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Simulation Modeling Practice on Occupant Evacuation in a Medium-sized Supermarket

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Simulation Modeling Practice on Occupant Evacuation in a Medium-sized Supermarket

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Abstract: The research mainly focused on the effect of staff density and exit conditions on total evacuation time. The results showed that with the increase of staff density, evacuation time often increases non-linearly. The function equation of evacuation time and number of occupants in case A was obtained through computer simulation. The augment of exit number or total export width can reduce the total evacuation time to improve evacuation efficiency. While, if the number of evacuees reaches to a certain value, evacuation time may increase non-linearly after being affected by the internal structure and the random distribution of occupant. Export position also has impact on total evacuation time. The results of the simulation have guiding significance on the design of building structures and personnel evacuation in emergency.

1. Introduction

With improvement on living standard and demanding for material culture, numerous medium-sized supermarkets have been built in China, therefore the study on personnel evacuation becomes a significant topic. At present, discrete models which include Cellular Automata Model [1], Multi-grid Model [2] and Lattice Gas Mode [3], are widely used in theoretical research and engineering application. In the field of researching on simulation model, Dirk Helbing used a model of pedestrian behaviour to investigate the mechanisms of panic and jamming by uncoordinated motion in crowds [4]. Weiguo Song used CAFE model to analyze the personnel evacuation performance to study on the personnel evacuation of large commercial center [5].

2. Simulation design

2.1 General situation of the market

The market internal layout references a medium-sized supermarket in Hefei. The total area of the market which consists of 69 goods shelves, 20 cashiers, 1 service desk, 4 exports and 2 emergency exits is 3600 square meters, and its length and width is 60 meters. The width of exports is 4 meters, and in order to compare, the width of emergency exits which are not used except in emergency takes half width of the former exits. Evacuees are randomly distributed in the initial stage and the assumption that occupant selects corresponding outlet to evacuate by obeying Proximity Principle is applied in emergency evacuation.

2.2 Simulation cases design
In the evacuation simulation, four different cases were taken to facilitate comparative analysis.

Table 1. The list of exit conditions and cases

Exports	Width（m）	Cases	State of exits
Exit 1	4.0	Case A	Exit 1,2,3,4 open
Exit 2	4.0	Case B	Exit 1,2,3 open,4 closed
Exit 3	2.0	Case C	Exit 1,2,4 open,3 closed
Exit 4	2.0	Case D	Exit 1,2 open,3,4 closed

3.Result and discussion

In Fig.1(a), after evacuating 5seconds, the slope of the two curves nearly parallel has little difference which shows that evacuation rate changes a little when the number of occupants is 600, 1000 and 1400. It also means that the evacuation process is relatively smooth and staff density has little impact on personnel evacuation efficiency in early stage. But in 30s, 45s, and 52s, three curves appear turning points，and then the slope of curves decrease obviously and the evacuation efficiency reduces leading to the extension of total time.
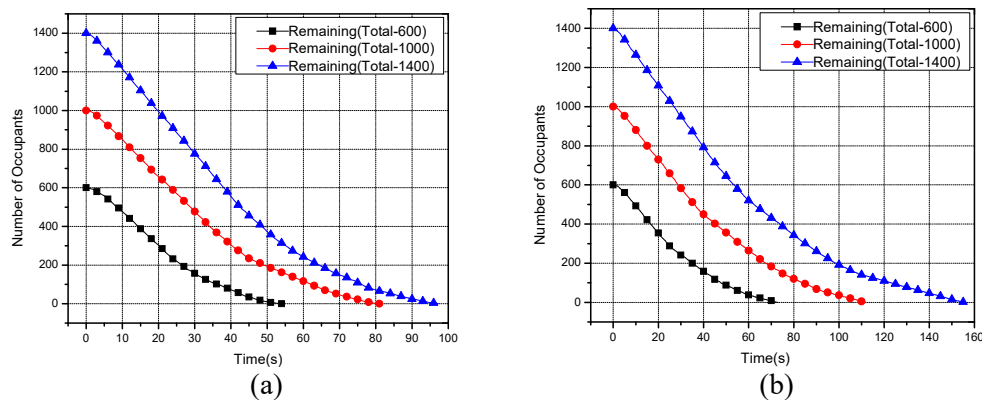

Fig.1 Number of occupants and egress time diagram in case A and B

In Fig.1(b), the total evacuation time is respectively 72 s, 111 s and 155 s which indicates that egress time has big difference under different staff density. There is no obvious difference between the development trend in Fig.1(a) and Fig.1(b), but the time differs a lot. Through comparing Fig.1(a) with (b), we can find that appropriate increasing export number or total width of exits can improve evacuation efficiency.

