The Center for Secure and Resilient Maritime Commerce (CSR)

This work is generously supported by the U.S. Department of Homeland Security under Grant Award Number 2008-ST-061-ML0002 through the Stevens Institute Center for Secure and Resilient Maritime Commerce.
Resilience in America’s Ports

- Issues
- Big Data
- How to Create Port Resilience
- Innovation in Port Resilience

Issues

- Security – Operational Efficiency Tradeoff → Balance
- Security – Resilience → what is the tradeoff/relationship?
- Do we all understand port resilience?
  - Many independent economic entities with different goals
- Planning for Port Resilience
  - Do we really know how to create Port Resilience?
  - Do we all have the same target for resilience outcomes?

- Big Data means big opportunities, big challenges
Big Data: Big Opportunities, Big Challenges

Double-edged Sword of BIG DATA

- Great potential, great obstacles
  - Today: many new sources, minute detail, high volume, real-time, potential to leverage RT data for a common operational picture
  - But: data is static, not readily available, not integrated, not validated, not easily processed into → Information → Knowledge

![Diagram showing the progression from Data to Wisdom](image)
Data → Information → Knowledge → Wisdom

<table>
<thead>
<tr>
<th>Situation</th>
<th>Data</th>
<th>Information</th>
<th>Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port closure</td>
<td>Risk impacts if cargo does not reach destination</td>
<td>Economic risk to region</td>
<td>Priority for 1st cargo permitted, Trade Resumption plan</td>
</tr>
<tr>
<td>Port closure</td>
<td>Alternate port capacities, expected delays</td>
<td>Validated options for cargo allocation</td>
<td>Priority for alternate port selection</td>
</tr>
<tr>
<td>Oil spill in waterway</td>
<td>Port conditions, currents, wind direction and speed</td>
<td>Anticipated migration and movement of spill</td>
<td>Optimal allocation of spill clean up resources and locales</td>
</tr>
<tr>
<td>Hurricane forecasted</td>
<td>Storm performance, wind strength, waterway structure</td>
<td>Prediction of storm surge</td>
<td>Port locations at most risk, requiring personnel and asset movement</td>
</tr>
</tbody>
</table>

Double-edged Sword of BIG DATA

- Great potential, great obstacles
  - Today: many new sources, minute detail, high volume, real-time, potential to leverage RT data for a common operational picture
  - But: data is static, not readily available, not integrated, not validated, not easily processed into → Information → Knowledge
BIG DATA

Land Side

- Facility Vulnerability Assessments
- Impact Assessments (1st & 2nd order)
- Commodity types
- Shoreline Sensitivity

Water Side

- Facility Contact Data
- Road, rail data and capacity
- Environmental Factors
- Cargo handling capacity

- Waterway data
- Intermodal capacity
- MSRAM

- MDA data
- Vessel location
- Vessel call history, crew data

- Terminal, Facility Data
- Incident information
- Wind strength & vector

- Surface temperature
- Salinity

ERMA Atlantic Bundles Data....some Data
Decision Timing & the Life Cycle of a Disruption

Speed Matters....
Real-time responses required....
Advance planning facilitates response speed

Creating Port Resilience
Supply Chain → Port Resilience

- Supply Chain Resilience:
  - In material science, resilience is the physical property of a material that can return to its original shape or position after a deformation that does not exceed its elastic limit.
  - In today’s business environment, resilience is widely used to characterize an organization’s ability to react to an unexpected disruption, such as one caused by a terrorist attack or natural disaster, and restore normal operations.
  - It’s the ability to recreate supply chain capabilities, to ‘bounce back’ from variations and disruptions

- Examples of port resilience?


