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# Evacuation Safety Assessment of Elderly and Children in High-rise Hotels in China

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***Abstract***

*Chinese high-rise hotels are large in size, densely populated, and have a lot of combustibles. Once a fire occurs, the fire and smoke spread rapidly, and once a fire accident occurs, it is easy to cause a large number of deaths. Fires have a greater impact on special populations such as elderly and children who move slowly. At present, research mainly focuses on the impact of high-rise building structures on evacuation consequences, but there is very little research on the safety evacuation consequences of elderly people and children in high-rise hotels. This paper focuses on the elderly and children living in high-rise hotels in China. We studied three scenarios in which the elderly and children were placed on high floors, middle floors, and low floors. For the above three scenarios, use pathfinder software for simulation, According to the simulation results, when the elderly and children are mainly concentrated in the lower floors (2nd and 3rd floors), the evacuation time is the shortest, 147 seconds. The evacuation time for the elderly and children on the middle floor (6th and 7th floors) is the longest, at 191.5 seconds. Compared to being placed on high floors, safely staying on low floors for all ages reduces evacuation time by 44.5 seconds and improves evacuation efficiency by 23.24%. The final safety evacuation plan is that in daily safety management, hotels should arrange elderly and children occupants on lower floors as much as possible to reduce the total evacuation time and improve personnel evacuation efficiency. This has great guiding significance in the safety management of high-rise hotels.*

***Key Words***: *High rise hotels, safe evacuation, evacuation of elderly and children, hotel management*

## 1. INTRODUCTION

According to the Chinese 《Code for Fire Protection Design of Buildings》GB50016-2014 (2018), hotels with a building height greater than 24m are considered high-rise hotels.

High rise hotels have large volumes, dense personnel, and a high amount of combustible materials, and

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fire accidents often occur. Once a fire accident occurs, it can easily lead to a large number of deaths. Fire has a greater impact on special groups such as elderly and children who move slowly, so it is necessary to conduct safety evacuation simulations for special groups in high-rise hotels.

Foreign experts and scholars began conducting research on personnel evacuation in the early 20th century and published research results on building personnel evacuation.

Ndree K et al. [1] used VR virtual technology to simulate the duration of evacuees waiting for elevators in high-rise buildings. The research results showed that people are willing to wait for the elevator for 5-20 minutes. Enrico et al. [2] used evacuation models to identify the optimal evacuation route. Liu Huifeng [3] used computer software to simulate the process of personnel evacuation and found that a fire on the ground floor of a high-rise apartment had a significant impact on personnel evacuation.In 2019, Angel et al.[4], and others established an analytical model for high-rise buildings to analyze the impact of evacuation distance and evacuation time delay on evacuation consequences.

In 2019, Aleksandrov et al.[5] simulated personnel evacuation and proposed an optimal evacuation strategy for high-rise buildings.

The above study considered the impact of high-rise building structures on evacuation results, but did not consider the impact on the safety evacuation results of the elderly and children.

Therefore, this paper used Pathfinder software to conduct a case study on a high-rise hotel in China, in order to simulate and evaluate the evacuation safety of the elderly and children, and determine a better evacuation plan.

## 2. INTRODUCTION TO SIMULATION SOFTWARE

Pathfinder is a simulation software developed by Thunderhead in 2009, based on the standards proposed by the Society of Fire Engineers (SFPE) for simulation. Pathfinder is an simulator based on personnel evacuation and movement simulation. It provides users with a graphical user interface for simulation design and operation, as well as 2D and 3D visualization tools for analyzing results. Therefore, this paper uses Pathfinder evacuation software to simulate it.

## 3. EVACUATION MODEL AND SIMULATION PARAMETER SETTINGS

### 3.1. Evacuation model

The hotel has 7 floors, with a height of 4.0 meters and an area of 800 square meters per floor. The first floor is a lobby with entertainment areas, restaurants, and a front desk. The 2nd to 7th floors are standard floors, with 11 guest rooms on each floor for 33 people and a lobby for 7 people. There are two elevators inside the building. Two evacuation stairs have also been set up, each with a height of 160mm, a width of 260mm, and a width of 150cm. There are 4 emergency exits on the first floor, with a width of 300cm. The standard floor plan is shown in Figure 1, and the elevation of the entire building is shown in Figure 2.

