Resilience of Ports and the Marine Transportation System

Katherine Chambers, Research Scientist with the Engineer Research and Development Center (ERDC)

with input from Drs. Ned Mitchell, Marin Kress, & Kyle McKay

September 25th, 2019
SAME Monthly Meeting, Wilmington NC
Overview

• US Army Corps Engineer Research and Development Center Overview: Mission Areas and Research to Support Resilience

• Deep Dives on two specific topics:
  • Response and Recovery efforts during 2017 Hurricane Season
  • DHS-USACE Joint Agency Port Resilience Assessment Guide Project
U.S. Army Corps of Engineers

WHERE WE ARE — U.S. ARMY CORPS OF ENGINEERS

Northwestern Division

South Pacific Division

Southwestern Division

Mississippi Valley Division

Great Lakes & Ohio River Division

North Atlantic Division

Transatlantic Division

Pacific Ocean Division

Korea

Japan

LEGEND

Visit and HQ Location

District and Division Co-located

Division Boundary

State Boundary
Civil Works Value to the Nation

- US Ports and Waterways convey >2B Tons of Commerce
- Foreign Trade alone creates >$160 B in Tax Revenues

- 3% of Nation’s Electricity: $800 M+ in sales
- Stewardship of 11.7 M Acres Public Lands
- 926 Harbors
- Environmental Restoration
- ~11,750 miles of Levees
- 12,000 miles of Commercial Inland Waterways
- 400 miles of Shoreline Protection
- Recreation Areas 370 M visitors/yr
- Emergency Responses
- 68,800 Regulatory Permit Actions
Corps Water Resource Challenges

- Climate Change
- Governance
- Federal Budget
- Legislative Changes
- Demographic Shifts
- Persistent Conflict
- Energy
- Increased demand for water
- Declining Biodiversity
- Globalization
- Disaster Preparedness and Response
- Environmental Values
- Degraded Infrastructure
Resilience Definition

- Prepare
- Anticipate
- Adapt
- Evolve
- Resist
- Absorb
- Recover
- Bounce Back

Presidential Executive Order 13653 (White House 2013)
Examples: Research to Increase Resilience of USACE Civil Works Missions

- **Navigation**
  - Marine Transportation System Performance
  - Structural Health Modeling
- **Flood Risk Management**
  - Multiple Lines of Defense
  - Wetlands and Storm Impacts
- **Environmental**
  - Thin Layer Placement
  - Vegetation Root Stimulant
- **Emergency Management**
  - Coastal Hazards System
Support to USACE Navigation Mission

- Understand baseline function of our navigation systems and the impacts of disruptions
- Evaluate and monitor project performance in real-time
### Navigation – Inland River Travel Time Atlas

#### Ohio River Vessel Movements, 2013

![Map of the Ohio River](image)

#### Ohio River Travel Times, 2013

<table>
<thead>
<tr>
<th>Origin / From (Ohio River Mile)</th>
<th>travel time (hrs)</th>
<th>Destination / To (Ohio River Mile)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<tr>
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<tr>
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<tr>
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<td>Louisville, OH (602)</td>
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<tr>
<td>Cincinnati, OH (470)</td>
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<td>51</td>
</tr>
</tbody>
</table>

### Upstream Direction

### Downstream Direction
Structural health monitoring (SHM) is the process of making a condition assessment, based on appropriate analyses of in-situ measured data, about the current ability of a structural component or system to perform its intended design function(s) successfully.

SHM when combined with probabilistic future loading and failure mode models is used to forecast remaining useful life.

Risk-informed decisions for prioritizing funding for future maintenance and repair activities.

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Support to USACE Flood Risk Management Mission

USACE Flood Risk Management aims to reduce overall flood and coastal storm risks.

