U.S. Inland Waterway Resilience to Support the Movement of Supply Chains

White Paper

U.S. Committee on the Marine Transportation System

Resilience Integrated Action Team[1]

Summary

Strengthening domestic supply chains is a U.S. national policy priority. To further this goal, it is essential to consider the resilience of the infrastructure systems that enable the movement of goods. In particular, understanding how different types of commodities utilize various transportation modes—and planning strategies to minimize disruptions to these services—is critical to effective supply chain management. Inland waterways are an essential component of a resilient multimodal transport system to underpin the domestic supply chain.

This report summarizes findings from two workshops designed to bring together experts representing both domestic inland waterway operations and management and international associations representing different transportation modes. These groups identified seven key attributes for a resilient transportation system: 1) foundational knowledge and understanding of the system; 2) redundant and maintained transportation infrastructure; 3) mapped interdependencies and known cascading effects; 4) authoritative data, information sharing, and advanced technological integration; 5) established strategic plans and crisis preparedness; 6) strong collaboration, communication, and governance; 7) shared knowledge and workforce development.

In addition to these attributes, experts identified several focus areas and recommendations for driving innovation to increase the resilience of supply chains using domestic freight networks and our inland waterways. First, creating a national multimodal model that includes connectivity, criticality, and capacity across modes would facilitate decision-making on increasing supply chain resilience to transportation disruptions. This model should be based on readily available data and provide the capability to understand the interdependencies between separate infrastructure systems.

Second, another fundamental requirement for effective decision-making is to have authoritative data and the ability to safely and securely share it across diverse partners.

[1] U.S. Committee on the Marine Transportation System Resilience Integrated Action Team, https://www.cmts.gov/Topics-Projects/Resilience/.

There are many authoritative datasets describing the movement and flows of commodities across both individual and multimodal systems.[2,3] However, no central location exists to access scenario planning-level information about the movement of supply chains across multimodal infrastructure systems. A centralized platform to share insights is necessary.

Third, key partners across all modes must assume accountability for the effectiveness and coordination of transportation systems that support the supply chain. Interagency teams or associations would provide a platform for structured communication and coordination of data, best practices, guidance, and training. Additionally, establishing a structured mechanism to engage academic institutions, industry partners, and laboratories would encourage innovative research efforts and provide meaningful support toward achieving these goals.

Background

Recent presidential executive orders aim to strengthen U.S. national prosperity through targeted support for domestic production. Our U.S. industrial base must be stronger, more secure, and more competitive to effectively and efficiently move goods and commodities from origin to destination on our intermodal freight networks. The U.S. inland waterway transportation system serves as the quiet backbone of this network, moving over 500 million tons of goods annually and serving diverse sectors including agriculture, manufacturing, construction, and energy. The waterway system consists of over 12,000 miles of waterways and 176 lock sites.[4] The lock and dam infrastructure supporting this system is aging and subject to unscheduled closures and other disruptions that can interrupt supply chains for weeks to months. The U.S. Army Corps of Engineers (USACE) Lock Unavailability Report notes that in 2023, locks underwent 7,571 periods of unavailability due to 5,856 scheduled shutdowns and 1,715 unscheduled shutdowns.[5]

A renewed focus on bolstering domestic production requires increasing the resilience of the inland waterway system. This system has unique infrastructure and maintenance requirements that support the function of commodity movement. Increasing system resilience means expanding the ability to prepare, recover, and adapt to a variety of unforeseen challenges or disruptions. In this context, resilience is considered a property of a system, not a threat-specific strategy. Therefore, any improvements to navigation infrastructure must be considered in tandem with other transportation modes to understand capability, capacity, and the resulting redundancy supporting commodity movement between systems. When identifying the best ways to increase the resilience of

[2] Freight Analysis Framework, https://www.bts.gov/faf.
[3] National Multimodal Freight Network, https://www.transportation.gov/freight-infrastructure-and-policy/NMFN.
[4] U. S. Army Corps of Engineers, Institute for Water Resources. https://www.iwr.usace.army.mil/Missions/Value-to-the-Nation/.
[5] U.S. Army Corps of Engineers, Lock Performance Monitoring System. Lock Unavailability Report, https://ndc.ops.usace.army.mil/ords/r/lpms/corps-locks/annual-lock-unavailability-report.

supply chains, the scope must include all major transportation modes and focus closely on their interactions.

Also key to increasing resilience is modernizing the technology that helps us monitor, maintain, and recover the functions that keep the supply chain moving. Without the support of these technologies, supply chain owners, operators, and managers would be forced to react to disruptions using only past experience, losing the capacity to anticipate and adapt to future requirements.

Expert Elicitation

The report's findings stem from two workshops designed to evaluate current capabilities, uncover gaps, and determine next steps for improving the resilience of multimodal supply chains. On September 4, 2025, the U.S. Committee on the Marine Transportation System (CMTS) Resilience Integrated Action Team (RIAT) virtually hosted 60 experts from federal agencies, laboratories, and academic partners to discuss domestic supply chains that rely on the inland waterway. On September 12, 2025, the International Transport Resilience Task Force convened 50 global experts both virtually and in-person in Memphis, Tennessee, to consider similar topics. The two workshops were complementary:

- The U.S. CMTS RIAT experts focused on the domestic inland waterway with consideration of connecting modes.
- The International Transport Resilience Task Force included global representation from a variety of transport organizations including the World Association for Waterborne Transport Infrastructure (PIANC),[6] European Aviation at EUROCONTROL,[7] International Union of Railways,[8] and the World Road Association.[9]

