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A Conceptual Resilience Framework for Transportation Infrastructure

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Motivation & Objectives

- Transportation infrastructure systems form part of the economic backbone of the United States.
- Transportation infrastructure resilience must be taken in consideration due to the frequent occurring of extreme hydrometeorological events.
- Comprehend transportation infrastructure resiliency, and its portraying factors.
- Develop a conceptual framework to aid future research to identify, measure and mitigate critical infrastructure in transportation systems.

Infrastructure Network

- As communities grow, society becomes dependent on many interdependence systems to provide services.
- Transportation systems serve before, during and after a disaster.

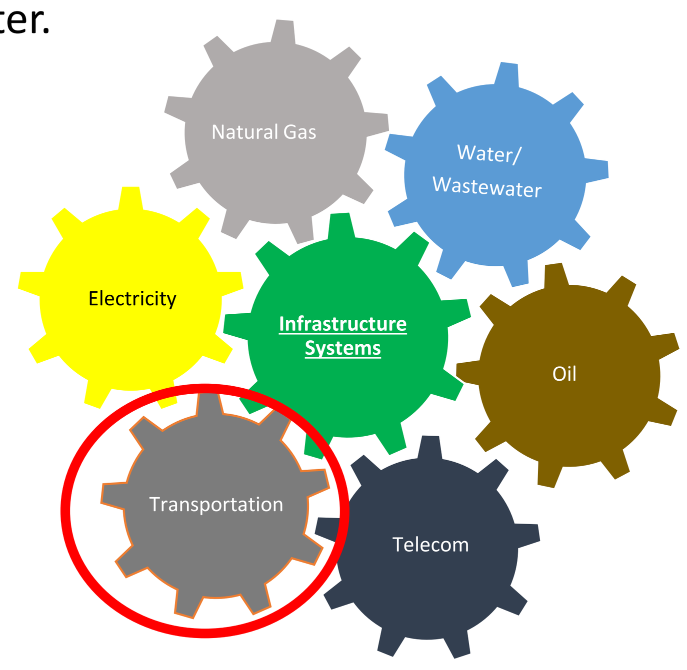


Figure 1. Interdependencies in Infrastructure Systems.

Resilience

- The presidential Policy Directive 21 (PPD21) defines resilience as "Ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions."
- In a recent study [1], linked resilience to been the inverse of vulnerability.

$$Vulnerability = \frac{1}{Resilience}$$

- Also, vulnerability can be viewed as a component of resilience, or resilience as a function of vulnerability among other factors [2].

Dimensions

- Technical: Physical systems and its interconnected components to be serviceable when subjected to extreme events.
- Organizational: Refers to the capacity of agencies/organizations to respond to emergencies and carry out critical functions.
- Social: Ability to reduce harm or suffer to communities and governmental jurisdictions, caused by the loss of critical services after an event.
- Economic: The ability to reduce both direct and indirect costs caused by events.

Fundamentals

- Robustness/Fault tolerant: Restrain damage to transportation asset and provide a capacity to withstand or overcome a given level of stress.
- Redundancy: The ability of elements and the entire structural transportation system to be substitutable or hold a backup system capable of satisfying the systems functionality in the event of disruptions.
- Resourcefulness/Adaptable: The state at which the system adapts to crises, based on diagnostic and damage awareness technologies.
- Response & Recovery: The ability to mobilize quickly to regain normality after a crisis or event, and learn after the events.

