A GIS-ORIENTED METHOD TO INVESTIGATE REGIONAL ECONOMIC IMPACTS CAUSED BY DISRUPTIONS IN TRANSPORTATION NETWORK

Rodrigo A. A. Nobrega
Bethany Stich
Di Miao
Charles O'Hara
Joseh Holland
Mississippi State University
Geosystems Research Institute

RESUMO
Economia e Transportes são setores correlacionados. Investimentos em Transportes devem considerar necessidades e oportunidades para promover desenvolvimento econômico. Este estudo retrata em uma abordagem moderna o relacioamento dessas duas areas usando dados reais econômia e cenários hipotéticos de rupturas em estruturas criticas de transportes. A pesquisa foca a indústria de móveis, responsável por larga parcela da receita no Mississippi. A presmissa é que o re-roteamento não planejado no sistema ferroviário que serve a indústria de móveis contribuirá para aumentar a crise econômica regional. Um modelo de análise geo-espacial composto por dados ferroviários e socio-econômicos foi elaborado para identificar rotas alternativas de transporte de modo efetivo. Os resultados mostram significativo aumento nas distâncias e o isolamento de regiões geográficas em resposta à ruptura de segmentos em diferentes cenários. A capacidade saturada da malha ferroviária em uso e as lacunas geográficas estimulam a revitalização de ferrovias existentes, porém não utilizadas no Mississippi.

ABSTRACT
Economy and Transportation are correlated fields. Investments in transportation must carry out needs and opportunities for economic development. This study encapsulates in a modern approach the relationship among these fields using economic data and hypothetical scenarios for disruptions in Critical Transportation Infrastructures. The research focused on furniture-based industry, which generated one of the largest profits in Mississippi. The assumption is that unplanned re-routing rail freights that serve the furniture will increase regional economic distress. A geospatial framework composed by railroad and socio-economic data was designed to identify alternative routes to flow goods in an economic-effective way. The findings show significant increase in distances and isolated areas as response of disruptions in vital segments. The status of saturation or over-capacity for the existing rails and the significant geographic gaps in the current railroad network are pointed out as great stimulus to revitalize existing rails no longer used in Mississippi.

1. INTRODUCTION

The history reports that significant developments in transportation network have been stimulated by geo-economic development plans. On the other hand, economic development always depends on feasible transportation system to flow people and goods. In a present-day view, transportation hubs attracted a lot of attention, not only those that shape global airline activity networks, but also national and regional intermodal networks to facilitate logistics as well. (Fleming and Hayuth, 1994; Bryan and O'Kelly, 1999; Horner and O'Kelly, 2001).

There is a widespread consensus that economic impacts of transportation are primarily showed through the drop off on construction and operation workforce and the impacts of accessibility change. Firstly, the construction and operation of the transportation facilities could contribute to the economy through direct and indirect job creation. Meanwhile, they develop many economic activities and opportunities that could improve the local income status. In addition, the change of accessibility that is derived from the transportation improvement will generate both direct and indirect impacts as well. The direct impacts refer to the saving of transportation user's costs, such as savings in vehicle operating costs,

reductions in travel time, and savings in accident costs. The indirect impacts are broad. Transportation improvements could lower the price and increase the competitiveness of the local commodities or services, attract the new investment, benefit regional industry development, and increase land value (Lewis, 1991).
As stated in Fletcher (2002), Geographic Information System (GIS) and Remote Sensing technologies play important roles to transportation planning and management from federal to municipal administration levels. GIS/RS have been invaluable in planning strategic responses, developing tactical emergence plans, formulating and carrying out mitigation programs and analyzing incident data for training and policy making processes.

This paper is part of major research investigations on economic development and transportation system. The researches aim to develop rational knowledge-base to support economic growth and revitalization of Mississippian railroads. GIS is a critical technology that enables the research team to capture and address a large variety of spatio-temporal variables to identify reasonable explanation. In a general sense, what is presented in this paper is a compendium of major efforts developed to support investigations on regional economic impacts trigged by changes transportation system. In this paper, the objective is to highlight the rising interdisciplinary efforts on Transportation, Economy and Geospatial Analysis toward the regional economic development in the State of Mississippi. The simulation of re-routing railroad freights follows realistic scenarios of natural and men-made disasters possible in the study area.

