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ScienceDirect

Procedia Engineering 135 (2016) 12 – 18

Procedia Engineering

www.elsevier.com/locate/procedia

Emergency evacuation model and algorithm in the building with several exits

Chang Liu[a], Zhan-li Mao[a,b,*], Zhi-min Fu[a]

[a]*The Chinese People's Armed Police Forces Academy, Langfang 065000, China*
[b]*State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230027, China*

Abstract

For the problems of evacuation with several exits under the limiting condition of fire smoke and routes capacity, an evacuation model combining of heuristic algorithm and network flow control was established in this study. Taking into account of routes capacity constraints, the aim of emergency evacuation is to minimize the total evacuation time for all people. The optimal evacuation path group, evacuation time and the number of evacuation in the evacuation network can be acquired through updating the evacuation network constantly and finding optimal routes iteratively. An example was presented to show the effectiveness and feasibility of this model and algorithm, and it can be used to explore the method to determine the optimal evacuation plan, while the actual routes inequality was not established.

Peer-review under responsibility of the organizing committee of ICPFFPE 2015

Keywords: fire smoke, building with several exits, capacity constraints, evacuation model

Nomenclature

$G(V,E)$	evacuation networks
V	vertex set, including three sub sets S , D and V . The S indicates source node; The D indicates set of sink nodes, $D=\{D_k \mid k=1,2,\cdots,K\}$; The V indicates middle node, $N=\{V_n \mid n=1,2,\cdots,N\}$
E	set of arcs, and e_{ij} indicates the arc between node i and node j
l_{ij}	length of arc e_{ij}
$h_{ij}(t)$	walking speed among an arc e_{ij} at time t
t_{ij}	travel time among an arc e_{ij}
c_{ij}	maximum capacity in a unit time among an arc e_{ij}, person/time
P_l	evacuation path, $l=1,2,\cdots,L$
PC_l	maximum capacity in an evacuation route, depending on minimum of c_{ij} among the aces of the evacuation route
f_l	number of evacuees passing path in a unit time, person/time
x	total number of evacuees

* Corresponding author. Tel.: 86-0316-2068512
E-mail address: maozhl@mail.ustc.edu.cn

Peer-review under responsibility of the organizing committee of ICPFFPE 2015
doi:10.1016/j.proeng.2016.01.072

x_{kl}	number of evacuees for going through P_l
T_{P_l}	travel time required for going through P_l
T	total evacuation time

1. Introduction

Nowadays, there are much taller and huger buildings in cities, and occupant evacuation problems become more important under building fires. It will render evacuees crowded easily once fire occurs, if occupant can't evacuate from the building timely, and it is extremely easy to cause serious casualties [1]. Therefore, it is particularly necessary to solve how make an optimal evacuation plan and evacuate occupant effectively in the fire, and it also need further studied as a scientific problem [2].

In recent years, the research on emergency evacuation has been carried out, and many scholars have adopted different methods to study the problem, which can be generally classified into mathematical analysis and computer simulation [3]. Mathematical analysis method is based on the mathematical model, and the actual parameters of evacuation are converted into a mathematical model to be solved, which can be classified into macroscopic models and microscopic models [4]. The microscopic models, such as cellular automaton model, multi lattice model and probability model, consider the evacuees' individual characteristics and interactions in evacuation process. However, the path selection of evacuees in the evacuation area can't be solved easily, due the size of the building is large. The macroscopic models ignore the individuals' behaviors in evacuation process and are based on network flow models, which can solve the problem of emergency evacuation paths [5]. Tjandra [6] proposed a single-source evacuation model， which a type of macroscopic models, to solve the routing problem. However, the capacity limit and priority of the path are also important to the choice of the evacuation paths, Chen [7] considered that evacuation routes could be calculated by Fast flow control algorithm, in order to get multiple optimal evacuation paths. Yang [8] established a mathematical model based on the minimum time of evacuation through giving priority to saturated shortest path. Additionally, some models have been reported on the optimization evacuation routes in case of fire smoke. Xie [9] proposed a shortest path model based on the definition of equivalent length under concentration of fire smoke and crowd density. Yuan [10] proposed that the evacuation speed of each arc in the evacuation network was expressed as a function of evacuation time and smoke diffusion, and built the optimal evacuation route algorithm.

The optimal evacuation paths can be calculated by above evacuation models, considering the uncertainty and dynamic of evacuation in some extent. However, different evacuation models are usually needed to build during different backgrounds. This work mainly considers the characteristic of the personnel density and fire smoke diffusion, and the optimal paths of evacuation in building with several exits are determined by minimizing total evacuation time. Additionally, this work explores the method to make the optimal evacuation plan, while the actual routes inequality is not established, and determines the significance of important arc in the evacuation paths.

2. Evacuation model

2.1. Assumption of the mathematical model

All tables should be numbered with Arabic numerals. Headings should be placed above tables, center justified. Leave one line space between the heading and the table. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which authors may find useful.

- It is a precautionary evacuation and all people to be evacuated obeying the command by evacuation plan.
- There are multiple exits and only one source, which capacity of every exit is limited.
- The capacity of every exit is transformed into an arc, and the capacities of other nodes are not limited.
- The speed of evacuees is not fixed among every arc in the evacuation network, and travel time among an arc is determined by the length of the arc and the speed of evacuees.
- The evacuation is required to preserve the FIFO (First-In-First-Out) property.
- Returning or cruising is not allowed.

If table footnotes should be used, place footnotes to tables below the table body and indicate them with superscript lowercase letters. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article.