

Stress-Testing The Resilience of Critical Infrastructure

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Abstract

Recent shocks and stressors have shown that public sector infrastructure has been built to be efficient but not resilient to disruption. There is currently no standardized approach to evaluate and score public sector investments based on how they will improve a country's resilience, making identifying and prioritizing policies which have a meaningful impact on resilience challenging. The proposed session will discuss a novel framework, which was developed by the UNDRR for assessing the resilience of a country's infrastructure across multiple domains at the national level. It will also present lessons learned from applying the methodology to the case of Trinidad and Tobago.

Introduction

In today's interconnected world, societies rely heavily on complex and interdependent infrastructure systems. While centralization of infrastructure has led to faster, more affordable, and advanced capabilities, it has also rendered systems vulnerable to systemic failures and cascading losses. In response, the United Nations' Sustainable Development Goal 9 (SDG 9) calls for the construction of resilient infrastructure capable of withstanding and recovering from the effects of various hazards efficiently.

To address the need for standardized methodologies to assess and improve a nation's infrastructure resilience, the United Nations Office for Disaster Risk Reduction (UNDRR) has developed a tiered resilient infrastructure tool that 'stress tests' infrastructure performance against a range of potential shocks. This tool offers a scalable and adaptable approach for countries and stakeholders, providing valuable insights into critical functions and infrastructure components that present the most significant systemic benefits if improved. Specifically, the tool offers novel capability to evaluate how complex infrastructure (i) withstands and absorbs shocks of various kinds, (ii) recovers and adapts to disruption posed by those shocks, and (iii) offers recommendations of how to improve infrastructure performance in a cost-effective manner.

interdependencies within modern infrastructure systems. This shortcoming leaves policymakers and infrastructure operators less prepared for disruptions that lack robust historical data (e.g., storms of unprecedented characteristics for a given country), or are fundamentally unknowable given the sheer complexity of infrastructure dependencies and requirements for service delivery (e.g., cybersecurity attacks to vulnerable information systems that connect to or govern infrastructure operations). Furthermore, the lack of a standardized approach for assessing infrastructure resilience can lead to inconsistent practices and hinder effective comparison between nations. A consistent and unified methodology allows for more accurate benchmarking and facilitates international collaboration in developing and implementing best practices. Applying the methodology in country supports improved stakeholder coordination and strengthened cooperation between different levels of infrastructure planning and management.

The UNDRR tiered resilient infrastructure tool addresses this gap by adopting a system-level approach, enabling policymakers to make more informed decisions to enhance infrastructure resilience. Adopting a comprehensive tool such as the UNDRR tiered resilient infrastructure tool can ultimately contribute to more resilient infrastructure systems globally, improving the overall ability of societies to withstand and recover from hazards.

The Policy Problem: A Need for a Comprehensive Stress Test for Infrastructure

Ensuring the reliability of critical infrastructure is a vital policy issue, as disruptions to these systems can have severe and far-reaching consequences. Existing approaches have often focused on component-level risk assessments, overlooking the complex

The UNDRR Methodology: Stress Testing Critical Infrastructure Systems

Tier 1: Screening Risk

The UNDRR Tiered Resilient Infrastructure Tool begins with a Tier 1 assessment, which aims to provide a

comprehensive understanding of the most crucial considerations for a given country. This involves (i) identifying and evaluating the importance of a country's critical functions, which are the essential services provided by various infrastructure components, and (ii) pinpointing and evaluating the risks that pose the most severe, long-lasting, and systemic harms to these critical functions.

Critical functions are assessed based on their interconnectedness with different economic sectors, thereby determining the broader economic impacts that could arise from disruptions. Similarly, risks are evaluated according to the threat, vulnerability, and consequences they present to the country. Multi-Criteria Decision Analysis (MCDA) is employed to score and connect these aspects, enabling the tool to be applied in both data-rich and data-poor environments and ensuring its broad applicability.

The outcome of the Tier 1 assessment is the identification of the infrastructure and risks that can compromise a country's operational capacity.

Tier 2: Evaluating System Dependency

Building on the results of Tier 1, the Tier 2 assessment focuses on pinpointing the most critical single points of failure within the country's infrastructure. This is achieved through two steps. First, the interconnections between risks and critical functions are identified, allowing for the adjustment of prioritization to account for potential cascading effects. This system-level approach acknowledges that many cascading failures occur at the intersections of interconnected systems.

