of carbon monoxide are still found in some metropolitan areas, although the carbon monoxide trend is down for nationwide.

Carbon monoxide diminishes oxygen distribution to the body's organs and tissues by coming in the bloodstream. Carbon monoxide can seriously affect people who suffer from cardiovascular disease; however, higher level of carbon monoxide can affect the healthy people as well. People who encounter high level carbon monoxide can have visual weakened, reduced stamina to work, reduced ability to think, etc. (EPA 1995).

Worldwide PM from energy production and transportation sources is a major pollutant. Public health costs related to mortality and morbidity from air pollutants are enormous (Uddin 2006). Millions of people die every year worldwide due to air pollution. The World Health Organization (WHO) reported a breakdown of deaths attributed to specific diseases, underlining that the vast majority of air pollution related deaths are due to cardiovascular diseases (WHO 2014), as follows:

"Outdoor air pollution-caused deaths – breakdown by disease:
- 40% – ischaemic heart disease;
- 40% – stroke;
- 11% – chronic obstructive pulmonary disease (COPD);
- 6% - lung cancer; and
- 3% – acute lower respiratory infections in children.

Indoor air pollution-caused deaths – breakdown by disease:
- 34% - stroke;
- 26% - ischaemic heart disease;
- 22% - COPD;
- 12% - acute lower respiratory infections in children; and
- 6% - lung cancer.

The new estimates are based on the latest WHO mortality data from 2012 as well as evidence of health risks from air pollution exposures. Estimates of people's exposure to outdoor air pollution

in different parts of the world were formulated through a new global data mapping. This incorporated satellite data, ground-level monitoring measurements and data on pollution emissions from key sources, as well as modelling of how pollution drifts in the air."

Carbon Dioxide is the main greenhouse gas emissions from human activities. Carbon Dioxide contributed about 82% of total U.S. greenhouse gas released through human activities in 2012. Carbon Dioxide naturally is produced by the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals; however, human activities are changing the carbon cycle by adding more CO_2 to the atmosphere (EPA 2014a).

Various concentration of carbon dioxide can initiate several human health effects. Exposure to 2 percent carbon dioxide within several hours can produce headache and exposure to 4 to 5 percent CO_2within few minutes can increase blood pressure (Schulte 1964). In addition, exposure to 7 to 10 percent carbon dioxide can produce unconsciousness or near unconsciousness within a few minutes and shortness of breath (EPA 2014b, NASA 1992).

**CO_2 Emission Data Synthesis for U.S. and Mississippi**
Ahlan (2015) contributed the sections on air pollution and CO_2 impacts in this chapter. Transportation is the second largest contributor of greenhouse gas emissions among all end-use sectors in the U.S. GHG emissions from transportation mostly are contributed by CO_2 emissions produced from the combustion of petroleum-based products. The largest source of transportation-related greenhouse gas emissions in the U.S. is passenger cars.

Figure 57 shows GHG emissions by end-use sector in the U.S. in 2011. Various economic end-use sectors in the U.S.A. produced 6,753 million metric tons of CO_2 equivalents (CO_2 Eq) or 6,753 teragrams (Tg) greenhouse gas emissions in 2011. Industry sector contributed 27.7 percent of the total greenhouse gas emissions from multiple economic end-use sectors in the U.S. in 2011; 27.5 percent were contributed by transportation sector; 17.2 percent were contributed by residential sector; 16.7 percent were contributed by commercial sector; and 10 percent were contributed by agriculture sector. In addition, 0.9 percent of the total greenhouse gas emissions were produced by multiple end-use sectors in U.S. territories, which are American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands (EPA 2014c). The GHG emissions data was shown in units of teragrams CO_2 equivalent to allow the GHG emissions of different heat trapping potential to be integrated for a direct comparison of various GHG emissions.

The industrial end-use sector involves CO_2 emissions from the combustion of fossil fuels from all industrial amenities and emissions resulting from the non-energy-related industrial process activities. The commercial and residential end-use sector emissions mostly come from generating

electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances.
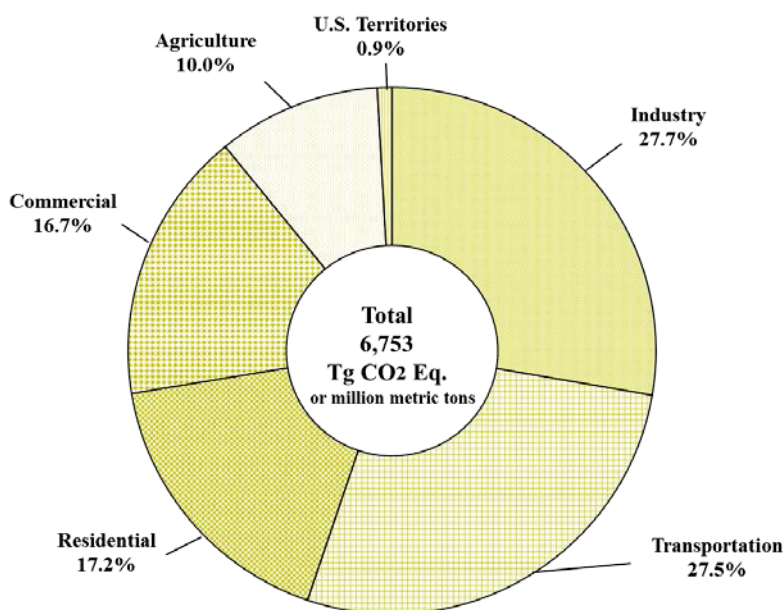
Source: "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012" U.S. EPA. Web. Accessed October, 28, 2014.
http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf

Figure 57. U.S. Greenhouse Gas Emissions by End-Use Sector, 2011

The other emissions of the commercial and residential end-use sectors were mostly related to the direct consumption of natural gas and petroleum products, such as cooking need. The agriculture end-use sector emissions are resulted from multiple processes, including livestock excrement management and agricultural soil management.

Greenhouse gas emissions from transportation end-use sector involve CO_2, methane (CH_4), nitrous oxide (N_2O), and various hydrofluorocarbons (HFCs). All three GHG gases (CO_2, CH4, and N_2O) are emitted through fossil fuel combustion. On the other hand, HFCs are the result of mobile air conditioners and refrigerated transport (EPA 2014d). Contribution of CO_2 was 94.9 percent of the total greenhouse gas emissions from transportation end-use sectors in the U.S. in 2011; 4.1 percent were contributed by HFCs; 0.9 percent were contributed by N_2O; and 0.1 percent were contributed by CH_4.

Figure 58 shows transportation end-use sector greenhouse gas emissions by source in the U.S. in 2011. Forty three percent of the total greenhouse gas emissions from transportation end-use sectors in the U.S. in 2011 were contributed by passenger cars; 22 percent were contributed by medium and heavy duty trucks; and 18 percent were contributed by light duty trucks, which include sport utility vehicles, pickup trucks, and minivans. In addition, 8 percent of the total greenhouse gas emissions from transportation end-use sectors in the U.S. in 2011 were

contributed by aircraft; 3 percent were contributed by ships and boats; and 6 percent were contributed by all other transportation sources. Figure 59 shows estimated CO2 emissions per passenger for various different transportation modes.
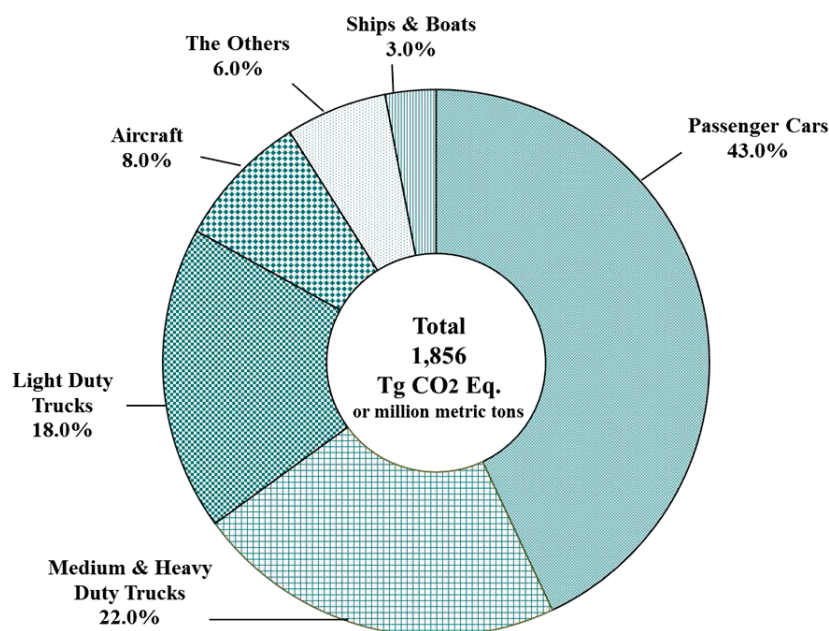
Source: "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012" U.S. EPA. Web. Accessed October, 28, 2014.
http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf