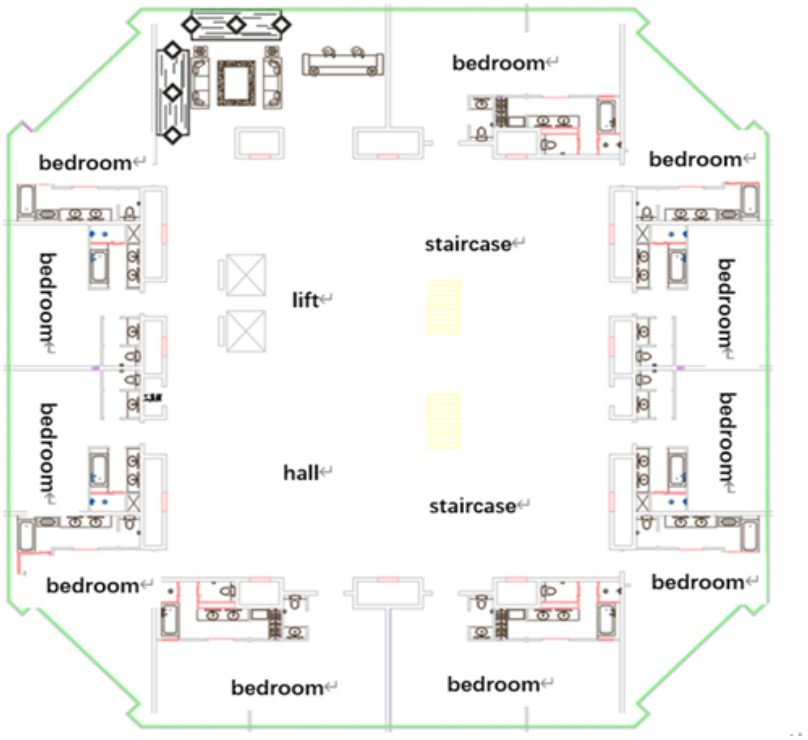


**Figure 1. High rise hotel floor plan**

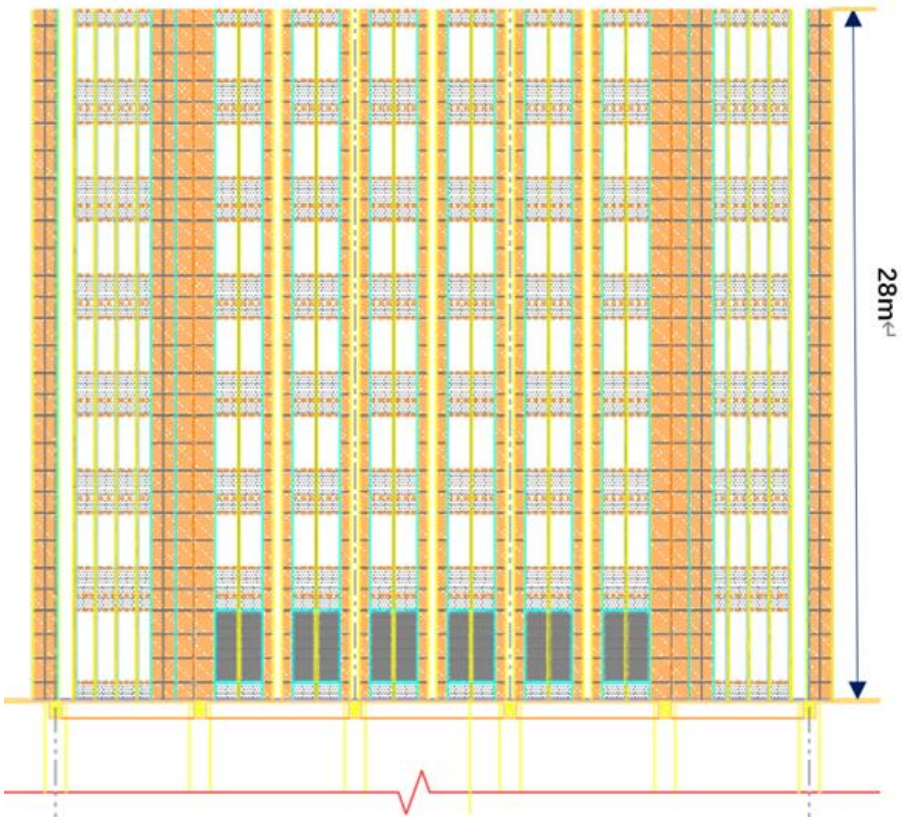


**Figure 2. Elevations of High rise Hote**

### 3.2. Basic parameter settings for evacuating pedestrians

（1）evacuate pedestrian types

In order to make the simulation of personnel evacuation more realistic, the evacuated pedestrians are divided into four categories: adult males, adult females, children, and the elderly.