Fig.2 is the fitting curve of evacuation in case A. In mathematical terms, the change of evacuation time is then given by the acceleration equation 1.
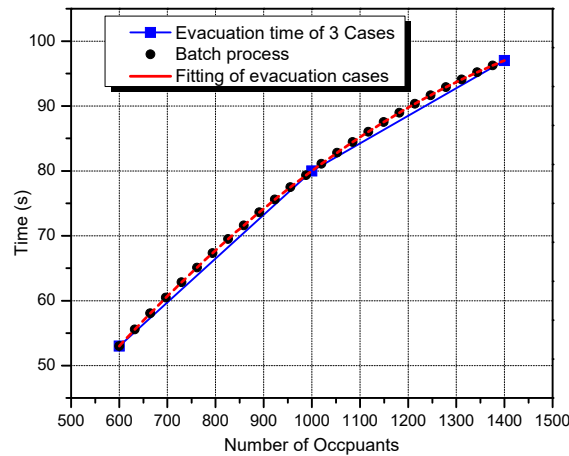
Fig.2 The fitting curve of evacuation time in case A

$$T = -3.125 \times 10^{-5} N^2 + 0.1175N - 6.25 \tag{1}$$

Where T is the total evacuation time, and N from 600 to 1400 is the number of occupants.

Other points were batched in Fig.2 so that the evacuation time can be obtained from the graph. The evacuation time in case A of other staff density can be predicted by applying the equation. Personnel evacuation in different staff density can be learned through calculation to generally realize the safety degree of evacuation in emergency.

In Fig.3(a), turning points in the three curves are appeared respectively in 39s, 50s, and 68s, and then the slope of curves decrease obviously that leads to the reduction of evacuation efficiency. In Fig. 3(b), the simulation results state clearly that total egress time is 72 seconds when the number of occupants is 600, 107 seconds for 1000, 138 seconds for 1400. From case C and D, we can see that the egress time in case C is shorter than in case D when the number is 600, 1000. While, the egress time in case C is longer when the number is 1400. This may attribute to the small difference between total exit width of case C and D.

When the number of evacuees is 600 and 1000 in case A, B, C and D, the simulation results are shown in Fig.4. Fig.5 is the personnel evacuation efficiency chart when there are 1000 evacuees in case A, B, C and D.
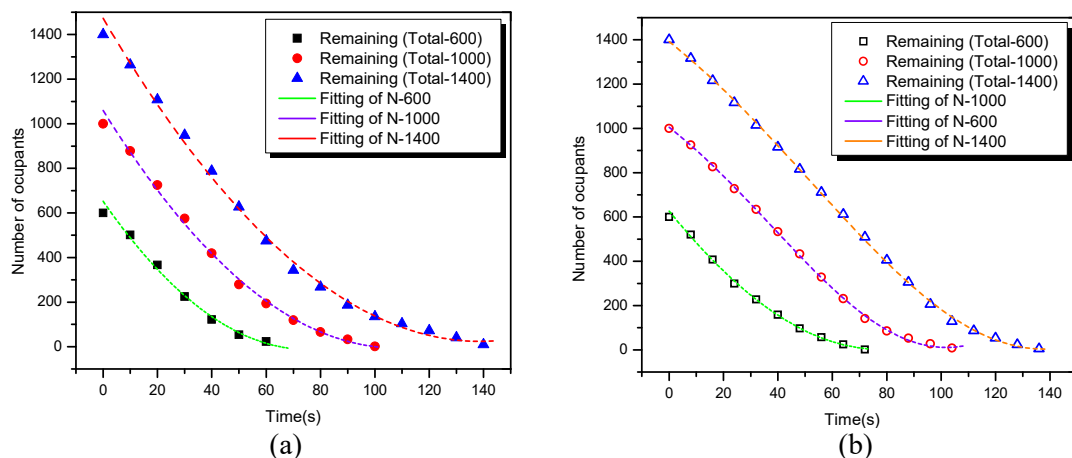

(a)

(b)