Figure 58. U.S. Transportation End-Use Sector GHG Emissions by Source, 2011

Dr Daniella Abreu (@Dr_Sustainable) tweeted at 1:48 PM on Sun, Aug 24, 2014:
CO2 per passenger via @NewEconomyMag #sustainability http://t.co/fFEcezxrKg
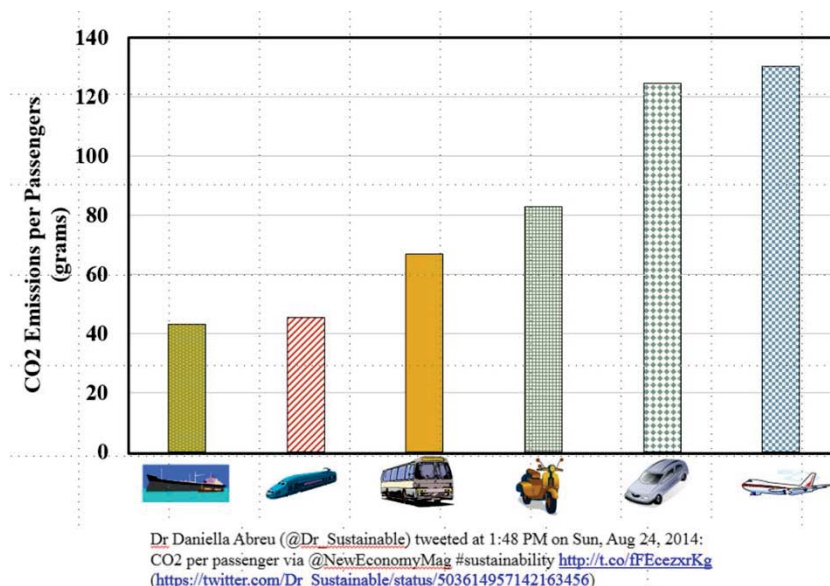(https://twitter.com/Dr_Sustainable/status/503614957142163456)

Figure 59. CO2 Emissions per Passenger for Various Different Transportation Modes

Uddin's study about air quality trend shows that particles 2.5 microns or smaller ($PM_{2.5}$) and Ozone are the main contributor to the poor air quality during summer time in the Southern

U.S.A. Particular matter, Ozone, nitrogen dioxide and carbon monoxide generate severe illness and health risks including respiratory problems, pulmonary diseases, and risk of premature death (Uddin 2006).

In regard to transportation-related emissions in Mississippi, Ahlan (2015) calculated vehicle idling emissions for I-10 in Mississippi Gulf Coast. There are five major cities in Mississippi Gulf Coast, but only two cities passed by I-10, which are Gulfport and Biloxi. As a result, the vehicle idling emissions were calculated on I-10 over Gulfport and Biloxi. Gulfport and Biloxi are in Harrison County. The idle is assumed to occur within a 10 km radius of the Gulfport and Biloxi cities. The vehicle idling emissions were calculated by using Equation 8.

$$Vehicle\ idling\ emissions =$$
$$number\ of\ traffic\ x\ idle\ time\ x\ idle\ emisions\ factor \qquad Eq.\ 8$$

First, the number of traffic in terms of AADT (average annual daily traffic) is calculated for each vehicle types. Second, the idle time is calculated based on the posted speed, travel time, and travel distance. Finally, the total vehicle idling emissions are calculated by using idle emission factor for each vehicle types. The calculations of AADT and total vehicle idling emissions are shown in separate tables.

Table 10 shows average of AADT (average annual daily traffic) at peak period on I-10 over Gulfport and Biloxi in Mississippi Gulf Coast. The AADT were obtained through the Mississippi Department of Transportation traffic count application. The AADT were within a 10 km radius of the Gulfport and Biloxi cities. The proportion of heavy-duty diesel vehicles (HDDV) and light-duty gasoline-fueled vehicles (LDGV)- and light-duty gasoline-fueled trucks (LDGT) were obtained from U.S. Department of Energy (ORNL 2014a). In the traffic number, 95.6 percent of the vehicles are LDGV or LDGT and 4.4 percent of the traffic are HDDV. The AADT peak period factors were obtained from the Gulf Coast Planning Commission (Gulf 2013). During the peak period time (6 to 9 am), the peak traffic was 58.9 percent of total AADT in Harrison County.

Table 10. AADT on I-10 over Gulfport and Biloxi in Mississippi Gulf Coast, 2012

A	B	C	D	E
City	Average AADT (within 10 km radius of the city)	Avg AADT at peak period		
		All	LDGV-LDGT	HDDV
		0.589 x B	0.956 x C	0.044 x C
Gulfport	54,500	32,100	30,688	1,412
Biloxi	67,250	39,610	37,868	1,742
Peak Hour Factor: 0.589		Percent of LDGV-LDGT: 95.6		Percent of HDDV: 4.4

The idle time was calculated by subtracting the travel time on I-10 at average speed with the travel time at posted speed. The posted speed was 70 mph, while the average speed was 55 mph during congestion hours (MDOT 2011). The total travel distance was 20 km. The calculated idle time was 3 minutes.

Table 11 shows daily vehicle idling emissions on I-10 in Mississippi Gulf Coast. The idle emissions factors were obtained from the U.S. Environmental protection Agency (EPA (1998). The idle emission factors are different for each type of vehicles. Three type of vehicles, light-duty gasoline-fueled vehicles (LDGV), light-duty gasoline-fueled trucks (LDGT), and heavy-duty diesel vehicles (HDDV) were used for vehicle idle emissions on I-10 in Mississippi Gulf Coast. In this study, the same idle factor for LDGV and LDGT was used by averaging both vehicle type idle emission factors.

Table 11. Daily Vehicle Idling Emissions on I-10 in Mississippi Gulf Coast, 2012

A	B	C	D	E	F
Pollutants	Idling Vehicle Emission Factors, g/min		Total Emission, g / day (for 3 min. idle time)		
	LDGV/LDGT	HDDV	Gulfport	Biloxi	Total
CO	7.155	1.58	665,411	821,094	1,486,505
VOC	0.432	0.211	40,665	50,180	90,845
NOx	0.114	0.945	14,498	17,889	32,388
PM10	-	0.042	178	219	397

Example: CO for Gulfport = 3 min. (30,688 x 7.155 + 1,412 x 1.58) = 665,411 g/day = 665.4 kg/day

Based on the idle emission factors, a passenger vehicle produces more CO and VOC than a diesel truck. On the other hand, a diesel truck produces more NO_x than passenger vehicles. PM_{10} are produced only by diesel trucks not passenger vehicles. Total daily vehicle idling emissions on I-10 in Mississippi Gulf Coast in 2012 were 1,486 kg of CO, 90 kg of VOC, 32 kg of NOx, and 0.4 kg of PM_{10}. As shown in Figure 60, CO is the largest contributor to the vehicle idling emissions, followed by VOC, NO_x, and PM_{10}. These air pollutants are also produced when the car is not idling; however, the proportions of VOC, NOx, and PM_{10} of total air pollutants weight are more than CO in this condition. The production of these harmful pollutants will be many times more at average travel speed. Although not analyzed in this study, these harmful emissions of CO, VOC, NO_2 can be calculated during travel time by using the simplified predictive equations developed from the simulations of EPA's Mobile6 program (Boriboonsomsin and Uddin 2006), as well as associated Ozone pollutant for summer days (Boriboonsomsin 2004).

For illustration, total CO_2 produced in Harrison County on I-10 and US-90 from daily through traffic is 584.3 metric tons per day calculated in the following section from annual emission of 213,269 metric tons using Equation 9.
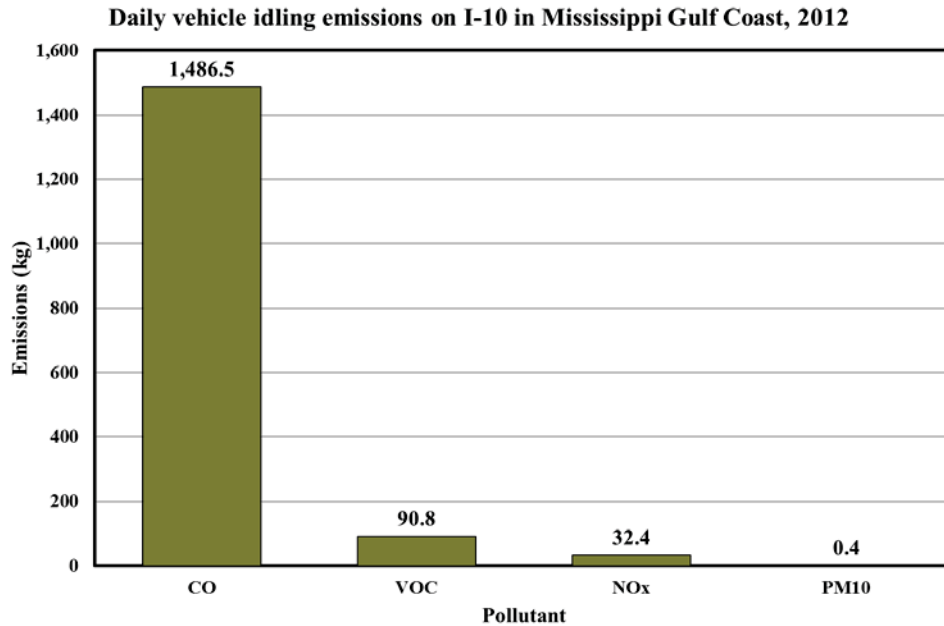
Figure 60. Daily Vehicle Idling Emissions on I-10 in Mississippi Gulf Coast, 2012

Road Transport Associated CO_2 Emissions in Mississippi

As discussed in the previous section, road and highway transportation is the largest contributor to transportation end-use sector greenhouse gas emissions in the U.S. Equation 9 was used to calculate CO_2 based on AADT using EPA methodology (Uddin 2012).

$$Total\ CO_2\ Emission\ \left(\frac{metric\ ton}{year}\right) = \sum_i \sum_j (AADT)_j \times L_i \times \frac{\propto_j}{\beta_j} \times \frac{365}{2,000}$$ Eq. 9

Where,

$AADT$: Average Annual Daily Traffic

L: Length of the road segment (km)

$i: County\ (i = 1,2,\dots,15)$

$j = Vehicle\ Type\ (j = 1\ and\ 2)$

   j =1 (car and light gas trucks) and J =2 (diesel trucks)

$\propto$: CO_2 Emission (lb/gal)

β: Fuel Consumption (km/gal)