According to the《China Children's Development Outline (2011-2020)》: Children aged 0-14 years old. According to the《Law of the People's Republic of China on the Protection of the Rights and Interests of the Elderly》: Elderly people aged 60 and above。

This paper considers the most unfavorable scenario for research, assuming that all rooms are fully occupied, with an average of 40 people per floor, a total of 210 people, including 90 adult males, 90 adult females, 15 children, and 15 elderly people.

According to the statistical results of literature [6], adult males account for 35%, adult females account for 35%, elderly people account for 20%, and children account for 10% in hotels. Therefore, there are 98 adult males, 98 adult females, 56 elderly people, and 28 children.。

（2）evacuate pedestrian speed

Based on experimental results[6] and references[7-8], considering the particularity of pedestrian evacuation, Table 1 provides the speed and body characteristic parameters of pedestrian evacuation. The parameter settings are shown in Table 1:

**Table 1. Speed and Body Characteristic Parameter Settings for Evacuating Pedestrians**

| Personnel Type | Speed（m/s） | Height（m） | Shoulder Width（m） |
|---|---|---|---|
| Children | 0.77, [9] | 1.30 | 0.30 |
| The old | 0.92, [10] | 1.60 | 0.50 |
| Adult male | 1.19, [11] | 1.70 | 0.50 |
| Adult female | 0.85, [11] | 1.60 | 0.45 |

（3）scenario

According to the research objectives, the scenario settings are as follows:

Script 1: The elderly and children are in the high-rise, with 56 elderly and 28 children on the 6th to 7th floors. Considering that children should be with adults, 14 adult males and 14 adult females are also on the 6th to 7th floor.

Scenario 2: The elderly and children are in the middle layer. 56 elderly people and 28 children are all on floors 4-5. script

Script 3: The elderly and children are on lower floors. 56 elderly people and 28 children are all on the 2nd to 3rd floors. Considering that children should be with adults, 14 adult males and 14 adult females are also on the 2nd to 3rd floors.

The detailed content of the script is shown in table 2.

**Table 2. Specific Situation of the Scenario**

| Scenario | Case | Floors | The old | Children | Adult male | Adult female |
|---|---|---|---|---|---|---|
| Scenario 1 | Elderly and Children in The Upper Floors | 1st floor | 0 | 0 | 28 | 28 |
| | | 2-3 floors | 0 | 0 | 28 | 28 |
| | | 4-5 floors | 0 | 0 | 28 | 28 |
| | | 6-7 floors | 56 | 28 | 14 | 14 |
| Scenario 2 | The Elderly and Children are in The Middle Layer | 1st floor | 0 | 0 | 28 | 28 |
| | | 2-3 floors | 0 | 0 | 28 | 28 |
| | | 4-5 floors | 56 | 28 | 14 | 14 |
| | | 6-7 floors | 0 | 0 | 28 | 28 |
| Scenario 3 | Elderly and Children on Lower Floors | 1st floor | 0 | 0 | 28 | 28 |
| | | 2-3 floors | 56 | 28 | 14 | 14 |
| | | 4-5 floors | 0 | 0 | 28 | 28 |
| | | 6-7 floors | 0 | 0 | 28 | 28 |

## 4. EVACUATION SIMULATION

### 4.1. Scenario1

Scenario 1, simulation scenario: The elderly and children are mainly concentrated on the 6th and 7th floors, and the simulation results are as follows:

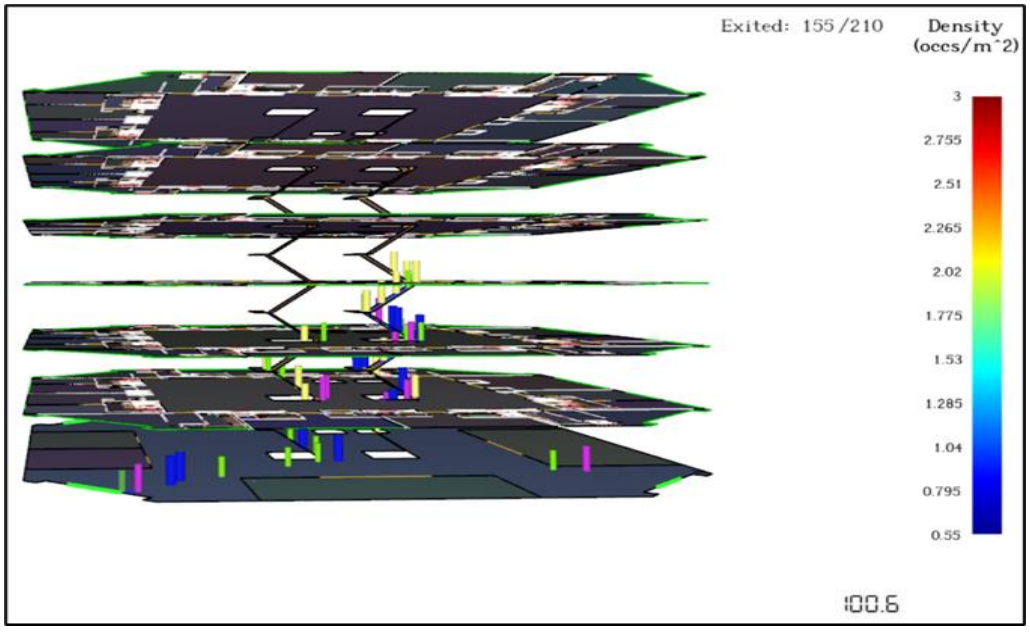


**Figure 3. Evacuation Situation at 100.6 seconds in Scenario 1**

As shown in the figure, the fastest time to reach the emergency exit for the elderly and children is 100.6 seconds. At this time, a total of 155 people arrived at the emergency exit.

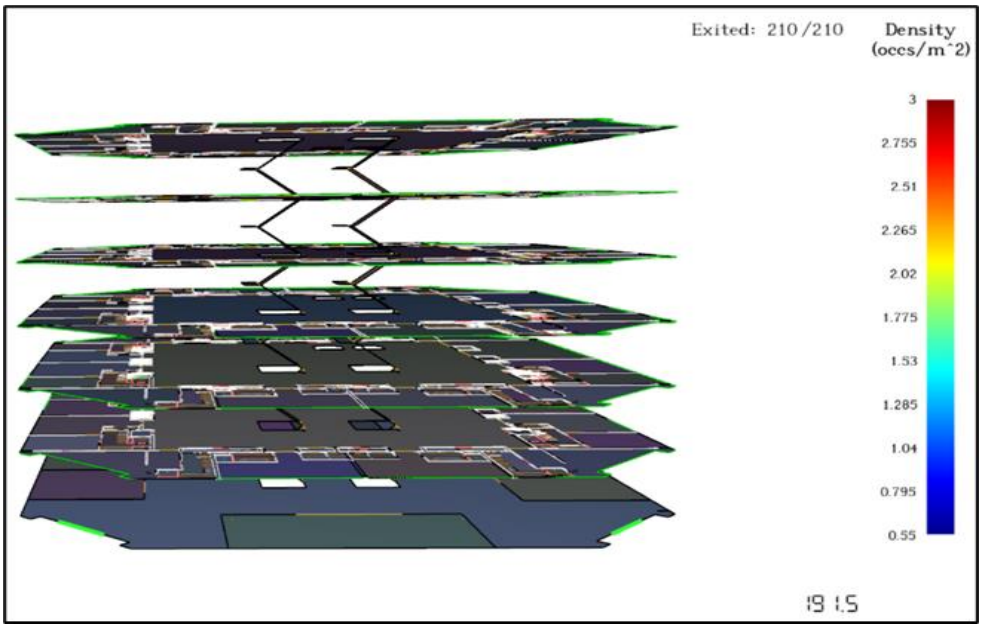


**Figure 4. Scenario 1 Total Evacuation Time**

As shown in the figure: The total evacuation time is 191.5 seconds. The last person to reach the emergency exit was an elderly person, with a time of 191.5 seconds.

