Predictive Port Resilience Tool to Assess Regional Impact of Hurricanes - Project Work Plan

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Abstract

The principal objective of this research is to develop a predictive tool for assessment and planning for resiliency of ports on a regional scale to hurricane events. The aim is to develop a stakeholder-focused tool to improve regional resilience. Through assessment of consequences of hurricane events as well as use of knowledge, innovation, and education, we seek to support and improve the regional preparedness of interconnected port systems. Considerations will include network and inter-dependence of ports in a region. We will study and consider strategies for managing identified risks as well as identify any additional risks and strategies to manage these risks.

The methodology for achieving the objectives will be based on modeling and simulation aimed at determining regional consequences of disruption caused by a major hurricane event. A regional scale multimodal mesoscopic simulation of a regional port distribution network will be developed. Using mesoscopic simulation platform, a quantitative assessment of regional port distribution capacity will be developed. We will address and study how risks affect resilience and use the simulation model to improve resilience and study systems impacts (throughput, delays, etc.). In addition, we develop port operation simulation model to capture physical, operational and management complexities and their interactions. Stakeholders will be engaged in determining the scope, challenges, and requirements for the proposed effort, as well as gathering information on related previous and ongoing efforts.

Outcomes of the project will include 1) A detailed report of recommendations for improved response and mitigation of damage; 2) a predictive tool to analyze regional port resiliency available for stakeholders to use; 3) The effort will support graduate students who will receive training in transportation simulation and modeling as they pursue their MS theses.

Project Overview

A predictive tool for assessing and planning for resiliency of ports on a regional scale to hurricane events will be developed. This research seeks to expand understanding of port resiliency and enhance the knowledge in the development of a stakeholder-focused tool to improve regional resilience. We use knowledge, innovation, and education, as well as modeling and simulation, in support of assessment of consequences of hurricane events, to seek improvements in the regional preparedness of interconnected port systems. Considerations will include network and inter-dependence of ports in a region. Fundamentally, ports cluster areas of the country, with multiple ports servicing the same region. Although these regions may be composed of separate local governmental jurisdictions, port clusters often share common historical, environmental, and topographic

systems. Because of transportation linkages that connect the movement of people and freight, they also share close economic ties. These shared cultural and transportation ties also mean that they also often share similar hazards and threats. US ports and container/intermodal terminals are critical links in the marine transportation system. Disruption at series of ports can have crippling economic effect in the coastal zone as well as the rest of the nation. Ports are vulnerable to natural disasters since they are fixed, publicly accessible entities. Port stakeholders have a vested interest in the long-term function and viability of ports, but no standardized measures for performance or resilience exist for regional ports. An approach to measuring resilience must be adaptable to the specific needs of the community using it, which quickly renders a national-scale resilience metric nearly impossible. Driven by global economic forces, ports have unique needs that should inform indicators to assess resilience over time. Quantitative methods and tools, stemming from engineering science and vulnerability studies, provide quick assessments of "resilience" at broad spatial scales, but do not dip below the surface into local scale, place-based, community resilience. Qualitative methods, on the other hand, help answer research questions that cannot be addressed with numerical data and dive into questions of attitude, perception, and social interaction.

Given the nature of resilience as a dynamic process, we study and consider strategies for managing identified risk. We address and study how risks affect resilience in a network of ports/container terminals in the region and our approach will bridge the gap between developing tools to assess resilience and understanding the process of resilience at the ports and the intermodal facilities in the region.

The end-user stakeholders will be engaged early to develop requirements for the tool, gather available data and identify POCs for obtaining feedback during the course of the project. The data requirements will, in general, be obtained from state departments of transportation and online data procurement resources. However, the insight and feedback provided by end-user stakeholders may have implications on data needs, which will be taken into account before finalizing the data acquisition plan. In conjunction with port authorities, US Coast Guard, DHS Centers of Excellence (COE) and other stakeholders, the scope and the requirements for the proposed methodology will be defined. Requirements for quantifying resiliency of the port system to a major hurricane event and rate of recovery from it will include (i) assessment of the level of threat, (ii) assessment of vulnerabilities of the port system, and (iii) determination of standard operating procedure in response to a disruptive event. It is anticipated that the proposed tool will have the following attributes. It will: (i) provide means to reduce risk; (ii) identify, assess, and monitor disaster risks and improve early warning systems; (iii) build a culture of safety and resiliency at all levels through use of knowledge, innovation, and education; (iv) reduce consequences from underlying risk factors; (v) improve disaster preparedness of ports and its water and land side capacity distribution; (vi) speed the post-disaster recovery; (vii) facilitate coordination of resumption of commercial service and relief activities; and (viii) improve interagency coordination and communication. Other requirements will be identified as part of the discussion with the stakeholders. A number of research efforts are underway focused on resiliency of coastal infrastructure as well as the transportation network. These include DHS funded work at CIRI, and at CREATE COE, decision-support tools for flood risks at RAND Institute, as well as lessons learned from previous storm events such as Hurricane Sandy. We will aim to develop an approach that will build on and be complementary to these efforts.