To ground the discussion in a real-world case study, the participants of both workshops were asked to consider the resilience of supply chains in the vicinity of Memphis, Tennessee. The city of Memphis is an intersection of major east/west and north/south infrastructure including highways, all five Class I railroads, gas pipelines that service the second busiest cargo airport in the world, and the 11th busiest inland port by tonnage.[10] These multimodal systems enable the movement of massive numbers of commodities across the nation in addition to supporting local services. The highway, rail line, and port all intersect via a series of four bridges that cross the Mississippi River. The area is located on the edge of the New Madrid earthquake fault zone which presents the second highest U.S. earthquake risk after the West Coast. The combination of these transportation risk factors is a challenge to the resilience of both regional and national supply chains. After reviewing

[6] The World Association for Waterborne Transport Infrastructure (PIANC), https://www.pianc.org/.
[7] European Aviation at EUROCONTROL, https://www.eurocontrol.int/.
[8] International Union of Railways (UIC), https://uic.org/.
[9] World Road Association (PIARC), https://www.piarc.org/en/.
[10] U.S. Department of Transportation, Bureau of Transportation Statistics. Top 25 Ports by Total Tonnage (2023). https://data.bts.gov/stories/s/Top-25-Ports-by-Total-Tonnage/iqfi-cuyv/.

the characteristics of the Memphis multimodal transport system, participants were asked the following general questions:

- What are the key components of a resilient multimodal transport system?
- What are the best tools, methodologies, and programs that have helped or will help with increasing the resilience of transportation networks and supply chains?
- Within the next 10 years, what are the most important future focus areas to improve knowledge and close technology gaps?
- What opportunities exist for partnership and collective action moving forward?

Lower Mississippi River in Memphis, Tennessee. Photo by Michelle Carns, CMTS, September 2025.

The following sections are a summary of the discussions generated from these questions to use in planning further action to increase the resilience of domestic supply chains.

Findings: Key Attributes of a Resilient Multimodal Transport System

Participants were asked to envision a resilient multimodal system and identify what makes that system resilient. Answers centered around seven key attributes detailed below. Most of these attributes are characterized in various currently available resources[11] that may prove useful for improving the resilience of multimodal supply chains and several areas of future focus to improve knowledge and capability gaps.

[11] The resources spotlighted within this document are not comprehensive and do not constitute endorsement by the CMTS or its members. For more information and website links, please visit the Appendix - Resource List section at the end of this paper.

Foundational knowledge and understanding of the system

This attribute encompasses comprehensive knowledge of the system, the goods that move through it, and the surrounding environment. This knowledge forms the basis for making informed decisions to improve resilience and includes:

1. System Knowledge – actionable information about physical infrastructure including condition, location, interdependencies, transfer points, critical components, existing capacity, and networked connections for commodities, people, communication, and emergency management.
2. Commodity Knowledge – awareness of highly critical commodities including their specific needs and infrastructure dependencies, shelf-life, value, delivery delay risks, existing vulnerability points, and a plan for the distribution of supplies and personnel to support essential services following a disruption.
3. Environmental Awareness – accurate forecasts and conditions for weather and river stage for the local area, accounting of uncertainty in weather predictions, and utilizing weather definitions that account for all transportation impacts.

Resource Spotlight

- **Bureau of Transportation Statistics (BTS) Port Profiles.** A snapshot of throughput and capacity measures for a port, such as information on vessel calls and the cargo types handled. Includes the top 25 ports by total tonnage, tonnage equivalent units (TEUs), and dry bulk tonnage. Websites: https://www.bts.gov/browse-statistical-products-and-data/port-performance/port-profiles, https://www.bts.gov/ports.
- **BTS National Bridge Inventory.** A geospatial bridge identification and condition tracking that maps bridges crossing navigable waterways, links each to its multiple official evaluation numbers, and associates them with potentially impacted ports and their identifications. By linking structural evaluation data with potential port impacts, it enables planners to identify and prioritize bridges whose failure would cause the most severe supply chain disruptions. These insights directly support port resilience by guiding monitoring efforts, maintenance planning, and investment decisions to protect critical transportation links. Data is obtained from the Federal Highway Administration and is part of the BTS National Transportation Atlas Database. Website: https://geodata.bts.gov/datasets/national-bridge-inventory/explore.
- **USACE Lock Operations Management Application (LOMA).** USACE owns a network of Automatic Identification System (AIS) stations along inland waterways to receive vessel position information and to broadcast safety messages to mariners. Broadcasts may include virtual aids to navigation and geographic notices (polygon-based warning messages) that display on electronic chart plotters. LOMA has the capability to broadcast local weather if attached to appropriate weather sensors. Publication: *Virtual Aids to Navigation (VATONs) from the USACE LOMA Program, 2018-2023* (https://apps.dtic.mil/sti/html/trecms/AD1229880/). For additional information please visit *Potential Lock Operations Management Application*

(LOMA)Hardware Installation Sites along the Ohio River to Improve Automatic Identification System (AIS) *Reception and Transmit Range,* https://apps.dtic.mil/sti/html/trecms/AD1222470/.

- **USA Trade Online Data**. Tool provided by the U.S. Census Bureau that grants user access to current and cumulative U.S. export and import data. Data is updated each month with the release of the latest U.S. International Trade in Goods and Services Report. Website: https://usatrade.census.gov/.
- **USACE Engineer Research and Development Center (ERDC) U.S. Freight Transload Facilities Dataset.** Provides location information (latitude, longitude, zip, city, county, state) for more than 9,000 facilities across the 50 U.S. states where freight may be transferred between waterways, railways, and roadways. Dataset lists the known modes and available direction(s) for freight transfers at each facility as of 2024. Publication: *U.S. Freight Transload Facilities*, https://dx.doi.org/10.21079/11681/49500.
- **ERDC Major Freight Corridors in the United States**. Maps and analysis of commodity flows on water, rail, and truck networks, developed by the USACE ERDC. Provides a comprehensive understanding of the routes and paths where products are transported through the surface multimodal transportation system. Identifies the corridors where most freight is transported, by commodity. Publication: *Major freight corridors in the US: mapping of commodity flows on waterborne, rail, and truck networks*, https://erdc-library.erdc.dren.mil/items/5a446f1c-9404-438f-b43c-f797fa55be14.
- **National Weather Service (NWS) Localized Weather and River Forecasts and Impact-Based Decision Support Services.** Local NWS Forecast Offices in an area can deploy to provide on-site weather/river forecasts during recovery efforts, if needed. In addition, daily briefings can be provided via email or virtually. Website: https://www.weather.gov/.
- **Federal Maritime Commission (FMC) Common Carrier Agreement Files**. Dashboards developed by the FMC to track changes in trade patterns, volume, rates, and services in international trade. Websites: https://www.fmc.gov/databases-and-publications/containerized-freight-statistics/; https://www2.fmc.gov/FMC.Agreements.Web/Public.