2. BACKGROUND OVERVIEW

2.1. Transportation and Economy

Transportation and economy have close relationship in the mutual promotion. Whether the transportation infrastructures are able to satisfy the mobility needs and ensure access to markets and resources positively relates to the economic opportunities. At the macro-economic level, transportation is linked to a level of output, employment, and income. Capital investment on the development and maintenance of transportation infrastructure is one of the most effective strategies that support the productivity growth and shoulder the nation's economic development. At the micro-economic level, transportation is linked to producer, consumer and production costs. According to Rodrigue *et al* (2006), on average, transportation accounts for about ten to fifteen percent of household expenditures and four percent of the costs of each unit of output. Nowadays in especial, the economic system tends to be global and geographic specialized. Such economic setting needs to be supported by an efficient transportation system.

As the economy relies more on the transportation system, an unplanned disruption in the freight-network system could generate larger economic losses, as reported after the Hurricane Katrina and other natural disasters. Therefore, the analysis the vulnerability of the transportation system and the assessment of economic impact due to transportation disruption could provide economic developers, policy makers, and administrators with rich information and valuable recommendations on the future transportation infrastructure design, local development plan, and disaster management. This information enables decision makers to develop proper transportation and economic plans by including the mutual promotion relationship of transportation and economy into consideration. Furthermore, this information could facility the development of a more effective guidance on disaster preparation, immediate response and long-term recovery.

2.2. Critical Transportation Infrastructures

From the operability, planning and logistic perspectives, Critical Transportation Infrastructure (CTI) is a terminology used to emphasize vital components responsible for make the transportation system work. It includes major arterial highways and bridges, international marine harbors; ports and airports; major railroads, terminal and stations; oil and gas pipelines, as well as the transportation control systems such as air traffic control centers and national rail control centers. If a component of a CTI is removed from service without proper planning, it would significantly affect the economic activities, environmental quality and public safety.

Memphis is one of the busiest transportation hubs in USA and perhaps the most complex example intentionally used in this investigation. The area concentrates busy port facilities, a huge cargo airport (FEDEX headquarter), and the junction of the five major rail companies in USA. Moreover, Memphis area is intersected by important highways, which are also used to rapidly distribute goods in Central and South USA. Despite functional, some of the components of the multimodal transportation system are susceptible to failure. CTI, such as the rail bridges that traverse the Mississippi River are vulnerable to natural or men-made events. Certain commodities have to be carried by water and/or railroads, and must be protected against fails or discontinuity in the freight service. Disruptions in such important rail segment could bring severe consequences and collapse the entire federal rail system.

2.3. Vulnerability of CTI to Natural and Anthropogenic Impacts

According Fletcher (2002), a threat to the CTI can be any event, incident or condition that has potential for removing a portion of the CTI or severely degrading its performance for a significant amount of time. Because of the ubiquitous presence in our society, every natural, accidental, criminal or other disruptive event, whether targeted at a transportation facility or not, will have some effect on travel and transportation. Figure 1 illustrates examples disruptions in railroads caused by man-made and natural disasters

Figure 1: Examples of disruptions in rail segments caused by men-made and natural disasters. (left) a rail bridge collapsed after a barge collision in Columbia River-Canada, (center) major damages in a rail bridge in Costa Rica in 1991 caused by liquefaction of soil, (right) CSX rails in the coastal area of Mississippi after hurricane Katrina in 2005.

Understanding the degree of the disasters and their potential risks requires knowledge concerning the geographic context, the patterns of human development and scientific understanding of natural events. Although each disaster is unique, common core information needs can be identified for a variety of CTI scenarios. In this study the authors highlight existing gaps in rail system and investigate how re-route freight can reflect in local economy, which is an exercise to overcome problems faced in the past. Lessons learned from Hurricane Katrina have been used to identify the magnitude of economic losses and strategies for support long term recovery plan..

2.4. The Power of Geospatial Analysis in Transportation

Some the most powerful features in the modern transportation planning processes are the maps portrayed by GIS. The concept is also valid for economic development studies. GIS gives to the users a capability to understand the ending product derived from complex geospatial data analysis. In the regional economic development field, the maps offer visual representation of location and the relationship between cities served by infrastructure transportation such as highways and rails.

GIS are capable of handling large amounts of data (Clevenger *et al*, 2002; and Singleton & Lehmkuhl, 1999), as well as bridge input-output data of existing models (O'Hara *et al*, 2000). For Hill *et al* (2005), the integration of GIS with economic and environmental information in a spatial context is a valuable approach for strategic policy development and decision-making. When coupled with physical or economic models, a GIS may be employed to transform and manipulate spatial and attribute data as needed to express values for evaluation criteria (Nobrega *et al* 2009).

