Developing an Analytical Framework for Optimizing Disaster Relief Preparedness to Coastal Hazards

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Project Objective

With the intent to improve the resilience of Hawaiian disaster relief supply chain, this project investigates the key factors influencing Hawai'i's disaster relief preparedness to coastal hazards to improve Hawai'i's disaster relief supply chain's resilience. In particular, it has the following objectives:

- Identify the key stakeholders for Hawai'i disaster relief preparedness, their responsibilities, and current preparedness.
- Through key stakeholder interviews, identify the primary coastal hazard and climate change scenarios of concern, preparation capacity in typical and extreme scenarios such as storage and warehouse capacity, existing plan and decision-making concerns and constraints, information sharing and coordination among stakeholders, and gaps to address in plans.
- Refine and abstract information to extract critical factors for developing an analytical framework using a simplified two-stage optimization model.

Problem Statement

With more recognition of climate change's advent and seriousness, it is widely acknowledged that coastal areas' existing infrastructure system could be disrupted more severely and frequently. The disaster relief supply chain provides essential goods to support the economy and community when the existing infrastructure system's ability to cope with the impacts is disrupted and overwhelmed (1). Its resilience becomes more prominent with the threats of climate change. The disaster relief supply chain is particularly vital to Hawai'i's communities, given Hawai'i's susceptibility to coastal hazards, sea-level rise, remoteness, and heavy dependence (over 90 percent) on imported goods and fuel. Combined with vulnerability analysis, this project uses information collected from stakeholder interviews to identify gaps and challenges in current preparedness, understand the decision factors and constraints, identify the possible alternatives, and develop an analytical framework for optimizing the supply allocation.

Research Methodology

This research was conducted through qualitative, in-depth interviews with emergency management stakeholders to gather information for a simplified quantitative warehouse location optimization model. Open-ended questions were selected to allow unexpected information to surface in the largely unknown territory of disaster relief supply chain resilience in the Hawaiian context. The typical case sampling and snowball sampling method (30) were utilized to engage key stakeholders in various backgrounds, such as Federal, State, and City and County Emergency Management agencies, transportation planning and operation agencies; non-profit organizations; and private sector suppliers (Figure 1). Through an analysis of interview responses, this research contributes to further understanding the current gaps in disaster relief preparedness, identifying possible strategies to cope with coastal hazards, and providing recommendations to bridge the gaps.

With information extraction from stakeholder interview, a simplified two-stage optimization model (31) is built to search for the optimal location and inventory allocation for warehouse beforehand to minimize potential disconnection and comply with the transportation network connectivity constraints, warehouse capacity constraints, and distribution center exposure constraints under various disaster scenarios.

Figure 1. Interviewee background

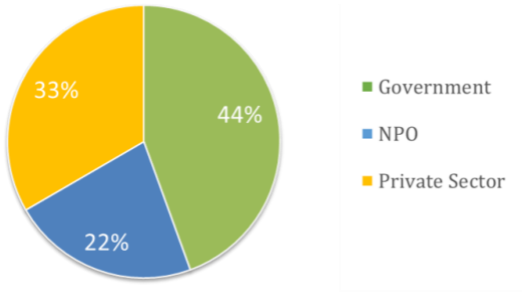

Figure 2. Warehouse Selected and Inventory Allocation

Results

The research team identified three major obstacles for Hawai'i Emergency Management (E.M.), they are: 1) many communities live along the shoreline, and thus the majority of the infrastructures are vulnerable to coastal hazards, 2) there is a need for better coordination between various organizations (e.g., between federal and state agencies and between government and private sectors), and 3) The "just in time" economy might not benefit from the response to and recovery from disasters.

Given these obstacles and constraints, we suggest the following to strengthen the disaster relief supply chain resilience on O'ahu: 1) Create more opportunities for various stakeholders to know each other's roles and responsibilities. 2) Facilitate more collaboration and coordination between multiple stakeholders (e.g., federal and state agencies and between governments and private sectors). 3) Include more stakeholders (e.g., private and non-profit organizations) into the disaster planning process and invite them to the regular disaster exercises. 4) Create backup plans and increase the relief supply redundancy to complement the "just in time" inventory for worst-case scenarios. 5) Develop plans to optimize the preposition of relief supply inventory to facilitate timely distribution to various communities after a disaster. GIS-based vulnerability analysis was performed to better understand which transportation road networks, alternative warehouse locations, and the potential distribution centers will be affected by the various flooding scenarios. The information was used to develop a simplified two-stage optimization model to optimize relief supplies' location and allocation under different coastal flooding scenarios. Figure 2 shows the five out of 32 candidate warehouse locations selected and optimized inventories, which could serve at least 80% of the population on Oahu under all six hazard scenarios considered (Hurricane category 1 to 4, 3.2 sea level rise, and extreme tsunami). Similar methods could be applied to develop more realistic plans with more accurate assumptions and capacity/demand estimations in future.

Reference

[1] Day, J. M., S. A. Melnyk, P. D. Larson, E. W. Davis, and D. C. Whybark. Humanitarian and disaster relief supply chains: a matter of life and death. Journal of Supply Chain Management, Vol. 48, No. 2, 2012, pp. 21-36.

[2] Keener, V. Climate change and pacific islands: indicators and impacts: report for the 2012 pacific islands regional climate assessment. Island press, 2013.