Optimize Evacuation Route Considering the Operational Cost as a Constraint

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ABSTRACT
Evacuation planning involves modeling, operation, and management of evacuation routes before and during emergency evacuation. This paper presents the development and examination of a route optimization model which considers the operational cost as a constraint. The study is focused on the situation when the backbone evacuation route, usually the interstate highway system, is over congested and some traffic need to be directed to local street networks. As intersections are the key control components of a street network, traffic operations at intersections cannot be neglected in route selection. In order to consider the operational cost in the modeling process, a street network is first presented by an extended graph network which has cost information associated with each node. Then, a system optimal traffic assignment approach is used to select and optimize the evacuation routes. The property of the approach is examined by a numerical test which includes a network composed of a backbone interstate highway and a grid network with over 30 intersections.

1. INTRODUCTION
Evacuation planning is a complicated process which mainly involves modeling, operation, and management of evacuation routes. Thanks to the interstate highway system, most of the evacuation plans have been made on the basis of the interstate highway to be the backbone of the evacuation route. This, however, may cause severe congestion on freeways due to the excessive traffic demand and/or interruptions by traffic accidents such as the case during Hurricane Rita in Texas. [1] When a backbone evacuation route becomes less effective, timely re-routing traffic to the adjacent street network is necessary.

A street network is composed of arterials, local streets and intersections (signalized and unsignalized). Intersection control strategies are normally designed to handle regularly distributed daily demand other than evacuation traffic. Signals are either isolated which works independently to serve single intersections, or synchronized with other signals to provide coordination along a series of intersections. Handling evacuation traffic on local streets usually requires changing of intersection control, which often involve deployment of human resources (such as traffic engineers, law enforcements and emergency personnel) and material resources (like signs, cones, barriers and ITS equipment) to favor fast and smooth movement towards one or two directions. [2] In such a situation, operational cost will apply when selecting proper evacuation routes.

Evacuation planning has been studied extensively in the past, most of which have been focused on routing and scheduling of evacuation traffic [3–8]. Offline planning uses mathematic models and traffic simulation tools to develop and evaluate route alternatives. Heuristic methods, for instance, are commonly used in offline planning to find optimal evacuation routes based on the principles of static traffic assignments. As the plan is prepared for future events, computation time is usually not a concern of offline models. It's not uncommon that an offline model runs more than a day to identify evacuation routes for a city with a million plus population, such as the model for the Twin Cities of Minnesota [9].

Real time evacuation models are developed to assist evacuation management during the event. Traffic conditions are monitored throughout the evacuation process and real-time adjustments are implemented according to the traffic information. Technically, it is based on dynamic traffic assignment which assigns traffic to different routes according to the travel time changes on each path, such as the work of Liu et al. [10] and Peeta and Mahmassani [11]. Although the concept is appealing, field implementation of real-time evacuation models has not been successful. [12] A sophisticated traffic surveillance network and a centralized traffic management system are prerequisite for online operation. In addition, the online models are often constrained by computation time when handling large networks.

In fact, rerouting caused by unexpected events during evacuation can also be planned offline by assuming the effect of the events. A situation commonly occurs during evacuation is the breakdown of the main evacuation route due to accumulative traffic demand and/or traffic incidents. The advantages of offline modeling include using static traffic assignment and no limitation on computational efficiency of the mathematic model. The challenging part, however, is how to take into account of the operational cost associated with the management of street roads in the modeling process.

In this study, a hypothetical evacuation network has been developed, which is composed of a major freeway and an adjacent street network, to demonstrate the route planning process under the condition that the backbone evacuation route (the freeway) is broken due to a severe traffic accident and rerouting of the traffic is through the adjacent street network. In order to consider the operational cost as a constraint of the optimization model, the road network is converted to an extended network with hypothetical input and output nodes. Such way, the operational cost is presented by the