Geospatial analyses have assisted transportation projects in different levels, such as corridor planning, construction, management and maintenance. Most of the current developments of geospatial analysis for transportation are derived from pioneer's efforts, such as: Geospatial Information Systems for Transportation (GIS-T) group, as shown in Miller (1999), as well the U.S. Department of Transportation - Research and Innovative Technology Administration (USDOT-RITA) by promoting the National Consortium on Remote Sensing for Transportation (NCRST) groups (http://ncrst.org/).

The GIS analyzes in this paper are restricted to planning process, where hypothetical interferences in the normal commodity-flow were simulated in order to compute the re-routed scenarios. Re-routing freights can trigger social-economic issues for regions where industry-clusters depend on certain commodities. In this study, the authors focused on the furniture industries installed in Mississippi.

3. STUDY AREA

This work is an exercise developed for the entire State of Mississippi. The study area includes adjacent critical infrastructures of terrestrial and water transportation, such as the rails and ports of New Orleans, Louisiana and Memphis, Tennessee. Mississippi is served by two of the major waterways in USA (Mississippi and Tennessee-Tombigbee systems), as well as significant railroads and highways. The geographic characteristics of the state make it susceptible to natural disasters. In fact Mississippi has historically experienced severe economic and humanitarian losses caused by flooding, hurricanes and tornadoes (Mississippi Emergency Management Agency, 2005). The susceptibility for disputing critical transportation infrastructures and the direct/indirect impacts that it will cause in local

economy have motivate the research. The study area, the rails network and cluster of furniture-based industry are illustrated in Figure 2.

Mississippi's economy is traditionally based on rural activities and lumber; however large manufactures and small businesses have been settled in the state in the recent decades. The density of population is relatively low with just few urban clusters if compared to other states in USA. For the socio-economic perspectives, the State of Mississippi presents significant issues compared to the federal standards. However, this study has been motivated by the interest to understand the positive and negative effects on the socio-economic condition when considering the use alternative rails other than the critical transport system.

Figure 2: The study area: the American railroad and waterway networks (right) and the location of the major furniture industries in the State of Mississippi (left).

4. PORTRAYING ECONOMIC DISTRESS

One of the objectives of this project is to estimate transportation and regional economic impacts due to a disaster. In this study, the economic impacts are demonstrated by the changes of the economic distress status of the region. The definition of the economic distress status is derived from the *Public Works and Economic Development Act of 1965, As Amended* (42 U.S.A.), which is a public law that aims to generate new employment and stimulate industrial and commercial development in the economically troubled areas. Since its establishment, federal government has used this law as the basis to distribute the grants or aid founds to facility the development of economically distressed areas. Economically distressed areas are indentified according to two criteria: 1) "LOW PER CAPITA INCOME– The area has a per capita income of 80 percent or less of the national average.", or 2) "UNEMPLOYMENT RATE ABOVE NATIONAL AVERAGE– The area has an unemployment rate that is, for the most recent 24-month period for which data are available, at least 1 percent greater than the national average unemployment rate.

This study uses the combination of these two factors to show the overall economic distress status of the Mississippi Regions. To this end, step by step, the authors develop a logic

classification matrix to indicate and rank the economic distress status. The first step consisted in categorize Mississippi regions according to their per capita income and unemployment status and assign codes to each category.
In order to portray economic distress for the transportation analysis, thresholds are identified per factor in accordance with the law. By using the thresholds, the economic healthy areas and economic distress areas were identified and sub-classified. Economically healthy areas are classified into the attainment category. On the other hand, the investigation looked close to the regions identified as under economically distressed and further sub-classified economic distress into four categories: competitive, transitional, at-risk and depressed.

Regions, whose per capita personal incomes or unemployment rates are ranked in the best 10 percentile of MS's economically distressed regions, fall in the competitive category. Regions, whose per capita personal incomes are ranked in the 50-90 percentiles or whose unemployment rates are ranked in the 10-50 percentile of MS's economically distressed regions, are recognized as transitional regions. Regions, whose per capita personal incomes are ranked in the 10-50 percentiles or whose unemployment rates are ranked in the 50-90 percentile of MS's economically distressed regions, are classified into the at-risk category. In addition, regions, whose personal incomes or unemployment rates are ranked in the worst 10 percentile of Mississippi's economically distressed regions, are identified as depressed regions. The tables 1 and 2 summarize the classification scheme for unemployment and personal income, respectively. The Figure 3 illustrates the economic distress category classifications, the related codes, and the regional economic distress status.

