Assessing the Feasibility of Inland Waterway Emergency Services

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Research Motivation

- Most emergency operations plans (EOP) assume standard modes of transportation will be available
- Few EOPs have contingency plans for overwhelmed or disabled transportation means
- Nation's inland waterways offer valuable resource
  - Over 12,000 miles of navigable waterways in the U.S.
  - Cost-effective mode of transportation
  - Barge capacity is much higher than other modes

Research Objective

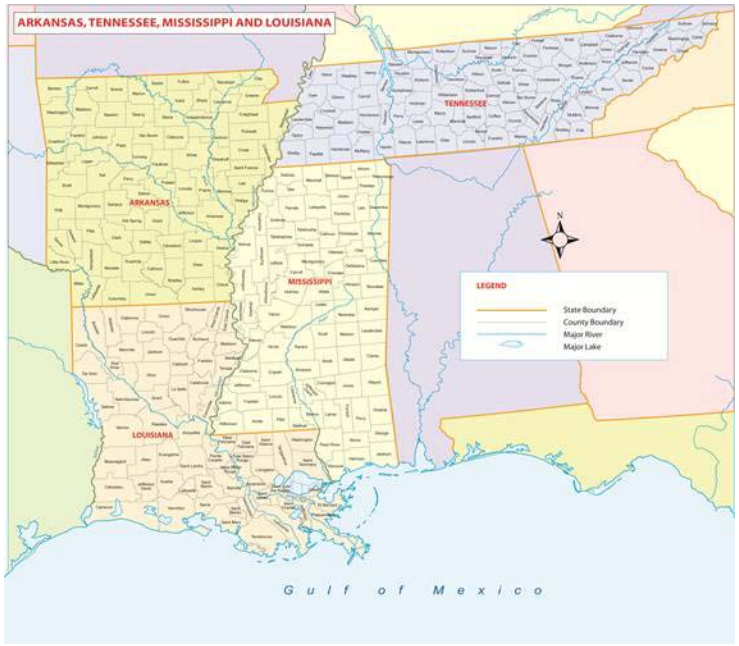
- Overall Goal
  - Improve emergency preparedness and disaster relief through utilization of inland waterway transportation
- Primary Objectives
  - Introduce measurable factors that can assess the potential of counties in the U.S. to benefit from inland waterways emergency response
  - Develop an index to help emergency planners in determining the feasibility and benefit of using barge-based emergency services in their emergency response planning

Waterways Emergency Service (WES) Factors

1. Accessibility to Navigable Inland Waterway
2. Population Demand
3. Social Vulnerability
4. Risk of Disaster
5. Limited Access to Medical Services
6. Limited Access to Resources
7. Limited Access to Transportation Modes

Case Study

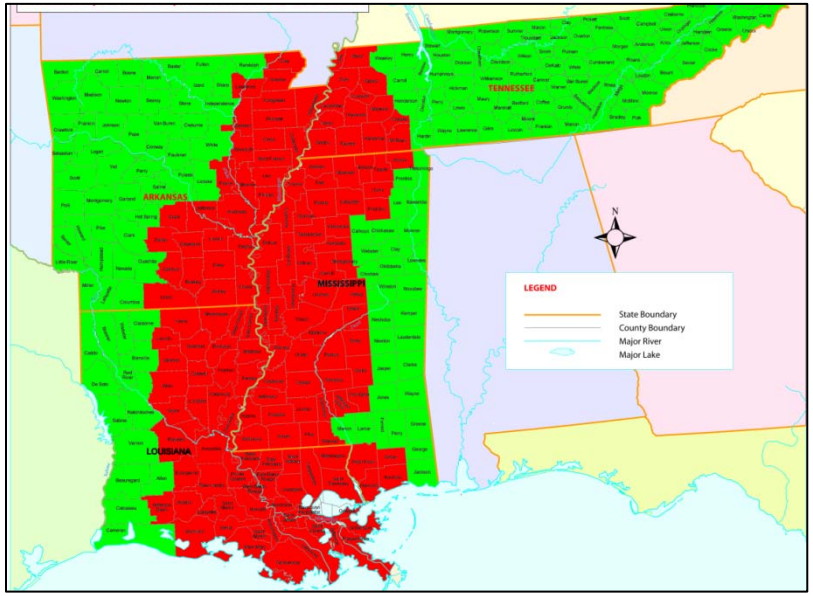
- Lower Mississippi River region
- Four states
  - Arkansas (75 counties)
  - Louisiana (64 parishes)
  - Mississippi (82 counties)
  - Tennessee (95 counties)
- Good representation of a significant multi-modal, rural transportation network