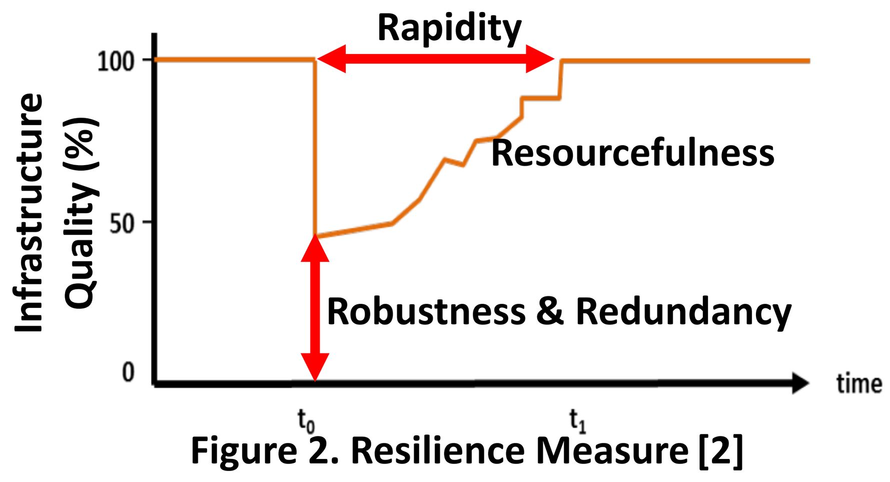


Figure 2. Resilience Measure [2]

