Analysis of Post-Disaster Planning using Delay from a Travel Demand Model and Taking Commercial Vehicles into Account

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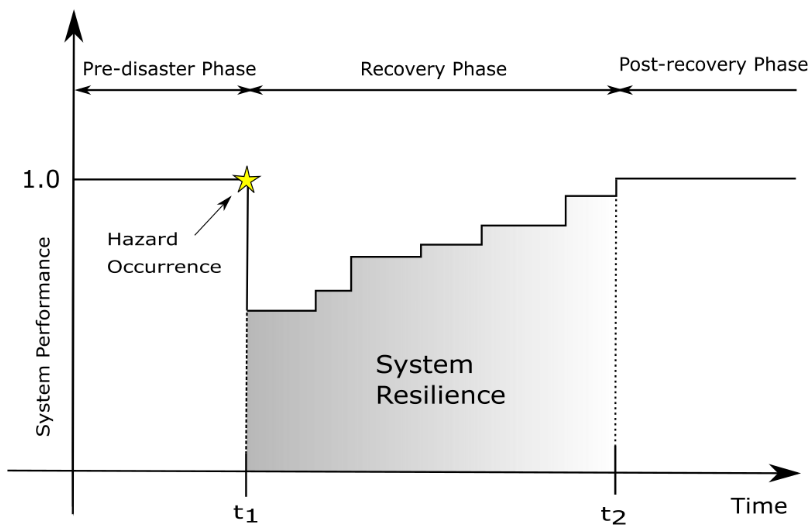
Transportation Network Resiliency

- U.S. National Infrastructure Advisory Council defined infrastructure resilience as "the ability to reduce the magnitude and/or duration of disruptive events."
  - NIAC. Critical Infrastructure Resilience. Department of Homeland Security, 2009.



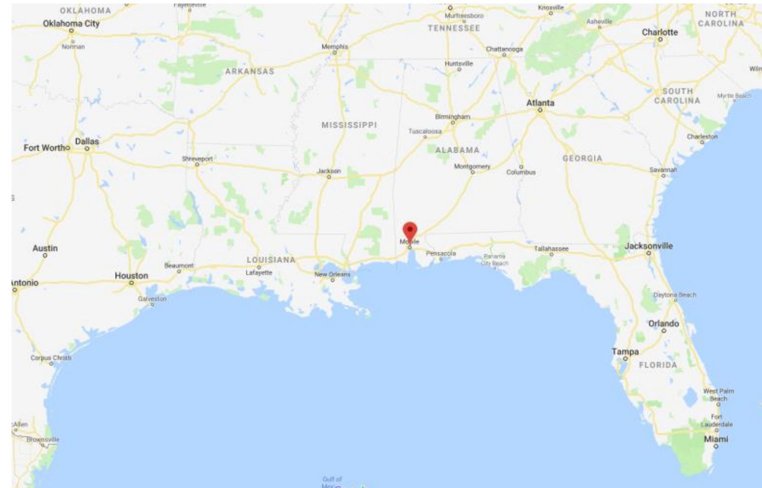
  - Bruneau, M., S. E. Chang, R. T. Eguchi, G. C. Lee, T. D. O'Rourke, A. M. Reinhorn, M. Shinozuka, K. Tierney, W. A. Wallace, and D. von Winterfeldt. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake spectra,* Vol. 19, No. 4, 2003, pp. 733-752.