Parameter	$Auto\ (j = 1)$	$Diesel\ Truck\ (j = 2)$
$\propto$	19.4 lb/gal	22.2 lb/gal
β	32.5 km/gal	9.4 km/gal

Assumption: $Auto\ AADT = 90.3\%\ of\ AADT$ $Truck\ AADT = 9.7\%\ of\ AADT$

Annual CO$_2$ Emission for I-10 and US-90 in Harrison County on the Gulf Coast: The total CO$_2$ emission produced by 2012 traffic on I-10 and US-90 in Mississippi Gulf Coast in 2012 is calculated using Eq. 9, as follows:

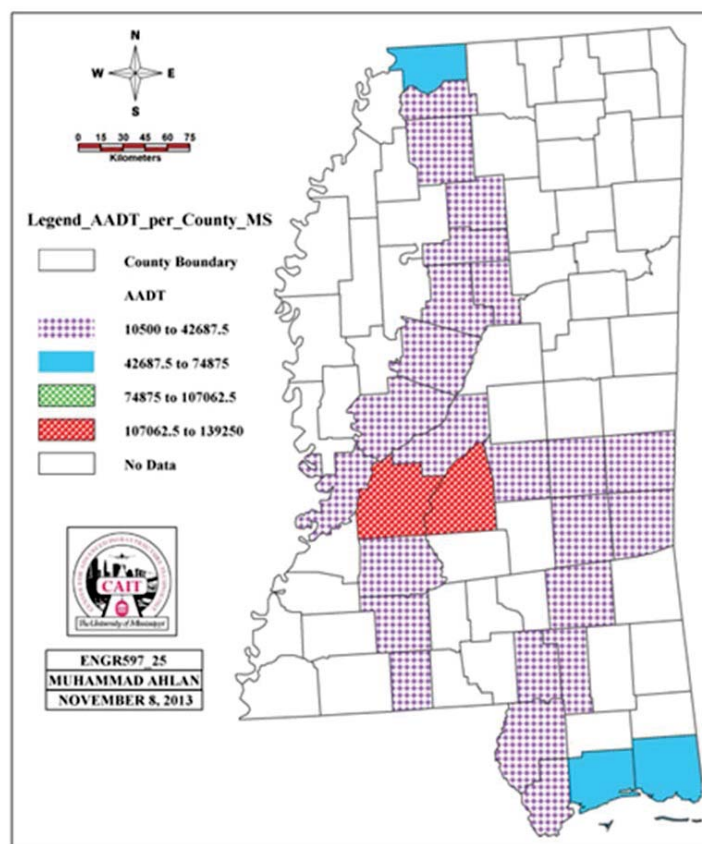|	
Harrison County's total traffic on I-10 and US-90	= 163,770 AADT
Through traffic on I-10 and US-90	= 47,000 AADT
Assumed average travel distance for through traffic	= 40 km per vehicle
Assumed traffic mix (5% of diesel truck, 95% of auto)	
Calculated CO$_2$ (Eq. 9) = 584,274.4 kg / day	Annual = 213,270 metric tons

Figure 61. Spatial Map of AADT of Interstate Highways by Counties in Mississippi

Annual CO$_2$ Emission for all Interstate Traffic in Mississippi: Figure 61 shows a spatial map of AADT for county buffers of Interstate traffic volume per year for 2012. After AADT data collection from go.mdot web site, CO$_2$ was calculated or all Interstate highways in Mississippi. These calculations were done by using Functional Attributes in GeoMedia Pro (GMPro) geospatial software (Intergraph 2013). The above Equation 9 was used to calculate the total annual CO$_2$ Emission from traffic per year on all interstates in Mississippi (I-10, I-20, I-55, and I-59). The total CO$_2$ emission produced for all intestates in MS was 3,258,320 metric ton/year or 3,928 metric ton/year/km of interstate.

Annual CO$_2$ Emission for Traffic all Counties in Mississippi: Ahlan (2015) calculated the carbon dioxide emissions associated with road and highway traffic by using VMT data (Uddin 2012, EPA 2005) as shown in Equation 10.

$$CO_2\ Emissions = \frac{VMT}{vehicle\ fuel\ efficiency}\ x\ pounds\ of\ CO_2\ emitted\ per\ gallon \qquad \text{Eq. 10}$$

Where, CO$_2$ Emissions, lb / year

VMT = Vehicle miles traveled per year

CO$_2$ emitted per gallon of gasoline = 19.4 lbs / gallon (assuming 99% of carbon is eventually oxidized)

CO$_2$ emitted per gallon of diesel = 22.2 lbs / gallon (assuming 99% of carbon is eventually oxidized)

Vehicle fuel efficiency for passenger vehicle = 20.3 mile per gallon of gasoline

Vehicle fuel efficiency for diesel truck = 5.9 mile per gallon of diesel

For more practical use, CO$_2$ emissions for passenger vehicle can be estimated by using Equation 11. Passenger vehicles include passenger car and light duty truck. Similarly, the CO$_2$ emissions for diesel trucks can be estimated by using Equation 12.

$$CO_2\ Emissions\ for\ all\ passenger\ vehicles, lbs = \frac{VMT}{20.3}\ x\ 19.4 \qquad \text{Eq. 11}$$

$$CO_2\ Emissions\ for\ all\ diesel\ trucks, lbs = \frac{VMT}{5.9}\ x\ 22.2 \qquad \text{Eq. 12}$$

The road transport associated CO$_2$ in Mississippi was calculated by using the VMT data for each county in 2010. The percentages of passenger vehicle- and diesel truck VMT were estimated by using national data (ORNL 2014b). Detailed results for each county were tabulated by Ahlan (2015) for the 2010 road transport associated CO$_2$ emissions in Mississippi. The total traffic associated CO$_2$ emission in 2010 was 24.3 million short tons or 21.8 million metric tons.

Passenger vehicles mostly contributed 70.7 percent of the CO$_2$ emissions, while 29.3 percent of the CO$_2$ emissions mostly were contributed by diesel trucks (Ahlan 2015). Figure 62 shows the top ten counties that had the highest number of road associated CO$_2$ emissions in Mississippi in 2010. The worst ten counties in Mississippi listed from the largest number of road associated CO$_2$ emissions in 2010 to the smallest were as follows: Hinds (2,307 thousand tons), Harrison (1,388 thousand tons), Rankin (1,208 thousand tons), Jackson (1,028 thousand tons), DeSoto (997 thousand tons), Lauderdale (792 thousand tons), Lee (783 thousand tons), Madison (643 thousand tons), Jones (574 thousand tons), and Forrest (494 thousand tons). This analysis demonstrates that besides traffic congestion on major highways, the two Gulf Coast counties (Harrison and Jackson) are within the top five counties producing traffic associated CO$_2$ emissions.
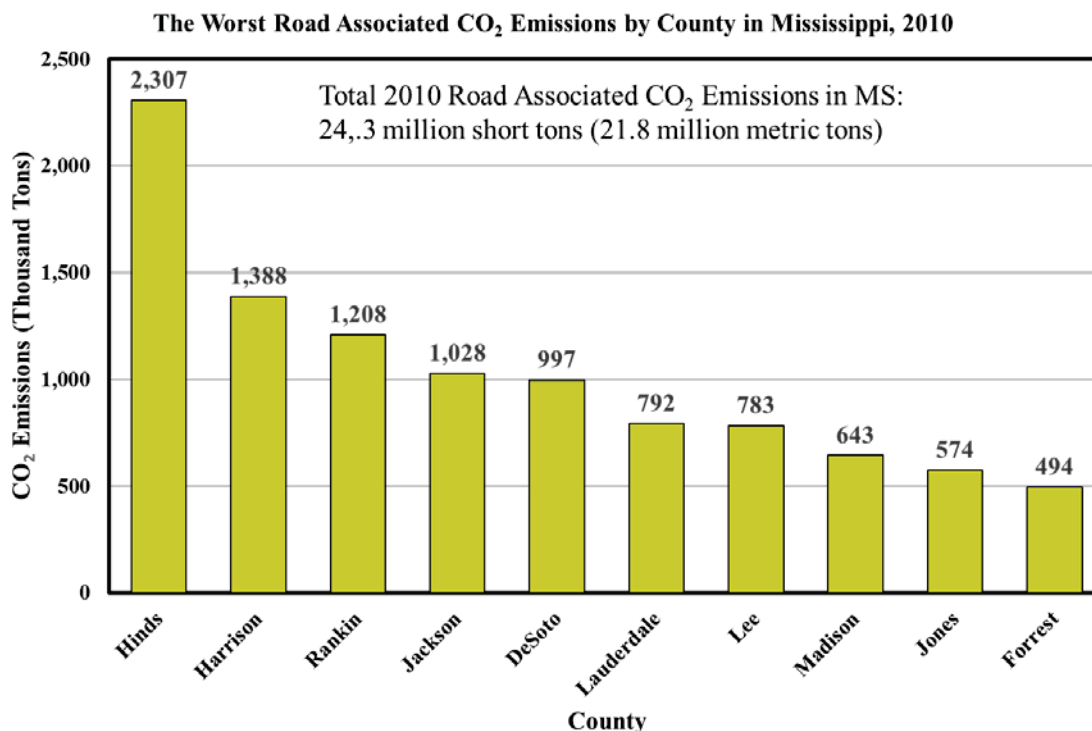
The Worst Road Associated CO₂ Emissions by County in Mississippi, 2010

Figure 62. The Worst Road Associated CO_2 Emissions by County in Mississippi, 2010

Annual CO_2 Emission for Traffic in Gulf Coast Counties and Reduction using Commuter Rail:
The CO_2 emissions that resulted from trip to work in Mississippi Gulf Coast counties were
calculated by using the number of vehicle trips. The number of vehicle trips was based on Figure
36 of this report. Equation 13 was used to calculate the trip to work-related CO_2 emissions in
Mississippi Gulf Coast counties.

$$CO_2\ Emissions = \frac{Number\ of\ Vehicle\ trips\ x\ travel\ length\ x\ pounds\ of\ CO_2\ emitted\ per\ gallon}{vehicle\ fuel\ efficiency} \qquad \text{Eq. 13}$$

Where,

       CO_2 Emissions = lb / year

       Travel length = km

       CO_2 emitted per gallon of gasoline = 19.4 lbs / gallon

       CO_2 emitted per gallon of diesel = 22.2 lbs / gallon

       Vehicle fuel efficiency for passenger vehicle = 32.5 km per gallon

       Vehicle fuel efficiency for diesel truck = 9.4 km per gallon

The associated trip length was estimated from the average vehicle speed and travel time. The
detail calculation was provided in appendix of the M.S. graduate report by Ahlan (2015). Table

12 shows the final results of trip to work-related CO_2 emissions (short tons per year) in Mississippi Gulf Coast counties.