The ERDC develops engineering guidance, tools, and models to allow better mitigation of risk and facilitate recovery after flooding events.
Hurricane Katrina on Mississippi Gulf Coast
- 236 people dead, 67 missing
- $125 Billion in damages

MS Coastal Improvement Program (MsCIP)
Comprehensive integrated approach to reduce future risks
→ Non-structural measures can be part of a comprehensive approach to reduce risks

Flood Risk Management – Multiple Lines of Defense

Waveland, MS
Flood Risk Management – Wetlands and Storm Impacts in Jamaica Bay, NY

- Numerical Modeling Waves & Storm Surge
- Modeled different vegetation coverage and raised bathymetry scenarios

Support to USACE Environmental Mission

USACE Environmental mission has two major focuses:
• Ecosystem Restoration
• Environmental Stewardship

Ecological systems self regulate and recover. The ERDC investigates how to emulate these abilities in USACE projects through nature-based features and other research.
Biopolymer application can enhance root growth and reduce soil erosion for earthen infrastructure

- Reduces shrinkage
- Regrowth in riparian zones post-construction
- Remediate sand boils

Control: Untreated Soil

Soil Treated with Biopolymer

2010 ERDC Biopolymer Patent No. 7,824,569

Developed under Military Engineering, now used for Civil Works Levee Stabilization
Environmental – Thin Layer Placement of Dredge Material

Thin Layer Placement
• Method to produce a specific layer thickness or ground surface elevation
• Allows construction of nature-based features like wetlands and other sensitive habitats.

Mobile Bay, AL
• TLP of 9 million cubic yards of sediment
• Sediments monitored, and modeled to determine how they are transported
Support to USACE Emergency Management Operations

In Emergency Operations, USACE has mission to support recovery, and assess and restore critical infrastructure.

ERDC provides data, tools, and decision-support to identify:

- Critical infrastructure & vulnerable regions
- Post-disaster damages (Mobile Infrastructure Condition Assessment)
- Time-dependent recovery
CHS stores a large suite of basis hurricane scenarios that cover statistical range of events

- Tracks and landfall locations
- Hurricane characteristics (min central pressure, forward speed, radius of max winds, etc.)
- Regional high-fidelity wave and surge response (e.g. coupled ADCIRC-STWAVE)

Use basis scenarios as support for surrogate model to rapidly and accurately predict response for any new hurricane scenario

https://chs.erdc.dren.mil
Resilience Over Time

- Prepare; Anticipate
- Resist; Withstand
- Recover Bounce Back
- Adapt; Evolve
- Resilience increased:
  - Less loss in functionality
  - Faster recovery time

Rebuilding, new projects, community awareness, etc.
Cycle of Resilience

Through data and experts elicitation, we can gather information on **how** the MTS was able to **Resist** and **Recover** to inform future **Adaptation** and **Preparation**

- Key actions or decisions
- Datasets to aid critical actions and decisions
- Interdependencies with non-feds
- Best practices
- Opportunities to increase resilience
The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System

*2018 and 2019 hurricane season addendum in progress – please consider contributing*
Katherine Chambers (ERDC-CHL) presents hurricane analysis results to the U.S. Committee on the Marine Transportation System Coordinating Board

- R-IAT requested by the Coordinating Board to ID lessons learned from 2017 hurricane season
- 12 member agencies
- 1 workshop with 35 workshop attendees
- Team co-lead by USACE-ERDC and NOAA
2017 Hurricane Season

- 17 named storms
- 7 U.S. landfalling storms
  - 3 major hurricanes: Harvey, Irma, Maria
- 25.8 million people affected
- 4.6 million registered for federal assistance with FEMA
- Weather events in 2017 amounted to $306.2 billion in cumulative costs which included hurricanes Harvey ($125B), Irma ($50B), and Maria ($90B)*

IMPACTED PORTS ACROSS TX, FL, PR, and VI

Hurricane Harvey landfall August 26
Hurricane Irma landfall September 10
Hurricane Maria landfall September 20
Gulf Region

Hurricane Harvey Cargo and Tanker Vessel Signal Density Plots

Created with ERDC Automatic Identification System Analysis Package (AISAP)

August 1, 2017
Tropical Storm Harvey will be named August 16

August 24, 2017
USCG declares Port of Houston under condition Yankee

August 25, 2017
USCG declares Port of Houston under condition ZULU

August 26, 2017
Hurricane Harvey makes landfall at Rockport & becomes a tropical storm over inland Texas

August 28, 2017
Harvey recedes towards the Gulf, record rainfall recorded at 51.88 in

September 4, 2017
Vessels queue at anchorage areas. Port reopens with restrictions September 6th.