Table 1: Classification scheme used to map economic distress based on unemployment

Category	Category break	Description	Code
Depressed	13.1-14.8	Regions whose unemployment rates rank in the highest 10 percentile of MS's economic distress	5
At-Risk	10.9-13	Regions whose unemployment rates rank in the 50-90 percentile of MS's economic distress regions	4
Transitional	9.3-10.8	Regions whose unemployment rates rank in the 10-50 percentile of MS's economic distress regions	3
Competitive	9.2	Regions whose unemployment rates rank in the lowest 10 percentile of MS's economic distress	2
Attainment	5.7-9.1	Regions whose unemployment rates are lower than the economic distress threshold, 9.2	1

Table 2: Classification scheme used to map economic distress based on personal income

Category	Category break	Description	Code
Depressed	51.26-59.06	Regions whose personal income rank in the lowest 10 percentile of MS's economic distress regions	5
At-Risk	59.07-65.71	Regions whose personal income rank in the 10-50 percentile of MS's economic distress regions	4
Transitional	65.72-75.85	Regions whose personal income rank in the 50-90 percentile of MS's economic distress regions	3
Competitive	75.86-79.99	Regions whose personal income rank in the highest 10 percentile of MS's economic distress regions	2
Attainment	80-	Regions whose personal income exceeds the economic distress threshold, 80	1

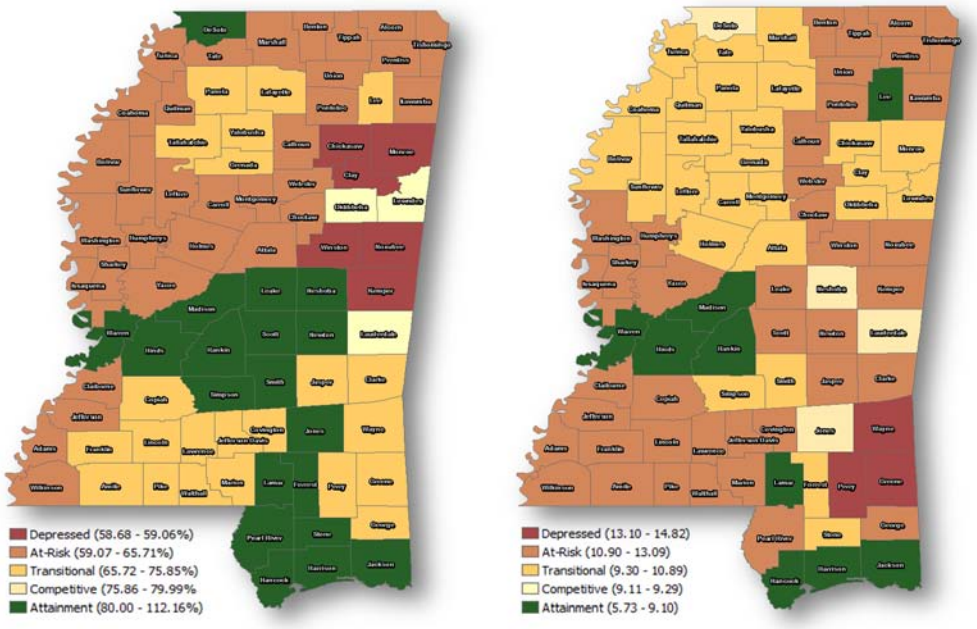
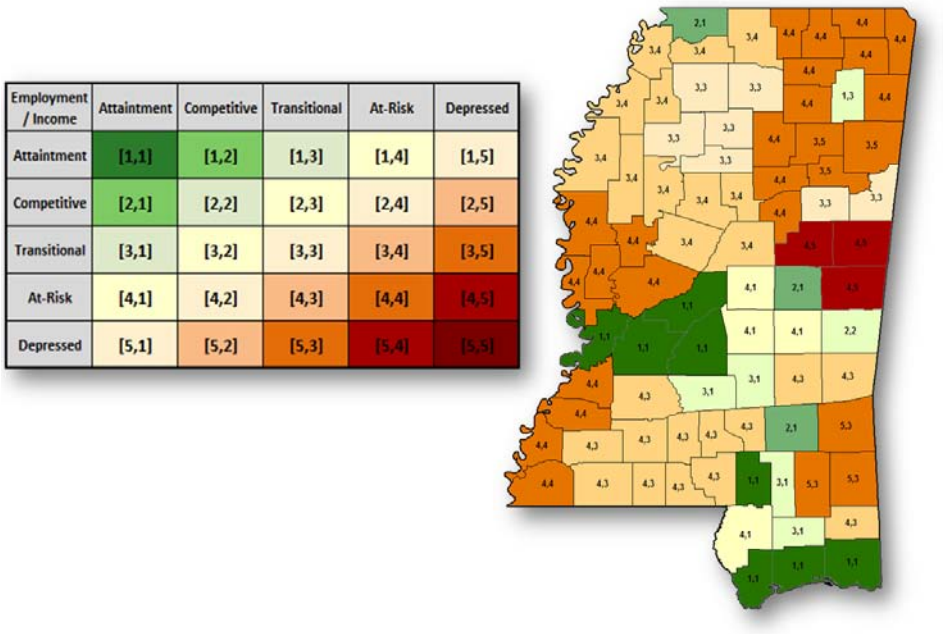