Future Focus

Any improvements, whether they be changes to response efforts, methodologies, or planning processes, must be grounded in readily available and accurate data about the infrastructure systems involved. However, there is presently no central location for accessing information about the multiple infrastructure systems that support supply chains. Ensuring key partners across all modes of transportation can coordinate effectively will allow for safer, stronger, and more resilient supply chains.

Redundant and maintained transportation infrastructure systems

This attribute includes well-maintained existing infrastructure, redundant systems and alternative routes, and the ability to shift between transportation modes to withstand disruptions.

1. Maintained Physical Infrastructure – physical assets are well-maintained, meeting both performance and availability requirements (e.g. bridges, cranes, and navigation channels). Key infrastructure assets have backup plans for disruptions, including surge capacity, backup system, alternate infrastructure, and temporary storage facilities.
2. Multimodal Redundancy and Alternatives – alternate routes are identified, planned and available. Modal shift capacity exists to transition between modes as needed, and if no capacity exists because of limitations, then alternate plans are identified.

Resource Spotlight

- **CMTS Federal Funding Handbook for the Marine Transportation System**. Created and maintained by the CMTS, the Sixth Edition of the Handbook provides a compilation of federal funding programs related to marine transportation system (MTS) infrastructure. These programs span a range of federal departments and agencies with a variety of interests in the MTS and are designed to stimulate the economy and benefit the public. Funding opportunities within these programs may be provided as grants, loans, loan guarantees, or as one of several other types of financial support. Several federal assistance resource centers provide support to help potential applicants navigate the different kinds of funding opportunities, including: The Build America Bureau (Department of Transportation (DOT)), the Water Infrastructure and Resiliency Finance Center (U.S. Environmental Protection Agency), Grants.gov, and others. Publication: *Federal Funding Handbook for the Marine*

CASE STUDY: MULTIMODAL REDUNDANCY

From 2020 to 2022, 50-year record low water on the Paraguay-Paraná waterway resulted in draft restrictions and reduced carrying capacity of ships on the river.

To address rising prices and cargo loss to foreign ports, cargo shifted to deeper Atlantic ports, which led to a sudden 48% increase in cargo for Bahía Blanca.

With limited railways and degraded roads, the port lacked adequate multimodal support. The cargo shift resulted in major road congestion, decreased relations with communities, traffic fatalities, and higher costs.

https://www.pianc.org/permanent-task-group-on-climate-change/

Transportation System, Sixth Edition, March 2024, https://rosap.ntl.bts.gov/view/dot/73618.

- **ERDC Multimodal Freight Routing Tool.** USACE ERDC tool to identify alternative shipping routes in the event of an unplanned closure of a transportation mode – such as a bridge, navigable waterway segment, roadway, or rail line. Capable of routing freight with origin and destination at Counties within the Continental U.S. sensitive to cargo type. Publication/case study: *Evaluating Transport of Stockpiled Mississippi River System Sand for Beach Nourishment and Other Uses*, https://dx.doi.org/10.21079/11681/49893.
- **DOT National Multimodal Freight Network (NMFN)**. The NMFN is being established by the Multimodal Freight Office at the DOT to assist states in directing resources toward more efficient movement of freight through planning, assisting prioritization of federal investments, and assisting in achieving federal policy goals. Website: https://www.transportation.gov/freight-infrastructure-and-policy/NMFN.

Future Focus

Critical to any plans, process, or communication regarding supply chain resilience is a multimodal model that includes connectivity, criticality, and capacity across modes. There are tools that exist within modes, and tools that accomplish these analyses for specific regions or case studies, but at present no publicly available tool exists to provide this analysis nationally. With these insights, it becomes much easier to conduct meaningful quantitative assessments of supply chain resilience within a region.

Mapped interdependencies and known cascading effects

A holistic understanding of hazard effects and how they interact with interdependencies is crucial for supply chain resilience as disruptions rarely remain isolated. Compound effects stem from the coincidence of multiple risks, amplifying their combined impact. Cascading effects happen when one event triggers a sequence of subsequent events. This attribute focuses on mapping the variety of interdependencies that exist across the supply chain, understanding how effects propagate, and ensuring that clear objectives are set for the system so that organizations can develop targeted interventions at critical junctions to maintain essential functions.

1. Interdependency Analysis – includes understanding the requirements and dependencies of each transportation system on surrounding utilities, infrastructure, and communities within which it operates. This includes established requirements for essential functions during a disruption.
2. Hazard Effects Analysis – this analysis includes an understanding of how the effects of hazards can propagate and result in secondary and tertiary impacts within and between transportation modes.