ERDC Navigation Data Performance Team: Katherine Touzinsky, Kenneth N. Mitchell, Patricia Dijoseph, Marin Kress
Hurricane Harvey

• **Challenges**
  • Flooding caused indirect impacts to supporting infrastructure
  • Lack of knowledge management and collaborative tools regarding port condition or status
  • Redundant information requests

• **Successes**
  • Early communication
  • Centralized information distribution
  • Pre-prioritized resource placement
  • Execution of drills and training
  • Early closure of energy facilities
  • Efficient restoration of ATONS following storm
  • Cross agency communication
  • Engagement with public sector for resource needs
  • Delegation of FEMA mission assignments
Hurricane Irma

• Challenges
  • Power outages
  • Debris removal between storms
  • Resource allocation between commerce, tourism, & EM
  • Equipment pre-positioning in FL
  • Availability of resources and funds

• Successes
  • Early communication on critical ports and supporting infrastructure
  • Critical Aids to Navigation identified in advance
  • Updated coastal imagery for fast surveys
  • Transportation and accommodation arrangements
  • Mobile integrated Survey Team kits when operating vessels of opportunity
  • Repurposing vessels directed to Texas
  • Coordination with local business advisory councils and initiatives
Hurricane Maria

• Challenges
  • Lack of space for shipping & seaport operations
  • Lack of supporting infrastructure (road, electric, water)
  • First responder challenges
  • Negative press
  • Balancing emergency supply with commercial supply

• Successes
  • First responders with Spanish language skills
  • Interagency collaboration and sharing of information
  • AIS-ATON utilized to help facilitate re-opening of San Juan by rapidly triaging ATONS in the field
  • Utilizing domestic shipping line partners
Summary: Best Practices for MTS Response and Recovery

• Established communication networks!
  • Hurricane Season Kickoff Meeting – held at start of hurricane season
  • Full Scale Hurricane Exercises
  • Area Port Coordination Committees

• Pre and post-storm port assessments
• Interagency efforts for navigation channel reopening
• ATON verification and resiliency
• Clear (and flexible) lines of communication
Summary: Opportunities to Enhance Response and Recovery

- Need for tools & protocols for prioritization at the regional or national level
- Pre-staging of survey teams & equipment
- Evaluating Port Status vs. Channel Status
- How to aid port employees returning to work
Federal Actions to Minimize Disruption and Enhance Resilience

Findings were identified by applying the Resilience Framework and separated into categories:

- Preparation actions
- Response and recovery actions
- Adaptation actions
Recommendations to Increase Resilience

PREPARE

• **Build relationships beforehand** – coordination teams, contracting mechanisms, resource staging

• **Prioritize key infrastructure systems and critical infrastructure interdependencies**

ABSORB/RESIST

• **Share data** across Federal agencies for recovery projects through interagency teams and data-sharing platforms

ADAPT

• **Develop a common operating picture** of the port system interdependencies, authorities, and essential land and maritime functions

• **Hold proactive planning scenario exercises** and interagency training sessions where prior lessons are communicated and incorporated

• **Promote or consider new cutting-edge methodologies** to understand infrastructure redundancies, reduce vulnerabilities, improve service or support
Port Resilience Decision Guide

Joint-Agency Project funded by Department of Homeland Security Cybersecurity and Infrastructure Security Agency

• The Guide will aim to provide a holistic understanding of port operations, the infrastructure systems that support these operations, and analysis methods that can be utilized to understand functional resilience and support investment and other decisions.