Conceptual Framework

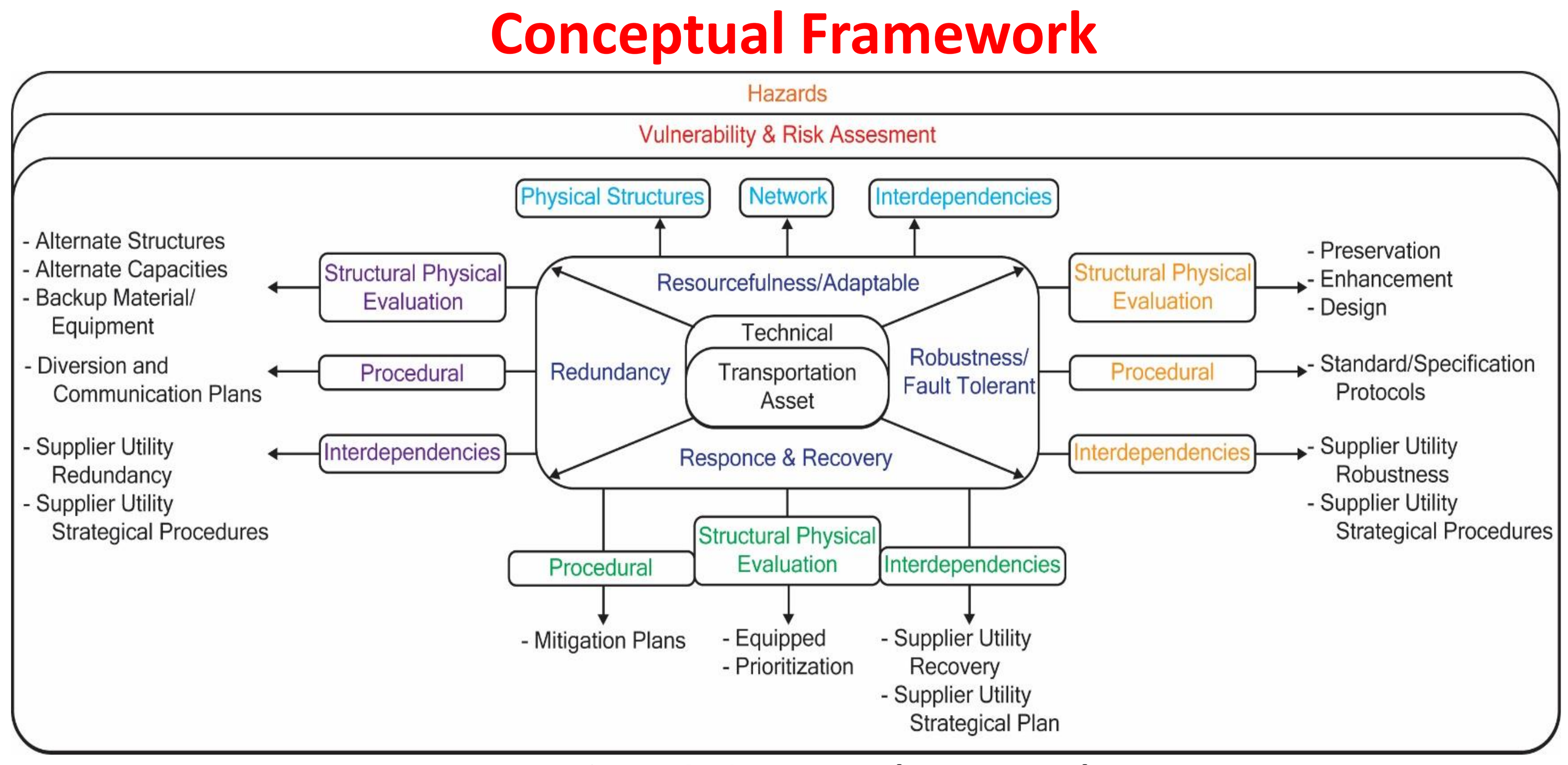


Figure 3. Conceptual Framework

Robustness & Fault Tolerant	Structural Physical Evaluation	Preservation	Capability to maintain structures in good shape by maintenance when required and constant scheduled inspections.
		Enhancement	Intensify and upgrade structures to improve resiliency and adjust as higher demands are present.
		Design	Structure meeting requirements and fall under good conditions.
	Procedural	Standard/Specification Protocols	Update and enhances codes to minimize risks and increase resiliency.
	Interdependencies	Supplier Utility Robustness	Suppliers and derived US departments of transportation are aware of measures in robustness issues.
		Supplier Utility Strategical Procedures	Update and enhance codes to minimize risks and increase robustness.
Redundancy	Structural Physical Evaluation	Alternative Structures	Alternative serving structures in case one structure fails.
		Alternative Capacities	Alternative structures delay time, and/or capacity.
		Backup Material/Equipment	Availability of backup source to provide necessarily adjustments transportation assets.
	Procedural	Diversion and Communication Plan	Circulate/spread plans of alternative serving structures to transportation users.
	Interdependencies	Supplier Utility Redundancy	Suppliers and derived US departments of transportation awareness of redundancy within suppliers utilities.
		Supplier Utility Strategical Procedures	Update and enhance codes to minimize risks and increase redundancy.
Resourcefulness & Adaptability	Physical Structures	Physical resources that would aid the community to adapt during an event (e.g. bicycle share programs, car pool lanes).	
	Network	Ability to communicate with citizens through mobile applications for their awareness of available resources.	
	Interdependencies	Measure of the awareness of other critical infrastructure systems of available resources.	
Response & Recovery	Structural Physical Evaluation	Equipped	The capability to maintain equipment for recovery operations, and agencies are highly equipped to efficiently recover.
		Prioritization	Proximity of resources based on most vulnerable structures.
	Procedural	Mitigation Plan	Organizations have in place strategic plans for most vulnerable scenarios.
	Interdependencies	Supplier Utility Recovery	Suppliers and derived US departments of transportation are aware of strategic plans and know how to act for fast recovery.
		Supplier Utility Strategical Plan	Suppliers and US departments are aware of changes in plans and are capable to adjust to changes.

Figure 4. Fundamentals Detailed Explanation

Risk Assessment in Pensacola Bay Bridge

1.) Hazards

- Name: Pensacola Bay Bridge
- Location: Pensacola, FL
- Asset is vulnerable to Hurricanes.
- Case Scenario: High Risks impact scenario that corresponds to a Category 5 with a surcharge of 20 ft.

