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A Reliability Evaluation of Lifeline Systems Effects on Fire Rescue

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Abstract:

In the process of actual fire rescue, the timeliness and success rate of fire rescues will be affected when only one lifeline system is considered and not considered the relationship among other lifeline systems. However, little research was paid attention to the relationship among different lifeline systems and the most of studies was focused on a single lifeline system. Therefore, it is important and significant to study on the interaction of different lifeline systems during the fire rescues. In this paper, a rescue model is built to evaluate the reliability of the effect of lifeline systems on the fire rescues. Many factors are considered including water system, traffic system, rescue workers, equipment and so on. The reliability of the influence factors are also presented. The reliability of fire rescue can be described and characterized efficiently by this model.

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Keywords: lifeline system, reliability, fire rescue, evaluation

Nomenclature

ϕ	rescue function	w	water source
r	roads	pm	rescue workers and materials
p_{pipe}	the property of pipeline and water supply	p	rescue workers
m	goods and materials;	r_c	roads connectivity;
$s_{\min}$	the shortest path.	k_{wi}	Important coefficient of i-th water source
R_w	the reliability of the water source	R_{iws}	water supply capacity of the i-th water source
R_{ws}	actual output of supplying water of the water source	R_{wn}	Water needed in disasters
R_p	reliability of rescue workers	R_m	The reliability of equipment and goods
R_{pm}	the total reliability of rescue workers and materials	R_s	the traffic reliability
R_{rj}	the reliability probability of connection from j-th rescue spot to the fire scene	l_{rj}	the coefficient of importance of path from j-th rescue spot to the fire scene
$R_{jrescue}$	the rescue ability of the j-th rescue station	Q	The output of supplying water, L/s
D	diameter of the pipeline, in	V	The equivalent velocity of the pipeline, m/s
C_i	construction factors	O_i	application of the building,
X_i	it is exposed to fire	$S_{combustion}$	burning area
NFF_i	the needed fire water, gal/min	k	The type of fire engines

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$S_{control}$	the fire area controlled	R_{pi}	the reliability of the No. *i* fireman
K_{pi}	important degree of the No. *i* fireman	R_{Fpi}	the actual reliability of fire rescue workers,
N_e	education background	N_F	number of fight
N_h	Health degree	R_r	The connectivity reliability of the roads
P_r	route connecting probability	R_{pmj}	Reliability of supplies in *j*-th rescue station
P_i	the communication of the buildings, such as connection coefficient or fire separation between the chosen buildings	S_{ijk}	the fire area controlled by the No. *j* fire engine whose type is k from No. *i* fire station, i=1,2,…,n, j=1,2,…,m)

1. Introduction

Lifeline systems generally include the systems of traffic, communication, water supply, power supply, air supply and some other systems supplying social services, which are considered as the key component of the infrastructure in a city. After fire disasters, it is crucial that whether the emergency rescues can be carry out immediately and effectively, and the rescues are the most important part. In the process of rescues, the effectiveness of fire rescue can be affected by the traffic and water supply systems and the smooth progress of fire rescue is safeguarded through the high personal quality and sufficient equipment, goods and materials. Some single systems have been studied, such as the water, traffic, fire-fighters, materials, and so on.

In the aspect of water supply system, Chen and his co-workers [1] have proposed a method to evaluate the municipal water supply capacity through the municipal fire hydrant, which is applied to some problems of production, fire protection and so on in daily life. Wang [2] has expounded some factors through some actual cases which should be considered during the process of the municipal water supply capacity test of pipelines. Afterwards, a method to determine fire flow in a city was presented after many methods used in developed countries are studied by Chen [3].

In the aspect of traffic, Steven D. et al. [4] have summarized the contingency plan about traffic after the earthquake happened in Los Angeles in 1994 and they studied the management of traffic system after emergency from the aspect of operation and management of traffic system. Thomas, et al. [5] proposed that the main reasons of traffic jams during the evacuation were the interweaving and conflict of the traffic flow at the intersections. A network model based upon the lanes was also proposed in order to choose the optimum path in the complicated road network for urgent evacuation. Zilla S.S., et al. [6] proposed that evacuation time of road network can be affected greatly by the interactions between pedestrians and the traffic through microscopic traffic simulation model based on the behaviour. Liu, et al.[7] have put forward a model to calculate the journey time of fire trucks and obtained the importance degree of some factors which have influence on the journey time.

In the aspect of fire-fighting equipment, Zhu, et al. [8] got an evaluation method for the fire fighting and rescue ability after they researched on the personnel, equipment, water supply, and road in regional rescue. An algorithm optimization was given by Liu [9] based on the actual fire-fighting work. It can simplify complexity of Dijkstra model and then improve the operational efficiency greatly.

In the aspect of overall planning during fire fighting, Zhu, et al. [10] have suggested that regional rescue should be established to handle the transregional disaster accident rapidly and effectively. And a mathematical model was also built to calculate the circle radius and it can be optimized according to the investment increase after the regional rescue was carried out. A new math model based on integration of several variables to calculate the average driving distance of the fire station was proposed by Tian [11]. An information system of fire prevention was established based upon the CAD system.

In the above research, only one lifeline system has been considered during fire rescues. However, study on the interaction of several lifeline systems was little. So the interactions among different lifeline system in fire rescues should be taken into account. In this paper, the rescue model is built to evaluate the reliability of fire rescue affected by the lifeline systems. Not only two lifeline systems, water and traffic system, are considered in the model, but also rescue workers, goods and materials and so on are also considered.

2. Theoretical model

The factors that affected the rescue process mainly include 2 aspects: (a) the time needed which rescue workers arrive at the disaster scenes and (b) the rescue technologies [12]. The former aspect can be influenced by the distance between the rescuers and the scenes, the traffic conditions and the traffic management technologies. The latter aspect can be affected by the rescue materials and equipment and the responding speeds and abilities of commanders and executants.