A Smart Port Resiliency and Planning Tool

By: Evangelos I. Kaisar and Manhar Dhanak
Florida Atlantic University

“7th METRANS International Urban Freight Conference”, Long Beach, CA
United States of America, October, 2017
Outline

- Introduction and Background
- Project Objective
- Methodology
- Case Studies
- Results & Discussions
- Stakeholders
- Conclusion
Freight Mobility – Truck Traffic 2020
Impact of Hurricane Harvey, Aug 30, 2017
Port Resiliency is the ability of a port to:

**ABSORB IMPACT OF AN EVENT**
- Preparedness/Planning/
  Reliability/Prevention/Mitigation

**RAPIDLY RECOVER FROM AN EVENT**
- Response/Impact
- Assessment/Reconstruction/Adaption

- Optimization towards a resilient port involves
  - Minimizing loss of capacity
  - Minimizing period of disruption
  - Providing and maintaining an adequate level of service during disruption
  - Maintaining security

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**Capacity Performance Measure vs. Time During a Disruption**
PROJECT OBJECTIVE

To develop a simulation-and-modeling based port resiliency assessment and planning tool that can be adapted, through a choice of interchangeable event modules, to predict consequences of an event based disruption to a Port and its waterside and landside distribution capacities. The aim is to support avoidance and mitigation of damage and capacity reduction, and aid rapid recovery from disruptions.
RESEARCH APPROACH

• Model and simulate port capacity distribution from available data
• Vessel arrivals/departures are simulated with a Monte Carlo approach
  – Monte Carlo Simulations estimate random variables from observed distributions
  – This requires significant empirical data to develop accurate distributions
• Broadly, the Vessel simulation consists of 5 primary steps:
  – Data collection/processing – development of arrival and dwell time distributions
  – Inverse Transform Sampling – Uses the distributions to generate random arrivals and departures
  – Goodness-of-fit – Testing the accuracy of the simulation
  – Calibration and Validation
  – Event Simulation
RESEARCH APPROACH – LAND SIDE

• Model and develop micro and meso scale simulations of landside transportation and port elements on the AIMSUN/VISSIM platforms
  – Characterize normal traffic patterns based on available data
  – Simulate event based disruptions and study impacts
• Model and Incorporate in AIMSUN/VISSIM intermodal port operations that govern throughput
• Calibrate and validate the models for normal operations
• Create Case Scenarios (Event, Location, Intensity)
• Analyze disruptive event simulations and identify and characterize consequences of the disruption
• Develop resiliency measures for making assessment of port resiliency and recommendations for improvements
Resiliency Measures

- Define key elements of the port: location of buildings, docks, road networks, traffic lights, locations of junctions etc.
- Identify critical functions of port elements and assess their vulnerabilities, represented by variables \( z = (z_1, z_2, z_3, \ldots) \), at the individual-element level and in the global context of the port.
- Identify and characterize external disruptors, represented by parameters \( p = (p_1, p_2, p_3, \ldots) \) that can impact port activities.
- Specify respondent decisions, represented by \( x = (x_1, x_2, x_3, x_4, \ldots) \), that may mitigate or exacerbate the vulnerabilities.
- Allow for uncertainties \( \epsilon = (\epsilon_1, \epsilon_2, \epsilon_3, \ldots) \) in the simulation response.
- Provide \( z, p, x \) as input to the Aimsun hybrid simulator, to be combined with a library of rules and models of operational dynamics and output simulated realizations \( f(x, z, p, \epsilon) \) of a set of measures, such as loss in capacity in a given scenario; Assign probabilities to \( x, z, p \) and simulated realizations \( f(x, z, p, \epsilon) \) and optimize.
- Example resiliency measure:

\[
R_{\varphi}(t_r|e^j) = \frac{\varphi(t_r|e^j) - \varphi(t_d|e^j)}{\varphi(t_0|e^j) - \varphi(t_d|e^j)} \forall e^j \in D
\]
Data Collection and Processing

- Probability distributions have been built for each port (Everglades, New Orleans, LA/LB) using one year of vessel traffic data (160,180 total observations) obtained from MarineTraffic.Com.