Figure 3: Economic distress of Mississippian counties for the period 2008-2010 based on Personal Income (left) and unemployment (right).

Next, in order to simplify the economic analysis, an economic distress classification matrix is presented by combining the unemployment and income economic distress codes. This classification matrix includes all the combinations of the unemployment and income economic distress conditions and enables each combination to have a unique code that is clear and intuitive (Figure 4). For instance, code 24 stands for the economic distress condition in which the region's unemployment factor is in the competitive category while its income factor is in the at-risk category. Besides the conditions, the matrix also shows the economic distress levels. With codes increasing in number, the severity of economic distress problem increase.



Employment / Income	Attaintment	Competitive	Transitional	At-Risk	Depressed
Attaintment	[1,1]	[1,2]	[1,3]	[1,4]	[1,5]
Competitive	[2,1]	[2,2]	[2,3]	[2,4]	[2,5]
Transitional	[3,1]	[3,2]	[3,3]	[3,4]	[3,5]
At-Risk	[4,1]	[4,2]	[4,3]	[4,4]	[4,5]
Depressed	[5,1]	[5,2]	[5,3]	[5,4]	[5,5]

Figure 4: Comprehensive map and legend that deliver the full information of the degrees and conditions of the regional economic distress status in the state of Mississippi.

The additive sum of codes for both categories provides a useful tool to symbolize overall conditions. Codes that are linked by the same dotted line have the same sum. That indicates that, overall, they are in the same economic distress level. Twenty five codes are classified into nine economic distress levels. Each economic distress level links to one specific color scheme, intentionally designed to facilitate the visualization. Totally, nine color ramps, which is range from green to red, are used to create the map. The use of this classification matrix for shade colors and labels of specific categories enables the team to create a comprehensive map that delivers the full information of the degrees and conditions of the regional economic distress status.

5. INTEROPERATING TRANSPORTATION AND REGIONAL ECONOMIC MODELS

Transportation routing models brings to the table the ability to play with large amount of freight information in a logic and straightforward manner. Freight analyses are indeed vital to establish accurate measurements of goods between origin and destination regarding different modes of transportation. Carriers maintain and update carload information. The commodity-freight information stored in these databases can feed the planning process in different levels of economic and land management analysis.

Because of its importance, the commodity-freight databases often present security issues, and as a consequence this type of data has been used by a restricted audience. This study uses a 2006 Carload Waybill Sample from the Surface Transportation Board (STB). Carload Waybill Sample is stratified data of carloads transported in American railroads per year. The data contain detailed information about rail carriers, commodity, tonnage, origin, destination, among others. In order to meet safety issues as well as narrow the amount of information down, the waybill data was subset. Only the commodity code #25 (Furniture) and derived products were made available for this investigation.

5.1. Disrupting the Railroad Network

This study used a multi-modal re-routing system. The system is non-commercial and was developed by the Center for Transportation Analysis of Oakridge National Laboratory, and it was constructed to simulate routes taken by freight shipments in the US Commodity Flow Survey. In this system, the network is composed of independently constructed single-mode networks for highway, rail, and water, along with a set of intermodal terminals and a terminal model to connect them. The result is a unified routable network, with a single node list, a single link list, and a topology defined by the links' endpoint nodes, a structure common to most network analysis programs (Peterson, 2000). To simulate disruption, the segments are selected in the map, their identification codes are added as constrains in the configuration file. Then, impedances are set to infinite, forcing those segments to be disregarded as network links.

