Holistic Assessment of Critical Infrastructure Resilience during Disasters (HACIRD)

A Case Study of the 2023 Kahramanmaras Earthquakes

Critical infrastructures (CIs) provide society with services essential for its proper functioning. Disasters can impact these CIs, disrupting their services, resulting in severe societal consequences, affecting both the economy and the well-being of the population. While research has been done previously on the performance of specific infrastructures during disasters, far less has been done focusing on the observed resilience from a holistic CI system-of-system perspective. This is done for the 2023 Turkish Kahramanmaras Earthquakes through a novel assessment framework.

In this thesis a framework, the Holistic Assessment of Critical Infrastructure Resilience during Disasters (HACIRD), was developed to both quantitatively and qualitatively assess observed resilience and interdependencies after disastrous events (Figure 1). The framework includes three types of assessments: individual CI, interdependency, and holistic.

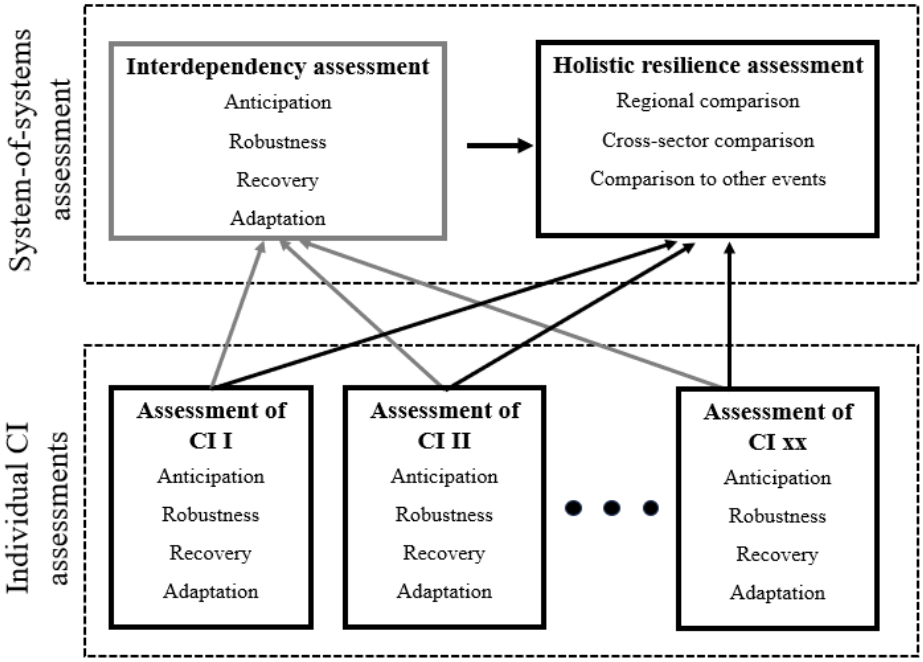

Figure 1. Framework for Holistic Assessment of Critical Infrastructure Resilience during Disasters (HACIRD)

The individual CI assessment, focus on each studied CI sectors resilience through its ability for: 1) *Anticipation* - Proactive measures taken by the system to prepare for the disaster, 2) *Robustness* - How the system managed to keep providing its services, which is quantitatively described as the minimum observed functionality, 3) *Recovery* - How the system managed to restore its operation to its intended normal level, which is quantitatively described as the time from the disaster to its restored to normal functionality. 4) *Adaptation* - How the system learned from the disaster and adapted the system to be better prepared for future disasters.

The interdependency assessment, assess how dependencies of services between CIs either impacted the robustness or recovery of other CIs during the disaster, and what was done prior to address such dependencies and future considerations of CI interdependency issues.

The holistic resilience assessment combines the individual assessments with the interdependency assessment, to examine similarities and differences in how CI sectors managed the impact caused by the disaster and how they restored functionality under the influence of interdependencies. This approach helps identify systematic issues of the CI system-of-systems for a nation or a region.

To demonstrate its practical usefulness and gain insights from a disaster, the HACIRD framework was applied to assess CI resilience during the February 6, 2023, earthquakes in Turkey. Central findings from the case study revealed a highly varying level of resilience across different infrastructures. For instance, the highway network demonstrated both a much higher robustness and recovery during the earthquakes than for example industries. Furthermore, most infrastructures demonstrated a high dependency on the functionality of the electricity infrastructure and most critical infrastructure recovery operations was highly dependent on telecommunication and transport infrastructure. However, there was also an apparent lack of activities conducted by CI operators concerning the identification and management of interdependencies particularly on a system-of-systems level.

The application encountered some challenges as it was challenging to obtain high quality data, and processing the data to fit the framework required the assessor to make many assumptions. It was particularly challenging finding data regarding CI operators anticipation and adaptation towards the disaster. Nevertheless, the application demonstrated the frameworks intuitive and logical approach for conducting post-disaster assessments of interdependent CIs. The results from the case study have the potential to make significant contributions, for example as input data for predictive tools or to build realistic scenarios for preparedness exercises, as well as providing CI operators and responsible agencies with better understanding of the infrastructures and system-of-systems response to the disaster regarding functionality and interdependencies.

Erik Kimblad
2024