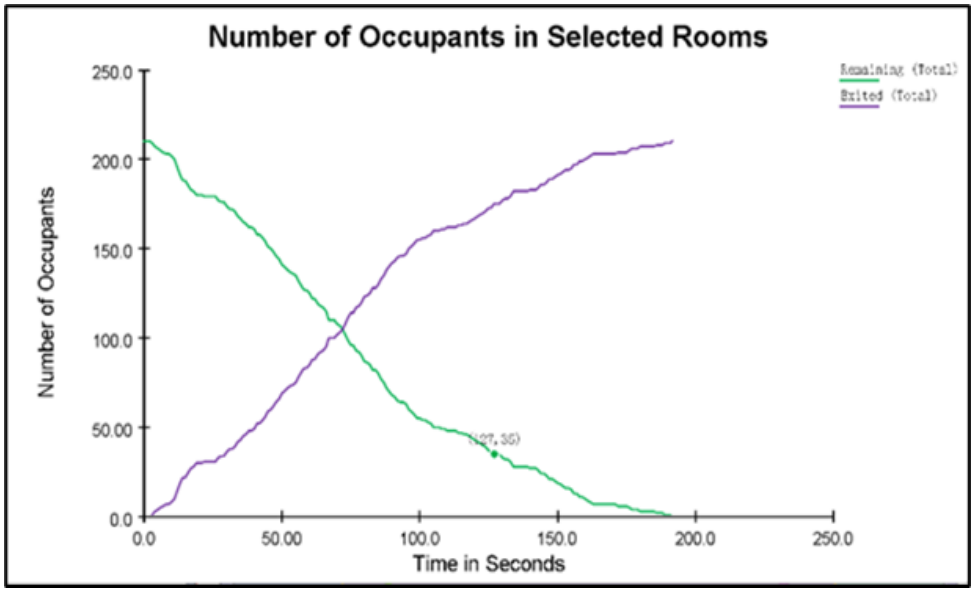


**Figure 5. Scenario 1 Personnel Evacuation Situation**

At 1100.6 seconds in the scene, most adults had already left the safety exit. The elderly and children are concentrated on the stairs on the 4th and 5th floors.

### 4.2 Scenario2

Scenario 2, Simulation Scenario: The elderly and children are mainly concentrated on the 4th and 5th floors. The simulation results are as follows:

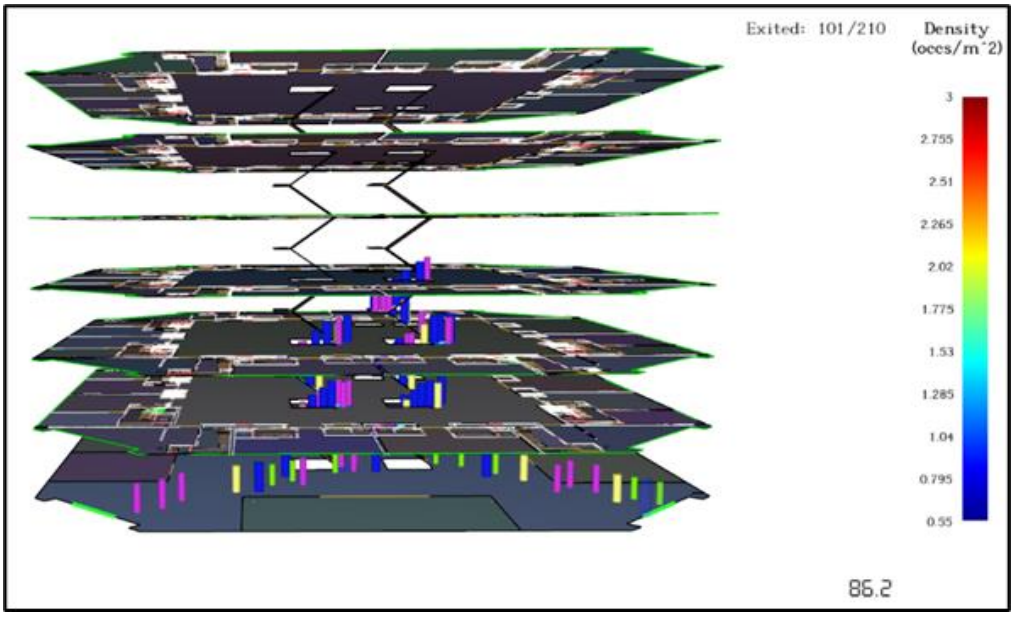


**Figure 6. Evacuation Situation at 86.2 seconds in Scenario 2**

As shown in the figure, the fastest time to reach the emergency exit for the elderly and children is 86.2 seconds. At this time, a total of 101 people arrived at the emergency exit.

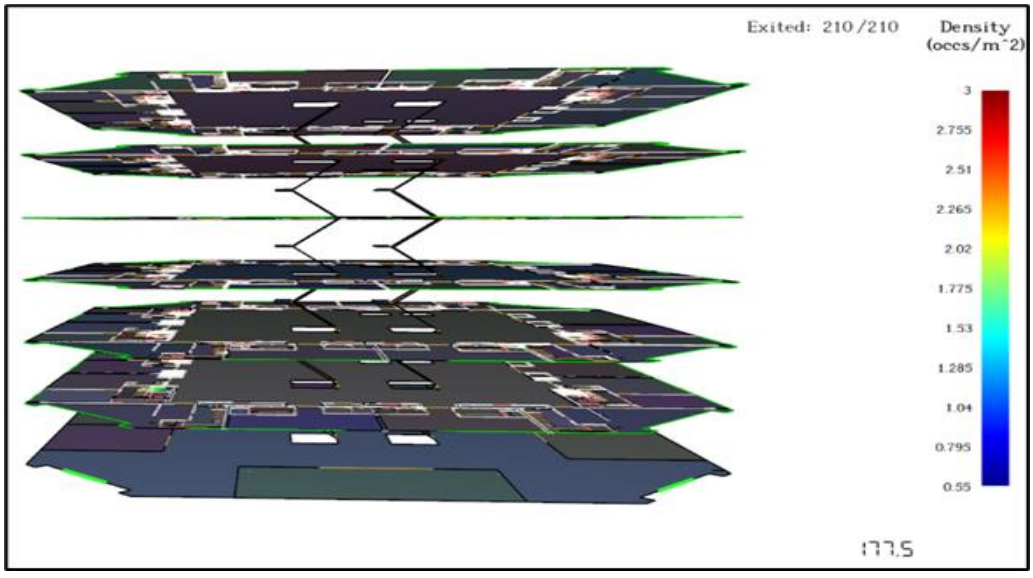


**Figure 7. Scenario 2 Total Evacuation Time**

As shown in the figure: The total evacuation time is 177.5 seconds. The last person to reach the emergency exit was an elderly person, with a time of 177.5 seconds.