Second, the Tier 2 assessment develops resilience-based Key Performance Indicators (KPIs) to further refine the scoring of critical functions by examining their response and recovery from disruptions across physical, cyber, and social domains. Resilience is defined as the ability of a system to absorb, recover, and adapt to disruptions, demonstrating the tool's risk-agnostic approach to assessing infrastructure responses to interconnected risks.

Employing expert-informed MCDA, the Tier 2 assessment generates a semi-quantitative model that reveals how a country and its interrelated components respond to threats. By combining the final scores and KPIs, specific single points of failure can be identified, offering decision-makers actionable insights into which investments and interventions can significantly enhance a country's resilience. This allows for the formulation of specific policy recommendations and the

ability to benchmark and compare the resilience added by various policy options.

Desktop Analysis: Trinidad and Tobago

Trinidad and Tobago, as a small island developing state, is particularly vulnerable to the impacts of natural disasters and other disruptive events. The country's heavy reliance on its energy sector and its geographic location make it susceptible to various risks, including hurricanes, earthquakes, and coastal flooding. As a result, disruption to national infrastructure can arise from various origins, and dramatically affect economic output and quality of life in ways that can take years to recover from.

The UNDRR Tiered Resilient Infrastructure Tool has been applied to various countries, including Trinidad and Tobago. In this case study, the Tier 1 assessment identified oil manufacturing as the most critical industry for maintaining the economy during disruptions. Consequently, the top three critical functions necessary for the country were electricity generation, electricity distribution, and hazardous materials management. The primary risks threatening these functions were found to be earthquakes, tropical storms, and coastal flooding.

The Tier 2 assessment revealed that accounting for interdependencies in Trinidad and Tobago's infrastructure did not alter the prioritization of critical functions and risks, but it did significantly change their scoring. In particular, the cyber and social components of these critical functions demonstrated a considerable potential for cascading disruptions across other vital functions. To improve these results, the data used in the assessment should be validated with national stakeholders, and additional subject matter experts should be engaged to refine the tool's recommendations further. The results of this case study led to two specific policy recommendations:

1. Prioritize investment in improving the resilience of cyber and social domains within the identified critical functions against the identified risks. Key Performance Indicators (KPIs) were generated for each domain and function, enabling policymakers to focus on specific areas that require improvement.
2. Policymakers should concentrate on enhancing the resilience of these systems, rather than merely managing the risks.

The Trinidad and Tobago case study demonstrates the value of the UNDRR tiered resilient infrastructure tool

by offering a practical example of its application. The tool's adaptability and scalability make it suitable for various contexts, providing valuable insights into a nation's infrastructure resilience. The case study showcases the tool's ability to reveal critical infrastructure components and risks that may have otherwise been overlooked, leading to more effective policy interventions and the allocation of resources where they can have the most significant impact.

Policy Recommendations and Lessons Learned

The increasing prevalence of unforeseen disruptions, such as the COVID-19 pandemic and climate change, highlights the need for robust and resilient critical infrastructure. The drive towards greater efficiency and interconnectedness has rendered many systems vulnerable to disruption. Traditional risk management methods have often been insufficient in addressing these complex, system-level challenges. To tackle these issues, we recommend the following policy actions:

1. Adopt a system-level approach: Governments should shift from focusing solely on component-level risk assessments to adopting a system-level approach, recognizing the interdependencies within modern infrastructure systems.
2. Embrace resilience-based strategies: In rapidly changing threat environments, such as those vulnerable to cyber-attacks or climate change, policymakers should adopt resilience-based approaches to ensure infrastructure can effectively absorb, recover, and adapt to disruptions.
3. Invest in research and development: There is a need for more system-level resilience frameworks that offer specific and actionable policy recommendations, like the one presented in this policy brief. Governments should invest in research to develop new methodologies, facilitating the broader adoption of these approaches across different sectors and regions.

Additionally, fostering international cooperation and information sharing is crucial for improving infrastructure resilience worldwide. Governments should collaborate and share best practices, lessons learned, and research findings to strengthen global efforts in building resilient infrastructure systems. By working together, policymakers can more effectively address common challenges and capitalize on the shared experiences of other nations in the quest for resilient and sustainable infrastructure systems. The UNDRR stress testing tool is one vehicle to comparably

evaluate infrastructure performance, and identify common needs, opportunities, and goals for many nations to further their infrastructure resilience.

By implementing these recommendations, policymakers can better address the challenges and opportunities presented by increasingly complex and interconnected infrastructure systems.

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