Table 12. Trip to Work-Related CO_2 Emissions in Mississippi Gulf Coast Counties

A	B	C	D	E
County	CO_2 for Auto, Ton/Year	CO_2 for Public Transport, Ton/Year	Total CO_2, Ton/Year	Potential CO_2 Reduction by Commuter Rail, Ton/Year
Hancock	314,899	14	314,913	31,490
Harrison	969,286	1,968	971,254	96,929
Jackson	860,482	617	861,099	86,048
Total	2,144,667	2,599	2,147,266	214,467

Total annual CO_2 emissions based on trip to work in Mississippi Gulf Coast counties are 2,147,266 short tons or 1,947,967 metric tons (~ 2 million metric tons). Vehicle trips that potentially can be integrated to the commuter rail are 34,185, which generate 214,467 short ton CO_2 emissions per year. As a result, 34,185 vehicle trips that produce 9.9 percent of total trip to work-related CO_2 emissions in Mississippi Gulf Coast counties can be integrated to commuter rail trips that produce lower CO_2 emissions and a reduction of about 10 percent in total CO_2.
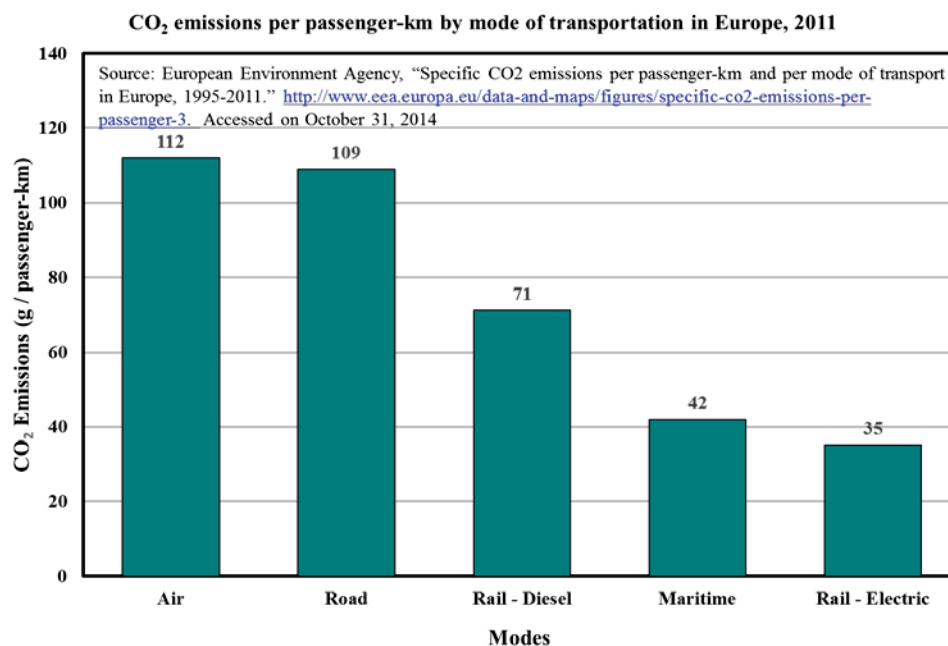

Figure 63. CO_2 Emissions in Grams per Passenger-km by Transportation Mode

Figure 63 shows the CO_2 emissions in grams per passenger-km for each mode of transport in Europe in 2011 (EEA 2013), as follows:

- The CO_2 emission for a road passenger for 1 kilometer $= 109$ g
- The CO_2 emission for a diesel-rail passenger for 1 kilometer $= 71$ g
- The CO_2 emission for an electric rail passenger for 1 kilometer $= 35$ g

Therefore, the diesel train CO_2 emission per passenger-km is 65 percent of those of the road auto passenger or 1,264,231 metric tons. This amounts a reduction of 442,481 metric tons in CO_2 emissions (0.44 million metric tons). In addition, the electric train mode CO_2 emissions per passenger-km were 32 percent of those of the road motor vehicle or a reduction of 859,677 metric tons per year (0.86 million metric tons). As a result, the application of commuter rail will decrease the CO_2 emissions by 35 to 68 % in Mississippi Gulf Coast counties depending upon the rail power technology. Additionally, the passenger rail service will improve air quality for the Gulf Coast communities.

3.5   Commuter Rail Service Operation and Asset Management for Rail Infrastructure

Asset Management for Passenger Rail Infrastructure
Asset Management System (AMS) technology is used to maintaining infrastructure assets at desired level of service at the lowest life-cycle cost (Uddin et al. 213). This framework includes development of GIS database for inventory, traffic and usage history, and condition monitoring. Using a set of decision and maintenance intervention criteria it helps to the timely application of choosing the best appropriate rehabilitation, repair, or replacement an asset at least present worth life cycle cost in regards to. This AMS framework is being widely adapted to aid in achieving sustainable infrastructure, primarily in transportation. The EPA states (EPA 2012): "A high-performing asset management program incorporates detailed asset inventories, operation and maintenance tasks, and long-range financial planning to build system capacity, and it puts systems on the road to sustainability."

Some of the benefits of asset management are as follows (EPA 2012, Uddin et al. 2013):
- Prolonging asset life and aiding in rehabilitation, repair, and replacement decisions through focused operations and maintenance.
- Meeting consumer demands with a focus on system sustainability.
- Budgeting focused on activities critical to sustained performance.
- Meeting service expectations and regulatory requirements.
- Improving responses to emergencies and natural disasters.
- Enhancing security and safety of assets.
- Reducing overall life cycle costs for both operations and capital expenditures.

Utilizing these strategies to the proposed commuter rail can help ensure a minimum life-cycle cost and possibly reducing the breakeven year.

There are many software options available to help aid in the implementation of asset management systems and the development of sustainable transportation systems. One of those programs is the Transit Asset Prioritization Tool (TAPT). TAPT is used to model rehabilitation and replacement needs for transit capital assets. The tool supports a wide range of different asset types, from BRT to light rail to monorail. This tool uses the data on an existing asset inventory, and predicts future conditions and performance, and helps prioritize asset rehabilitation and replacement. The tool includes models for vehicles and non-vehicle assets which can be modeled based on asset age or condition (TCRP 2012). This could be a useful tool for the proposed Mississippi Gulf Coast commuter rail system to help minimize the life-cycle cost and help provide more sustainable passenger transportation.

Relevance to MDOT Multiplan Report

MDOT's "Multiplan" report documents "Mississippi's Unified Long-Range Transportation Infrastructure Plan" (MDOT 2011). Multiplan's 2035 goals are:
1. *Accessibility and Mobility:* Improve Accessibility and Mobility for Mississippi's People, Commerce and Industry
2. *Safety:* Ensure High Standards of Safety in the Transportation System
3. *Maintenance and Preservation:* Maintain and Preserve Mississippi's Transportation System
4. *Environmental Stewardship:* Ensure that Transportation System Development is Sensitive to Human and Natural Environment Concerns
5. *Economic Development:* Provide a Transportation System that Encourages and Supports Mississippi's Economic Development
6. *Awareness, Education and Cooperative Processes:* Create Effective Transportation Partnerships and Cooperative Processes that Enhance Awareness of the Needs and Benefits of an Intermodal System
7. *Finance:* Provide a Sound Financial Basis for the Transportation System

The implementation of a passenger/commuter rail could potentially meet all of the "Multiplan" goals. Financially any mass transit alternative is a large cost up-front, but commuter rail alternative is economically viable within eight years and very beneficial over the course of time.

Implementation Statement

With the growing population of Mississippi, over a 15% increase from 1990-2010, the state could benefit from the addition of a passenger rail line. With the growing population, along with shifting economic trends, a passenger rail would be able to alleviate some of the burden of traffic congestion from single occupancy vehicles commuting through I-10 and US-90 highway corridors. This could also be beneficial to the consumer financially with the future rise in price of fuel. From an environmental standpoint, less fossil-fuel vehicles on the roads would mean a decrease in harmful air pollutants and CO_2 emissions. It is estimated that 0.86 million metric tons). As a result, the application of commuter rail will decrease the CO_2 emissions by 35 to 68

% (0.44 million metric tons for diesel trains and 0.88 million metric tons for electric train) in Mississippi Gulf Coast counties depending upon the rail power technology.

The project viability is evident from the key results of the economic impact study where the commuter rail lines can operate on profit within two years of full operation. Additional benefits include providing safe driving alternatives of "*Casino Train*" to casino patrons on the Mississippi Gulf Coast which accounted for 14.8 million patrons in 2012 and 52% of all gaming associated revenue in Mississippi. The recommended "*Casino Train*" in E-W corridor rail will enhance highway safety by reducing number of automobiles and save lives considering the reduction in alcohol related driving accidents since the rejuvenation of the coast nightlife and casino business. The support of all the cities, public, and employers in the corridor will be essential. There is a dire need for the restoration of the passenger rail service as shown by the return on passenger rail infrastructure investment, which is important to secure federal and non-federal funding, as well as Public-Private-Partnership (PPP) funding mechanisms.