In order to generate feasible railroad disruption situation in Mississippi, five scenarios are presented. The Figure 5 outputs the five situations. The map is color-coded per county served by rails. The color ramp ranges from green (low tonnage flow) to red (high tonnage flow). In addition, the width of the segments is proportional to the volume of flown.

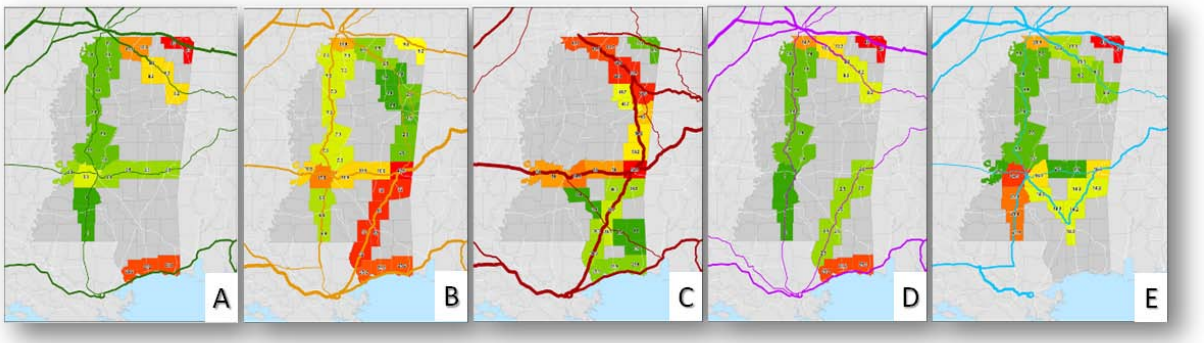


Figure 5: Scenarios used in this study. (A)Normal flow, (B) Mississippi River bridge down in Memphis-TN, (C) Memphis metropolitan area disrupted, (D) Mississippi River bridge down in Vicksburg-MS and (E) general disruption along the rails in the coastal area.

The first scenario (A) considers normal flow, where no segments are disrupted. The idea is to provide basis to correlate with economic distress map. The second scenario (B) considers disruption in the Mississippi Bridge in Memphis-TN. This particular segment is a junction of several carriers and the traffic is extremely heavy and intense. The third scenario (C) takes all segments of the metropolitan area of Memphis out of the circuit. This is a chaotic situation, but realistic considering the geologic activity of the New Madrid Fault. Similarly to second scenario, the fourth (D) considered disruption in the Mississippi River bridge in Vicksburg-MS. Barge collision or extreme weather events such as flooding can trigger these scenarios. The fifth and last scenario (E) takes the railroads in New Orleans-LA and Mississippi coastal counties out of the circuit. In this scenario, the team reproduced the disruption of CSX rails after the hurricane Katrina in 2005. The idea is to validate the study using statistics and real data from long term economic recovery plan in the Mississippian coastal counties (not reported in this paper).

5.2. Understanding the Outputs Regarding Furniture and Lumber Industries

To better understand the interaction of furniture and timber industries in situations where critical rails are disrupted, the authors ran five scenarios. As shown in Figure 2, there is a cluster of furniture industries in the northeast part of Mississippi. Under normal conditions, these clusters are served by a key railroad (Figure 5A). This situation is not the best, and it forces the freight to flow through Memphis-TN, which is been saturate and any increase in volume or traffic can reflect delays.