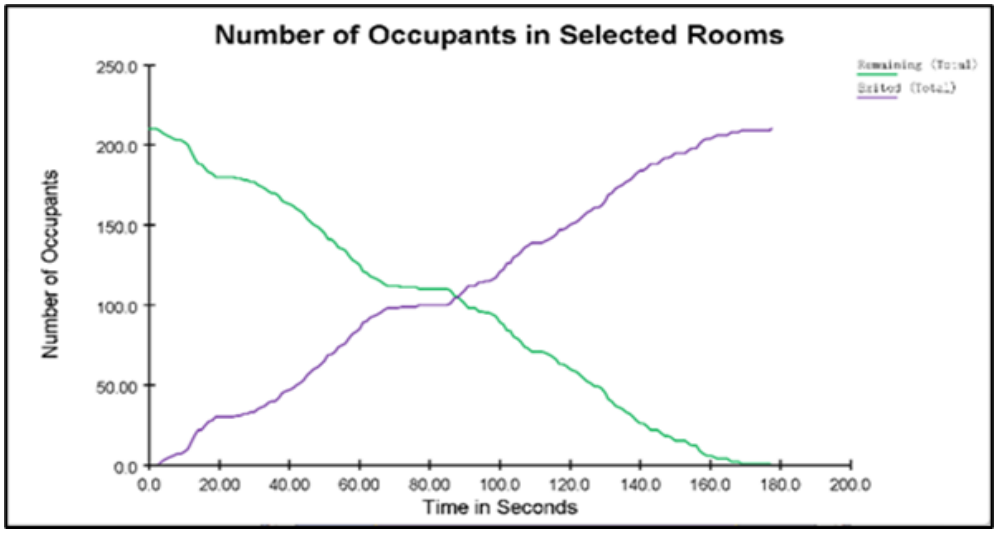


**Figure 8. Scenario 2 Personnel Evacuation Situation**

Scenario 2, the elderly and children are trapped on the 4th and 5th floors. This is because men are more likely to occupy a favorable position. The elderly and children will be squeezed out of the evacuation team.

### 4.3. Scenario 3

Scenario 3, Simulation Scenario: The elderly and children are mainly concentrated on the 2nd and 3rd floors. The simulation results are as follows:

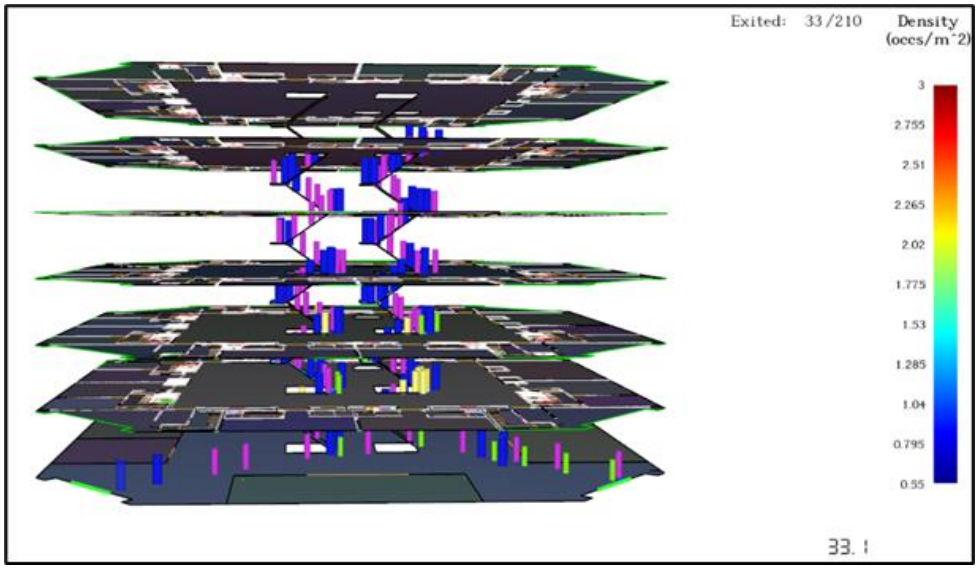


**Figure 9. evacuation situation at 33.1 seconds in Scenario 3**

As shown in the figure, the fastest time for the elderly and children to reach the emergency exit is 33.1 seconds. At this time, a total of 33 people arrived at the emergency exit.