4.   RESEARCH PRODUCTS AND IMPLEMENTATION STATEMENT

4.1 Publications and Presentations

Publications and Presentations

A paper on traffic microsimulation conducted for the Mississippi DOT project, based on the thesis of a former M.S. student, was published in an international peer-reviewed ATS journal.

(This Miss DOT project won the 2014 AASHTO award of Sweet Sixteen projects.)

Graduate M.S. Report/Thesis and PhD Dissertation

Ahlan, Muhammad. (2014). Geospatial Applications for Mobility, Travel Demand, Transport Infrastructure, and Associated Impacts on the Environment. M.S. Graduate Report, University of Mississippi, December 2014. (Advisor: Dr. W. Uddin)

Cobb, Seth. (2015). Economic Viability and Societal Benefits of Integrated Multimodal Freight Corridors and Sustainable Passenger Transportation. M.S. Thesis, University of Mississippi, August 2015. (Advisor: Dr. W. Uddin)

Additionally, the following publications/papers/conference presentations are related to the goals of NCITEC projects:

(One book, one book chapter, one journal paper and two papers in refereed published conference book/online proceedings, four papers in conference proceedings, and eleven other conference presentations)

Book Published

Uddin, W., W.R. Hudson, and Ralph Haas (2013). *Public Infrastructure Asset Management*. McGraw-Hill, ISBN 0071820116. (Book published, July 2013) This second revised and expanded edition of our 1997 *Infrastructure Management* book includes several new sections on flood disaster examples, rapid flood impact assessment using remote sensing imagery and geospatial technologies, and examples of life cycle benefit cost analysis for flood disaster mitigation and protection of built infrastructure.

Other new topics include supply chain management, use of remote sensing imagery and geospatial technologies, asset management practice for transportation and other lifeline public infrastructure, and value engineering applications for investment decision making.

Book blog post. http://infrastructureglobal.com/dr-robert-khayat-ole-miss-chancellor-emeritus-infrastructure-improvement-cannot-be-delayed-if-we-are-to-continue-as-a-vital-nation/

YouTube video: http://youtu.be/LiHqJInrFy0

Book Chapter

Uddin, W. (2014). Chapter 23 "Mobile and Area Sources of Greenhouse Gases and Abatement Strategies," in *Handbook of Climate Change Mitigation and Adaptation*, edited by Wei-Yin Chen, John M. Seiner, Toshio Suzuki and Maximilian Lackner, Springer. (Updated Chapter 23 of the 2012 Handbook in December 2014. The reference book is available in 2016). http://www.springer.com/energy/renewable+and+green+energy/book/978-3-319-14408-5

Journal and Refereed Conference Books/Online Proceedings

Mohamed Jaafar, Z.F., Y. Najjar, and W. Uddin. (2016). Asphalt Pavement Roughness Modeling using the Artificial Neural Network and Linear Regression Approaches for LTPP Southern U.S. States. *Compendium, 95th Annual Meeting of Transportation Research Board*, Washington, DC, January 11, 2016. (Peer reviewed)

Uddin, W., McCarty, T., and Sharma, J. (2015). Environmental Sustainability and Energy Considerations for Life-Cycle Analysis of Transportation Infrastructure Systems. *ASCE Special Publication, International Symposium on Systematic Approaches to Environmental Sustainability in Transportation (ISSAEST)*, University of Alaska, Fairbanks, pp. 227-240.

Headrick, Jessica and W. Uddin. (2014). Traffic Flow Microsimulation for Performance Evaluation of Roundabouts and Stop-controlled Intersections at Highway Overpass. *ATS - International Journal of Advances in Transportation Studies*, Issue, XXXIV, November 2014, pp. 7-18.

The above paper on traffic microsimulation is based on a former M.S. student on the Mississippi DOT project. (This Miss DOT project won the 2014 AASHTO award of Sweet Sixteen projects.)

Conference Proceedings and Presentations

Uddin, W. (2016). Pavement Design, Construction & Condition Management– Lessons Learned. *9th Airfield Engineering and Asset Maintenance Summit Conference*, Dubai, UAE, February 1-4, 2016. (Invited lecture, full travel support by the Organizers)

Durmus, Alper and W. Uddin. (2016). Assessing Structural Integrity of Bridge Superstructure Subjected To Extreme Flood Simulation. Bridge Data Analysis Working Group (BDAWG) Forum on Pavement Data Analysis, *95th Annual Meeting of Transportation Research Board*, Washington, DC, January 9, 2016. (Peer reviewed)

Mohamed Jaafar, Z.F. and W. Uddin. (2016). Development of Asphalt Pavement Roughness and Rutting Models by using LTPP Database and Considering Maintenance and Rehabilitation History. Data Analysis Working Group (DAWG) Forum on Pavement Data Analysis, *95th Annual Meeting of Transportation Research Board*, Washington, DC, January 9, 2016. (Peer reviewed)

Uddin, W. (2015). Flood Modeling & Evaluation of Impact in Infrastructure. Panel on

Innovated Technological Trends in Highways, *9th Congress and Exhibition, CBR&C 2015 and BRASVIAS 2015*, ABCR – The Brazilian Association of Highway Concessionaires, Brasília, Brazil, September 14 – 16, 2015. www.cbrcbrasvias.com.br www.abcr.org.br (Invited lecture, full travel support by the Organizers)

Uddin, W., McCarty, T., and Sharma, J. (2015). Environmental Sustainability and Energy Considerations for Life-Cycle Analysis of Transportation Infrastructure Systems. Presentation, *International Symposium on Systematic Approaches to Environmental Sustainability in Transportation (ISSAEST)*, University of Alaska Fairbanks, August 2-5, 2015, Fairbanks, Alaska.

Uddin, W. (2015). Appraisal of Mechanistic-Empirical Pavement Design Guide for Highways Being Implemented in United States and Complimentary Needs for Pavement Asset Management. *6th ICONF BMP, 6th International Conference Bituminous Mixtures and Pavements*, Aristotle University of Thessaloniki (AUTh), June 10-12, 2015, Thessaloniki, Greece.

Uddin, W, Altinakar, M.S. and Durmus, A. (2015). Extreme Flood Simulations to Assess Inundation Impacts and Structural Integrity of Transportation Infrastructure Assets. *The 2015 Critical Infrastructure Symposium*, The Infrastructure Security Partnership (TISP) and the Society of American Military Engineers (SAME), April 20-21, 2015, Baltimore, Maryland.

Altinakar, M.S., M. McGrath, V.P. Ramalingam, and W. Uddin. (2015). Two-Dimensional Flood Modeling for the Assessment of Impacts on Critical Infrastructures. *University Transportation Center (UTC) Conference for the Southeastern Region*, University of Alabama at Birmingham. Birmingham, Alabama, March 26-27, 2015. (presented by Altinakar and Uddin, regional UTC conference)

Durmus, A., Nguyen, Q., McGrath, M.Z., Altinakar, M.S., and Uddin, W. (2015). Numerical Modeling And Simulation of Extreme Flood Inundation To Assess Vulnerability of Transportation Infrastructure Assets. *University Transportation Center (UTC) Conference for the Southeastern Region*, University of Alabama at Birmingham, March 26-27, 2015, Birmingham, Alabama.

Uddin, W., Cobb, S., Sherry, P. and Eksioglu, B. (2015). Economically Viable Intermodal Integration of Surface and Waterway Freight Transport for Sustainable Supply Chain. *University Transportation Center (UTC) Conference for the Southeastern Region*, University of Alabama at Birmingham, March 26-27, 2015, Birmingham, Alabama.

Durmus, A., Q. Nguyen, M.Z. McGrath, M.S. Altinakar, W. Uddin. (2015). Numerical Modeling and Simulation of Extreme Flood Inundation to Assess Vulnerability of Transportation Infrastructure Assets. *94th Annual Meeting of the Transportation Research Board*, The National

Academies, Washington DC. TRB Online Proceedings, January 10-14, 2015. (published and presented by Uddin, international conference)

Uddin, W. (2015). Aircraft Safety on Airfield Pavements with Standing Water and Slush. Workshop 143- Influence of Airfield Surface Irregularity on Aircraft Life, *94th Annual Meeting of The Transportation Research Board*, Washington, DC, January 10-15, 2015.

Uddin, W. and Zul Fahmi M. Jaafar. (2013). Achieving sustainability without compromising long-term pavement performance for road infrastructure assets. *Online Proceedings, First Conference, 2013 IJPC - International Journal of Pavements Conference*, São Paulo, SP, Brazil, December 9-10, 2013. http://www.ijpavement.com/2013-ijpc-papers/

Uddin, W. (2013). Geospatial Technologies for Highway Asset Management and Natural Disaster Risk Reduction Planning. keynote lecture, *2013 IJPC - First Internal Journal of Pavements Conference*, São Paulo, Brazil, December 9-10, 2013. (This trip was at no cost to the project. Dr. Uddin was an invited guest of the conference organizer professors from Mackenzie University, São Paulo, Brazil, who co-chaired the 2013 IJPC conference.)

