3:15: Infrastructure Interdependencies

Background

In recent years, critical infrastructure and other essential services that are necessary for our communities to function properly have become increasingly interconnected and interdependent. This critical infrastructure includes energy (electric power, natural gas, fuels); telecommunications, transportation (rail, road, maritime); water and wastewater; banking and finance; emergency services; government services; healthcare systems; food production; dams and levees; and manufacturing and distribution. To a large degree, this trend toward increased connectivity has been created by our growing reliance on digital systems for the management and operation of our infrastructure. This interconnectivity and the resulting interdependencies exist at multiple levels and in increasing levels of complexity. They extend beyond communities, states, and nations, with the potential for unexpected vulnerabilities with significant consequences.

Management of critical infrastructure during post-disaster recovery needs to be supported by a comprehensive recognition that the recovery of infrastructure can be affected by the interdependencies that exist between different systems. A fundamental characteristic of these interdependencies is that the failure of one infrastructure system can result in the failure of other interdependent infrastructures, leading to a cascade of failures. Although governments, emergency, and business continuity practitioners are beginning to focus on interdependencies, we remain limited in our understanding of them, the vulnerabilities they create, and how to prevent or lessen their impacts. Disruptions in one infrastructure can cascade, ultimately affecting more than one infrastructure, affecting essential government services, businesses, and individuals in an entire region with far-reaching health and human safety, economic, environmental, and national security consequences.

Examples of Infrastructure Dependencies and Interdependencies

Water and wastewater systems, are dependent on a wide range of infrastructures and other essential services, including electricity to power pumps and control systems, petroleum for transportation of repair and maintenance personnel, communications to handle the ordering of chemicals and other supplies and equipment and direct operations, all modes of transportation for supply and shipping, and financial systems to support billing, payments, and other business services. Likewise, electric power utilities depend on natural gas, coal, and petroleum to fuel generators, as well as on road and rail transportation to deliver fuels to the generators, water for cooling and to reduce emissions, and telecommunications to monitor system status and system control, e.g., Supervisory Control and Data Acquisition (SCADA) systems and energy management systems.

Similarly, other types of infrastructure depend on water and electric power and other infrastructure services.

- Computers, process control, telecommunications, and other systems that run infrastructures depend on water for cooling. Water systems may require electric power for operating pumps and need logistics and transportation for supplying water treatment chemicals.

- Natural gas fuels generators in the electric power system. Electric power in turn may be required to operate the systems that are essential for delivering gas (e.g., control systems, storage operations, and compressor stations).

- A substation in an electrical distribution system can provide electric power to a key telecommunication switching center, and rail transportation depends on electric power for signaling, crossing protection, monitoring, and other terminal operations. Under certain conditions, failure or loss of power in a substation directly affects operations at a telecommunication switching center.

- The telecommunications center, in turn, supports SCADA systems for natural gas and oil pipelines, as well as electric power, water, and transportation systems that support electric power.

- Agriculture and food processing, warehousing and distribution, and manufacturing are dependent on all forms of infrastructure including electricity for processes and refrigeration, communications for shipping and logistics; transportation for shipping materials and products, and financial systems to support purchasing of materials and sales of goods.

When infrastructure failures occur and repair crews and replacement components are needed, service providers also depend on other infrastructures, including telecommunications, information technology, fuel, and transportation systems Other dependencies, because of their location or exposure to the environment, are not physically linked but are coupled. A common utility corridor consisting of overhead or underground electric power transmission and distribution lines, underground pipelines, and telecommunications cables illustrates such dependencies. Multiple infrastructure assets are often co-located. Transmission lines for electricity and telecommunications often share the same support systems. Water and wastewater lines often run parallel to one another. The proximity of these systems has the potential to increase vulnerabilities and the potential for simultaneous outages created by hazard events.

Another type of dependency can exist in complex systems without a direct link. The failure of a substation, for example, can lead to the reconfiguration of the electric network, which, in turn, can overload a similar substation within the system if the demand exceeds capacity. In such cases, a direct link usually does not exist, and the failure occurs only when certain conditions are imposed (e.g., maximum load conditions). Natural hazards, such as earthquakes or extreme weather conditions, show how threats can affect multiple infrastructures at the same time. Such threats also reveal interdependencies that can complicate or delay response and mitigation or recovery of a particular infrastructure from an incident. Similar circumstances were experienced in the aftermath of Hurricane Katrina. Water infrastructure was intentionally kept offline in many locations because the power had not been restored to sewer pumps and lift stations. Allowing water systems to operate without pumps and lift stations to effectively convey wastewater would have resulted in significant environmental and human health impacts. Once the power to lift stations was restored, both water and wastewater systems returned to normal functionality.

Mississippi Infrastructure Summary

While the nation's infrastructure earned a "C-" in the 2021 Infrastructure Report Card, Mississippi faces infrastructure challenges of its own. The 2020 Mississippi Infrastructure Report Card gives Mississippi a "D+". Mississippi's infrastructure challenges are directly related to aging infrastructure, lack of routine maintenance, inconsistent data collection, and limited funding. These challenges directly impact the quality of life in Mississippi and potentially threaten commerce in the State.