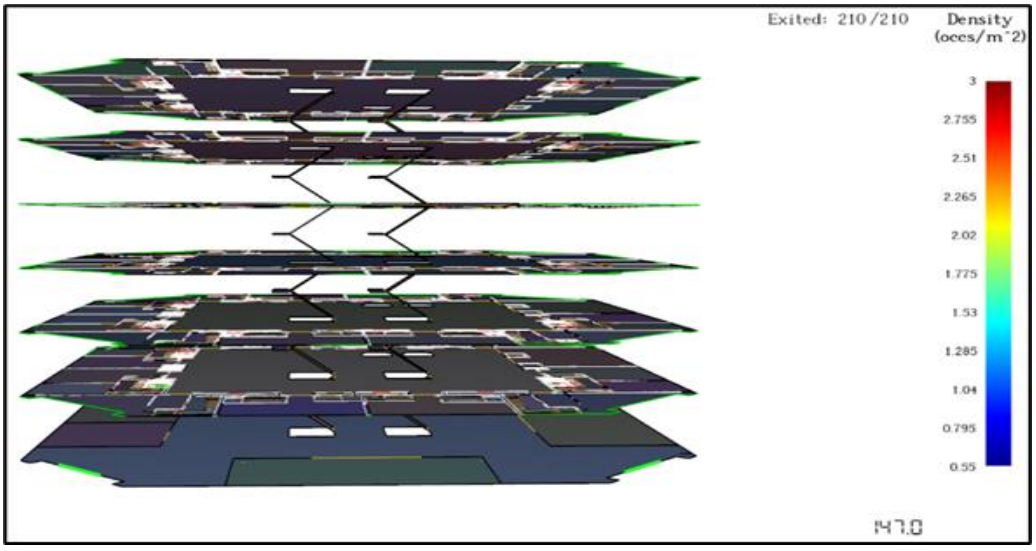


**Figure 10. Scenario 3 Total Evacuation Time**

As shown in the figure, the total evacuation time is 147 seconds. The last elderly person arrived at the emergency exit in 134.4 seconds.

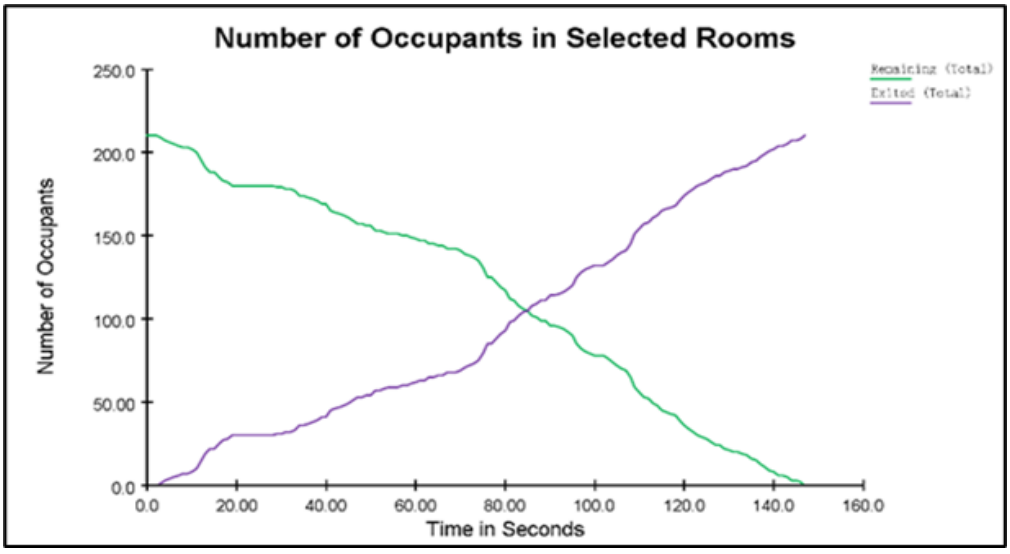


**Figure 11. Scenario 3 Personnel Evacuation Situation**

Scenario 3, the elderly and children are not easily pushed down the evacuation stairs, and the evacuation speed is fast.

## 5. EVALUATION PLAN

Case 1: Elderly and children in high-rise buildings, evacuation time is 191.5 seconds, which is the longest. Case 2: The elderly and children are on the middle floor, and the evacuation time is

177.5 seconds. Case 3: Elderly and children are on lower floors, with an evacuation time of 147 seconds, which is the shortest. So the best evacuation plan is scenario 3, where the elderly and children are on lower floors. The importance of the above evaluation conclusion is as follows: In daily safety management, hotels should try to arrange the elderly and those with children on lower floors to reduce the total evacuation time and improve the efficiency of personnel introduction.

## 6. CONCLUSION

In order to improve the safety management level of hotels and reduce accidents, casualties, and losses. This paper uses pathfinder software to simulate three scenarios.

From the above simulation results, it can be seen that when the elderly and children are mainly concentrated on lower floors (2nd and 3rd floors), the evacuation time is the shortest, at 147 seconds. The elderly and children are on the middle floor (6th and 7th floors), with the longest evacuation time of 191.5 seconds. Due to the slow evacuation response and speed of the elderly and children, it is difficult to approach the evacuation exit. Elderly and children can safely stay on lower floors, reducing evacuation time by 44.5 seconds and improving evacuation efficiency by 23.24% compared to higher floors.

The conclusion is that placing the elderly and children on lower floors for a shorter total avoidance time is beneficial in reducing accidents.

This study can provide effective solutions for hotel safety management.

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