A New Models for Emergency Evacuation under the Disaster Condition

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ABSTRACT:

People must face many disasters every day, which cause losses in property and human lives. It is significant how to establish the emergency evacuation model and for high density population in large areas according to the actual situation of their emergency evacuation. This paper put forward a Multi-levels Emergency Evacuation Model (MEE) based on the collective evacuation for high density of population in large areas under the earthquake condition in China, which firstly find the best ways from the multi-gathering points(Origins) in the disaster area to multi-settling points(Destinations)in the safe area based on the road impedance such as the traffic, road speed limit and pavement damage to weight the evacuation ability of road network, and secondly determine the evacuation auto numbers on the every routes which is at the target to deliver all the evacuating people from the Origins to Destinations in the shortest time. The experiment area is Dezhou city in Shandong province of China, and an emergency evacuation platform was put up according to the multilevel emergency evacuation model using Google map API and C# as development platform, and the result show us that MEE is promised to be a new methods for emergency evacuation.

1. INTRODUCTION

The disasters were recurrent around the world during the last several years. Taking some cases for example, on May 12, 2008, the grievous earthquake struck Wenchuan County, Sichuan province in southwestern China that has taken 70, 000 people away, made 370, 000 wounded and more than 10, 000 disappeared or so. The day on April 14, 2010, the quake which hit 7.1 on the Richter scale happened in Yushu county, Qinghai province with 2, 220 people dead and 70 missing. The more terrible is the 9.0 magnitude earthquake in the eastern waters of Honshu island that resulted in 13498 deaths and 14734 disappearances on March 11, this year. They are not unique, but have their counterparts. On October 23, this year, 481 were deceased in eastern Van province of Turkey under the quake measuring 7.2. The awesome figures by quakes show that the recurrent earthquake disasters have a serious influence on social stability, development and public safety. So, coping with emergencies to safeguard the public lives and properties has being the cardinal issue of researchers all over the world. Model for emergency evacuation has to start with road network, with affecting the efficiency, and selecting evacuation path which transfers the stricken persons from hazardous area to secure area is the principal problem of constructing the model for emergency evacuation. From 1960s on, the researchers have proposed many emergency evacuation models for kinds of disasters: In the 1970s, Lewis(1985) proposed transportation planning for hurricane evacuations. In the next followed decade, the Virginia State of America advanced NETVACI (Antoine G et al, 1998). Cova (2003) put forward a network optimal flow model for lane based evacuation routing. Jernigan and Post.etc (2000)proposed macro-level evacuation modeling analysis system which is named evacuation travel demand forecasting system. Franzese and Han(2001) developed a computer-based incident management decision aid system. Zou and Yeh.etc (2005)proposed a simulation-based emergency evacuation system for ocean city Maryland under hurricane attacks. U.Petruccelli (2003)research the knowledge under earthquake evacuation. Yuan Yuan et al. (2008) established path select model for emergency evacuation.

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Under the internal concrete condition of collective transition and the network from multi-gathering points to multi-settling points when severe disasters struck, this paper discusses the distribution of multi-gathering points in the hazardous area and multi-settling points in the secure area, the respective suffers density in the corresponding gathering points, the respective accommodation of the corresponding setting points and the number of government vehicles for evacuation according to the computer simulation, and analyses the spatial point matching, path selecting and vehicle allocating methods during the evacuation model construction process. This paper takes Shandong province in China as the experimental area, based on WEBGIS and GOOGLE MAP API with computer programming language, to build the earthquake emergency evacuation platform.

2. CAPACITY OF ROAD EVALUATING

There are two goals need achieved when we evacuate persons from the disaster area to the safe area on the situation of quakes, that is to say, efficiency and safety. The efficiency indicates transition all victims from gathering points to setting points as soon as possible, relate to the road grades, the speed limits, the road length and the traffic flow and so forth. The safety denotes in the evacuation process we should ensure the victims safe because when passing through a part of disaster zone that building collapses, road surface damages and landslides were caused by the quakes. The strongest transportation capacity is equivalent to the lowest impedance on the contrary. Integrating it with the spring bounce model in physics: $F = k \times \Delta x$, we propose one methods for structural objective function evaluation on road capacity, with the impedance as the criterion.