Fig.3 The fitting curve of evacuation time in case C and D

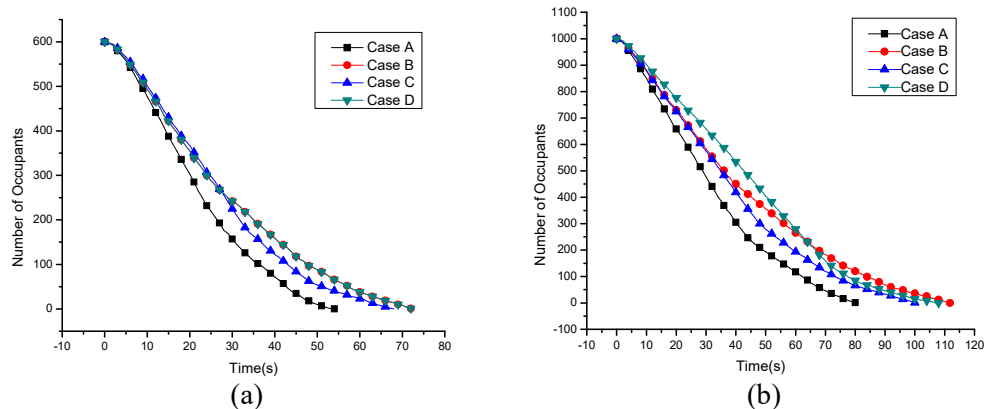(a)   (b)

Fig.4 Number of occupants and egress time diagram in case A、B、C and D

In Fig.4 (a), the curves of case B and D are nearly coincide, which means when the total number of people is 600, whether exit 3 is open has no influence on evacuation. Even though the exit conditions are different, the whole evacuation time of case B, C and D differ not too much, the egress time under case A is relatively shorter. In general, the more exits, the shorter of evacuation time, and the more benefit for safety evacuation. In Fig.4 (b), when the overall number of people add up to 1000 in case B and D, the evacuation time of case B is by no means less than D as usual. Therefore, the total evacuation time not always reduce along with the increase of total exit width or the number of the exports, because it may increase nonlinearly under the influence of the structure of the internal layout and the random distribution of occupants.
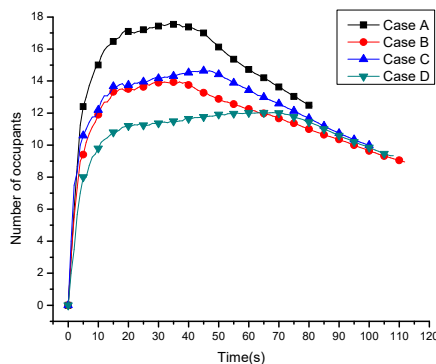

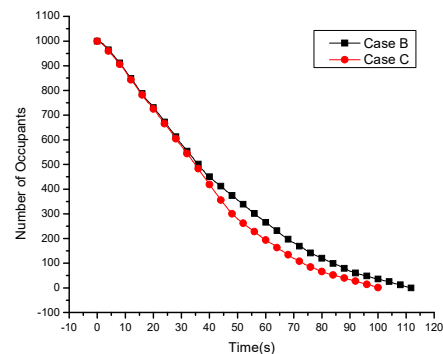Fig.5 Personnel evacuation efficiency chart in
case A、B、C and D

Fig.6 Number of occupants and egress time
diagram in case B and C

In Fig. 5, the evacuation efficiency in case A is the highest and then is the efficiency in case C. After 65s, the efficiency in case D is higher than it in case B.

So as to analyze the effect of export position on egress time more efficient and more effectively, 1000 people were considered in the simulation under case B and C. The result of the simulation was shown in Fig.6. In Fig.6, the two curves completely coincide before 31 seconds in the evacuation, so exit position has no effect on evacuation efficiency before 31s. But after 31s, evacuation efficiency begins to change. In general, outlet position has influence on egress time. In this simulation model, using exit 4 is more advantageous to the emergency evacuation than exit 3.

4.Conclusions

The paper mainly focused on the effect of exit conditions and staff density on evacuation time. The conclusions are as follows:

(1) With the density increasing, the evacuation time often increases non-linearly. (2) Appropriate

increasing exit number can improve the evacuation efficiency and reduce the total evacuation time to assure occupants safety. But the total evacuation time not always reduce nonlinear along with the increase of exit width or the number of the exports. (3) Exit position has certain influence on egress time.

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