Risk Management Framework & ISO 31000

1. Vulnerability assessment
2. Mitigation planning & implementation
3. Ongoing Monitoring & Measurement
4. Crisis Management/Emergency Response

Figure 1: Risk Management Process (based on ISO 31000)

Ref.: Graphic from ANSI/ASIS SCRM 1-2014
Creating Port Resilience

- Vulnerability and Response Assessment
  - Identify risk sources, response capabilities/capacities

Nearly an Unlimited Source of Enterprise Risk

- Strategic Risk: Negative Media, New Competition, Technology Choices, Perceived Quality, Mkt Share Battles
- Hazard Risk: Cargo Losses, Earthquake, Bldg Fire, Facility Loss, Wildfire, Epidemic, Tornadoes, Ice Storm
- Operations Risk: Logistics Route Failure, Denial of Service Attack, Key Supplier Loss, Personnel Loss, Health & Safety Violations

Ref: Dr. Debra Elikins, General Motors
Creating Port Resilience

- Vulnerability and Response Assessment
  - Identify risk sources, response capabilities/capacities

How capable are domestic US ports?

Assessing Response Capabilities: Capacity Assessment Absorbing Volume Post-Disruption

<table>
<thead>
<tr>
<th>Commodity/Conveyance</th>
<th>Min Capacity Needed to Absorb Volume of Top Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container</td>
<td>26%</td>
</tr>
<tr>
<td>Top 3 Ports: Los Angeles, Long Beach, NY/NJ</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>23%</td>
</tr>
<tr>
<td>Top 3 Ports: Houston, South Louisiana, Baton Rouge</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>16%</td>
</tr>
<tr>
<td>Top 3 Ports: Mobile, Pittsburgh, Hampton Roads</td>
<td></td>
</tr>
<tr>
<td>Food and Farm Products</td>
<td>50%</td>
</tr>
<tr>
<td>Top 3 Ports: So. Louisiana, New Orleans, Plaquemines</td>
<td></td>
</tr>
<tr>
<td>Manufactured Equipment</td>
<td>18%</td>
</tr>
<tr>
<td>Top 3 Ports: Los Angeles, NY/NJ, Hampton Roads</td>
<td></td>
</tr>
<tr>
<td>Petroleum</td>
<td>16%</td>
</tr>
<tr>
<td>Top 3 Ports: Houston, NY/NJ, South Louisiana</td>
<td></td>
</tr>
<tr>
<td>Raw Materials</td>
<td>5%</td>
</tr>
<tr>
<td>Top 3 Ports: Duluth-Superior, NY/NJ, So. Louisiana</td>
<td></td>
</tr>
</tbody>
</table>
Creating Port Resilience

- **Vulnerability and Response Assessment**
  - Identify risk sources, response capabilities/capacities

- **Ongoing Monitoring**
  - To assess required response
  - ERMA available now – but scope is limited

- **All-hazards Continuity Plans**
  - Backup for critical infrastructure and systems (Port infrastructure, Intermodal, Waterways, Terminals)
  - For each failure mode/predictable outcome
  - Response plans, how will cargo in/out be processed?
  - Restarting operations/trade resumption
  - Do you have the governance to respond? Jones Act/Sandy

Supply Chain Failure Modes – Predictable Outcomes

All disruptions result in a loss of one or more of these capacities:

- Capacity to acquire materials (supply)
- Capacity to ship/transport
- Capacity to communicate
- Capacity to convert (internal operations)
- Human resources (personnel)
- Financial flows
Unlimited Sources of Enterprise Risk

Response Options by Failure Mode

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Resilience Action</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of supply / materials</td>
<td>Use multiple sources, multiple locations</td>
<td>Spread risk across firms, locations</td>
<td>Higher cost to qualify suppliers, lower volume leverage</td>
</tr>
<tr>
<td></td>
<td>Use single source</td>
<td>Known supplier</td>
<td>Vulnerable to disruption w/o multi-site back ups</td>
</tr>
<tr>
<td></td>
<td>Modify product to use standard parts</td>
<td>Reduces part invty cost, complexity</td>
<td>Costly to modify existing materials standards</td>
</tr>
</tbody>
</table>
Continuity Plans

Continuity Plans for Port Resilience

Maritime Policy & Management
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tmpm20