Uddin, W. and M.S. Altinakar. (2013). NCITEC Project 2012-25: Disaster Protection of Transport Infrastructure and Mobility Using Flood Risk Modeling and Geospatial Visualization–Overview and Progress to Date. Presentation of project overview, *First NCITEC conference*, Starkville, Mississippi, October 31-November 1, 2013. (Attended by the NCITEC consortium partners including UM project PIs, faculty, and students)

Non-peer Reviewed Publications
Uddin, W. Sherry, Patrick, and Eksioglu, Burak. (2014-2015). Economic Viability of Mississippi Gulf Coast Rail Service Revival. White paper proposal for commuter rail initiative on the Mississippi Gulf coast, Updated November 11, 2015. (Presented to several folks interested in this topic for their feedback. It is posted on CAIT/NCITEC web page and SlideShare). http://www.slideshare.net/waheeduddin/mississippi-gulf-coast-rail-revival-ncitec-white-paper-background-cait

Honors and Awards
Dr. W. Uddin:
- 2015 Senior Research Award, School of Engineering, University of Mississippi
- 2014 inductee of the University of Texas CAEE Academy of Distinguished Alumni
- 2014 Life member, American Society of Civil Engineers (ASCE)
- Mississippi Transportation Institute (MTI), member of Board of Directors since March 2014
- Gulf Region Intelligent Transportation Society (GRITS), member of Board of Directors, 2009-2012

- Invited member of European project COST Action TU1208 "Civil Engineering Applications of Ground Penetrating Radar," coordinated by "Roma Tre" University, Rome, Italy, since 2012.

Students
- Holt, Elizabeth. (2015). Benefits of highway and Rail Intermodal Integration for NAFTA Supply Chain Corridors. Paper for 2015 ITE Paper Competition, Institute of Transportation Engineers District 5, March 2015. Best Undergraduate Paper 1st District Award (certificate and cash award)
- Sims, Haley. (2014). Impacts of Rapid Urbanization on Transport and Energy Demands along the Mississippi River Transportation Corridor. Paper for 2014 ITE Student Paper Competition, Institute of Transportation Engineers District 5, February 2014. Outstanding Undergraduate 1st Place District Award (certificate and cash award).

4.2 Research Products and Technologies

The project objective was accomplished by using spaceborne remote sensing and geospatial technologies for mapping and visualization of Gulf Coast counties and cities, transportation corridors and connecting major city hubs. Geospatial databases were created by CAIT research team for transportation networks in Mississippi. The following research products were created to accomplish project objectives, which can be used for future traffic flow, freight, supply chain, and natural disaster resilience related research projects:

- *Geospatial database and spatial maps*: For highway and rail networks in Mississippi, travel demand data, and economic data for the three counties of Mississippi on the Gulf Coast.
- *LCA Program for rail-highway integration evaluation*: Another project product is a simple-to-use computer spreadsheet program that incorporates value engineering application of life cycle assessment benefits and costs for passenger rail and multimodal highway alternatives. The program is designed for present worth analysis considering all agency costs, economic cost and travel time saving and economic benefit streams, traffic flow models, and present worth LCA methodology. It has default data from the Gulf Coast passenger rail corridor study. Additionally, Excel templates files include comprehensive analysis of travel time, out-of-pocket costs, and CO_2 emission.
- *Best Practice Guide for Commuter Rail*: The white paper on the Gulf Coast Rail Revival Study for Economic Viability serves as the "best practice guide" for consideration by government transportation agencies, private transport operators, rail companies, cities, and other bus transit and rail stakeholders. The last update of the white paper was on November 11, 2015. (The project news story and the white paper are included in Appendix.) http://www.olemiss.edu/projects/cait/ncitec/NCITEC-WhitePaper-GC.pdf http://news.olemiss.edu/um-engineering-partnership-producing-problem-solving-research/

- *Other products*:

  The following ACCESS databases were created using Intergraph's GeoMediaPro geospatial software but it can be exported to other geospatial/GIS programs:
    - 2014 United States All (including Alaska and Hawaii)
    - 2013 Buffer of Mississippi-River-States
    - 2014 State of Mississippi spatial maps for rail and highway network, county population, cities and travel demand
    - 2014-2015 Gulf Coast spatial maps for commuter rail and mono rail alignments
    - US-Mexico-Canada Geospatial database of NAFTA transportation networks
    - 2014 Word spatial map (includes Tibet and new countries of Timor and South Sudan)
    - 2015 South America and Brazil buffers; Amazon forest region; and two major urban areas of Rio de Janeiro and Sao Paulo

  These databases include the 2010 population data of states and counties; highway and rail inventory maps of US-Canada- Mexico. Examples are provided in the final report of NCITEC Project 2012-27 (Uddin et al. 2016). Several examples of spatial maps created on the Gulf Coast Passenger Rail project are included in previous chapters.

The following transportation agencies, industry organization and businesses are possible stakeholders for mass transit infrastructure and services who can benefit by using the above research products and white paper:
  - Mississippi DOT planning division and intermodal and rail/transit offices
  - Gulf Coast Transit Authority (CTA) providing bus transit services to the City of Biloxi, the City of Gulfport. and Harrison County on the Mississippi Gulf Coast
  - Cities of Gulfport Port and Biloxi; Port Authority of each of these cities
  - Oxford-University Transit (OUT) service, Oxford, Mississippi
  - The National Railroad Passenger Corporation (Amtrak)
  - USDOT Federal Highway Administration (FHWA), Federal Rail Administration (FRA)
  - American Public Transportation Association (APTA)
  - National Association of Railroad Passengers (NARP)
  - CSX Rail and other rail operators; Association of American Railroads (AAR)

4.3 Overall Benefits of Sustainable Commuter Rail Transit

Environmental Benefits

The project viability is evident from the key results of the economic impact study where the commuter rail lines can operate on profit within two years of full operation. Additional benefits include providing safe driving alternatives of "Casino Train" to casino patrons on the Mississippi Gulf Coast which accounted for 14.8 million patrons in 2012 and 52% of all gaming associated revenue in Mississippi. The recommended "Casino Train" in E-W corridor rail will enhance

highway safety by reducing number of automobiles and save lives considering the reduction in alcohol related driving accidents since the rejuvenation of the coast nightlife and casino business.

From an environmental standpoint, less fossil-fuel vehicles on the roads would mean a decrease in harmful air pollutants and CO_2 emissions. It is estimated that 0.86 million metric tons). As a result, the application of commuter rail will decrease the CO_2 emissions by 35 to 68 % (0.44 million metric tons for diesel trains and 0.88 million metric tons for electric train) in Mississippi Gulf Coast counties depending upon the rail power technology. Additionally, the passenger rail service will improve air quality for the Gulf Coast communities.

Other Societal Benefits
The project is likely to make an impact on the public and society beyond the bounds of science, engineering, and the academic world on areas such as:
- Enhancing public understanding of supply chain transport impacts on urban communities and the environment through visualization products which are easy to understand and communicate with government stakeholders, businesses, media, and the general public.
- Adapting the developed approaches for supply chain infrastructure, intermodal corridor integration, and logistics, and traffic demand management.
- Offering geospatial products for landuse planning, traffic flow control policies, and pavement safety evaluation for roads, airports, intermodal pavements, container parking, and ports.
- Implementing the developed methodologies and web-based social networking tools to build a better public understanding of sustainable supply chain management and reduce degrading effects on the environment and communities
- Recommending new approaches of financing resources for infrastructure investments to reduce severe backlogs due to inadequate federal and state funds.

4.4 Recommendations and Future Work

It is recommended that Mayors association and businesses on the Gulf Coast, transportation infrastructure agencies, passenger rail service, and freight rail stakeholders consider the research products developed in this project and benefits outlined to address the mobility needs, funding deficit and reduction in transportation related anthropogenic carbon emissions. The integrated intermodal highway-rail infrastructure networks can be managed as a PPP enterprise so that each team player works in a complementary spirit and not competing as rail and highway auto modes do now for serving mobility needs of the public, commuters, employers, and supply chain businesses.

It is recommended that the ANN modeling methodology be used in a future detailed rail transit study to predict the revenue streams for future 10 years so that the predicted benefits can be used for more accurate analysis of present worth life cycle costs and benefits. Note that in the current

study, the indirect benefit, such as sales tax revenue, is assumed at its 2012 value for future years. An accurate modeling can increase present worth benefits and lead to an earlier breakeven year.

Additionally, a pilot field study will be useful for harvesting of lost energy of vibrations from train-rail operations, as shown in the laboratory research in another NCITEC project 2013-31 by McCarty and Sharma (Uddin et al. 2015).

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APPENDIX

"Ole Miss Engineer" News Story on Gulf Coast Rail Project

White Paper on Revival of Gulf Coast Passenger Rail Service

FULL SPEED AHEAD

Transportation research drives Gulf Coast intermodal integration

BY LINDSEY ABERNATHY

Two University of Mississippi civil engineering students' work in the School of Engineering's Transportation Modeling & Visualization Laboratory could help shape the future of rail transit on the Mississippi Gulf Coast and intermodal freight corridors in the U.S.

Seth Cobb, a senior from New Albany, and Haley Sims, a junior from Ridgeland, work as research assistants for civil engineering professor Waheed Uddin, director of UM's Center for Advanced Infrastructure Technology (CAIT). The students contribute to geospatial research and mapping for two projects for the National Center for Intermodal Transportation for Economic Competitiveness.

"We both took a class in geospatial analysis taught by Dr. Uddin, which is mapping software on the computer," said Cobb, who has worked in the lab since fall 2012. "We create maps with the data that they [Uddin, undergraduate and graduate students] gather so that you can easily see and understand it for spatial analysis."

Cobb and Sims are part of a project team that seeks to identify major transportation corridors involving shipping ports, Mississippi River waterways, highway networks and rail infrastructure. In addition, the team seeks to evaluate the economic viability, safety, disaster resiliency, revenue and funding aspects of integrated, selected segments of the corridors. Because U.S. companies spend trillions of dollars a year on

This map shows the major cities and transportation corridors along the Mississippi Gulf Coast.

freight logistics, the project's findings could prove valuable.

"Normally most of the freight transport is being moved by trucks on highways," Uddin said. "They are not very good at going long distances between states because they take space on the road, especially near urban areas. There's also a problem with safety, fuel consumption and emissions. We're trying to find the optimum way for freight transport by intermodal integration."