2.1 Objective function evaluation on road capacity

With the road impedance as the evaluation criterion, when it is a constant, the longer the road is, the stronger the impedance is, likewise, the two roads of the same length but different values of impedance, whose impedance is stronger with the longer length. The impedance is determined by two key factors: one is the transportation speed impedance determined by the road class, the speed limits, the road width and the traffic flow and so on, the other is the disaster impedance resulting from the road collapses and countercheck. According to the fore-mentioned theory, we can get the objective function evaluation on road capacity as follows:

$$P = \mathrm{Min} \sum \alpha 1 \times Ti + \alpha 2 \times Di \quad (1)$$

Ti denotes the efficient transportation time of some path. Di denotes the damage degree of some path surface. $\alpha 1$ and $\alpha 2$ denote the coefficients in the object function which is decided by experts' experience and actual road condition. To make it easy, we assume $\alpha 1 = 1, \alpha 2 = 1$ in the after-mentioned experiment, that is, efficient transportation time and the weight of the damage degree of the relevant path are identical.

2.2 Objective function solution

According to the fore-mentioned theory we derive the object function in formula 1, and then solve the unknown quantity to get the summation P. Based on the past research and analysis on the road network data, many computation methods for road impedance have been proposed (Wang W.Q. and Zhou W et al. 2004; Zhuang Y. and Lv Sh., 2005), but we pick the model of calibration over again on the BPR function, rising in the research on traffic capacity, which is the key project in the ninth five-year plan, to formulate as below:

$$\mathrm{Ti} = \frac{\mathrm{ti}}{\alpha 1} \times [1 + \frac{Qi^{\beta}}{Ci}] \quad \alpha 1 = \mathrm{V0} \times \frac{[1+Qi/Ci]}{Vd} \quad \beta = \alpha 2 + \alpha 3 \times (\frac{Qi^3}{Ci}) \quad (2)$$

Qi（pcu/h）denotes the road flow in the real time. Ci（pcu/h）denotes the road capacity. ti denotes the running time according to the designing speed. V0（km/h）denotes the average speed. Vd（km/h） denotes the designing speed depending on the road ranking. α1、α2、α3、β denotes regression parameters and correction factor respectively, with the actual values in the literature (Wang W. and Deng W., et al. 2001).

The disaster impedance often has a close correlation with the disaster type, the geographical conditions and economic situation in the location. It's the letter's key point that evacuation on the condition of earthquake, so we use the following formulation which proposed by Xu Tianben and Lv Jianghui (2002) to compute the disaster impedance.

$$\mathrm{Di}=\mathrm{Pbi} \times \mathrm{Si} \times \mathrm{Ei} \quad (3)$$

Pbi denotes the damage probability of the road. Si denotes the impedance degree of the same road. Ei denotes the corresponding exposure level.

$$\mathrm{Si}=\mathrm{Hi}/\mathrm{Di} \quad (4)$$

Hi denotes the average height of buildings in the road. Di denotes the valid width of the correspondent road.

$$\mathrm{Ei}=\mathrm{ki}/\mathrm{Li} \quad (5)$$

ki denotes the building density in the road. Li denotes the length of the road.

3. MODELING MULTI-HIERARCHY EMERGENCY EVACUATION

Modeling multi-hierarchy emergency evacuation is based on the road network data in the actual time, according to the road capacity evaluation criterion under the disaster, deriving from the fore-mentioned research, we can gain the support of the real-time and handled road network data, and then construct the multi-hierarchy evacuation model. We establish it according to the three levels.

3.1 Spatial points matching

The central mission of the model is to evacuate the people from the multi-gathering points in the disaster area to the multi-settling points in the secure area when disaster is striking. How to finish the evacuation from a certain gathering point to some setting points needs the points matching on the basis of the spatial property between the gathering point and setting point. This paper supposes that the epicenter locates a certain center of the experimental area, then designates the dangerous region, buffer zone and safe region by simulating quake magnitude, and picks multi-gathering points and multi-settling points in the corresponding zones. The points must satisfy certain criteria. The gathering points ought to be in the disaster region which is convenient to gathering people, where is no tall building, which is far away from the disaster origin and which is near to the traffic hub zone. The setting points ought to be in the safe region away from the dangerous area. We usually take hospitals, schools and squares as setting points in consideration of factors such as the relief materials conveyance, the real-time cure to victims and adopt ability for evacuation persons. As long as the points are fixed, we can match the multi-gathering points and the multi-settling points by spatial analysis.

(1) Spatial analysis and Voronoi diagram

Spatial analysis is an analysis technology of spatial data based on the location and morphological feature of geographic object, with the goal of learning about the events in space, extracting and conveying spatial information. Spatial analysis includes spatial location, spatial distribution, spatial morphology, spatial distance, spatial orientation, topology, similarity and relevance amounting to five aspects. In this paper we mainly rely on the spatial location, spatial distribution, spatial orientation and topology of multi-gathering points and multi-settling points, and settle the matching problem according to the dissection trait of Voronoi diagram.

The Voronoi diagram (Franz A. and Rolf K., 1996) is correlative with discrete points, divided the plane into several region with only one point in it, which is the nearest assemble points to the only point. It is used for spatial dissection whose