2019-12

Managing Materiel Distribution in an Uncertain Environment

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http://hdl.handle.net/10945/69991

NPS NRP Executive Summary

Managing Materiel Distribution in an Uncertain Environment

Report Date: 12/31/19 Project Number (IREF ID): NPS-19-N068-A

Naval Postgraduate School Graduate School of Operational and Information Sciences

NAVAL RESEARCH PROGRAM

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MANAGING MATERIEL DISTRIBUTION IN AN UNCERTAIN ENVIRONMENT

Period of Performance: 01/01/2019–12/31/2019

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Prepared for:

Topic Sponsor Lead Organization: N4 - Material Readiness & Logistics

Topic Sponsor Organization (if different): OPNAV N4iL - Logistics Analytics Branch (LAB)

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EXECUTIVE SUMMARY

Project Summary
The U.S. Navy's supply chain stretches all around the globe and is needed to support the fleet in many theaters for maintaining maritime superiority. However, supply chains can be subject to disruptions that slow the flow of supplies throughout the network, and such disruptions may severely hinder the readiness of ships operating in distant theaters. The most common culprit for peace-time supply chain disruptions is adverse weather, which is especially true in waters that are prone to major tropical storm systems. With these concerns in mind, this project formulates six optimization models aimed at advising logistics mission planners in how to best prepare for and/or respond to these contingencies. The models presented fall into both a reactive family, responding to the disruptions as they occur, and the proactive family, planning for disruptions based on their likelihood before they occur. These models utilize optimization and probability components in different ways to generate supply routes through a network vulnerable to uncertain disruptions. The results are analyzed in order to determine the suitability of use of the models in several disruption scenarios

Keywords: *logistics, supply chains, disruptions, network models, shortest path*

Background
Logistical support is crucial to the success of most military operations and allows the U.S. Armed Forces to maintain operational flexibility and superiority. Our focus is on U.S. Navy logistics and how to maximize the likelihood of effectively supporting ships, aircraft, and personnel deployed around the world. Degradations to a logistical supply network may interfere with the U.S. Navy's ability to operate effectively in a forward theater.

The U.S. Navy supply chain is subject to disruption that may impede the flow of supplies to customers in forward deployed locations. Some examples of major disruptive events that have occurred include volcanic ash resulting in partial or total disruption of air traffic, labor disputes halting shipping terminal activities, industrial accidents damaging port facilities, natural phenomenon such as seismic activity, and cyber-attacks or other random computer outages.

Some work on improving and analyzing network resilience is presented in Clark (2017) and Ross (2014). While both use attacker/defender problem optimization to analyze a network's resilience, Ross (2014) adds an optimization model for random hazards, which is similar to our approach to disruptions. Xu et al. (2015) demonstrate possible modelling of the disruptions to a supply chain as an attacker-defender game in order to prevent large amounts of damage to a military logistical system from a targeted attack.

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Findings and Conclusions

We developed six optimization models—five proactive models and one reactive—that strive to deliver items through the supply network to a demand location as quickly as possible. When the network is not subject to disruptions, this problem is a standard network shortest path problem. However, since we are interested in networks subject to possible disruptions, the travel times along the arcs are uncertain.

We modeled disruptions as random occurrences with known or estimated probabilities. This assumption is more suitable for a disruption due to natural causes such as weather than disruption due to interdiction by an adversary. The latter better fits contested situations where strategic, game-theoretic considerations are more appropriate.

We tested our models on a hypothetical scenario that involves a major conflict called Global War 2030 and the major theater of operations is in the Philippine Sea. The logistical support in this scenario involves delivery of supplies from Hawaii to hypothetical U.S. installations on the Philippine Islands. The resupplies are shipped through the sea routes and air routes of the theater, from Hawaii through the large port cities of Cebu or Manilla, Philippines, and then on to their final destination. All steps of this supply chain use multiple delivery methods, which may have differing times to delivery, risks, or costs of use.

Three different cases of weather patterns, of increasing severity, were used to create disruptions. These cases each presented different results that, when analyzed, provided insight into each model's benefits and drawbacks in dealing with disruptions as well as their computational complexity and feasibility of implementation.

First, the reactive model had one major shortcoming: it assumed that there would be no future disruptions, and so it always used the baseline travel time to find the fastest route through the network. While it made no assumptions about the type of disruptions or their independence, assuming that disruptions would not occur could result in the model choosing a highly risky arc, which could otherwise be avoided.

Next, some of the proactive models were too conservative in that they tried to find routes that avoided any disruptions, even those that caused only minor delays. The best proactive models weighed the pros and cons of taking a route with potential disruptions and would not necessarily try to avoid all disruptions. These effective proactive models generated contingency plans that seamlessly updated the route in real-time in response to a disruption.

Every model examined in this project has strengths and weaknesses that could be relevant to a decision maker looking for an effective supply route in a network subject to disruptions. Though there is not one single best model to use in all situations, all of the models offer different approaches to responding to disruptions and present several alternatives. The decision maker can evaluate the various routes presented by the models and their associated metrics and make a more informed decision about which model's solution may be the best route for a given situation.

Recommendations for Further Research

First, a more in-depth analysis of reactive model could provide more insight into the exact differences between proactive and reactive approaches. This could be done by analyzing the path taken by each of the different proactive models, given a randomly generated outcome of the network on which the reactive model was simulated. This would provide more concrete information for comparisons between the different models' total travel times despite the different objective functions each one optimizes.

Next, we could consider scenarios where the disruption probabilities vary over time. The models that generate detailed contingency plans should excel in these situations

Another possible subject for future work could be to tweak the reactive model to account for risk to some degree. The reactive model has nice properties: it often performs well and is fast to compute. Unfortunately the reactive model can perform very poorly in situations where it ignores likely and significant disruptions. Consequently any modifications that would limit these significant downsides in the reactive model would be very beneficial.

References

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