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SIMULATION OF FLOOD EVACUATION OPERATIONS IN PIERREFONDS, MONTRÉAL

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ABSTRACT

This study focuses on simulating the evacuation of a neighborhood of Montréal, Québec, Canada in the event of flooding. Two strategies are simulated, and it is concluded that a significant reduction in the average evacuation time per family can be obtained by appropriate scheduling of the evacuation buses.

1 INTRODUCTION

Every year, Montréal faces floods of different levels due to a high intensity of snowfall and quick melting of that accumulated snow during spring. Necessarily, a fast evacuation requires thorough planning and evaluation of alternatives. Evacuation strategies may differ between locations due to, for instance, the available resources (transportation, medical, human), number of people affected, and governmental policies. Simulation is, therefore, a perfect tool for development and evaluation of location-specific evacuation strategies. Although there is a substantial literature on evacuation operations (Santos and Aguirre 2004), we found that most flood-specific evacuation studies are either focused on human behavior during the evacuation (Simonovic and Ahmad 2005) or develop dedicated software packages that incorporate hydrodynamic, forecasting and economic aspects (Ahmad and Simonovic 2006), but do not necessarily focus on the effect of evacuation transportation types and their scheduling. Furthermore, to the best of our knowledge, simulation has not been previously used to evaluate evacuation processes in the boroughs besides Rivière des Prairies in Montréal. Thus, we propose a simulation model for evaluation of evacuation times with different transportation types in one of these boroughs, considering the locations of shelters and medical facilities.

2 PROBLEM DESCRIPTION

Our study focuses on the Pierrefonds-Roxboro borough in the northwestern part of Montréal, located along the Rivière des Prairies, covering around 26.97 km^2 with a total population of approximately seventy thousand (http://ville.montreal.qc.ca/). The goal of the study is to determine the bottleneck transportation resource, evaluate the average evacuation time per family, and propose a strategy for reducing the evacuation time. To address the lack of publicly available data on evacuation processes, we contacted an official from The Ministry of Public Security of Québec. He provided approximate previous flood statistics (e.g., average number of influenced families). The evacuation center location, transportation methods and the proportion of family size were gathered from the Montréal municipality website and by interviewing volunteers who took part in evacuation operations. Some distributions of the transport velocity and load/unload times were taken from a study about a non-combatant evacuation operation carried out by the US army (Scheer 2011). Distances were calculated as shortest paths using Google Maps.

3 SIMULATION MODEL

To determine the average evacuation time per family and find the most efficient evacuation means, a simulation model was developed in Rockwell Arena. According to Ministère de la Sécurité Publique, about 600 houses were flooded by the 2017 spring flood in Montréal. Our model is based on entities that are family units instead of individual evacuees since families tend to behave as a unit. Therefore, a total of 600 entities are created in our model, with different classifications of family size, i.e., single, couple, and family. Our model assumes several transportation modes: by foot, private vehicles, helicopters, ambulances, and buses. The goal is to get all the evacuees to the central evacuation center (EC), located at Pierrefonds Comprehensive School, and to shelter homes in Hampstead. The search-and-rescue helicopters hover over the flooded regions to help the trapped victims to get to the EC. People who are able to walk are guided to the nearby gathering stations and the buses transfer them to EC. Those who own a vehicle are guided through specific routes to EC. At the EC, the victims go through the medical department where patients who require excessive medical care are sent to the Glen Hospital, Vendôme, via ambulances or helicopter. Other evacuees are sent to shelter homes located in Hampstead via buses or their own vehicles.

Our baseline strategy is inspired by Scheer (2011) based on a non-combatant evacuation operation. For the flood situation in Montréal, we introduce gathering stations and rescue teams for different kinds of evacuees. Evacuees who need immediate medical attention are transported from the EC directly to the hospital by helicopter or ambulance. Under the baseline strategy, buses wait until they are full and then proceed to the EC or the shelter. In this case, buses are found to be the bottleneck, with the 95% CI for waiting time for the shelter bus being [41.6, 42.7] minutes and for the bus to EC being [37.4, 37.9] minutes, respectively. To improve the situation, we implement a schedule for the bus so that it does not wait to be full but instead waits for only five minutes before departing. Considering that the main goal is reduction in evacuation time when a flood occurs, cost analysis of an evacuation is not considered in our study.

4 RESULTS AND CONCLUSION

We simulate both the baseline and the alternative strategies for 217 replications in Rockwell Arena, which ensures that the half-width of the total evacuation time is under 30 minutes. Performing a paired t-test based on the results of the simulation, we see a significant improvement in the average evacuation time per family, as shown in Table 1, with an average reduction of 36.47%. Thus, our study shows the potential benefit of using simulation for planning evacuation transportation in the City of Montréal.

Table 1: Comparison between two strategies (95% Confidence Interval).

Performance Metrics	Without Scheduling (min)	With Scheduling (min)
Total evacuation time	[1890, 1910]	[1900, 1920]
Evacuation time per family	[81.40, 82.00]	[51.80, 52.00]

REFERENCES

Ahmad, S., and S.P. Simonovic. 2006. "An Intelligent Decision Support System for Management of Floods". *Water Resources Management* 20(3): 391-401.

Santos, G., and B. E. Aguirre. 2004. "A Critical Review of Emergency Evacuation Simulation Models". Preliminary Paper No. 339, Disaster Research Center, University of Delaware, Newark, Delaware.

Scheer, A. M. 2011. *Noncombatant Evacuation Operations in EUCOM*. Master thesis, Department of Operational Sciences, Air Force Institute of Technology, Dayton, Ohio.

Simonovic, S. P., and S. Ahmad. 2005. "Computer-Based Model for Flood Evacuation Emergency Planning". *Natural Hazards* 34(1): 25-51.