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Abstract

Optimization Modeling Approaches to Evacuations of Isolated Communities

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Isolated communities are particularly vulnerable to disasters caused by natural hazards. In many cases, evacuation is the only option to ensure the population's safety. Isolated communities are becoming increasingly aware of this threat and demand solutions to this problem. However, the large body of existing research on evacuation modeling usually considers environments where populations can evacuate via private vehicles and by using an existing road infrastructure. These models are often not applicable to remote valleys and islands, where road connections can be disrupted or do not exist at all. The use of external resources is therefore essential to evacuate the population. How to systematically evacuate an isolated community through a coordinated fleet of resources has not yet been researched. This dissertation thesis addresses this knowledge gap by designing a new routing problem called the Isolated Community Evacuation Problem (ICEP) that optimally routes recovery resources between evacuation pick-up points and shelter locations to minimize the total evacuation time. The research presents derivations of the initial model for (a) emergency planning and (b) response purposes to give emergency planners and researchers tools to prepare for and react to an evacuation of an isolated community. For (a), a scenario-based two-stage stochastic program with recourse considers different emergency scenarios to select the optimal set of

recovery resources to hold available for any evacuation emergency. Furthermore, the dissertation explores efficient structure-based heuristics to solve the problem quickly. For (b), the assumption of certainty over the size of the affected population at the time of evacuation is relaxed. Approaches from robust and rolling-horizon optimization are presented to solve this problem. Moreover, meta-heuristics are explored to solve the problem to optimality while overcoming the complexity of the problem formulation. Finally, an in-depth, real-world case study that was conducted in collaboration with first responders and emergency authorities on Bowen Island in Canada is presented to test and evaluate the applicability of the proposed models. This case study further informed the official evacuation plan of the island. This collaboration demonstrates the potential of full integration of the research approach with local emergency expertise from the affected area and highlights the data requirements that need to be met to maximize the use of the model.