Figure 5. Pensacola Bay Bridge failure

2.) Statistical Analysis

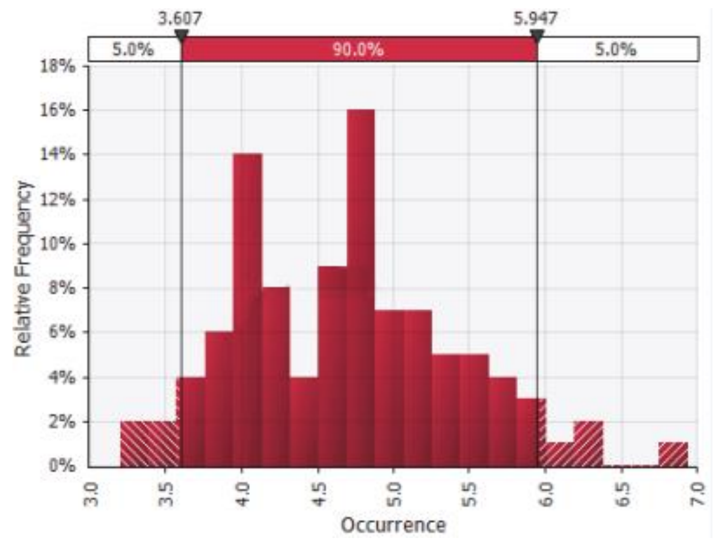


Figure 6. Likelihood of Occurrence

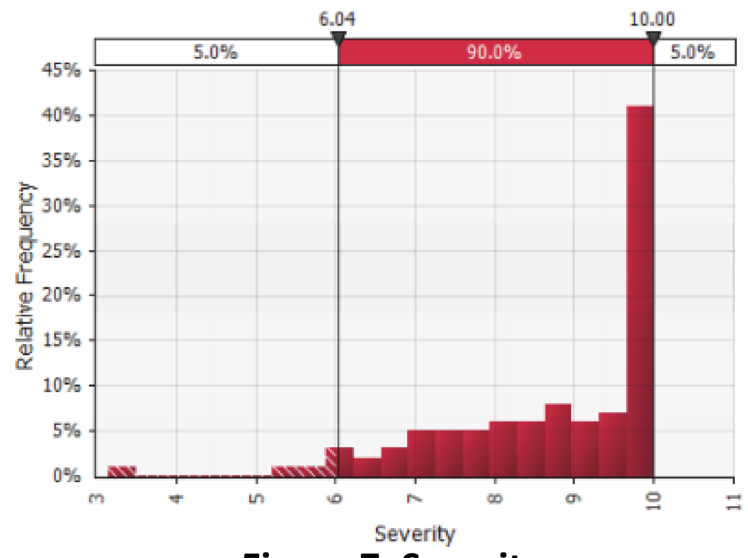
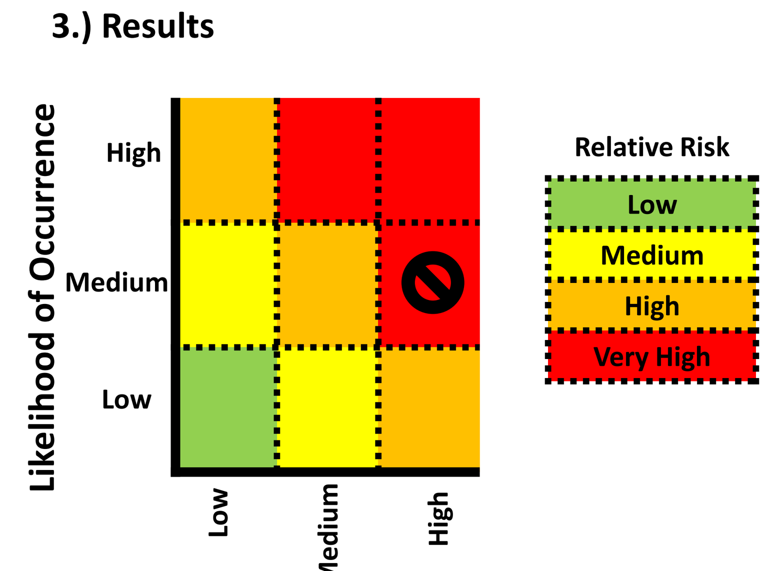


Figure 7. Severity

3.) Results



Conclusions

- The developed framework can be applied to many structural systems in transportation infrastructure.
- Future research is needed to identify other indicators in targeted assets.
- Framework needs to be updated to account the organizational, social and economic aspects of resiliency.

Acknowledgement

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References

[1] Molarius, R., Könönen, V., Leviäkangas, P., Zulkarnain, Rönty, J., Hietajärvi, A. M., and Oiva, K. (2014). "The extreme weather risk indicators (EWRI) for the European transport system." *Natural Hazards*, 72(1), 189–210.

[2] Hughes, J., and Healy, K. (2014). *Measuring the resilience of transport infrastructure*.