Resource Spotlight

- **Modeling Complex, Multi-Vector Disruptions to the Marine Transportation System.** The Modeling of Complex, Multi-Vector Disruptions (MCAT) tool was developed by the Command, Control, and Interoperability Center for Advanced Data Analysis Center led by Rutgers University, the Center for Risk and Economic Analysis of Threats and Emergencies led by the University of Southern California, and the Center for Accelerating Operational Efficiency Center led by Arizona State University; all Department of Homeland Security (DHS) Centers of Excellence. Using economic modeling to investigate pre- and post-incident mitigation and resilience strategies, MCAT is a decision-support tool to improve risk management at the local, regional, and national level. MCAT is used to estimate cascading economic impacts of complex disruptions. DHS Centers of Excellence website: https://www.dhs.gov/science-and-technology/centers-excellence; MCAT Publication: *Complex Economic Consequence Analysis to Protect the Maritime Infrastructure*, https://create.usc.edu/wp-content/uploads/2022/11/IEEE_HST_MCAT_November-2022.pdf.

Future Focus

A model of multimodal connectivity has been identified as a promising opportunity for future development. This model could also incorporate the ability to understand interdependencies across different infrastructure systems and to represent compound hazards. By integrating high-impact, low-probability events, hazard modeling can more effectively reveal these interconnections and potential cascading effects. Moreover, if these models can incorporate flexibility in assessing systems at the micro-, meso-, and macro-scale, then the quality of modeling and the options for applying the information to planning and response efforts will increase.

Authoritative data, information sharing, and advanced technological integration

Data and information sharing form the backbone of effective decision-making during disruptions. Integrating new technologies will result in powerful tools to support these decisions. The ability to integrate diverse data sources, provide metadata and update frequencies, model complex scenarios, and communicate uncertainty appropriately allows supply chain stakeholders to anticipate disruptions and coordinate responses. Technology can help identify vulnerabilities, simulate disruption scenarios, and coordinate responses across complex networks with improvements ranging from AI-assisted decision support to modeling and communication platforms. However, technology must be integrated with human expertise and organizational readiness to be grounded in reality.

1. Data Management and Sharing – data has frequent and documented updates and comes from diverse and authoritative sources. The mechanisms to access this data are reliable and shared between stakeholders and across transportation modes.
2. Technological Integration – advanced technology is integrated across the regional supply chain. For example, communications platforms are established to support communications and visibility, and models of integrated transportation systems can result in informed planning, real-time response decisions, and new AI insights for complex resilience problems. It is important that these technologies are well communicated, and training is available to develop adaptive capacity through skills development.

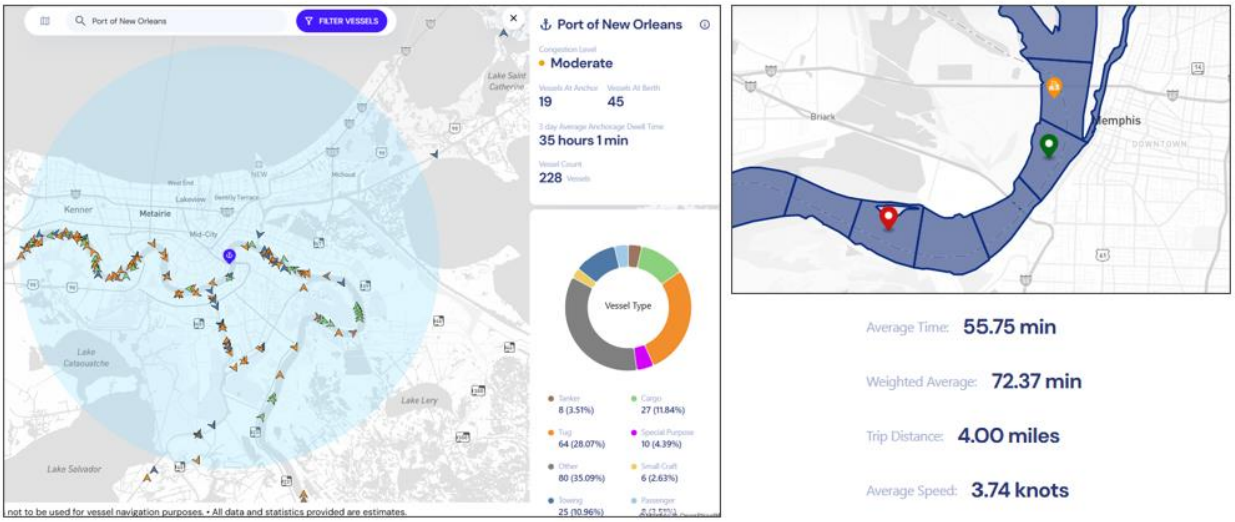
Resource Spotlight

- **BTS Waterways Intelligence Monitoring System (WIMS)**. WIMS is a real-time marine transportation system monitoring tool, which provides daily transit counts and times for the inland waterways. The WIMS tool provides vessel calls, berthing times, and anchorage time statistics for coastal ports. Made by Trabus Technologies for the U.S. DOT BTS. Website: https://wims.trabus.com/login.
- **BTS National Transportation Atlas Database (NTAD)**. The NTAD is a collection of national geospatial datasets of modal and intermodal transportation facilities and networks; flows of people, good, vehicle, and craft over the transportation networks across all modes; and social, economic, and environmental conditions that affect or are affected by the transportation networks. Users can browse, download, and use NTAD data for analytical and visualization purposes. Website: https://data-usdot.opendata.arcgis.com/
- **DOT Freight Logistics Optimization Works (FLOW)**. A public-private partnership among industry and government to build a forward-looking, integrated view of supply chain conditions in the United States. FLOW data helps forecast how current capacity and throughput will fare against future demand, helping participating companies anticipate changes in supply chain throughput and take proactive step to mitigate previously unanticipated delays. The FLOW program collects purchase order information from importers in addition to logistics supply, demand, and throughput data from participants (e.g., beneficial cargo owners, ocean carriers, ports, terminals, railways). The United States DOT anonymizes, regionally segments, and aggregates the data. Participants then receive FLOW data that provides a broad, daily view of the current conditions of the overall logistics network, beyond what they may observe within their own operations. Website: https://www.transportation.gov/freight-infrastructure-and-policy/flow.