Failure modes in the maritime transportation system: a functional approach to throughput vulnerability
Oyvind Berle *, James B. Rice Jr. & Bjørn Egil Asbjørnslett
* Department of Marine Technology, Norwegian University of Science and Technology, Trondheim, Norway
& Massachusetts Institute of Technology, Cambridge, MA, USA
Available online: 07 Oct 2011
MARIT. POL. MGMT., NOVEMBER 2011,
VOL. 38, NO. 6, 605–632
### Table 4: Elaboration of failure modes for ports

<table>
<thead>
<tr>
<th>Port</th>
<th>Failure mode: Loss of</th>
<th>Elements that may be backed up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Port supplies, utilities and infrastructure</td>
<td>Electricity, wastewater, water, roads, rail, land area, inventory, tugboats</td>
</tr>
<tr>
<td>Transportation</td>
<td>The ability to move goods and people within and through the port</td>
<td>Transportation providers, trucks, lifts, stackers, gantry cranes, chassis</td>
</tr>
<tr>
<td>Communication</td>
<td>Communication, coordination and information systems across port players</td>
<td>Phone lines, mobile phone, data systems and networks, internet access</td>
</tr>
<tr>
<td>Internal operations / Capacity</td>
<td>The ability to move and position vessels, maintain safety and security, invest, develop and market port.</td>
<td>Berth spaces and lengths, support vehicles and vessels, business strategies</td>
</tr>
<tr>
<td>Human resources</td>
<td>Personnel operating port functions, supporting business</td>
<td>Port authority, pilots, managers, security, technicians</td>
</tr>
</tbody>
</table>

### Table 5: Elaboration of failure modes for terminals

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Failure mode: Loss of</th>
<th>Elements that may be backed up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Terminal supplies, utilities and superstructure</td>
<td>Electricity, wastewater, water, land area, inventory, spare parts</td>
</tr>
<tr>
<td>Transportation</td>
<td>The ability to move goods and people within the terminal</td>
<td>Transportation providers, trucks, vans, lifts, stackers, gantry cranes, chassis</td>
</tr>
<tr>
<td>Communication</td>
<td>Communication, coordination and information systems within terminal and to port</td>
<td>Phone lines, mobile phone, data systems and networks, internet access</td>
</tr>
<tr>
<td>Internal operations / Capacity</td>
<td>Loading / unloading, processing, documentation, Capacity</td>
<td>Storage space, cranes, conveyors, stackers, inventory</td>
</tr>
<tr>
<td>Human resources</td>
<td>Personnel operating terminal</td>
<td>Longshoremen, stevedores, drivers, managers, security, technicians</td>
</tr>
</tbody>
</table>
### Innovation in Port Resilience

#### Table 7: Elaboration of failure modes for intermodal connections

<table>
<thead>
<tr>
<th>Intermodal connections</th>
<th>Failure mode loss of</th>
<th>Elements that may be backed up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Infrastructure leading to public infrastructure systems, supplies for transportation and maintenance</td>
<td>Roads, rails, bridges, channels, fuel, parts, chassis</td>
</tr>
<tr>
<td>Transportation</td>
<td>Equipment for moving and transloading goods for surface transportation</td>
<td>Trucks, lifts</td>
</tr>
<tr>
<td>Communication</td>
<td>Oversight and the ability to document and coordinate cargo shipment, communication</td>
<td>Routing systems, communication with providers, IT systems,</td>
</tr>
<tr>
<td>Internal operations / Capacity</td>
<td>The ability to transload goods between surface transportation and vessels, including processing and storage. Personnel responsible for managing and performing transloading operations</td>
<td>Inventory, spare chassis, storage and transloading space, Drivers, management, planners</td>
</tr>
</tbody>
</table>
Innovation in Port Resilience

- Port Mapper (CSR, MIT)
  - Cargo capacity, alternate port visualization and ID tool

- Magello (CSR, Stevens Institute of Technology)
  - Emergency response and management visualization tool

- Other....
Port Disruption Response – Cargo Allocation

• What are the options for cargo allocation in the event of a disruption?
  – Need capacity
  – Proximity to disrupted port
  – Match cargo type – containers go to container terminals, dry bulk goes to dry bulk terminals, etc.