Scenarios (B) and (C) could bring interesting perspectives for the State of Mississippi that will potentially receive substantial increase in volume. A single disruption in the Mississippi Rail bridge in Memphis-TN will directly decrease the volume of furniture and derivate products that flow through the northeast industry cluster. However, the volume is expected to increase substantially in other rails at south toward the port of New Orleans-LA. On the other hand, a general disruption of rails in Memphis area will amplify the use of northeastern, central and southern rails in the State. These scenarios will request carriers on flow commodities through secondary rails, which can reflect in revenue and job creation in the counties served by these rails. Besides, the dense the rail network in use for furniture commodities, the bigger the accessibility for furniture and lumber industries.
As for the scenarios (D) and (E), the volume of commodities that flows in the State will decrease, even considering the long distance between disrupted segments and the cluster of

furniture industry. This situation illustrates the lack of alternative rails and the necessity of densification of the railroad network. Table 3 summarize basic information derived from each scenario

Table 3 Classification scheme used to map economic distress based on personal income

Simulated Scenarios for Furniture Industry	# Counties Directly Served by Rails	Extension of Rails used in MS (Km)
Normal Flow	30	1.126,38
Memphis Bridge Down	41	1.647,16
Memphis Rails Down	34	1.481,08
Vicksburg Bridge Down	32	1.142,47
MS Coastal Rails Down	33	1.294,23

6. FINDINDS, CONCLUSIONS AND FUTURE STEPS

Findings as shown in this investigation are helping the research team to improve a rational knowledge-base toward the identification of needs and solutions across Economy and transportation fields. GIS is allowing significant progresses. It supports the team to manage factors and facts in a broad vision other than focusing in isolated scenarios for transportation or economic studies. The interdisciplinary achieved in this investigation and the relevance of the findings have stimulated the continuity of the research and levered substantial funding to expand the research for few more years. These research deliverables illustrate disruptions and economic impact patterns that will affect community and commerce flow, therefore planners in economic development, transportation, land use and emergency evacuation can work with identical data to find solutions towards resiliency. For the academic standpoint, it is been an excellent opportunity for teaching, research and extension.

Current steps involve GIS to couple re-routing and regional economic models. Ongoing efforts concentrate on integrating the forecasted freight flow disruptions patterns with specific economic modeling tools, such as REMI® to determine the economic impacts which will be utilized to develop visualizations that illustrate the impact an anthropogenic/or natural disaster would have on the region's transportation network. Pre and post Hurricane Katrina statistics from US Census of Bureau have been compared to the statistics from scenario (E) and the REMI outputs as well in order to validate the framework.

Although, GIS is also been used to provide information derived from transportation and socio-economic data, other than coupling the re-routing and REMI models. Some analysis such as density (Figure 6), clusters, gravitational origin/destination models and least-cost paths have providing significant inputs to feed the multi-criteria decision making, vital to modern transportation planning process.

Although, one of the pictures to be discussed in future steps is the use o re-routing simulations to predict regional economic growth. If in one hand disruptions in critical transportation segments such as rails can enhance regional economic distress, on the other hand, re-routing freights to old rails segments can lever the revitalization process of small communities and therefore open job opportunities that will attenuate negative indexes in the local economy. Figure 7 shows a predictive scenario to increase flow and regional accessibility in north-central Mississippi by restoring the existing Columbus-Greenville

Railroad. It's expected to alleviate the congestion in Memphis and provide a direct connection to the I-69 corridor.

Figure 6: A GIS output illustrating the density of operational railroads and the major furniture industries in Mississippi. Dark blue indicates high density, low density and gaps are illustrated in light blue.