• The Guide will be tailored for use by PSAs, AAPAs, USCG, and other Federal agencies.
FY19 Appropriations Act resulted in $292.7M for the Port Infrastructure Development Program to improve port facilities at coastal ports.

Five Outcome Criteria:

1) advance technology-supported safety and design efficiency improvements;

2) bring facilities to a state of good repair and improve resiliency

3) promote efficient trade in energy resources

4) promote exports of manufacturing, agriculture, or other goods; and

5) Support the safe flow of agricultural and food products, free of pests and disease, domestically and internationally. Accordingly, the Department
Bring facilities to a state of good repair and improve resiliency...

...by addressing current or projected vulnerabilities in the condition of port transportation facilities. If a project advances this outcome, this section of the application should describe how the project will contribute to a state of good repair by improving the condition or resilience of existing transportation facilities and intermodal connectors including the project’s current condition and how the proposed project will improve it, and any estimates of impacts on long-term cost structures or impacts on overall life-cycle costs.
Focus Question

How can the existing body of knowledge on port and maritime resilience be integrated and expanded to create a holistic guide for assessing and improving the resilience of a port or port system?
Study Framework

Objective 2 – ongoing (ERDC)
ID agency/academic methods to be applied

Objectives 1 - ongoing (DHS)
Literature and RRAP Review to Characterize System

Objective 3 – planning (joint)
Case Studies at Three Scopes to Develop and Validate

Objective 4 – planning (joint)
Use and validate Guide with partners

Draft the Port Resilience Assessment Guide and share on web platform

Key Partners:
- ERDC
- DHS CISA
- DHS S&T Centers of Excellence
- CMTS
- Technical Advisors
Characterize the MTS
Single Port, MTS Port Network, Inland Waterway

Characterize each Scope
- Key stakeholder groups
- Key decisions and objectives for assessments
- ID critical functions
- Critical infrastructure systems
- Regulatory/statutory environment
AIS data to observe regional patterns in vessel traffic

ID Assessment Methods

Review Resources & Literature

- Channel Portfolio Tool utilizing Waterborne Commerce Data
- Automatic Identification System Analysis Package utilizing USCG National AIS Database
Waterborne Commerce Data

to understand major commodity flows, connectivity and timing
Travel Time Atlas on inland river systems

• Provides historical and near real-time waterway transit times between origins and destinations
• Publically accessible (FY18)
• Example Applications:
  • Voyage planning
  • River Information Services
  • Multi-modal connectivity
  • Traffic monitoring

POC: Patricia.K.Dijoseph@usace.army.mil
Observe Vessel Densities Over Time

Hurricane Harvey Cargo and Tanker Vessel Signal Density Plots

*Created with ERDC Automatic Identification System Analysis Package (AISAP)*

- **August 1, 2017**: Tropical Storm Harvey will be named August 16
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*ERDC Navigation Data Performance Team: Katherine Touzinsky, Kenneth N. Mitchell, Patricia DiJoseph, Marin Kress*
- Understand baseline function of our navigation systems and the impacts of disruptions
- Evaluate and monitor project performance in real-time
Analyze inter-port flows and connectivity
Understand disruption impacts to networks

Page Ranked Network Analysis during Hurricane Harvey

- Calcasieu
- CorpusChristi-PortAransas
- MatagordaPortLavacaComfort
- Pascagoula
- PortArthur
- PortBeaumont
- PortEverglades
- PortFreeport
- PortGalveston
- PortHouston
- PortTexasCity
- PortVictoria
- PortofMiami
- PortofTampa
- SouthwestPass
Resilience Resource Overload!