• While there are ~361 ports in the US
  – Not every port is an option
  – Concentration of commodity types reveals vulnerability

• Which port handles which cargo?
  – To date, we can only answer using intuition but not data
  – So we developed a tool to identify cargo allocation options

Cargo Allocation/Capacity Model

• Used 5 Years of annual port data (Army Corps of Engineers)
  • Segmented by commodity (SIC), port and cargo flow direction

• Augmented with port location information, water- and land-based distances between ports

• Created Excel-based model to understand port capacity in greater detail
Capabilities of Model/Tool

Cargo Allocation/Capacity Model Capability: The user can...

- Fail single port and identify alternate port options for cargo
- Fail multiple ports and identify alternate port options for cargo

But you need an analyst to use it...

so we made a visual app called

Port Mapper

- Fail port and allocate different amounts of cargo to different ports
- Calculate port capacity requirements

What would happen if Los Angeles could not handle containers? Where could the volume go?
Continued: LA constraint. Where could the volume go if only the top 10 container ports were used?

What if So. Louisiana could not handle Food & Farm Products? Where could the volume go?
Continued: So. Louisiana constraint. Where could the volume go if only the top 10 ports were used?

Baltimore – SIC Coal & Lignite
Baltimore – SIC Coal & Lignite Option Report

<table>
<thead>
<tr>
<th>Port Name</th>
<th>Commodity Group</th>
<th>2009</th>
<th>2008</th>
<th>2007 Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALTIMORE, MD</td>
<td>Coal</td>
<td>14,244,900</td>
<td>16,407,300</td>
<td>11,481,400</td>
</tr>
<tr>
<td>WILMINGTON, DE</td>
<td>Coal</td>
<td>45</td>
<td>32,450</td>
<td>214</td>
</tr>
<tr>
<td>PHILADELPHIA, PA</td>
<td>Coal</td>
<td>116,831</td>
<td>30,639</td>
<td>432</td>
</tr>
<tr>
<td>CAMDEN-GLOUCESTER, NJ</td>
<td>Coal</td>
<td>254</td>
<td>43,040</td>
<td>0</td>
</tr>
<tr>
<td>RICHMOND, VA</td>
<td>Coal</td>
<td>0</td>
<td>0</td>
<td>134</td>
</tr>
<tr>
<td>NEWPORT NEWS, VA</td>
<td>Coal</td>
<td>13,018,600</td>
<td>21,659,200</td>
<td>17,261,000</td>
</tr>
<tr>
<td>HAMPTON ROADS, VA</td>
<td>Coal</td>
<td>27,751,500</td>
<td>41,032,900</td>
<td>34,799,900</td>
</tr>
<tr>
<td>NORFOLK HARBOR, VA</td>
<td>Coal</td>
<td>14,179,300</td>
<td>19,371,800</td>
<td>17,651,000</td>
</tr>
</tbody>
</table>