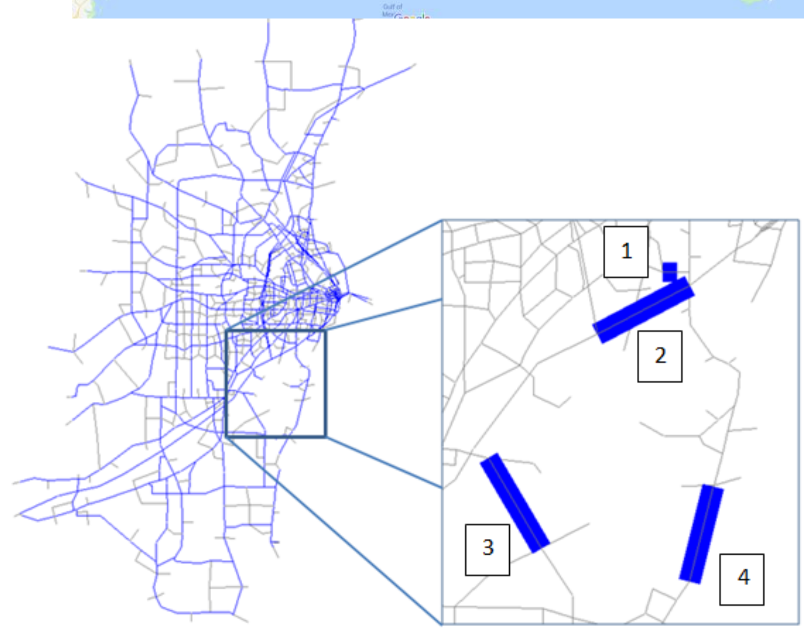
Question

- Can we use travel delay to optimize bridge repair schedule, including freight concerns?
- Two replacement scenarios
  - Equal Repair Times
  - Different Repair Times
- Assumptions of the methodology …
  - 1) Only one bridge can be repaired at a time.
  - 2) All destinations are constant.
  - 3) Cost is not one of the constraints.

Case Study: Mobile, AL

- Hurricane impacts the Dog River
- Four Bridges
  - 1. McVay Drive
    - 13,000 vehicles per day
  - 2. Interstate 10
    - 80,000 vehicles per day,
  - 3. AL Highway 193
    - 20,000 vehicles per day, and
  - 4. AL Highway 163
    - 4, 000 vehicles per day.





Modeling Design

- Travel Time on impacted bridges set to 9,999 minutes.
- Assigned independent trip tables
  - Commercial Vehicles
  - Passenger Cars
- Assigned such that commercial vehicles have initial preference

Modeling Design (Contintued)

- Delay is a function of volume/capacity ratio
  - $TT_i = TT_0 * \left(1 + a * \left(\frac{V}{C}\right)^b\right)$
- Cost of time
  - Passenger Car = $17.67/hour
  - Commercial Vehicle = $94.04/hour
    - 2015 Urban Mobility Scorecard Methodology, http://mobility.tamu.edu/ums/congestion-data/
- Community Delay
  - Community Delay = Σ {[Travel time (new) – Travel time (original)] * roadway volume}

16 Modeling Combinations

Combination	Bridges Removed
All Bridges Present	None
One Bridge Removed	1
	2
	3
	4
Two Bridges Removed	1 and 2
	1 and 3
	1 and 4
	2 and 3
	2 and 4
	3 and 4
Three Bridges Removed	1 and 2 and 3
	1 and 2 and 4
	1 and 3 and 4
	2 and 3 and 4
All Bridges Removed	1 and 2 and 3 and 4

Delay Costs

Scenario	Delay Costs ($)	Increase in Delay Costs ($)
None – Base Condition	384,981.63	-
1	390,248.46	5,266.83
2	565,496.84	180,515.21
3	400,805.31	15,823.67
4	390,469.28	5,487.64
1 and 2	573,581.65	188,600.01
1 and 3	406,958.95	21,977.32
1 and 4	396,091.98	11,110.35
2 and 3	588,064.05	203,082.42
2 and 4	675,387.66	290,406.03
3 and 4	428,024.49	43,042.86
1 and 2 and 3	605,852.34	220,870.71
1 and 2 and 4	673,115.40	288,133.77
1 and 3 and 4	433,580.78	48,599.15
2 and 3 and 4	695,176.53	310,194.90
1 and 2 and 3 and 4	708,173.68	323,192.05

Repair Schedules

Repair Scenario	1	2	3	4	5	6
First	1	1	1	1	1	1
Second	2	2	3	3	4	4
Third	3	4	2	4	2	3
Fourth	4	3	4	2	3	2

