Resilience of Transportation Infrastructure in India: Are we there yet?

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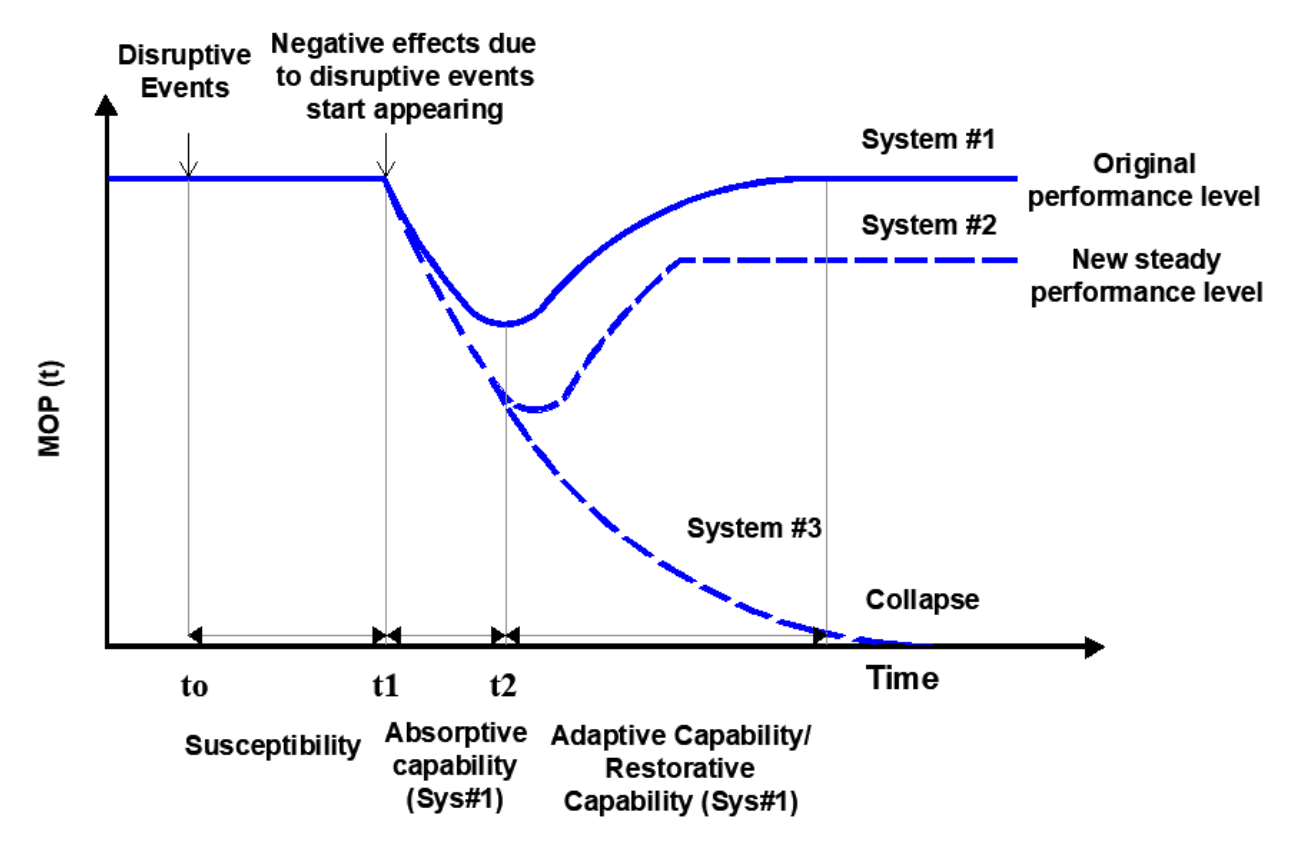
Need for Resilient Transportation System

- Mobility is a cornerstone of economic and societal progress.
- Escalating natural disasters globally strain transportation infrastructure, with substantial economic losses.
- Transportation is pivotal in disaster management and mitigating climate change impacts.
- Mitigation and Adaptation measures - like energy efficiency and green technologies.
- Transportation uniquely empowers crisis management, aiding in evacuation and rescue efforts.
- Effective disaster recovery hinges on efficient transportation systems.
- Resilient transport systems foster resilience in communities, fortifying them against challenges.
- Resilience, as defined by the UNRRR, is the capacity to withstand, adapt to, and recover from hazards efficiently.
- Resilience addresses uncertainties and potential disruptions in transportation systems.
- Lack of resilience carries profound economic implications, affecting transportation networks.

Resilience in Transportation sector

- Ports are a significant focus of resilience research due to their crucial role in global trade and international relations (Wan et al., 2018).
- Developed nations prioritize the development of robust transportation infrastructure, while developing nations are more vulnerable to the impacts of natural disasters (Nipa et al., 2023; Pan et al., 2021; Wan et al., 2018).
- Resilience in the literature is interpreted in various ways, such as the capacity of a system to rebound from unforeseen events (Liao et al., 2018) or its ability to adapt to disturbances caused by unforeseen conditions (Zhou et al., 2019).
- Some studies consider a system's capacity to recover from or adapt to shocks when creating models for system resilience (Tang et al., 2020).
- Resilience can be distilled into a system's ability to continue functioning in the face of adversity or the time it takes to return to normal operations (Zhou et al., 2019).

Concept of Resilience



(Source: Nipa, T. J., & Kermanshachi, S. (2021). Dimensions of Resilience Measurement in Critical Transportation Infrastructure. In International Conference on Transportation and Development 2021 (pp. 302- 312)).