SUMMARY OF TRAFFIC TOTAL
WATERBORNE COMMERCE OF THE PORT OF NEW YORK

<table>
<thead>
<tr>
<th>Port Name</th>
<th>Commodity Group</th>
<th>2009</th>
<th>2008</th>
<th>2007 Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>PITTSBURGH, PA</td>
<td>Coal</td>
<td>27,377,300</td>
<td>31,350,000</td>
<td>24,399,700</td>
</tr>
<tr>
<td>BRIDGEPORT, CT</td>
<td>Coal</td>
<td>5,161,880</td>
<td>3,940,040</td>
<td>2,879,700</td>
</tr>
<tr>
<td>NEW HAVEN, CT</td>
<td>Coal</td>
<td>0</td>
<td>20,900</td>
<td>19,000</td>
</tr>
<tr>
<td>ERIE, PA</td>
<td>Coal</td>
<td>27,939</td>
<td>18,321</td>
<td>0</td>
</tr>
<tr>
<td>BUFFALO, NY</td>
<td>Coal</td>
<td>487,183</td>
<td>516,511</td>
<td>279,751</td>
</tr>
<tr>
<td>CONNEAUT, OH</td>
<td>Coal</td>
<td>1,163,040</td>
<td>640,300</td>
<td>8,475</td>
</tr>
<tr>
<td>NEW LONDON, CT</td>
<td>Coal</td>
<td>683,562</td>
<td>854,351</td>
<td>655,176</td>
</tr>
<tr>
<td>ASHTABULA, OH</td>
<td>Coal</td>
<td>2,353,040</td>
<td>2,485,040</td>
<td>1,308,970</td>
</tr>
<tr>
<td>PAIRPORT HARBOR, OH</td>
<td>Coal</td>
<td>13,088</td>
<td>10,881</td>
<td>0</td>
</tr>
</tbody>
</table>

Port of Stockton – Ammonia Options

[Map showing shipping routes and ports]
Port of Stockton – Ammonia Option Report

<table>
<thead>
<tr>
<th>Port Name</th>
<th>Commodity Group</th>
<th>2009</th>
<th>2008</th>
<th>2007 Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOCKTON, CA</td>
<td>Chemicals</td>
<td>331,842</td>
<td>290,697</td>
<td>182,153</td>
</tr>
<tr>
<td>SACRAMENTO, CA</td>
<td>Chemicals</td>
<td>17,634</td>
<td>16,834</td>
<td>12,122</td>
</tr>
<tr>
<td>OAKLAND, CA</td>
<td>Chemicals</td>
<td>888</td>
<td>36,645</td>
<td>12,237</td>
</tr>
<tr>
<td>PORT HUENE ME, CA</td>
<td>Chemicals</td>
<td>0</td>
<td>3,108</td>
<td>0</td>
</tr>
<tr>
<td>LOS ANGELES, CA</td>
<td>Chemicals</td>
<td>1,460</td>
<td>1,372</td>
<td>1,448</td>
</tr>
<tr>
<td>LONG BEACH, CA</td>
<td>Chemicals</td>
<td>1,144</td>
<td>1,694</td>
<td>418</td>
</tr>
<tr>
<td>PORTLAND, OR</td>
<td>Chemicals</td>
<td>96,595</td>
<td>106,487</td>
<td>78,685</td>
</tr>
<tr>
<td>TACOMA, WA</td>
<td>Chemicals</td>
<td>1,483</td>
<td>1,528</td>
<td>827</td>
</tr>
<tr>
<td>SEATTLE, WA</td>
<td>Chemicals</td>
<td>267</td>
<td>131</td>
<td>92</td>
</tr>
<tr>
<td>TULSA, PORT OF CATOOSA, OK</td>
<td>Chemicals</td>
<td>60,000</td>
<td>55,000</td>
<td>60,000</td>
</tr>
<tr>
<td>VICTORIA, TX</td>
<td>Chemicals</td>
<td>0</td>
<td>2,450</td>
<td>0</td>
</tr>
<tr>
<td>TEXAS CITY, TX</td>
<td>Chemicals</td>
<td>30,234</td>
<td>0</td>
<td>10,066</td>
</tr>
<tr>
<td>HOUSTON, TX</td>
<td>Chemicals</td>
<td>314,328</td>
<td>316,188</td>
<td>291,475</td>
</tr>
<tr>
<td>FREEPORT, TX</td>
<td>Chemicals</td>
<td>546,220</td>
<td>397,606</td>
<td>383,297</td>
</tr>
<tr>
<td>GALVESTON, TX</td>
<td>Chemicals</td>
<td>17,459</td>
<td>7,143</td>
<td>0</td>
</tr>
<tr>
<td>BEAUMONT, TX</td>
<td>Chemicals</td>
<td>724,338</td>
<td>648,664</td>
<td>209,885</td>
</tr>
<tr>
<td>PORT ARTHUR, TX</td>
<td>Chemicals</td>
<td>18,443</td>
<td>29,754</td>
<td>93,258</td>
</tr>
</tbody>
</table>