- All possible combinations
- 24 Bridge repair options

Two Repair Scenarios

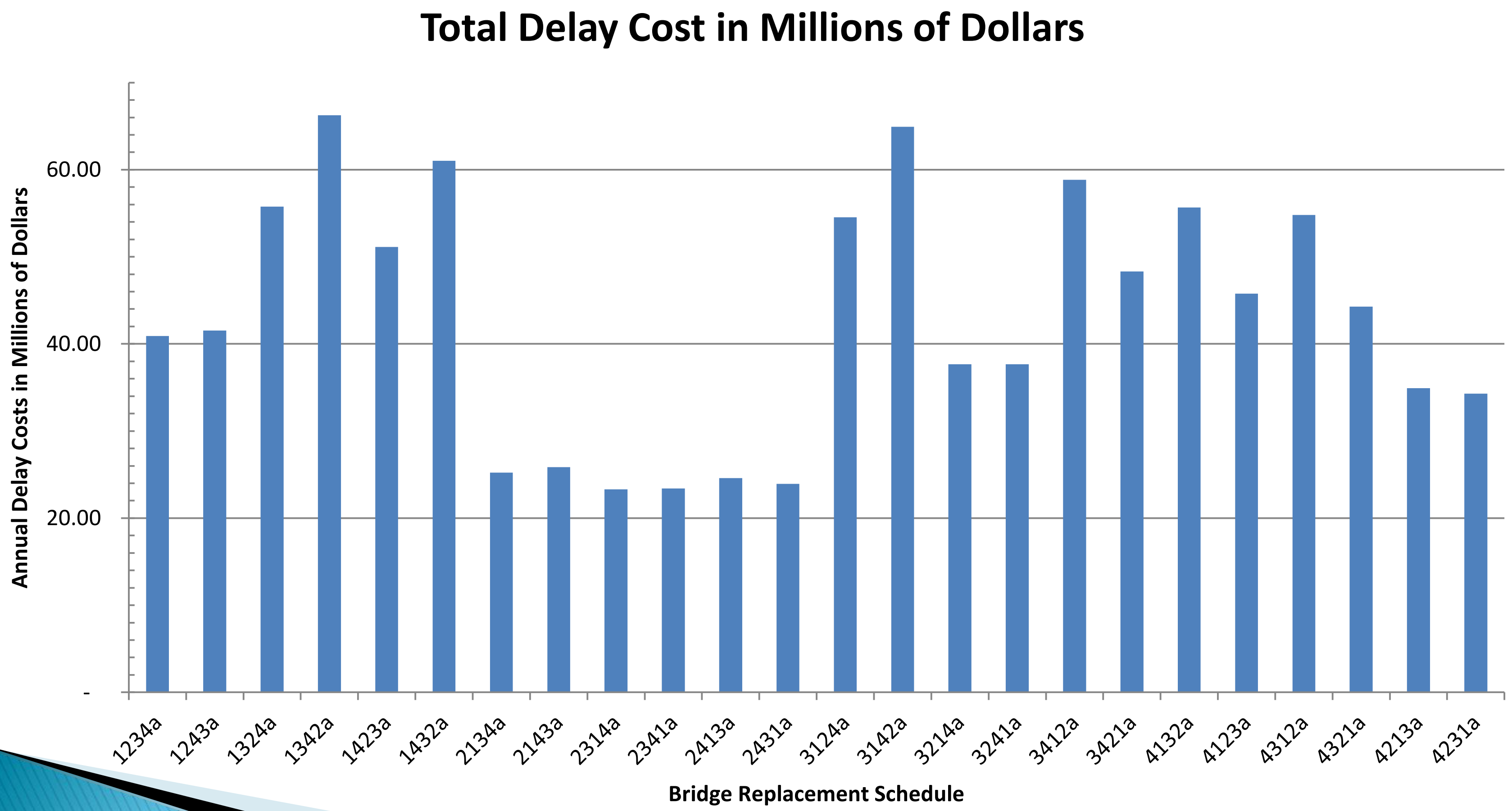
- All bridges take the same time to repair
  - Each bridge takes 60 days

- Different bridge repair times
  - Bridge 1 – 120 days
  - Bridge 2 – 60 days
  - Bridge 3 – 40 days
  - Bridge 4 – 20 days.

Cost Comparison – Same Repair Time

Repair Schedule	Total Delay Costs In Million Dollars	Repair Schedule	Total Delay Costs In Million Dollars
1-2-3-4	40.92	3-1-2-4	54.54
1-2-4-3	41.54	3-1-4-2	64.93
1-3-2-4	55.76	3-2-1-4	37.68
1-3-4-2	66.26	3-2-4-1	37.66
1-4-2-3	51.14	3-4-1-2	58.83
1-4-3-2	61.02	3-4-2-1	48.31
2-1-3-4	25.22	4-1-3-2	55.66
2-1-4-3	25.84	4-1-2-3	45.78
2-3-1-4	23.30	4-3-1-2	54.79
2-3-4-1	23.39	4-3-2-1	44.28
2-4-1-3	24.58	4-2-1-3	34.91
2-4-3-1	23.94	4-2-3-1	34.28