Future Focus

Reliable data and the capacity to share it is a fundamental requirement for effective decision-making. Presently, no platform exists to share supply chain data across modes or even across federal agencies that manage different modes. A centralized web-based

platform to share insights would greatly enable future supply chain resilience assessments.



Screen capture of Waterway Intelligence Monitoring System user interface for the Port of New Orleans. Information provided includes vessels in the vicinity, their types, average speed, and dwell times. Source: Bureau of Transportation Statistics, https://wims.trabus.com/login

Established strategic plans and crisis preparedness

This attribute involves taking proactive measures to anticipate and manage disruptions. These measures include strategic planning for future resilience improvements, emergency preparedness planning, and risk assessment through scenario planning.

1. Solid Strategic Planning and Alignment – Strategic planning for resilience should be considered a competitive advantage rather than merely a defensive action, representing a forward-thinking business approach. Resilience improvement plans should begin with a clear definition of resilience and well-socialized objectives that are integrated into an organization's regular business processes. This will allow good understanding of decision-making processes so that recommendations to increase resilience make sense.
2. Risk Assessment and Scenario Planning – proactive scenario planning to manage systemic risks, test response plans, and weigh emergency response actions. Participants should be encouraged to imagine the impossible, then the inevitable – encouraging anticipatory thinking and preparedness for low-probability, high-risk events. These risk assessments ensure knowledge and consideration of future conditions, response options to a variety of hazards, and associated failure modes across the entire system. For multimodal systems, risk assessments should consider cross-modal dependencies and model expected disruptions as well as high-impact and low-probability events.

3. Effective Disaster Preparedness – This attribute includes both planning and action. Examples include established emergency preparedness and crisis response plans based on scenario planning and risk assessments, pre-positioned emergency supplies, pre-established contractual or legal frameworks ready for quick action, and a trained, well-coordinated regional cadre of first responders. Disaster preparedness plans should include defined levels of service to establish clear parameters for response and recovery planning. This allows a targeted return to normalcy for priority services and functions.

Resource Spotlight

- **CMTS Supply Chain Tabletop Exercises.** Discussion-based tabletop exercises to identify policies, procedures, and regulations governing the resumption of trade following a supply chain disruption and identifying strategies to mitigate supply chain disruption impacts. These exercises are facilitated by the CMTS Supply Chain and Infrastructure Integrated Action Team and include participants from the federal government, MTS industry, state and local representatives, and academics. Publications: *Port of Cleveland, Ohio: Supply Chain Disruption Tabletop Exercise — After Action Report*, https://rosap.ntl.bts.gov/view/dot/80599; *Port of Baltimore, Maryland: Supply Chain Policy Tabletop Exercise After Action Report*, https://rosap.ntl.bts.gov/view/dot/73669.
- **Vanderbilt Resilience Investment Planning.** A decision support tool being developed by Vanderbilt University to evaluate the return on investing in climate resilient infrastructure. Once development is complete, this analytical tool will calculate the present value of making an investment to enhance the resilience of critical infrastructure to various climate disasters under future climate scenarios. Publication: *How flood-resilient port infrastructure can reduce economic impacts of climate change*, https://www.tandfonline.com/doi/full/10.1080/10286608.2025.2460220.
- **DHS Integrated Supply Chain Analysis.** A capability of the DHS Supply Chain Resilience Center, the analysis serves as a hub where industry and government come together to address supply chains that support the reliable functioning of critical infrastructure that provide essential services. Website: https://www.dhs.gov/scrc.
- **Transportation Security Administration (TSA) Online Exercises / Industry Collaboration.**The TSA Exercise Information System (EXIS®) assists security planners to build and manage exercise planning teams and share best practices and lessons learned. Offered at no cost, the system provides users with resources to design, document, and evaluate exercises for all transportation modes. Website: https://exis.tsa.dhs.gov/default.aspx.

- **Argonne Success Path Methodology.** An analysis of the safety and reliability of equipment, indicating vulnerable areas in need of addressing. The difference between the Success Path Methodology and other more traditional probabilistic assessments is that the methodology focuses on what equipment and human interventions are necessary for success, as opposed to evaluating countless failure scenarios. Website: https://www.anl.gov/esia/assessing-risk-the-success-path-methodology.

Future Focus

Resilience assessment and planning is often kept separate from capital investment planning or business planning. In the future, planning should consider the long-term business case for resilience investments. Better understanding of the business case and operational decision-making frameworks will result in several outcomes – better integration of modeling outcomes, integration of resilience into standard procedures, and an awareness of the cost of *not* considering resilience-building strategies.

Another key area of concern for strategic planning is misalignment of regulatory and jurisdictional policies across organizations and government systems that support the supply chain. Making thoughtful changes to these policies can increase resilience by creating a more supportive regulatory environment for adaptation measures.

Strong collaboration, communication, and governance

This attribute highlights the importance of human factors and organizational structures in building resilience. It includes effective community engagement, partner communication, thoughtfully coordinating across traditional barriers or silos, ensuring clear governance, and defining responsibilities for effective coordination.

1. Community Engagement and Partner Communication – thoughtful identification of a diverse and representative group of stakeholders and decision-makers to ensure understanding and communication between these groups. For example, an awareness of neighborhoods surrounding a port and how they would

MAKING THE BUSINESS CASE FOR RESILIENCE

In its 2024 publication "Climate Change Costs to Ports and Waterways: Scoping the Business Case Assessment for Investment in Adaptation," PIANC identified the business case for investment in resilience. Adaptive action results in a triple dividend:

1. Economic losses avoided
2. Safeguard investments through risk reduction
3. Social and environmental benefits

Avoided damages and disruption-related losses are another key benefit of investing in resilience.

These concepts are familiar to corporate decision makers but often not infrastructure managers.