Used by USCG planning/responding to Hurricanes Sandy & Irene: “the only source for the data”

[Map of United States with arrows indicating traffic]

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Possible Future Developments

• Integrate with freight flows to hinterland, intermodal
• Integrate into a single environment for COP

• Scenario development: disruption changes land and port conveyances

Daily Flows

Post-Disruption Flows

Magello

(CSR, Stevens Institute of Technology; Project Lead Investigator & Director of CSR, Dr. Julie Pullen)
Innovation in Port Resilience – Magello (CSR Stevens)

- **Magello**
  - Allows end user to visualize *ultra-high-resolution* port environment data on a Google Earth™ platform
  - Ongoing monitoring, situation assessment
  - Emergency response and management tool

- **Data Capabilities**
  - Urban: terrain, roads, AIS, ports
  - Ocean: surface temp, currents (direction, velocity, HF radar), acoustics, salinity
  - Air: temp, wind (velocity, vector), rain, air quality
  - Hazard: earthquake, contaminant release, explosion, oil spill
  - Coast: shoreline sensitivity, hydro lines, land use, AOR

Magello Objective: Combine data in single tool to aid emergency response
Magello

- Intuitive interface
- Real-time data, crowd-source info
- Platform change to enable mobile device access
- Ultra-high-resolution models
- Urban effects, multi-access levels
- Designed with broad range of apps to compliment, augment industry/gov’t platforms (ERMA, SAROPS)

Magello Overview – AIS, Buildings, Surface Temps, Currents, Terrain, Roads, Winds
Contaminant source, buildings, wind vectors - NY

Shoreline sensitivity index, Ports – San Francisco
AIS, land use – San Francisco

Tracking tool – New York
Oil Spill, Shoreline sensitivity index – New York

Innovation in Port Resilience – Magello (CSR Stevens)

- Intuitive interface
- Real-time data, crowd-source info
- Platform change to enable mobile device access
- Ultra-high-resolution models
- Urban effects, multi-access levels
- Designed with broad range of apps to compliment, augment industry/gov’t platforms (ERMA, SAROPS)
And More....
CCICADA, CREATE, ADCIRC, VACCINE, Future

Future/Other Innovations in Port Resilience

- Other DHS COE contributors
  - CCICADA: Command, Control and Interoperability Center for Data Analysis (Rutgers)
  - CREATE: National Center for Risk and Economic Analysis of Terrorism Events (USC)
- cgSARVA (VACCINE, Purdue)
  - Search-and-rescue prediction visualization tool
- ADCIRC (Coastal Hazard Center, UNC-CH)
  - Storm surge modeling, dredging feasibility, modeling tides
- Future
  - Integrating/fusing all of these analytical tools into one system to provide a Common Operational Picture
Get real-time data, integrate it, share with the community for a Common Operational Picture

Wisdom in decision-making

Knowledge – RT situational awareness, data-based risk mgt, priorities

Information
Integrated via
Magello, CG1View, Watchkeeper, etc.? 

Real-time Data 

Time

Key Decision Point 

Result – higher quality decisions made real-time, results in fewer losses, faster recovery, more efficient and effective response

Get real-time data, integrate it, share with the community for a Common Operational Picture

Wisdom in decision-making

Magello, COP

MSRAM, Port Mapper, cgSARVA, ADCIRC

Port volumes, conditions, real-time

Time

Key Decision Point

Result – higher quality decisions made real-time, results in fewer losses, faster recovery, more efficient and effective response
Resilience in America’s Ports
• Big Data
• Continuity Planning for Outcomes
• Innovation in Port Resilience
  – Port Mapper
  – Magello
  – Future – COP

Thank you
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jrice@mit.edu
617.258.8584

http://ctl.mit.edu
http://ctl.mit.edu/research/port-resilience
http://portmap.mit.edu/port_mapper_g01.php