R4 resilience framework:-

- Rapidity (Speed of recovery by avoiding disruptions)
- Resourcefulness (Presence of resources to diagnose problems and initiate solutions
- Redundancy (Presence of alternate elements to satisfy functional requirements)
- Robustness (Ability to provide functionality after being exposed to disasters)

(Liao et al., 2018b; Nipa et al., 2023)

Integrating Resilience in Research

Author	Approach
X. Zhang et al., 2018	A non-linear function for resilience-based design optimization, minimizing cost while meeting resilience constraints.
Liao et al., 2018	An optimization model integrated preparatory and recovery actions under budget and time constraints.
Markolf et al., 2019	Highlighted the importance to consider the indirect effects of climate change.
Tang et al., 2020	Created a hierarchical Bayesian network model to capture multidimensional concerns in system resilience.
Cantillo et al., 2019	Proposed a probabilistic model for network vulnerability evaluation that considered social costs and deprivation costs associated with network disruptions.
Q. Zhang et al., 2020	Used AHP to develop a vulnerability index
Wang et al., 2019	A framework for long-term adaptation planning for UK roadways, prioritizing cost-effective adaptation methods using a Fuzzy Bayesian Reasoning (FBR) model.
Liu et al., 2019	A framework for measuring lifespan performance - a methodology for assessing and enhancing infrastructure resilience.

Integrating Resilience in Practice

Policies and Strategies:

- *Florida Department of Transportation (FDOT):* FDOT has developed a resilience action plan to examine the potential effects of extreme weather events and future disasters on transportation infrastructure. The plan includes efforts to avoid, reduce, or mitigate the effects of hazards and aims to put the policy into practice through various departmental plans and initiatives.

- *Oregon Resilience Plan:* Oregon's plan addresses the resilience of critical infrastructures, including transportation. It includes design considerations and estimations of probable fatality rates, prioritizes backbone routes, and ranks them accordingly.

- *Australian Resilience Policy:* Australia has created a critical infrastructure resilience policy that recognizes the significance of essential infrastructure, such as transportation systems. The policy encourages collaboration with infrastructure owners and operators, knowledge exchange, identifying weaknesses, and strengthening critical infrastructure resilience through strategic imperatives.

Integrating Resilience - INDIA

Author	Approach
Bhavathrathan & Patil, 2018	Used system travel time as a performance indicator to determine network resilience.
Singh et al., 2018	Evaluated the vulnerability of urban road networks to floods by integrating meteorological data, land use functions, and hydrodynamic models
Vajjarapu et al., 2020	Developed a methodological framework to evaluate climate change adaptation strategies.
Patil & Bhavathrathan, 2020	Proposed an innovative approach to identify critical links within road networks, assessing the impact of each link on network capacity.
Mukesh & Katpatal, 2021	Introduced the Flood Vulnerability Road Mobility Index (FVRMI) for evaluating vehicular mobility on road networks during flood conditions.
Vajjarapu et al., 2021	Developed a composite adaptability index using economic, social, and environmental pillars.
M.S et al., 2022	Developed a road network resilience index based on serviceability using the Analytical Hierarchy Process - Multiple Evaluation Criteria (AHP-MCE).

Resilience in Practice

1. The World Bank-funded Himachal Pradesh State Transformation Project, which aims to build mountain roadways that are climate risk resistant.

2. The Green National Highways Corridor Project led by the Ministry of Road Transport and Highways, Government of India, focusing on building and maintaining secure and environmentally friendly national highway corridors, with a strong emphasis on mainstreaming climate resilience in project design and implementation.

Data constraints and Methodological challenges

- **Evolving Interpretations –** Continuously evolving ideas and interpretations
- **Data Constraints -** Limited data resource management in local organizations.
- **Data Quality and Sharing-** Accurate data and the lack of data sharing among stakeholders.
- **Data Collection Costs -** Costly and time-consuming.
- **Complex Network Models:** Complex transportation network models make analysis difficult and expensive.
- **Location-specific limitations**
- **Modeling Issues -** Commuting errors and the use of outdated models.
- **Integration Complexity -** Incorporating the diverse characteristics that affect resilience.

Gaps and Barriers

- **Measurement consensus:** what is the best way to measure resilience, given its multifaceted nature?
- **Limited disaster scenarios:** networks that have never experienced a disaster or on disasters that have already occurred.
- **Neglect of unpredictability:** the unpredictable nature of disasters in terms of frequency and severity.
- **Lack of standard procedure:** There is no standard procedure or strategy for organizations to examine their strengths and weaknesses and create customized plans.
- **Interdependencies neglected:** interactions of the transportation system with other systems and its surroundings.
- **Limited inclusion of vulnerable populations:** the input of vulnerable populations, is largely disregarded.
- **Challenges in operationalization:** lack of knowledge and funding.
- **Coordination requirements:** internal and external organization coordination, tools, and matrices.
- **Lack of long-Term focus:** Short-term transportation planning often fails to prioritize resilience, necessitating awareness-raising and education.

Scope and Conclusion

1. Developing standardized performance metrics for evaluating and analyzing resilience.
2. The complexities and interdependencies between transportation systems and other critical infrastructure systems warrant further study and representation.
3. Multi-hazard resilience of transportation systems, presents intriguing scenarios and research questions.
4. Integrating local expertise and community involvement for enhancing resilience.

We need systems that are flexible, responsive and robust.

To develop a resilient transportation infrastructure, strong measurement frameworks, interdisciplinary collaborations, and community involvement are all required.

Thank You..