For more information: *Climate Change Costs to Ports and Waterways: Scoping the Business Case Assessment for Investment in Adaptation*, https://www.pianc.org/publication/climate-change-costs-to-ports-and-waterways-scoping-the-business-case-assessment-for-investment-in-adaptation/

be impacted by a disruption. Effective communication should include a mass communication channel to share a common operational picture during a disaster response.

2. Coordination Across Barriers – solid communication and consensus between owners and operators, between infrastructure managers and infrastructure users, between transportation modes, and across jurisdictions. In addition to communications channels between these groups, there should be an analysis to understand silos of responsibility across organizations and to understand and navigate any differences in policies between jurisdictions.
3. Established Governance and Responsibilities – a clarification of roles and responsibilities between partner organizations in an emergency. This includes aligning role-players that are involved with interdependent systems, ensuring buy-in and political support for resilience initiatives, and managing both stakeholder and general public expectations during supply chain disruptions.

Resource Spotlight

- **DHS Homeland Security Information Network**. A platform that provides a collaborative workspace for interagency communication and cooperation which enables the safe and secure sharing of Sensitive but Unclassified information among federal, state, local, territorial, tribal, international and private sector partners. Website: https://www.dhs.gov/homeland-security-information-network-hsin.
- **U.S. Center for Maritime Innovation (USCMI).** Sponsored by the Maritime Administration, USMCI supports the study, development, assessment, and deployment of innovative initiatives to drive transformative change for the U.S. maritime industry and the U.S. MTS. The Center's scope is to support a wide range of maritime research and innovation critical to a safe, efficient, and competitive MTS. USCMI research focuses on

BEST PRACTICE: RESILIENT RAILWAYS NETWORK

The International Union of Railways has established the Resilient Railways (RERA) Program to create guidance and gather case studies for infrastructure and operational resilience to hazards including rain, temperatures, wind, and cyber.

Guidance and best practices are compiled from the input of over 200 collaborators within the RERA network and are available online at: https://uic.org/

maritime energy, maritime operations, U.S. maritime competitiveness, and maritime resilience. Website: https://www.uscmi.org/.

Future Focus

Multimodal supply chains would greatly benefit from structured institutional coordination that results in training and templates for supply chain resilience planning exercises, case studies and best practices, key point-of-contact lists for multimodal planning efforts, and regional and national forums to facilitate discussion across modes.

Shared knowledge and workforce development

This attribute highlights the critical role of a skilled workforce in maintaining supply chain resilience. By developing a resilience-competent workforce, sharing best practices, and providing clear technical guidelines, organizations can build institutional knowledge and capacity to respond to disruptions. This knowledge transfer is particularly valuable for preparing for low-frequency, high-impact events where direct experience may be limited.

1. Thoughtful Workforce Development and Training – training on resilience principles is available for employees and experienced personnel are available to assist with supply chain disruptions that are well-versed in the application of resilience concepts. Organizations ensure that these employees are supported and that the bench is deep with future experts in training.
2. Shared Knowledge & Technical Guidance – best practices, technologies, and new studies are essential for building collective knowledge and capabilities across regions and organizations. These findings should be shared. For more established principals, technical guidelines exist and capture on how to implement these principles and practices. These guidelines include best practices, case study examples, and are periodically updated based on learned experiences.

Resource Spotlight

- **Federal Emergency Management Agency (FEMA) National Disaster & Emergency Management University**. Comprehensive training, professional development, and education continuum for emergency management professionals to ensure that the U.S. remains secure and resilient. Comprised of three specialized schools supporting different emergency management career paths and specialized communities: the Emergency Management Institute; School of Disaster Leadership; and School of National Resilience.
  Website: https://training.fema.gov/.
- **World Association for Waterborne Transport Infrastructure (PIANC).** PIANC unites international experts to write leading-edge technical reports to be shared broadly across the international community. The organization includes four technical Commissions cover the different areas of waterborne transport infrastructure: inland navigation (InCom), maritime navigation (MarCom),

recreational navigation (RecCom) and environmental matters (EnviCom). These Commissions host working groups are convening to produce guidance on a wide variety of topics, including Port Resilience Assessments. Website: https://www.pianc.org/ongoing-working-groups/.

Future Focus

There is an important opportunity to clarify leadership in developing training materials, identifying best practices, and establishing guidance that supports resilience across a multimodal supply chain. Ideally, this information will be experience-based, regularly updated, and readily accessible to a wide range of interested partners. Both international and domestic organizations are well-positioned to meet these needs by bridging traditional silos and promoting the exchange of knowledge across modes, regions, and countries. Additionally, creating a structured mechanism for engaging academic partners and laboratories can help inspire innovative research and provide meaningful support for future research efforts.

Conclusion

Strong domestic supply chains rely heavily on the resilience of the national multimodal transportation network, with inland waterways serving as a foundational backbone. As demonstrated by the expert elicitation workshops, achieving true system resilience requires moving beyond reactive, threat-specific fixes towards a proactive and integrated approach that views resilience as a fundamental property of the entire system. By focusing on the seven key attributes identified by domestic and international experts, decision makers can better anticipate and manage disruptions. And finally, to operationalize these attributes and close existing capability gaps, three primary recommendations must be prioritized: develop a comprehensive data-driven model that maps connectively, criticality, and capacity across the MTS and linked transportation modes, establish a centralized and secure platform to integrate data sharing for scenario-level analyses and real-time decision support, and create structured mechanisms for interagency and public-private collaboration.

Appendix - Resource List:[12]

All resources identified throughout this report are summarized here in one section.

1. **BTS Port Profiles**. Provides a dashboard of throughput and capacity measures for a port, such as information on vessel calls and the types of cargo handled. Includes the Top 25 ports by total tonnage, TEUs, and dry bulk tonnage.

[12] The resources spotlighted within this document are not comprehensive and do not constitute endorsement by the CMTS or its members.