The students also work on a project that is evaluating the economic impact of restoring a passenger rail service on the Gulf Coast. The rail service, which used to serve the coast tri-weekly, was suspended after Hurricane Katrina hit the area in 2005. Since then, auto and freight traffic volume has continued to increase on I-10 and the U.S. 90 coastal highway, and is expected to grow. The project would integrate commuter rail travel with auto traffic to ease the auto

travel demand on existing coad corridors, offer economically competitive and safer travel, and reduce air pollution.

"We're getting all of the data and showing all the different information to hopefully get [the rail] reopened," Sims said. "We're taking it from the angle of making commuter rail attractive and economically viable for the region so that people within this corridor and commuters from surrounding counties can use the rail to travel to work, and that will take more traffic off of the highways."

Uddin said that in addition to offering a commuter rail service, another option would be to service the casinos on the coast, providing safe transport to and from the casinos and keeping more vehicles off the roads, which would reduce congestion and auto emissions.

Uddin said that the students are impressive both in the lab and in the classroom. In addition to working 20 hours weekly in the transportation lab, both
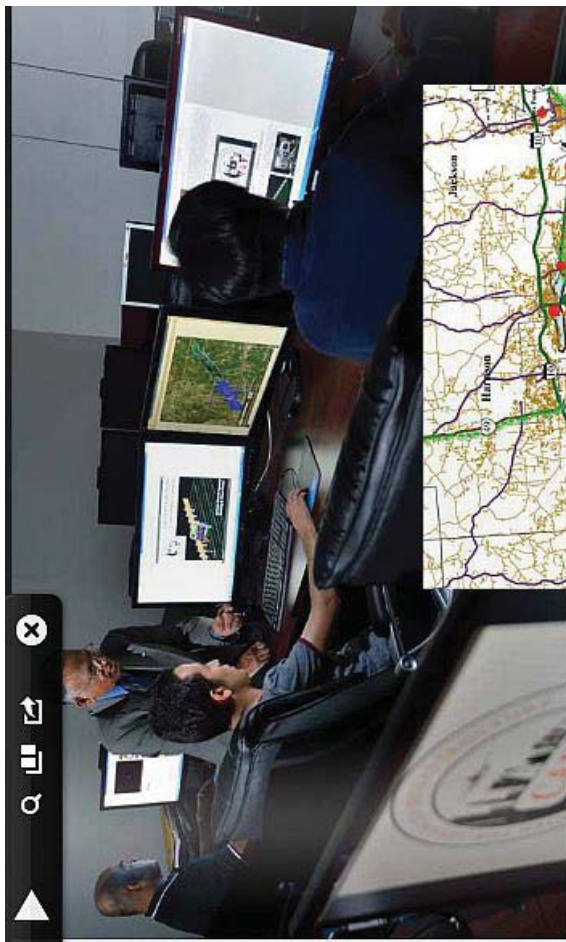
Sims and Cobb have worked on other hands-on projects.

Cobb's term project for Civil Engineering 570 included spatial maps of the Oxford-University-Transit (OUT) routing and asset management using a new research analysis tool developed by a transit research project of the U.S. National Academies. At the end of the project, the transit software consultant used Cobb's evaluation to enhance the product.

"I did a term project on the OUT buses, and Dr. Uddin was given an infrastructure software that allows you to insert your fleet information and evaluate when you will need maintenance on your fleet, your budget and all the economic factors and emission factors," Cobb explained. "It was a new kind of software that hadn't been used. I used it in my class project, and we wrote a review of things that were wrong so they could use it to make corrections."

In April, Sims won first place from the Institute of Transportation Engineers for the best undergraduate paper in the Deep South section and ITE Southern District. For the paper, Sims analyzed carbon dioxide emissions from states bordering the Mississippi River.

"I did the paper based on a term project from the geospatial course of Dr. Uddin," Sims said. "I wanted to use that research, but I obviously needed to direct it toward something transportation-based, so I did more research and it turned into the impacts of rapid urbanization on the transportation and energy demands of these 10 states."

The students use GeoMedia Pro software for geospatial mapping that has been provided by Intergraph Corp. to CAIT since 2005 at no cost.

"It just takes tons and tons of amounts of information and makes it visual, so you can look at a map and know that [the] state of Louisiana had over 200 million tons CO_2 emissions," Sims said. "It helps people be able to look at it and understand a little bit better what we do, as opposed to looking at a bunch of numbers."

Sims and Cobb said that Uddin's research focuses primarily on Mississippi,

'Casino' train for East-West corridor and 'Beach' train for North-South corridor proposed for Mississippi Gulf Coast. (map produced by CAIT Transportation Modeling & Visualization Lab)

and they enjoy being involved in work that may actually help the state.

"He really likes to do anything that can help Mississippi," Cobb said. "Mississippi is the primary focus on any of the projects that we do, and then we can expand from there."

Upon graduation, Cobb will pursue a Master of Science degree at UM and will continue contributing to transportation research projects. Sims plans to continue her education, either through graduate school, law school or by entering the workforce and pursuing her professional engineer's license.

"I'm so excited about these two students," Uddin said. "With me, students have to work from day one on research. Hopefully the work they've done with me will help them land better jobs." ✦

"We're taking it from the angle of making commuter rail attractive and economically viable for the region so that people within this corridor and commuters from surrounding counties can use the rail to travel to work, and that will take more traffic off of the highways." –Haley Sims

Economic Viability of Mississippi Gulf Coast Rail Service Revival

NCITEC Mississippi State University

CAIT The University of Mississippi

NCIT University of Denver

November 2015

WHITE PAPER

Economic Viability of Mississippi Gulf Coast Rail Service Revival

Background and Research Needs:

Major problems with Mississippi Gulf Coast cities include the following: high congestion on highways during peak hours, increased volume of commercial traffic and safety risks to other auto motor traffic, high level of vehicle emissions, and lack of public transportation options for the underserved. Coastal communities face extreme traffic congestion during hurricane evacuations, which is a major hurdle for federal, state and local emergency management agencies. The ultimate long-term solution for these major problems of the Mississippi Gulf Coast is to implement an efficient rail system, which can reduce auto traffic on roads, traffic congestion on major highways, safety risks, and vehicle emissions. The primary objective of this project and white paper is to propose sustainable rail strategies for serving commuters transportation to major employers and patrons/visitors to casinos, beaches, and other places of tourist attraction within the coastal highway corridors. The recommended passenger rail strategies are intended to maximize their benefits and efficiencies compared to the current highways and roads, which are the only means of mobility in the Mississippi Gulf Coast cities. This project focuses on passenger mobility needs of Mississippi Gulf Coast cities, surrounding communities, and government and private employers. The proposed commuter rail framework integrates passenger rail service for commuters in the Gulf Coast counties and visitors with local economies.

According to the 2012 Census data for Mississippi, about 82% of auto traffic is reported in the Gulf Coast counties and 11-13% of person-trips by car/van pool. Transit bus trip share per county was 0.02% in Hancock, 0.89% in Harrison, and 0.32% in Jackson County. The existing Coastal Transit Authority (CTA) operates its fleet of 29 buses mostly in Harrison County. Typically over 49,000 vehicles travel daily on I-10 just east of the Mississippi state line and similarly over 46,000 vehicles per day traffic volume is reported at the western state line. Daily traffic volume swells to over 57,000 on I-10 in Harrison County and over 125,000 combined on I-10, I-110, and US-90 highways in Harrison County. This indicates the large number of trips made within the three coastal counties. Using a utility function of trip shares for auto versus commuter rail, it is estimated that 10% vehicle trips or up to 34,000 vehicle users in these counties can potentially use commuter rail service at competitive fare costs. The Mississippi DOT's strategic planning reports indicate that most of the Interstate-10 corridor through these counties has average speeds (in both directions) at or below 55 mph (88 kmph) that is 21% lower than the posted speed of 70 mph (112 kmph). The report indicates significant traffic congestion during rush hours. This leads to fuel wastage and increased travel time by auto road users, as well as driving stress and public health hazards associated with harmful vehicle emissions. Commuters using rail service will not worry about road congestion and driving stress.

The Amtrak sunset service from Miami to Los Angeles through New Orleans served the Mississippi Gulf Coast triweekly during nighttime hours. The Amtrak sunset service was first interrupted in 1993 after the worst rail disaster in Amtrak history. The Amtrak passenger rail service was suspended during the 2005 Hurricane Katrina disaster due to destruction of the rail infrastructure. This nightly service served 53,300 passengers annually or about 1,025 passengers per week. It did not serve regular commuters similar to the daily commuter rail services operated between NY-NJ/DC, Detroit-Chicago, and counties around Chicago. Currently, Amtrak coastal rail is not operational through Alabama and Mississippi, therefore taking away a valuable public transportation mode for the underserved and/or vacationers to casinos and beaches. Next, technical feasibility and economic competitiveness evaluation are presented for alternative strategies of passenger/commuter rail service in East-West (E-W) Coastal corridor south of I-10 and North-South (N-S) Corridor along east of US-49. These rail

corridors already exist and are used by freight train lines. The commuter rail service will be implementable through shared used agreements with the freight rail operators.