Methodology

A two-fold approach will be adopted, involving 1) stakeholder engagement to determine the scope, challenges, and requirements for the proposed effort, as well as gathering information on related previous and ongoing efforts, in support of avoiding duplication, and 2) tool development based on modeling and simulation aimed at determining consequences of disruption caused by a major hurricane event.

Modeling and simulation will involve first modeling the port systems and establishing baselines for normal port operations on the waterside and landside in the selected region, based on archived statistics collected over a period of time. **Baseline models for port landside involves utilizing available traffic volumes, speeds, and signal timings information provided by the Department of Transportation data , These data will be collected for the area outside each port as well as the intermodal transportation systems within each port. These data will be used as input for simulating the landside operations and capacity.** Based on available data, baseline operations are established in terms of port service and throughput. . The baseline model will enable simulation of a typical day at the ports in the region and associated regional status. On the waterside, the baseline models involve establishing arrival, departure and dwell times of vessels at the port as well as normal level of service. MTS travel time statistics for the region will be compiled for different classes of vessel and by direction (inbound/outbound; upstream/downstream) using a straightforward comparison of the time-stamped position reports as unique vessels moved through the various geo-fenced watch areas of interest. **Collectively, this data will be gathered from the National Automatic Identification Systems (NAIS) onboard each vessel which records the vessel's location on nearly a second by second basis. The NAIS data** will be used to generate two performance indicators, average vessel dwell time within the port areas of interest and net vessel transits into and out of the port areas of interest. The simulation of baseline vessel operations will be conducted using the Monte Carlo simulation approach of Inverse Transform Sampling. Monte Carlo simulations work by estimating unknown values from observed distributions. Applying the Inverse Transform Sampling Method, baseline vessel arrivals and their corresponding dwell times will be simulated for ten years and their results averaged and compared to historical data for typical conditions at the ports. These models will collectively serve as establishing the landside and waterside baseline for the region. The basis of the simulation on the landside are integrated micro-simulation platforms, Aimsun NG (Xiao et el., 2005) and/or PTV Vissim, that are used in transportation simulations by various state and federal agencies, as well as by academia worldwide. A regional scale multimodal mesoscopic simulation of a regional port distribution network will be developed. In our modeling, we will formulate an operational model to determine the system activities and corresponding performance of system operations. Once the baseline models are established, various disruptive scenarios, corresponding to different levels of threat, will be simulated to determine the consequences of the disruption and assess effectiveness of a range of responses. As part of the modeling process, we will define a set of events that can disrupt the system and identify ways in which each event can affect the operation setting. The tool will be demonstrated quantitatively through statistical analysis and measures of effectiveness, and qualitatively through heat map charts and other level of service indicators, and visually with videos of the simulation. The model will be modified to incorporate events and their impact on the system operation

and decisions that can change the system will be defined. Using mesoscopic simulation platform, a quantitative assessment of regional port distribution capacity will be developed, and the best design will be selected in anticipation of a worst-case event. In assessing consequences of a disruption, Monte Carlo method will be used to generate a range of possible outcomes and the best solution would be determined using the Brute Force method.