1. Accessibility to Navigable Inland Waterway Factor

Factor	Description	Metric	Scale	Value
Accessibility to Navigable Inland Waterway	Proximity of a community to a navigable inland waterway. Emergency response is not feasible for communities located too far from a navigable inland waterway.	Distance between county population centroid and closest inland port/terminal	Accessible (≤ 3hr drive @ 35mph) = 1	1
			Inaccessible (> 3hr drive @ 35 mph) = 0	0

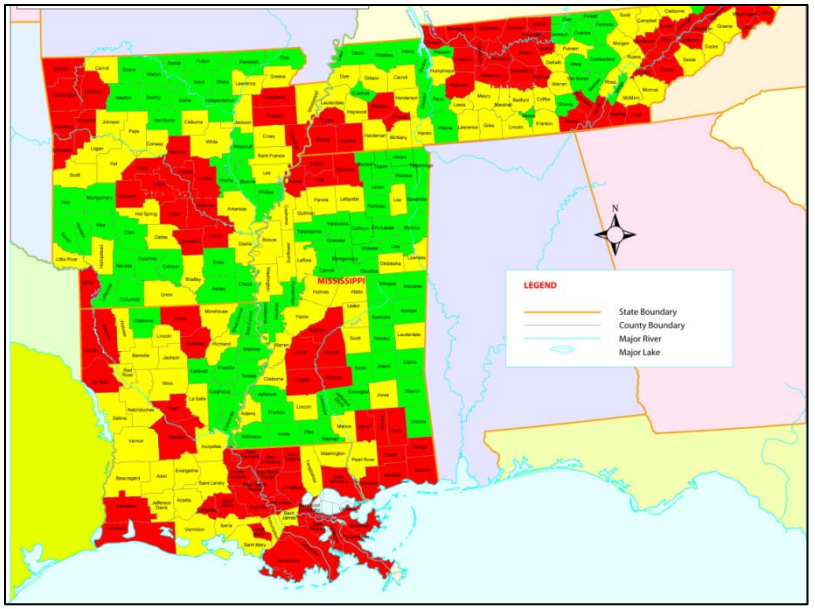
SOURCE: U.S. Census Bureau. *Centers of Population Computation for 1950, 1960, 1970, 1980, 1990, 2000, and 2010,* http://www.census.gov/geo/www/2010census/centerpop2010/county/CenPop2010_Mean_CO05.txt, Accessed October 30, 2011 (2011).



2. Population Demand Factor

Factor	Description	Metric	Scale	Value
Population Demands	Size of population and its proximity to metropolitan areas. Important for identifying the level of services that may be needed during an emergency.	Rural-Urban Continuum Code	Low (7 - 9)	1
			Med (4 - 6)	2
			High (1 - 3)	3

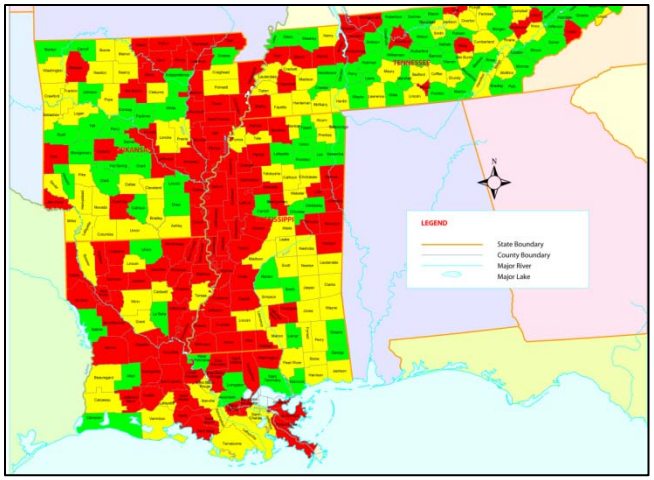
SOURCE: U.S. Department of Agriculture Economic Research Service (USDA ERS), "Measuring Rurality: Rural-Urban Continuum Codes" http://www.ers.usda.gov/briefing/rurality/ruralurbcon/, Accessed April 21, 2011 (2004).