Key Results and Recommendations:

A detailed review was undertaken for the existing rail and bus transit technologies being used in several U.S. cities. The study revealed that trams and street rail cars, bus rapid transit (BRT), high-cost light rail transit (LRT) and high-speed rail (HSR) modes are not feasible for the rural area on the Mississippi Gulf Coast due to degradation of highway traffic capacity from lane occupancy and rail track intrusion, as well as added safety risks of mixed multimodal traffic. Consequently, these modes are not technically feasible from value engineering perspectives of functional and safety requirements. Further analysis showed that a dedicated E-W monorail line on elevated guide track infrastructure between I-10 and US-90 highway corridors serving casinos from Biloxi to Gulfport is feasible technically and economically viable in the long term. However, the monorail line is not recommended due to very high initial capita cost. The final recommended passenger rail strategies include: (1) a commuter rail *"Casino Train"* in E-W corridor of the existing CSX rail from New Orleans to Mobile and (2) a second commuter rail line *"Beach Train"* in N-S corridor of the existing KCS rail from Hattiesburg to Gulfport in Mississippi. The two proposed rail services will operate at 60 mph (96 kmph) under agreements with the existing freight rail lines and preferably with rail electrification system. The commuter rail service will have daily operations at each hour during morning and evening peak hours and every two hours in between until midnight. Additional trains will be operated on weekends starting Friday evening to serve casino patrons all the way from New Orleans in the west to Mobile in the east. These recommended rail strategies are intended to reduce auto traffic by up to 34,000 vehicles daily on major highways serving Mississippi Gulf Coast cities.

Table 1 shows other salient features of the value engineering analysis of life cycle costs and benefits of each rail line. There will be one maintenance yard for maintenance and storage, which is included in the cost of E-W commuter rail. The study analyzed county and city commuter data, highway traffic data, capital costs, annual operation and maintenance cost, revenues from fares and advertising, and additional revenue from concessions on stations and shuttle service providers. Other benefits include an increase in income from casino patrons and tourists/visitors, additional gaming and sales tax revenues, and fuel cost savings as a result of moving a significant number of auto commuters to rail lines. Economic development impacts will create total 500 jobs, which can absorb 427 jobs expected to be lost due to the closure of Gulfport shipyard. Table 1 considers only rail related jobs created for each alternative and does not calculate the boost to the state economy by future attracted casino/tourist traffic and potential manufacturing of train stock. The combined capital cost is $562 million and the benefit-cost ratio is one after one year of full operation considering all revenues and economic benefits. Considering direct revenues only (fare, advertising on train and stations, annual fee charges to concessions on stations and shuttle service operators), the breakeven period is 6 to 9 years until the commuter rail service will become financially self-sustaining.

It is estimated that this capital sustainable mobility project will boost Gulf Coast economy because infrastructure spending generally adds up to twice the dollar amount in the region's economy. Figure 1 shows the existing transportation infrastructure and Figure 2 shows the two commuter rail lines serving employers in the region and casinos on the coast. The success of the Gulf Coast rail service lies in integrating passenger/commuter rail with the auto traffic for reasonable daily ridership which can ease auto travel demand on the existing highway corridors, offer economically competitive and safer travel, and reduce air pollution. An average commuter makes the decision of modal choice by comparing the out-of-pocket costs and travel time to destination. Therefore, it will be essential to provide intermodal connectivity by shuttle bus service and employer incentives to use the rail service. Additionally, it will

be crucial to have the support of all cities, the Gulf Coast Planning Commission, Gulfport Port, Mississippi DOT and other public agencies, casino industry, convention and tourism centers, and other employers on the Gulf Coast. States of Alabama and Louisiana will be other stakeholders.

Table 1. Value engineering analysis of life cycle benefits and costs for Gulf Coast rail lines

NCITEC 2013-33: Mississippi Gulf Coast Rail Restoration Study (5% Annual Discount Rate Assumed)				
Rail Alternative	**Commuter Rail E-W**		**Commuter Rail N-S**	
CL Length; Track	200 km; CSX rail track		110 km; KCS rail track	
Rail Infrastructure	6 train stocks; 10 stations		4 train stocks; 3 stations	
Initial Infrastructure Cost	$335.2 Million		$226.9 Million	
Riders per Day	20,000		10,000	
Present Worth Cost-Benefit Analysis	Cost	Benefit	Cost	Benefit
1-Year Present Worth Analysis, $ Million	344	344	230	247.1
5-Year Present Worth Analysis, $ Million	375	1,489	247	1,030
10-Year Present Worth Analysis, $ Million	407	2,656	263	2,110
20-Year Present Worth Analysis, $ Million	450	4,287	286	2,907
50-Year Present Worth Analysis, $ Million	504	6,279	313	5,049
Breakeven Year	Year 1		Year 1	
(Using all revenue sources, fuel saving, and economic benefits)				
Benefit/Cost Ratio	1.0		1.1	
Breakeven Year (considering only direct revenues)	*Year 6*		*Year 9*	
CO_2 Emission reduction (due to less cars on highways):	2,397	Tons per Year	1,253	Tons per Year
Added Sales Tax Revenue Assumed:	Annual 5%		Annual 2.5%	
Annual 10% Added Casino Patrons & Visitors/Tourists:	1.48 Million		(added boost to state economy)	
Total Jobs created from commuter rails:	500		(added economic benefits)	
Data sources: U.S. Census Bureau, American Community Survey 2012; National Transit Database; Mississippi DOT				

The project viability is evident from the key results of the economic impact study (Table 1) where the commuter rail lines can operate on profit within two years of full operation. Considering only direct revenues of fare and concessions/advertisement the commuter rail alternatives for both corridors can reach breakeven within 9 years (Table 1 and Figure 3). Additional benefits include providing safe driving alternatives of *"Casino Train"* to casino patrons on the Mississippi Gulf Coast which accounted for 14.8 million patrons in 2012 and 52% of all gaming associated revenue in Mississippi. The recommended *"Casino Train"* in E-W corridor rail will enhance highway safety by reducing number of autos and save lives considering the reduction in alcohol related driving accidents since the rejuvenation of the coast nightlife and casino business. Moreover, the state and local emergency management agencies and the Mississippi DOT would be able to use the North-South *"Beach Train"* rail for safe mass evacuation of coastal communities in case of a coastal hurricane disaster.

Furthermore, a public-private-partnership (PPP) model of financing and worldwide bid invitation will lead to a new train manufacturing industry in Mississippi. The results of this can be extended to the entire Gulf Coast, from Florida to Louisiana, using the historical demographic and economic data of the region. Reduction of carbon dioxide (CO_2) from reduced number of autos on the area roads and highways will enhance the sustainable operation of passenger rail service on the Gulf Coast. The current effort to establish a high-speed train service in the eastern Atlantic corridor from New York to Jacksonville, Florida will provide access to train passengers in Southern Alabama, Mississippi Gulf Coast and Louisiana. This is possible if Florida extends the commuter rail service from Jacksonville to

Panama City and connects to Mobile, the eastern terminal of the proposed commuter rail service. Similarly, train passengers from Chicago and St. Louis to New Orleans on the existing Amtrak line will have easy train access to the Mississippi Gulf Coast, Alabama, and Florida. The proposed Gulf Coast rail revival will increase the Amtrak ridership too. Active solicitation of the Federal Rail Administration (FRA) funding should be pursued by the states of Mississippi, Alabama, Florida and Louisiana to accomplish the revival of this E-W coastal rail network from Panama City to New Orleans, which will increase economic benefits to all four Gulf Coast states.

Figure 1. Existing transportation infrastructure on Mississippi Gulf Coast (GoogleEarth image)

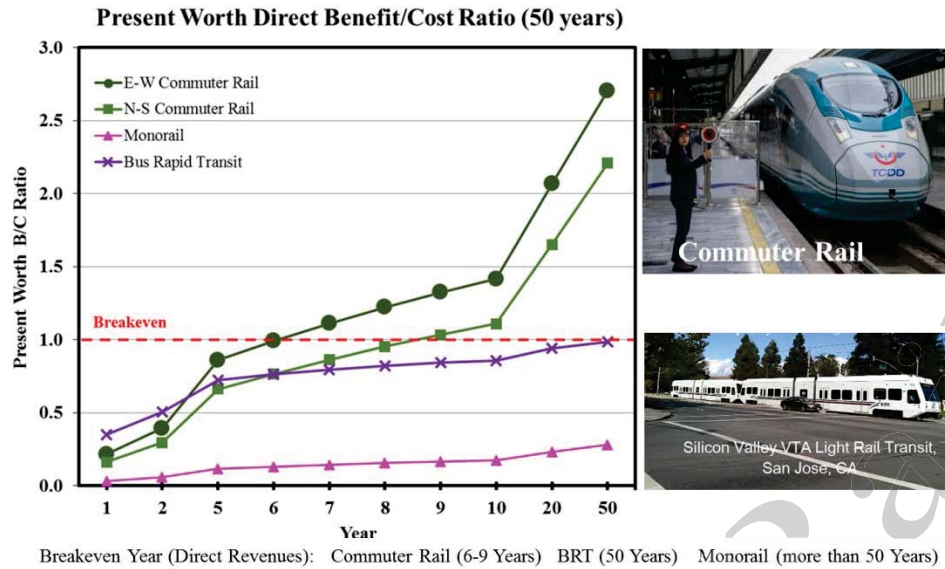Figure 2. Proposed E-W *"Casino Train"* and N-S *"Beach Train"* commuter rail lines

Figure 3. Life cycle economic analysis of breakeven years using mass transit alternatives for Mississippi Gulf Coast

Highlights of Gulf Coast Commuter Rail Revival:

The commuter rail service will be financially self-sustaining in 6 to 9 years based on annual direct revenues.

Casino Train, E-W	*Beach Train, N-S*
• *"Casino Train"* in E-W corridor of the existing CSX rail from New Orleans to Mobile	• *"Beach Train"* in N-S corridor of the existing KCS rail from Hattiesburg to Gulfport
• Sustainable mobility for up to 34,000 vehicle users	• Service for coastal residents to employers in north
• Reduction in traffic congestion on I-10 & US-90	• Reduction in emissions and public health hazards
• Safe travel alternatives for casino patrons from within the coastal counties, New Orleans, and Mobile	• Safe mass evacuation of coastal communities in case of a coastal hurricane disaster
• Increase of 1.48 million casino patrons & revenue	• Total 500 new jobs and boost to regional economy

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