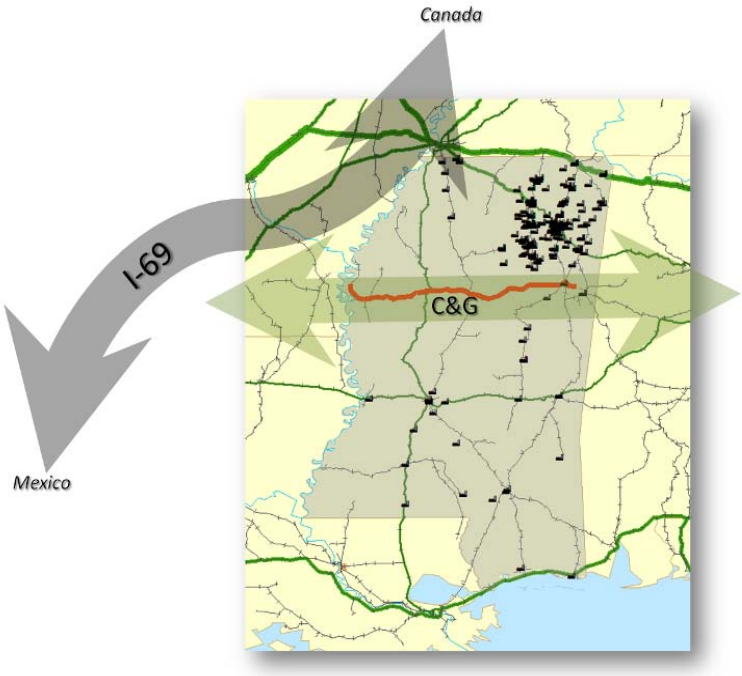


Figure 7: The proposed revitalization/reactivation of Columbus-Greenville (C&G), which will offer a straightforward connection toward the Mississippi River and I-69 corridor. Regarding the saturated capacity of the rails in Memphis-TN, C&G is a strategic alternative to increase the flow of goods across the State. It is expected to increase revenue for furniture, timber and automotive industries in Mississippi.

Acknowledgments
The authors thank the Center for Transportation Analysis of Oakridge National Laboratory for providing the re-routing model and waybill freight data, as well as the Southeast Regional Research Initiative of the U.S. Department of Homeland Security for sponsoring this investigation.

REFERENCES

Bryan, D. L., O'Kelly, M. E. (1999). "Hub-and-Spoke Networks in Air Transportation; an Analytical Review". Journal of regional Science, Vol. 39, N. 2, pp 275-295.

Clevenger, A. P., Wierzchowaki, J., Chuszcz, B., Gunson, K. (2002), "GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation packages", Cons. Biol. Vol. 16, pp 503-514.

Fleming, D. K., Hayuth, Y. (1994). "Spatial Characteristics of Transportation Hubs: Centrality and Intermediacy". Journal of Transport Geography, Vol.2, N.1, pp 3-18.

Fletcher, D. (2002). "The Role of Geospatial Technology in Critical Transportation Infrastructure Protection" In: National Consortium on Remote Sensing in Transportation - Infrastructure. "Spatial Information Technologies in Critical Infrastructure Protection". Report of U.S. Department of Transportation, Research and Special Programs Administration (http://www.ncgia.ucsb.edu/ncrst/research/cip/CIPAgenda.pdf)

Hill, M.J., Braaten, R., Lees, B.G., Veitch, S.M., and Sharma, S. (2005), "Multi-criteria decision analysis in spatial decision support: the ASSESS analytic hierarchy process and the role of quantitative methods and spatially", Environmental Modeling and Software Vol. 20, pp. 955–976

Horner, M. W., O'Kelly, M. E. (2001). "Embedding Economies of Scale Concepts for Hub Network Design". Journal of Transport Geography, Vol. 9, N. 4, pp. 255-265.

Keeling, D. J. (2007). "Transportation geography: new directions on well-worn trails. Progress in Human Geography", Vol. 31 pp. 217-225.

Lewis, D. (1991). Primer on Transportation, Productivity and Economic Development, National Cooperative Highway Research Program Report.

Miller, H. J. (1999). "Potential Contributions of spatial Analysis to Geographic Information Systems for Transportation GIST-T". Geographical Analysis, Vol. 31, N. 4, pp. 373-339.

Mississippi Emergency Management Agency (2005). The emergency management law. Mississippi Code of 1972, Title 33, Chapter 15.

Nobrega, R. A. A., O'Hara, C. G., Sadasivuni, R., Dumas, J. (2009). "Bridging Decision Making Process and Environmental Needs in Transportation Corridor Planning". Management of Environmental Quality International Journal, v. 20, n. 6, pp 622-637.

O'Hara, C. G., Davis, A. A., Kleiss B. A. (2000), "A decision support system for prioritizing forested wetland restoration in the Yazoo Backwater Area, Mississippi, working paper", United State Geological Service - Water Resources Investigation Report 00-4199. United States Geological Service, Pearl, MS.

Peterson, B. (2000) CFS Multi-modal network documentation. Center for Transportation Analysis, OakRidge National Laboratory.

Rodrigue, J.-P., Comtois, C. and Slack, B. 2006: The geography of transport systems. New York: Routledge.

Singleton, P.H., Lehmkuhl, J. (1999), "Assessing wildlife habitat connectivity in the interstate 90 Snoqualmie Pass corridor, Washington", In: Proceedings of the third International Conference on Wildlife Ecology and Transportation, September 13-16, 1999. Missoula MT. (eds Evink, G., Garrett, P., and Ziegler, D.). pp 75- 84. Florida Department of Transportation. Tallahassee FL. Report No. FL-ER-73-99.

The Public Works and Economic Development Act of 1965, As Amended (42 U.S.A.)