3. Social Vulnerability Factor

Factor	Description	Metric	Scale	Value
Social Vulnerability	Social, economic, demographic, and housing characteristics that influence a community's ability to respond to, cope with, recover from, and adapt to environmental hazards. Useful for identifying which counties may need the greatest assistance during an emergency.	National percentile ranking of the Social Vulnerability Index (SoVI)	Low (0.01 - 33.33)	1
			Med (33.34 - 66.66)	2
			High (66.67 - 99.99)	3

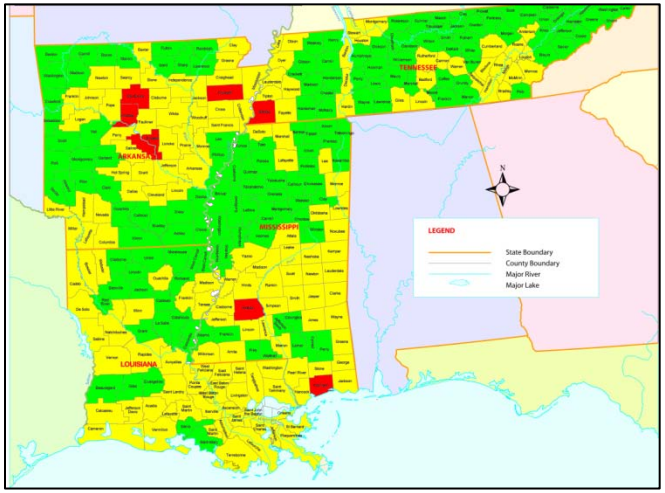
SOURCE: Hazards and Vulnerabilities Research Institute, *Social Vulnerability Index for the United States 2000, http://webra.cas.sc.edu/hvriapps/SOVI_Access/SoVI_Access_Page.htm,* Accessed April 2, 2011 (2008).



4. Risk of Disaster Factor

Factor	Description	Metric	Scale			Value
Risk of Disaster	The risk of tornado, earthquake, flood, or terrorist attack. Useful for identifying which counties are most likely to need inland waterway-based emergency assistance.	Combined risk level of tornado, earthquake, flood, and terrorism	**Tornado**: Low (<2.5), Med (2.5 - 4.99), High (≥5)	Total	Low (4 - 6)	1
			Earthquake: Low (<20), Med (20 - 79.9), High (≥80)		Med (7 - 9)	2
			Flood: Low (<3), Med(3 - 4), High (>4)		High (10 - 12)	3
			Terrorism: Low = 1 , Med = 2, High = 3			

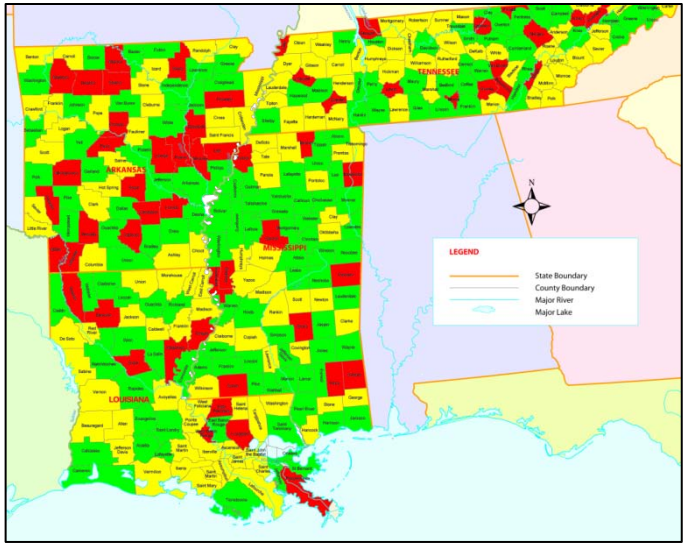
SOURCES: The Tornado Project, *Tornadoes 1950-1995,* http://www.tornadoproject.com/, Accessed April 2, 2009 (1999), U.S. Geological Survey. Seismic Hazard Maps, from http://earthquake.usgs.gov/earthquakes/states/, Accessed July 19, 2010 (2009), and Federal Emergency Management Agency, U.S. Department of Homeland Security *Declared Disasters by Year or State,* http://www.fema.gov/news/disaster_totals_annual.fema #markS, Accessed April 9, 2011 (2011)