This research will leverage and adapt archival NAIS data for resilience analyses of the coastal ports affected by Hurricane Matthew. The NAIS technology uses the VHF radio spectrum to broadcast and receive real-time information concerning vessel identity, dimensions, position, speed, and headings, among other fields. All commercial vessels operating in or bound for U.S. waters are mandated to carry NAIS technology by the Maritime Transportation Security Act of 2002(46 USC 70113, 70114). The U.S. Coast Guard is involved in developing standards for NAIS message formatting, and has established an archive of historical NAIS data as part of its Nationwide Automatic Identification System program[1]. As part of this effort, archival vessel position reports will be used to establish a baseline of navigation channel and port operations under routine non-event conditions. Port operations leading up to Hurricane Matthew and observed losses in system functionality following the storm will be used to quantify the resiliency of the various ports using time dependent performance analysis. This type of analysis is critical when investigating the efficacy of the recovery process protocols and management strategies employed in the days and weeks following a major disruptive event. The model and our approach can be used in other regions of the country to adapt the tool for consideration of regional natural disasters or hazards.

Measure of effectiveness: The development will be carried out in close consultation with identified end users and stakeholders who will be engaged and provided progress reviews of the development. Their feedback will be sought. Performance of the system will be determined through validation of the results against available data for Hurricane Mathew (2016). The waterside and landside simulation model goodness-of-fit will be evaluated using regression analysis, comparing model calibration parameters such has volume, speed, capacity, and dwell-time. The calibration process will target a coefficient of determination of 0.90 or higher. The model validation will also use regression analysis to quantify the validity of the model on transit time and daily output. The validation will target a coefficient of determination at or greater than 0.80. **The regression analysis will use an error rate of +/- 5 percent (alpha = 0.05) and a 95 percent confidence interval for both the land and waterside simulations.** The system performance and resiliency will be measured using time-dependent resiliency plots.

Identified Tasks and Schedule

The following tasks and estimated schedule are identified:

[1] Farhadi, N., Parr, S., Mitchell, K., Wolshon, B. Use of Nationwide Automatic Identification System Data to Quantify Resiliency of Marine Transportation Systems. Journal of the Transportation Research Board, No. 2549,2016, pp.9-18

Task 1. Kick-Off Meeting - Meet with US Coast Guard Champion and stakeholders to seek feedback on scope of the project is and discuss requirements (May, 2018).

Task 2. Research, identify, collect and analyze available data on the aftermath of previous natural and human-caused disaster impacts on ports. Engage DHS COEs, the US Coast Guard, Port Authorities other federal and local agencies and other stakeholders in the process of identifying threats and hazards and strategies for mitigation and improve coordination of public and private security efforts. (May – June, 2018)

Task 3. Develop strategies for the development of the proposed tool. Simulation model evaluation and selection; Code landside transportation infrastructure; Code waterside freight arrival and departure operations; calibration and validation of the codes (June – Sept, 2018)

Task 4. Develop disaster test scenarios and conduct necessary simulations and case studies, based on risk management considerations. Analyze model output (Sept – Nov, 2018)

Task 5. Develop the modeling tool with the defined attributes, develop resilience framework and recommendations for regional resiliency through engagement with stakeholders.

Task 6. Demonstrate and evaluate the tool using available data (for example, Hurricane Mathew) (Dec, 2018 – March, 2019)

Task 7. Prepare final report and develop presentations to disseminate research results (April – May, 2019)

The effort will support one graduate students at each of the partner institutions and one undergraduate student at FAU. The students will help gather the required data from the various ports, help in developing the models and using them to simulate the scenarios that will be considered, and help in developing the project reports. The students will receive training in transportation simulation and modeling as they pursue their graduate and undergraduate studies. The research effort will lead to graduate theses for the two graduate students, and enable them to look for opportunities with USCG and the maritime and transportation industries.

Project Milestones and Performance Metrics:

The following project milestones and performance metrics are identified. The milestones and the performance metrics will be reviewed with the project champion at the kick-off meeting and updated.

#	Milestone Description	Decision Point (State the criteria and date for "go" decision)	Performance Metrics	Output
M1	Kick-Off Meeting with Stakeholders	July 2018; Agreement on project scope, deliverables and tool transition plan	Stakeholder feedback	A project scope and requirements document