The 2020 Mississippi Infrastructure Report Card reveals the following:

- There are 73 public-use airports with a five-year demand of $350 million for capital improvements and large maintenance projects. Rising costs of construction resulting in a greater dependence on external funding equates to an estimated $175 million shortfall over the next five years.
- 1,603 (9.4%) of the State's 17,072 bridges are structurally deficient. It is estimated that approximately $1.6 billion is needed for bridge repairs or replacement throughout the State.
- 71% of the state-regulated dams have an Emergency Action Plan. 36% of state-owned dams are in poor or unsatisfactory condition with approximately $1.21 needed to repair all of Mississippi's non-federally owned dams.
- $2.035 billion in wastewater infrastructure needs over the next 20 years.
- Mississippi has over 77,000 miles of public roads, with 43% in poor condition.
- $561 per motorist per year in costs from driving on roads in need of repair.

Historic and Recent Infrastructure Incidents

Jackson, Mississippi Water Treatment Plant Failure – August-September 2022

Flooding from the Pearl River in late August 2022 caused a failure of the O.B. Curtis Water Treatment Plant in the City of Jackson resulting in approximately 150,000 residents of the City without access to safe drinking water. On August 29, 2022, Governor Reeves declared a state of emergency and President Biden declared a federal disaster to trigger federal aid. The lack of water forced many stores and restaurants in Jackson to close, while local schools and universities moved to virtual learning. Most of the City's hospitals have independent water supplies and were not affected by the crisis. As of 2023, concerns still exist in the City over the quality of the drinking water with many residents continuing to boil water or use bottled water. Full system repair costs are estimated at $1 billion and to date, the City has received approximately 60% of that amount through a variety of federal grant sources.

Water Main Breaks – Winter 2017/2018

At the end of 2017 and the beginning of 2018, an unusually severe winter weather event in Mississippi caused problems for Jackson's infrastructure, resulting in a citywide emergency declaration from the Public Works director. At the beginning of the event, there were 32 "significant" water main breaks across the city. A final count of water main breaks confirmed that the year's total was 231 breaks. In a single day, 25 breaks occurred, surpassing the previous high of 22. The city's water treatment plants were operating at maximum capacity because of a quickly dwindling water supply from the breaks. Due to the frozen pipes and inadequate water pressure, Jackson Public Schools were closed for approximately 10 days.

Bridge Closures

On April 10, 2018, Governor Phil Bryant ordered the closing of over 100 deficient Mississippi bridges after receiving a warning letter from the U.S. Department of Transportation. Governor Bryant declared a state of emergency, closing 83 bridges on April 10, 2018. Since then, the number increased to 106. The bridges were inspected and deemed unsafe by the Mississippi Office of State Aid and Road Construction and the federal National Bridge Inspection Standards. Independent consultants were conducting bridge inspections around the state for almost a year. It was part of an action plan created by the Federal Highway Administration and state agencies. The bridges will remain closed until brought up to code.

Recommendations - Mitigation Approach

The challenge of comprehensively understanding infrastructure interdependencies presents an opportunity for innovative approaches to mitigation to ensure operational continuity following hazard events affecting Mississippi. Widespread and prolonged service disruptions can result in significant regional economic and psychological impacts that have the potential to impact commerce and result in the relocation of residents in affected communities. At the same time, economic constraints pose additional challenges for states, localities, and stakeholder organizations, which have limited manpower, funds, and technical expertise to assess and identify appropriate mitigation actions related to all-hazards vulnerabilities from interdependencies.

Regardless of the affecting hazard event, there is a need for a comprehensive, state-wide strategy to improve the resilience of our infrastructure and other essential services to ensure the resilience of the communities that depend on them. This all-hazards, multi-jurisdiction, cross-sector approach to preparedness and resilience includes detection, prevention, mitigation, response, recovery/restoration, training, exercises, and community outreach. It requires utilities and other service providers to examine external linkages that affect their operations and business continuity. It also necessitates bringing together public, private, and non-profit stakeholders with state and federal partners in collaboration to share information and understand and address regional vulnerabilities and consequences posed by infrastructure interdependencies.

As we prepare for the future, we must utilize new approaches, materials, and technologies to ensure our infrastructure is more resilient, allowing for a quick recovery from significant weather and other hazard events; and sustainable, allowing for communities to improve the “triple bottom line” with clear economic, social, and environmental benefits. Specific strategies and approaches to consider that will improve communities’ resilience and sustainability concerning infrastructure interdependence may include:

- Development of active community resilience programs for severe weather and seismic events to establish communications systems and recovery plans to reduce impacts on the local economy, quality of life, and environment.

- Consideration of emerging technologies and shifting social and economic trends when developing new and upgrading existing infrastructure, such as autonomous vehicles, distributed power generation and storage, and larger.

- Improved land use planning at the local level to consider the function of existing and new infrastructure, the balance between the built and natural environments, and population trends in communities of all sizes.

- Support for research and development into innovative new materials, technologies, and processes to modernize and extend the life of infrastructure, expedite repairs or replacement, and promote cost savings.

- Encourage the development of continuity of operations plans for primary infrastructure operators, local businesses, and government entities on all levels to aid in recovery efforts and to assist these entities in their efforts to return to normal operations as quickly as possible following a disaster event.