5. Limited Access to Medical Services Factor

Factor	Description	Metric	Scale	Value
Limited Access to Medical Services	Number of community hospital beds per 100,000 people, available in the areas. Important for identifying the necessity of medical services that may be brought to the area during an emergency.	Number of community hospital beds per 100,000 people	Low (>317)	1
			Med (1 - 317)	2
			High (0)	3

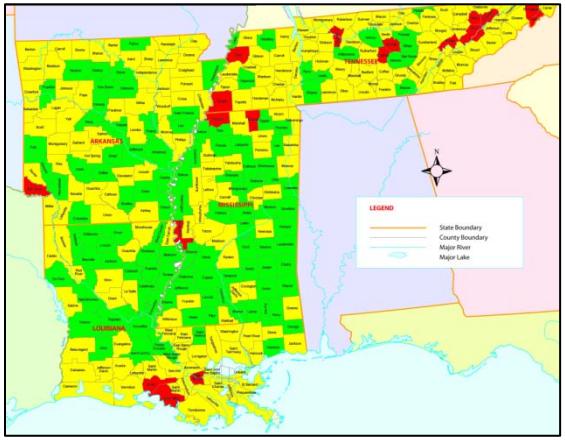
SOURCE: U.S. Census Bureau. *County and City Data Book: 2007, Table B-6. Counties – Physicians, Community Hospitals, Medicare, Social Security, and Supplemental Security Income*, http://www.census.gov/statab/ccdb/cc07_tabB6.pdf., Accessed October 1, 2009 (2007).



6. Limited Access to Resources Factor

Factor	Description	Metric	Scale			Value
Limited Access to Resources	Availability of resources including clean water supply, power supply, temporary housing, and fuel supplies. This factor is important in identifying the necessity of providing resources via barge.	Combined availability level of water supply and irrigation systems; electric power generation, transmission, & distribution; number of hotels, motels, B&B, other travel accommodation, RV parks and camps, rooming and boarding houses; number of gasoline station establishments. To be consistent, all the metrics are measured per 100,000 people.	**Clean Water**: Low (>8), Med (1 - 8), High(0)	Total	Low (4 - 6)	1
			Power: Low (>7), Med (1 - 7), High(0)		Med (7 - 9)	2
			Temporary Housing: Low (>23), Med (1 - 23), High(0)		High (10 - 12)	3
			Fuel: Low (>67), Med (1 - 67), High(0)			

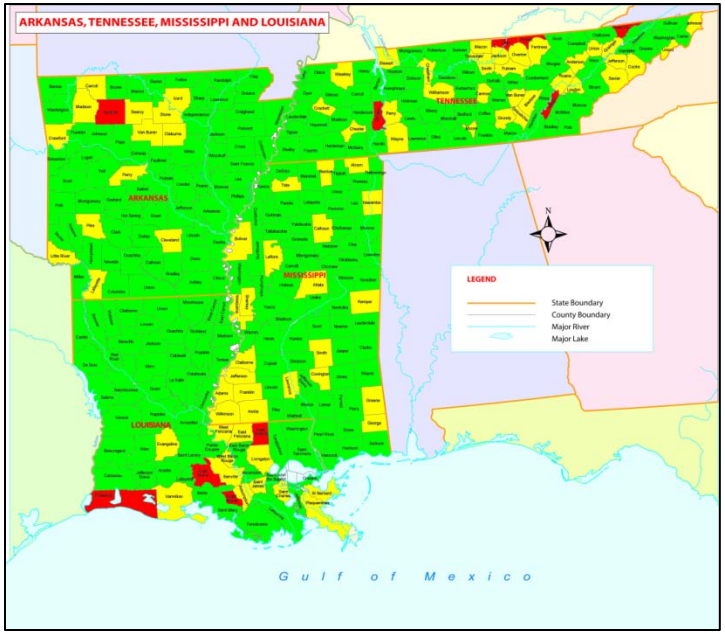
SOURCES: U.S. Census Bureau. *County Business Patterns (NAICS)*, http://censtats.census.gov/cbpnaic/cbpnaic.shtml, Accessed October 10, 2011 (2008A) and U.S. Census Bureau. *Population Estimates*, http://www.census.gov/popest/estimates.html, Accessed October 21, 2010 (2008B).