M2	Data collection completed	August 2018; Sufficient data is available for project development	Critical datasets from at least five regional ports acquired	Pool of critical vessel and ground transportation data developed
M3	Simulation Model development completed	October 2018; Models are successfully calibrated and validated	Landside and waterside calibration and validation coefficient of determination will be equal to or greater than 0.90 and 0.80, respectively.	Validated simulation models ready for applications.
M4	Case studies completed	January 2018; Experimental scenarios have been tested successfully	Regression analysis of the resiliency plots will show a coefficient of determination greater than or equal to 0.80.	Reports of the completed cases studies of the simulation model
M5	Resilience framework developed	March 2019; Recommendations for improving regional port resiliency	Framework replicates consequences of past events to within 75% accuracy	A detailed recommendation report; a predictive tool to analyze port resiliency available for stakeholders to use.
M5.1	A peer review article submitted to TRB	March 2019	Number of citations and article downloads	Work peer reviewed and published for dissemination to the research community
M6	Final Technical Report	June 2019	Number of citations and report downloads	Final technical report for dissemination to the public and researchers; a manual for the predictive tool

Outcomes and Outputs

Outcomes of the project will include 1) A detailed report of recommendations for improved response and mitigation of damage; 2) A predictive tool to analyze regional port resiliency available for stakeholders to use; 3) The effort will support graduate students who will receive training in transportation simulation and modeling as they pursue their MS theses; 4) A technical conference and a draft journal publication will be provided upon conclusion of the research.

Transition Plan

The proposed framework of the resiliency tool being considered for modeling and simulation of an event-based disruption at the port, and development of resiliency strategies, significantly benefits from use of the sophisticated software platform Aimsun and/or PTV

Vissim with their built-in libraries of algorithms for simulating intermodal transportation. Each port is unique. Therefore, detailed baseline model of each port and its transportation network, together with custom Monte Carlo-based optimization algorithms, would be developed and established on the Aimsun or PTV Vissim software platform. Baseline and disruption-scenario based simulations would then be run to determine the consequences of the disruption. A set of selected regional ports will be modeled as part of the study. Once developed and validated, it is proposed to implement one of the following alternative plans for transition of the proposed tool:

> The validated tool be housed within the newly-established USDOT supported Freight Mobility Research Institute at Florida Atlantic University, where it would be made available for web-based (or otherwise) access and service **to the USCG and other DHS-approved stakeholders and researchers** for predicting consequences of a regional disruption to local ports, and assessing and planning for improved resiliency of the ports. Further development of the framework and associated decision-support tools would be nurtured as desired. **FAU would run a required port simulation for the modeled ports, needing support for approximately one to two weeks of a graduate student's time per simulation, depending on the complexity of the required simulation, and provide the results to the stakeholder. Alternatively, a fixed annual cost support can be negotiated for providing required simulations and including modeling of additional new ports**.

These options will be discussed with the project champion and the selected option will be adopted. Feedback from the project champion is needed prior to work plan approval.

Stakeholder Engagement

The Project team will actively collaborate with the Port Authorities and USCG in conducting the project. Specific end users will be engaged early to develop requirements for the tool, gather available data and identify POCs for obtaining feedback during the course of the project. Engagement will include frequent phone calls, face-to-face work sessions and regular electronic correspondence. As part of Task 1, champion entity at USCG has been identified. The project champion will be engaged in the project kick-off meeting and throughout the 12-month project on a monthly basis or mutually agreed timeframe via conference calls or physical meetings. Other stakeholders, including port authorities, will be engaged on a quarterly basis. A stakeholder workshop will be held in December, 2018, inviting participants from all the ports considered in the study as well as from other agencies.

We will work closely with the USDOT funded Freight Mobility Research Institute (FMRI) at FAU and Southeastern Transportation Research, Innovation, Development and Education (STRIDE) Center, and Regional Transportation Center at University of Florida.

The proposed effort is consistent with DHS Mission 5: Strengthen National Preparedness and Resilience that call for facilitating recovery following a disaster through promotion of infrastructure resilience guidelines and development of continuity plans for communities, government entities, and private-sector organizations. It is also consistent with Mission 2: Secure and Manage our Borders that calls for strengthening the security and resilience of the global supply chain and the international travel system through establishing and enforcing security standards and plans that maintain or restore infrastructure capabilities,

including at ports, to be resilient from attacks and natural disasters. The proposed effort is aimed at developing tools that facilitate assessment and planning for evolving threats and hazards to a port and its waterside and land-side distribution capacity, in support of avoidance and mitigation of damage and capacity reduction, and aiding rapid recovery from disruptions.

Programmatic Risks

Responses to events typically take time to become known. Therefore getting response data for recent events may not be sufficient. We will augment available data with historical data. Stakeholders may not want to release certain data. We will engage them early on to ensure cooperation.