Website: https://www.bts.gov/browse-statistical-products-and-data/port-performance/port-profiles. See also https://www.bts.gov/ports.

2. **BTS National Bridge Inventory**. A geospatial bridge identification and condition tracking that maps bridges crossing navigable waterways, links each to its multiple official evaluation numbers, and associates them with potentially impacted ports and their identifications. By linking structural evaluation data with potential port impacts, it enables planners to identify and prioritize bridges whose failure would cause the most severe supply chain disruptions. These insights directly support port resilience by guiding monitoring efforts, maintenance planning, and investment decisions to protect critical transportation links. Data is obtained from the Federal Highway Administration and is part of the DOT BTS National Transportation Atlas Database.

   Website: https://geodata.bts.gov/datasets/national-bridge-inventory/explore.

3. **USACE Lock Operations Management Application**. USACE owns a network of AIS stations along inland waterways to receive vessel position information and to broadcast safety messages to mariners. Broadcasts may include virtual aids to navigation and geographic notices (polygon-based warning messages) that display on electronic chart plotters. LOMA has the capability to broadcast local weather if attached to appropriate weather sensors.

   Publication: *Virtual Aids to Navigation (VATONs) from the USACE LOMA Program, 2018-2023* (https://apps.dtic.mil/sti/html/trecms/AD1229880/). For additional information please visit *Potential Lock Operations Management Application (LOMA) Hardware Installation Sites along the Ohio River to Improve Automatic Identification System (AIS) Reception and Transmit Range* (https://apps.dtic.mil/sti/html/trecms/AD1222470/).

4. **USA Trade Online Data**. Tool provided by the U.S. Census Bureau that grants user access to current and cumulative U.S. export and import data. Data is updated each month with release of the latest U.S. International Trade in Goods and Services Report.

   Website**:** https://usatrade.census.gov/.

5. **ERDC U.S. Freight Transload Facilities Dataset.** Provides location information (latitude, longitude, zip, city, county, state) for more than 9,000 facilities across the 50 U.S. states where freight may be transferred between waterways, railways, and roadways. Published by USACE's ERDC, the dataset lists the known modes and available direction(s) for freight transfers at each facility as of 2024.

   Publication: *U.S. Freight Transload Facilities*, https://dx.doi.org/10.21079/11681/49500.

6. **ERDC Major Freight Corridors in the United States.** Maps and analysis of annual commodity flows on water, rail, and truck networks, developed by USACE's ERDC. Provides a comprehensive understanding of the routes and paths where products are transported through the surface multimodal transportation system. Identifies the corridors where most freight is transported, by commodity.

   Publication: *Major freight corridors in the US: mapping of commodity flows on waterborne, rail, and truck networks*, https://erdc-library.erdc.dren.mil/items/5a446f1c-9404-438f-b43c-f797fa55be14.

7. **NWS Localized Weather and River Forecasts and Impact-Based Decision Support Services.** The National Oceanic and Atmospheric Administration's NWS products and services support daily decisions of the response and resilience community. Local NWS offices can deploy forecasters and provide on-site weather/river forecasts during recovery efforts.

   Website: https://www.weather.gov/.

8. **FMC Common Carrier Agreement Files.** FMC developed dashboards using commercial sources of trade data to track changes in trade patterns, volume, rates, and services in international trade. Some information collections include OSRA mandated containerized freight, effective vessel-operating common carrier and marine terminal operator agreement filings, and confidential service contracts and monitoring data.

   Websites: https://www.fmc.gov/databases-and-publications/containerized-freight-statistics/; https://www2.fmc.gov/FMC.Agreements.Web/Public.

9. **CMTS Federal Funding Handbook for the Marine Transportation System, Sixth Edition, March 2024**. Created and maintained by the CMTS, the Sixth Edition of the Handbook provides a compilation of federal funding programs related to MTS infrastructure. These programs span a range of federal departments and agencies with a variety of interests in the MTS and are designed to stimulate the economy and benefit the public. Funding opportunities within these programs may be provided as grants, loans, loan guarantees, or as one of several other types of financial support. Several federal assistance resource centers provide support to help potential applicants navigate the different kinds of funding opportunities, including: The Build America Bureau (DOT), the Water Infrastructure and Resiliency Finance Center (U.S. Environmental Protection Agency), Grants.gov, and others.

   Publication: https://rosap.ntl.bts.gov/view/dot/73618.

10. **ERDC - Multimodal Freight Routing Tool**. A USACE ERDC tool to identify alternative shipping routes in the event of an unplanned closure of a transportation network link – such as a road bridge, a navigable waterway segment, roadway, or rail line.

Capable of routing freight with origin and destination at Counties within the Continental U.S. sensitive to cargo type.

Publication/case study: *Evaluating Transport of Stockpiled Mississippi River System Sand for Beach Nourishment and Other Uses*, https://dx.doi.org/10.21079/11681/49893.

11. **DOT National Multimodal Freight Network (NMFN)**. The MNFM is being established by the Multimodal Freight Office at the U.S. DOT to assist states in directing resources toward more efficient movement of freight through planning, assisting prioritization of federal investments, and assisting in achieving federal policy goals.

    Website: https://www.transportation.gov/freight-infrastructure-and-policy/NMFN.

12. **Modeling Complex, Multi-Vector Disruptions to the Marine Transportation System**. The Modeling of Complex, Multi-Vector Disruptions (MCAT) tool was developed by the Command, Control, and Interoperability Center for Advanced Data Analysis Center led by Rutgers University, the Center for Risk and Economic Analysis of Threats and Emergencies led by the University of Southern California, and the Center for Accelerating Operational Efficiency Center led by Arizona State University; all DHS Centers of Excellence. Using economic modeling to investigate pre- and post-incident mitigation and resilience strategies, MCAT is a decision-support tool to improve risk management at the local, regional, and national level. MCAT is used to estimate cascading economic impacts of complex disruptions.