7. Limited Access to Transportation Modes Factor

Factor	Description	Metric	Scale	Value
Limited Access to Transportation Modes	Accessibility to railroad system or airports. If a county does not have easy access to other modes of transportation it has higher potential to benefit from waterway-based transportation.	Railroad passes through the county and/or at least on public airport is located in the county	Both railroad and airport(s) are accessible	1
			Railroad or airport is accessible	2
			Neither railroad nor airport is accessible	3

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, *National Transportation Atlas Database,* http://www.bts.gov/publications/national_transportation_atlas_database/2010/, Accessed October 12, 2011 (2010).

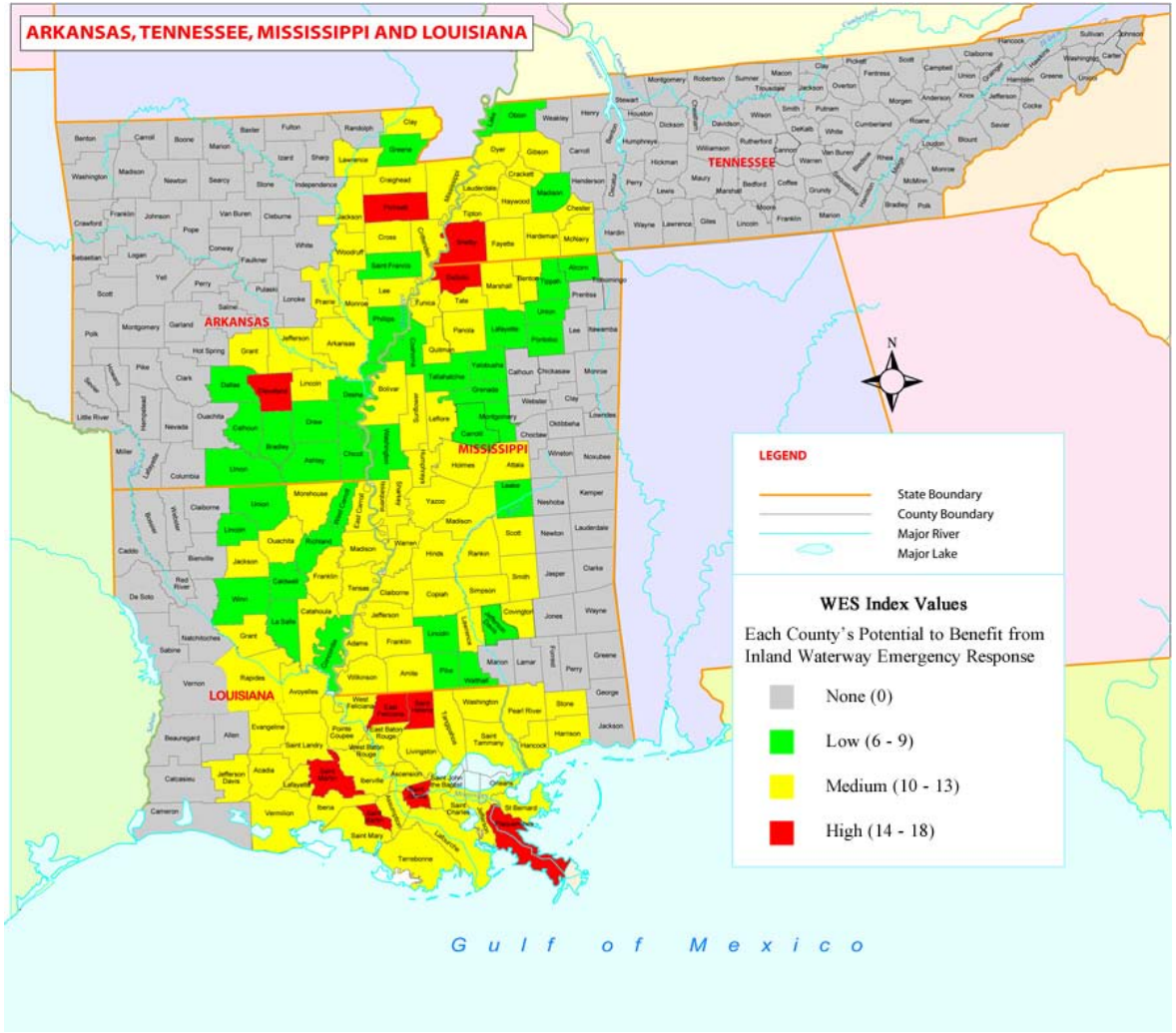


Waterway Emergency Service Index

$$WES\ Index = A(PD + V + R + M + LR + T)$$

- A Accessibility to Navigable Inland Waterways
- PD Population Demand
- V Social Vulnerability
- R Risk of Disaster
  - Tornado
  - Earthquake
  - Flood/Hurricane/Tropical Storm
  - Terrorist Attack
- M Limited Access to Medical Services
- LR Limited Access to Resources
  - Clean Water Supplies
  - Power Supplies
  - Temporary Housing
  - Fuel Supplies
- T Limited Access to Transportation Modes

WES Index – Case Study Results



- In our four state region
  - Thirty nine counties (12%) have low
  - Ninety seven counties (31%) have medium
  - Nine counties (3%) have high potential to benefit from waterway-based emergency response
- 171 counties (54%) do not have access to the Mississippi river

Modeling Approach

1. Develop an optimization model to help the emergency planners to determine the minimum number of barges required