- For the analysis, vessels are grouped by cargo type:

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Everglades</th>
<th>New Orleans</th>
<th>Long Beach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Oil / Chemical</td>
<td>335</td>
<td>2604</td>
<td>762</td>
</tr>
<tr>
<td>2. Timber / Cement / Asphalt</td>
<td>16</td>
<td>48</td>
<td>10</td>
</tr>
<tr>
<td>3. Reefer</td>
<td>0</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>4. Ro-Ro / Veh. Carrier</td>
<td>62</td>
<td>22</td>
<td>199</td>
</tr>
<tr>
<td>5. Heavy Load Carrier</td>
<td>606</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6. Container / Bulk Carrier / Tanker</td>
<td>2239</td>
<td>4637</td>
<td>1385</td>
</tr>
<tr>
<td>7. Passenger</td>
<td>726</td>
<td>222</td>
<td>1391</td>
</tr>
</tbody>
</table>
Calibration and Validation

- The Calibration process involves evaluation of the performance of the simulation model in comparison with the data from which it was generated. The Coefficient of Determination ($R^2$) was used to evaluate the model fit.

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Goodness-of-Fit ($R^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Everglades</td>
</tr>
<tr>
<td></td>
<td>Arrival TOD</td>
</tr>
<tr>
<td>1. Oil / Chemical</td>
<td>0.945</td>
</tr>
<tr>
<td>4. Ro-Ro / Veh. Carrier</td>
<td>0.919</td>
</tr>
<tr>
<td>6. Container / Bulk Carrier / Tanker</td>
<td>0.996</td>
</tr>
<tr>
<td>7. Passenger</td>
<td>0.999</td>
</tr>
</tbody>
</table>

- Validation process involves comparing model prediction for a different set of data.
  - An additional six months of data have been obtained from MarineTraffic.Com for validation, which is underway.
Simulation Port Operations
Simulation Port Operations – Truck Module
Simulation Port Operations – Train Module
HURRICANE SANDY IMPACT ON PORT OF NEW YORK AND NEW JERSEY (2012)

8-Day Port Closure

AIS Vessel Traffic at New York Harbor, November, 2012
Resiliency metric: Dwell-Time Resiliency (DTR)

• After the closure on Oct 28th, the system transitions to a disruptive state, reaching its maximum on Oct 31, 2012.

• The recovery event was the reopening of the harbor, after which the vessel activity began the transition into a stable state.
HURRICANE SANDY IMPACT ON PORT OF NEW YORK AND NEW JERSEY (2012)

Daily Inbound and outbound vessels

Resiliency metric: Net Vessel Transit Count Resiliency

Greater New York Port Area Performance & Resiliency
AIS density plot of vessel traffic near the Galveston Entrance Channel
Six-month Vessel Traffic Summary for Galveston Offshore Anchorage Area

Performance Measures: Vessel Entry (Blue), Vessel Exit (Red), and Vessel Dwell Time (Green)
Galveston Net Vessel Transit Counts

Galveston Net Vessel Transit Count Resiliency

Galveston Bay Performance and Resiliency
SCENARIOS:

Storm Surge / Flooding on the East Coast
- Port Everglades
  - Major cruise passenger port
  - Leading container port in Florida
  - Main port in South Florida for petroleum products
  - FTZ (Foreign trade zone No. 25) – largest in Florida
  - 32 berths
  - Easy Access to Interstate and Airport

Labor Dispute / Strike on the West Coast
- Port of LA/Long Beach
  - Over 150M/70 short tons of cargo each year
  - Over 10M people each year
  - 50+/80 Berths

Oil/Bio-Hazard Spill on the Gulf Coast
- Port of New Orleans
  - Over 9M short tons of cargo each year
  - Over 1M people each year
  - 3 Slips, 17 Berths
Port/Landside Traffic Simulation

- Collect Travel Times on Various Stretches of the Roads (SR 84, I-595 Port Entrance)
- Model Building Includes Roads with Port Freight Traffic Movements
- Contact FDOT, Broward TMC requesting information on Traffic Light Timings and Traffic Counts
- Meso-Micro Simulation Platform AIMSUN/VISSIM : Truck Network
Network of Port Everglades Access Roads

Corridors of Interest

- Intersection at A1A & Eisenhower Blvd.
- Intersection at Eisenhower Blvd & SE 24th St.
- Intersection at Port everglades Expy & Eller Dr.
SIMULATED FLOODING SCENARIO AT PORT EVERGLADES

Fort Lauderdale, Broward County, FL

Waterside: Three Slips

Landside: Main Entrances:
- SE 17th St. entrance.
- SE 24th St. entrance.
- Eller St. entrance.
- McIntosh Rd
Flooding Elevations
A two-day flooding event was simulated at Port Everglades beginning June 30th, 2016 and ending July 2nd, 2016.