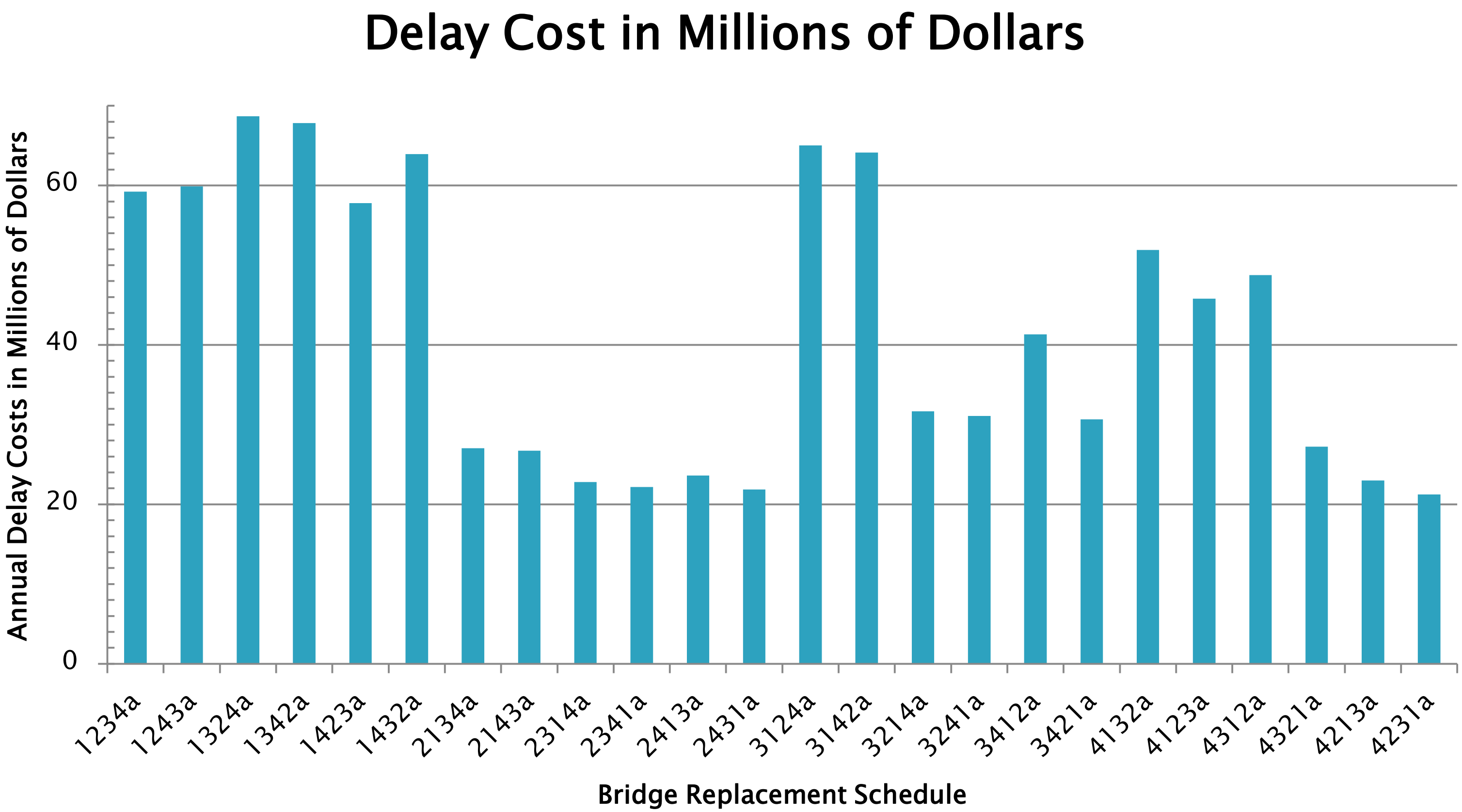
Cost Comparison – Same Repair Time



Cost Comparison – Different Repair Times

Repair Schedule	Total Delay Costs In Million Dollars	Repair Schedule	Total Delay Costs In Million Dollars
1-2-3-4	59.23	3-1-2-4	65.04
1-2-4-3	59.89	3-1-4-2	64.14
1-3-2-4	68.67	3-2-1-4	31.66
1-3-4-2	67.83	3-2-4-1	31.07
1-4-2-3	57.8	3-4-1-2	41.32
1-4-3-2	63.94	3-4-2-1	31.64
2-1-3-4	27.05	4-1-3-2	51.92
2-1-4-3	26.72	4-1-2-3	45.79
2-3-1-4	22.78	4-3-1-2	48.76
2-3-4-1	22.19	4-3-2-1	27.25
2-4-1-3	23.62	4-2-1-3	22.99
2-4-3-1	21.87	4-2-3-1	21.23

Cost Comparison – Different Repair Times



Conclusions

- Resiliency analysis using delay
- Different repair schedules – same repair time
  - 2-3-4-1 using constant value of time
  - 2-3-1-4 using weighted freight value of time
- Methodology is transferable to other locations/disaster scenarios
- Commercial vehicles must be considered separately

Thank You