2. Considering the resource limitations, formulate an optimization model to determine the optimal starting location for the available barges in order to provide maximum WES coverage
3. Develop a multi objective optimization model that combines objectives 1 and 2

Goal Programming Formulation

$$Min\ \alpha v_1 d_1 + (1-\alpha) v_2\ d_2$$

$x_i \leq \sum_{j \in P} \sum_{k \in P} y_j\, d_{jk}\, a_{ik}$ — For uncovered county, x_i <= 0

$\sum_{j \in P} \sum_{k \in P} y_j\, d_{jk}\, a_{ik} \leq m x_i$ — For covered county, x_i >= 0

$\sum_{j \in P} y_j - d_1 \leq t_1$ — Deficiency variable for objective 1

$\sum_{i \in C} w_i x_i + d_2 \geq t_2$ — Deficiency variable for objective 2

$x_i, y_j \in \{0,1\}$ — Binary variable constraint

$d_1, d_2 \geq 0$ — Non-negativity of deficiency variables

Results

- Parameters
  - $d_{jk} = 12$
  - $t_1 = 1$
  - $t_2 = 1179$
  - $\alpha = 0.5$
- Results

  Number of Barges Required = 2

  Number of Covered Counties = 110 (76% Coverage)
- Optimal Locations

7	15
Clairborne County	Memphis

Public Ports on Lower Mississippi River

Port Number	Port Name	Port Number	Port Name
1	Plaquemine	11	Greenville
2	St. Bernard	12	Yellow Bend
3	New Orleans	13	Rosedale
4	South Louisiana	14	Helena
5	Greater Baton Rouge	15	Memphis
6	Natchez	16	Osceola
7	Clairborne County	17	Caruthersville
8	Vicksburg	18	New Madrid
9	Madison Parish	19	Hickman
10	Lake Providence		

Summary

- Developed a index and decision support methodology to aid emergency managers in designing an efficient and effective inland waterway-based emergency response system
- Conducted case study
- Future work
  - Heuristic development
  - Explore resource allocation on barges
  - Consider the use of watercrafts other than barge