MARINE TRANSPORTATION SYSTEM RECOVERY PLAN (MTSRP)

FOR

[Insert COTP Zone Name]

[Insert Geographic Relevant Graphics]

Assessing Interdependencies

Hazard & Impact Modeling and Simulation

Analyzing Supply Chain Risks

A Port Management Self-Assessment

Understanding How Prepared Your Port Organization is for a Disaster

Navigating to port resilience

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Assessment Method Selection: Tiered Framework for Selecting Methods & Resources

TIER 1
- Seek to understand and prioritize the critical functions of the system
  **Outcomes**—quickly IDs critical functions, key sectors, and any easy wins. If more information is needed to control for resilience identifies info necessary for Tier 2.

TIER 2
- ID structure of the system including cascading events during disruption by utilizing both experts and observational data
  **Outcomes**—reveal structure of system and interrelated components to be able to compare project or investments.

TIER 3
- Analyze the system’s key functions and structure throughout disruptions and drops in function
  **Outcomes**—qualitative metrics and understanding of the recovery process in order to ID intervention opportunities and management plans.

Proceed through tiers until there is adequate information for decision making.
<table>
<thead>
<tr>
<th>Tool Example</th>
<th>Single Port</th>
<th>MTS Port Network</th>
<th>Inland Waterway</th>
</tr>
</thead>
</table>
| **Tier 3**   | - Bayesian Network Analysis (Schultz et al 2016)  
- Assessment and Measurement of Port Disruption (Weaver 2019) | Outstanding Need for methodologies! | - Bayesian Kernel Critical Infrastructure Analysis of L&D (Baroud 2014) |
| **Tier 2**   | - Scenario-based exercise with expert elicitation (many examples) | - PORT MAPPER (Trepte and Kai 2014)  
- Multiple Port Vulnerability Indicators Methodology (Becker 2018) | - Collaborative Modeling to Support Adaptive and Resilient Water Resource Governance in the Inland Northwest (King and Thorton 2016) |
| **Tier 1**   | - Port Resilience Index (NOAA 2016)  
- MTS Recovery Plan Guidelines (USCG 2018) | - Supply chain resilience planning  
- Dredge Optimization Scheduler (USACE 2018) | - Improving Freight Transportation Resilience in Response to Supply Chain Disruptions (NCRFP 2019) |
Guide Development: Match Resilience Methods and Resources to an Assessment Process

<table>
<thead>
<tr>
<th>Method Tier</th>
<th>LAY THE FOUNDATION</th>
<th>CRITICAL INFRASTRUCTURE IDENTIFICATION</th>
<th>RISK ASSESSMENT</th>
<th>COMMUNITY INFRASTRUCTURE RESILIENCE PLAN DEVELOPMENT</th>
<th>IMPLEMENTATION &amp; MAINTENANCE</th>
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<tr>
<td>I</td>
<td>NOAA Port Resilience Index</td>
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<tr>
<td>II</td>
<td>RRAP Assessment</td>
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</tr>
<tr>
<td>III</td>
<td>MTS Port Network Analysis</td>
<td>Bayesian Network Analysis</td>
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</table>

Additional Guidance and Resources
- Guidance for where in the planning process the assessment is applied
- Guidance on critical functions and infrastructure
- Guidance for including response to risks
- Guidance on stakeholders, regs, statutes
- Guidance on implementing results, including funding

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Interested in adding your perspective for response and recovery during 2018 and 2019 hurricane seasons?

https://www.surveymonkey.com/r/6MKNHXL

**Additional Questions?**

Full 2017 Hurricanes report available for download at:

Or contact -

Katherine Chambers
Katherine.F.Chambers@usace.army.mil
Decision Guide Process

• Identify Purpose, Problem, and Assessment Champion
• Identify Scope and Questions
• Identify and Organize Participants and Stakeholders
• Define Critical Functions and Performance Objectives
• Select an Assessment Method
• Define Functions and Characterize the System
• Identify Critical Infrastructure and Dependencies
• Assess Risk of Disruption and Response of System
• Develop and Evaluate Alternative Resilience Enhancements with Decision Makers
• Implementing Results in Support of Decision Making