    DHS Centers of Excellence website: https://www.dhs.gov/science-and-technology/centers-excellence.
    MCAT Publication: https://create.usc.edu/wp-content/uploads/2022/11/IEEE_HST_MCAT_November-2022.pdf.

13. **BTS - Waterways Intelligence Monitoring System (WIMS).** WIMS is a real-time marine transportation system monitoring tool, which provides daily transit counts and times for the inland waterways. Provides vessel calls, berthing times, and anchorage time statistics for coastal ports. Made by Trabus Technologies for the U.S. DOT BTS.

    Website: https://wims.trabus.com/login.

14. **BTS National Transportation Atlas Database (NTAD)**. The NTAD is a collection of national geospatial datasets of modal and intermodal transportation facilities and networks; flows of people, good, vehicle, and craft over the transportation networks across all modes; and social, economic, and environmental conditions that affect or are affected by the transportation networks. Users can browse, download, and use NTAD data for analytical and visualization purposes.

Website: https://data-usdot.opendata.arcgis.com/.

15. **DOT Freight Logistics Optimization Works (FLOW)**. A public-private partnership among industry and government to build a forward-looking, integrated view of supply chain conditions in the United States. FLOW data helps forecast how current capacity and throughput will fare against future demand, helping participating companies anticipate changes in supply chain throughput and take proactive step to mitigate previously unanticipated delays. The FLOW program collects purchase order information from importers in addition to logistics supply, demand, and throughput data from participants (e.g., beneficial cargo owners, ocean carriers, ports, terminals, railways). The DOT anonymizes, regionally segments, and aggregates the data. Participants then receive FLOW data that provides a broad, daily view of the current conditions of the overall logistics network, beyond what they may observe within their own operations.

    Website: https://www.transportation.gov/freight-infrastructure-and-policy/flow.

16. **Supply Chain Tabletop Exercises.** Discussion-based tabletop exercises to identify policies, procedures, and regulations governing the resumption of trade following a supply chain disruption and identifying strategies to mitigate supply chain disruption impacts. These exercises are facilitated by the CMTS Supply Chain and Infrastructure Integrated Action Team and includes participants from the federal government, MTS industry, state and local representatives, and academics.

    Publications: Port of Cleveland, Ohio: Supply Chain Disruption Tabletop Exercise — After Action Report, https://rosap.ntl.bts.gov/view/dot/80599; Port of Baltimore, Maryland: Supply Chain Policy Tabletop Exercise After Action Report, https://rosap.ntl.bts.gov/view/dot/73669.

17. **Vanderbilt - Resilience Investment Planning.** A decision support tool being developed by Vanderbilt University to evaluate the return on investing in climate resilient infrastructure. Once development is complete, this analytical tool will calculate the present value of making an investment to enhance the resilience of critical infrastructure to various climate disasters under future climate scenarios.

    Publication: How flood-resilient port infrastructure can reduce economic impacts of climate change, https://www.tandfonline.com/doi/full/10.1080/10286608.2025.2460220.

18. **DHS Integrated Supply Chain Analysis**. The DHS SCRC was developed to establish an entity to address critical supply chain vulnerabilities and disruptions that impact the U.S. economy and the protection of critical infrastructure. The SCRC relies on integrated supply chain analysis to anticipate, monitor, and respond to supply chain risks.

Website: https://www.dhs.gov/scrc.

19. **TSA Online Exercises / Industry Collaboration.** The TSA Exercise Information System (EXIS®) assists security planners, build and manage exercise planning teams, and share best practices & lessons learned. The system provides users with resources to design, document and evaluate exercises for all transportation modes and is offered at no cost.

    Website: https://exis.tsa.dhs.gov/default.aspx.

20. **Argonne Success Path Methodology**. An analysis of the safety and reliability of equipment, indicating vulnerable areas in need of addressing. The difference between the Success Path Methodology and other more traditional probabilistic risk assessments is that the methodology focuses on what equipment and human interventions are necessary for success, as opposed to evaluating countless failure scenarios.

    Website: https://www.anl.gov/esia/assessing-risk-the-success-path-methodology.

21. **DHS Homeland Security Information Network (HSIN)**. A platform that provides a collaborative workspace for interagency communication and cooperation which enables the safe and secure sharing of Sensitive But Unclassified material. Stakeholders include federal, state, local, tribal, territorial, international, and private sector.

    Website: https://www.dhs.gov/homeland-security-information-network-hsin.

22. **U.S. Center for Maritime Innovation.** Sponsored by the Maritime Administration, the USCMI supports the study, development, assessment, and deployment of innovative initiatives that drive transformational change for the U.S. maritime industry and the U.S. MTS. The Center's scope is to support a wide range of maritime research and innovation critical to a safe, efficient, and competitive MTS. USCMI research focuses on maritime energy, maritime operations, U.S. maritime competitiveness, and maritime resilience.

    Website: https://www.uscmi.org/.

23. **FEMA National Disaster & Emergency Management University.** Comprehensive training, professional development, and education continuum for emergency management professionals to ensure that the U.S. remains secure and resilient. Comprised of three specialized schools supporting different emergency management career paths and specialized communities: the Emergency Management Institute; School of Disaster Leadership; and School of National Resilience.

    Website: https://training.fema.gov/.

24. **World Association for Waterborne Transport Infrastructure (PIANC).** PIANC unites international experts to write leading-edge technical reports to be shared broadly across the international community. The organization includes four technical Commissions cover the different areas of waterborne transport infrastructure: inland navigation (InCom), maritime navigation (MarCom), recreational navigation (RecCom) and environmental matters (EnviCom). These Commissions host working groups are convening to produce guidance on a wide variety of topics, including Port Resilience Assessments.

    Website: https://www.pianc.org/ongoing-working-groups/.