The Application of Quickest Flow Problem in Urban Evacuation Planning

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ABSTRACT

The provision of evacuation plan for people living in populated urban area is necessary to reduce the possible casualties under disasters. Time-varying quickest flow problem (TVQFP), which can simultaneously optimize the evacuation schedule, evacuation locations and evacuation routes, is adopted to optimize the evacuation planning of a city to minimize the clearance time of residents in danger. The integration of optimization model with GIS environment enables emergency managers to easily identify possible bottlenecks and to observe evacuation patterns in vivid pictures for further analysis and evaluation.

Keywords

Time-varying network, quickest flow problem, urban evacuation, GIS.

INTRODUCTION

Human has been beset by disasters. Nature disasters, industrial accidents, and terrorist attacks are increasing at an alarming rate [1]. As a rapidly increasing of population in urban area, it is appearing that we are more vulnerable than ever to cope with these catastrophic events. Evacuation of people from the hazardous region(s) is *per se* a way to reduce the ill effects of disasters and evacuation planning is *prima facie* a critical component in emergency management. A number of simulation models have been developed for evacuation management and they generally are categorized as macro traffic simulation modes and Meso-simulation models. Excellent reviews of urban evacuation modeling can be found in [3, 4, 5]. However, most of models mentioned above are simulation-based models. The simulation-based models simulate the movement of each entity. Optimization-based models, on the other hand, treat the occupants as homogenous flow circulating through evacuation network. Dynamic network , which bases on its corresponding static network by expanding network over a time horizon, has attracts the interesting of researchers of various backgrounds. In this paper, a time-varying quickest flow based on dynamic network flow, is proposed to optimize the evacuation schedule, destinations as well as routes in a system optimization.

THE OPTIMIZATION OF EVACUATION PLANNING OF A CITY

In this section, a GIS based optimization model is established and is applied in the optimization of evacuation plan of a city prone to disasters. The advantages of a GIS-based system are that information can be quickly and easily updated from a variety of sources, which includes available evacuation routes, the distribution of population, cars per family, the position of special facilities, such as fire stations, the police offices and the emergency shields, etc. GIS can be adopted for evaluating, displaying, sending, and receiving information to the emergency management personnel. The integration of optimization model with GIS is a perfect solution for emergency management and evacuation planning. Generally, to perform a regional evacuation analysis, three kinds of attribute data must be prepared as shown Fig. 1, the attributes data of road network, the attributes data of resident district, the attributes data of emergency shelters.

A city with the population of 14550, as shown in Fig.2, is adopted as an example for our analysis. The road network is composed of 912 intersections and 2072 roads. There are 5 emergency shelters located in the city. At present, the detail population distribution isn't available, so we hypothetically distribute 129 resident districts as shown in Fig.2. There are many possible evacuation scenarios that can be developed which depend upon the area to be evacuated, the time of day, the presence of background traffic, emergency vehicles, etc. One of the anticipated worst scenarios – the full evacuation of all persons living in this area at night is considered. It must be pointed out that the departure time of evacuees has significant effects on the traffic operational conditions, the severity of traffic congestion, and therefore total clearance time. If all occupants are instantly loaded into the network, which, most of time, will lead to the over-congestion of whole road network and significantly increase the total clearance time.

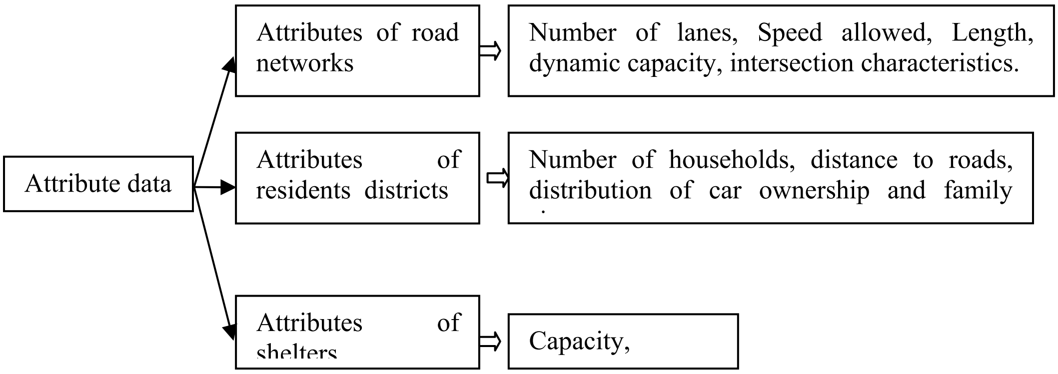

Fig. 1 The basic attributes data for evacuation analysis

Vice versa, if the pre-evacuation time delay too long, the pre-evacuation time will become a dominate factor compared with the time spending on journal. So, appropriate approaches must be adopted to determine optimal evacuation departure time. Here, we assume that evacuees will be mobilized simultaneously as soon as the evacuation order is issued (just prepare for leaving but not necessary be loaded into network). Then an optimal load schedule can be deduced.

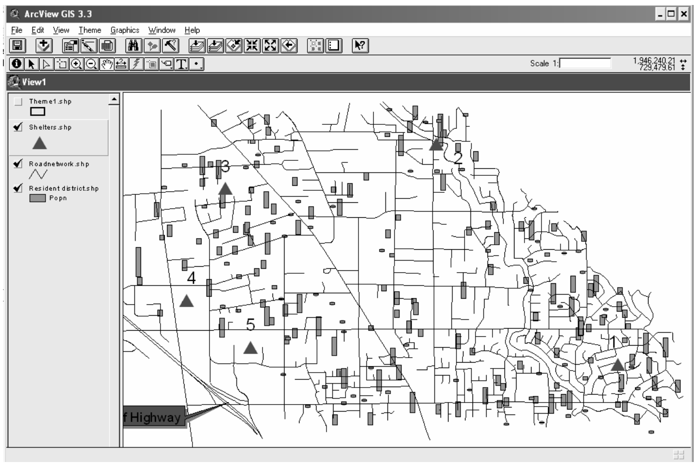

Figure.2 The GIS map of a City (network, population distribution and shelters).

CONCLUSIONS

The current optimization model is based on a global view-point, or in a system optimum, so the behavior aspect of evacuees can't be modeled. In fact for a real evacuation, it is more likely that evacuees will view an evacuation from their individual point, or in a user optimum. But optimization model can be used to make relative comparisons with other alternatives or be used as a benchmark to test the feasibility of evacuation plan. It is also noticeable to point out that the evacuation plan produced by this model is only one of many possible optimal solutions. Time-varying quickest flow problem is quite suitable for evacuation planning as capacity of roads or intersections may vary with time as the influence of adverse environments such as floods or lethal gas. Dynamic network reflects time-varying features and optimizes the whole evacuation process in a system optimum. Moreover, it can be used to determine the bottlenecks and alleviate the congestion so as to decrease the total clearance time. The integration of optimization model with GIS can provide us a versatile and easy-to-use way to operate our model and to show our results in vivid picture.

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