6 of the 8 container terminals located to the south of the port are damaged by flooding and are inoperable for a 48-hour period.

All container vessels arriving during this period are shifted to the 2 operable terminals located in the northern portion of the port.

After the 48-hour period, the damaged terminals are restored to full operation, however, the flood has caused a backlog of container vessels.

Port operators are faced with a decision: 1) continue to work on 12-hour shift or 2) move to a 24-hour shifts until the backlog is addressed.

The tool obtains Dwell time resiliency in support of quantifying and informing decision makers about the potential impact of 12-hour and 24-hour operations.
SIMULATED FLOODING SCENARIO AT PORT EVERGLADES – 2 Day Port Closure
Vessel Dwell Time Resiliency

**Simulated 12-Hour Operations**

- 29-Jun: 100.00%
- 30-Jun: 71.43%
- 1-Jul: 29.73%
- 2-Jul: 68.25%
- 3-Jul: 91.01%
- 4-Jul: 100.00%
- 5-Jul: 100.00%
- 6-Jul: 100.00%

**Simulated 24-Hour Operations**

- 29-Jun: 100.00%
- 30-Jun: 93.55%
- 1-Jul: 68.25%
- 2-Jul: 100.00%
- 3-Jul: 100.00%
- 4-Jul: 100.00%
- 5-Jul: 100.00%
- 6-Jul: 100.00%
Port/Landside Traffic simulation using micro-simulation platform:

Road Shut Down Sequence & Impacted Exit Routes

Response Decision-making:

- Determine if port is operational
- Stop incoming traffic and allow for evacuation
- Determine whether the roads are safe for travel
  - Clear any foreign object debris off roads and blocking drains
- Highest elevation route would be most effective
- Manipulate signal timings to effectively allow travel out of port
Micro-level Simulation
Traffic Impact Analysis

- Zones to produce traffic.
- Gates to consume the traffic produced by zones.
- Paths from the zone to gates.
Port of New Orleans Model
Average Delay

Average Delay - Normal Conditions (Series 1), 25% HGV (Series 2), 50% HGB (Series 3), and 75% HGV (Series 4)

Average Delay - Normal Conditions (Series 1), 25% HGV (Series 2), 50% HGB (Series 3), 75% HGV (Series 4), 75% HGV w/ Signal Optimized Intersection (Series 5)
Stakeholder Engagement

• Brief provided to USCG RDC, Sept, 2015
• Brief provided to AMSC, Ft. Lauderdale, Florida, Aug 2016
  – Participants: Local port representatives, USCG, MARAD, and CBP
• Stakeholder Workshop on Port Resiliency held at FAU in December, 2016
  – Participants: representatives from USCG, the US Army Corps, Port Everglades, Port of Palm Beach, MARAD, Local and National agencies, and academia.
• Several detailed discussions with port operators and USCG personnel
• Conducted IRB approved survey of stakeholders
Proposed Plan for Tool Transition

- Modeling and simulation require special software and expertise – not expected to be resident within stakeholder entities
- Propose housing the Tool within the newly established USDOT supported Freight Mobility Research Institute at FAU
  - Provide access and service to stakeholders for predicting consequences of a disruption at a Port and planning for mitigation of impact of a disruption
  - Nurture further development of the Tool
  - Support other complementary DHS-funded efforts in Port resiliency
Proposed Plan for Tool Transition

• Further development needs include
  – Improvement to event modeling and simulation corresponding to different levels of various threats
  – Collection of pertinent port disruption data related to recent hurricanes (Mathew, Irma) to support Tool validation and improvement – regional impact on a series of ports
  – Collection of additional port operations data to support improvements to micro-level modeling of intermodal transportation within ports
Questions

PRESENTER
EVANGELOS I. KAISAR
ASSOCIATE PROFESSOR & DIRECTOR
FREIGHT MOBILITY RESEARCH INSTITUTE
(FMRI)

Thank you.