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Simulation Analysis of Safety Evacuation in University Experiment Building

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Abstract

According to the actual situation of a university, the emergency evacuation simulation is modeled based on the physical sign, evacuation speed and personnel ratio using the pathfinder software.The experimental construction export utilization rate is compared with the preliminary simulation scenario. The simulation results show that the utilization rate of evacuation stairs and evacuation exits is significantly improved.The optimized solution can provide the most effective evacuation passage, and the research results can provide the basis for the rational planning and management of evacuation passage in university experiment building.

Key Words: *Experimental building ， Path detection software ， Emergency evacuation; Simulation*

1. INTRODUCTION

The laboratory of higher vocational institutions is an important place for laboratory training, vocational skills training and assessment, vocational skills competition, professional research projects, production activities and industry-academic integration. With the support of national key development and scientific and technological innovation, the number of laboratories in universities is increasing, involving a large number of professional departments, experiments, training, scientific research and production. In 2015, for example, a gas canister exploded in a laboratory at Xuzhou University's Institute of Chemistry, injuring five people and killing one in a failed rescue attempt. In 2021, a student in the powder handling department of Nanjing University's School of Materials exploded magnesium-aluminum powder in an experiment due to an error in operation, killing two people and injuring nine others.The accident caused a stir in society.

Related scholars at home and abroad have conducted a number of studies on the emergency evacuation of university-related educational environment personnel, and researchers, such as Nuria Brickatone, have demonstrated that it is critical to build relevant safety evacuation models to incorporate human psychological and physiological factors into the models[1]. Rodrigo Machado Tabares 、 Stephen Marshall etc. are manual model analysis (PEMMA) and fire model analysis to find the general laws of evacuation by comparing data

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on the safe evacuation time available to evacuees (ASET) and the required safe evacuation time (RSET). Coskun Sahin, Jon Rokne, and Reda Alhajj simulate human behavior during an emergency evacuation and combine intelligent models and fuzzy logic to simulate common behavior at the emergency exit and incorporate fuzzyness into the model, allowing them to capture human behavior during an evacuation more naturally.Based on pathfinder, Wang Jintao and others design and adjust the evacuation scene of the lecture building by changing the location of the entrance and the width of the stairs of the university lecture building, simulate the evacuation of personnel at the entrance of the lecture building and the stairs on each floor, and provide reference materials on the emergency evacuation design of these buildings according to the evacuation process and evacuation time analysis.

In most previous studies, the effects of reduced visibility and smoke on evacuation during fires have been studied, and the effects of personnel allocation on evacuation and emergency routes for simulated building evacuation and extreme situations have been lacking.

Taking the university experiment building as an example, the numerical simulation is carried out by way-finding software. The aim is to provide references for improving fire emergency safety and evacuation efficiency in similar university laboratories, and to provide basis for fire safety management, fire emergency personnel evacuation and emergency planning.

2. INTRODUCTION TO PATHFINDER SIMULATION ENGINEERING SOFTWARE

Pathfinder is a simple and intuitive smart agent emergency escape assessment system developed by Thunderhead Engineering in the United States[2]. Not only does the software provide an advanced visualization user interface for everyone, it also has the effects of three-dimensional animation. In addition, the software-embedded cartoon library is more realistic and graphic-effective than similar simulators, and the three-dimensional triangular grid design contains many items that can be fully set up. In addition, the software-embedded character library is more realistic and graphic-effective than similar simulation software, and contains many configurable items, such as a three-dimensional triangular grid design[3].

These real-life populations provide users with a real-life feel, and Pathfinder enables thousands of users to seamlessly complete real-time animation simulations, providing a group of users with more scientific data in modeling simulation analysis. The software has SFPE mode and Steering mode, which adopt the concept of Fire Protection Design Manual, and during the mode, pedestrian walking speed depends on the population density of each room, and the flow of people passing through the exit depends on the width of the exit[4]. Steering mode uses a combination of path planning, induction mechanism, and collision handling to control pedestrian movement, and when the path at the nearest point between people exceeds a certain threshold, the algorithm creates a new path and changes the pedestrian trajectory. Typically, Pathfinder software uses a three-dimensional grid model to simulate human evacuation in normal and emergency situations, grid decomposition has high visibility while speeding up calculations, clearly seeing evacuation dynamic processes, and is suitable for the evaluation and analysis of large-scale complex buildings by recording evacuation data and simulating evacuation processes.

3. COMPOSITION OF THE EXPERIMENT

3.1 an overview of the architecture

A junior college experimental building was selected as the subject of the study for simulation analysis. The total introduction area of the building is 2677.5 ㎡, the height of the building is 14m, and there are four stairs and two escalators connected to the second floor, and there are a total of five emergency exits in the building. The building structure has the largest evacuation area on the first floor according to the rules and symmetry, and the arrangement of the third floor of the experimental building is similar to that of the second floor. The middle area of the second and third floors is 17.5m long and 7m wide, and is used for the upper-floor transparent glass mining design. The experimental building is shown in Figure 1.

Figure 1. Experimental Building

3.2 Parameters of the number of people

According to the most unfavorable principle, we will mock and choose 12 p.m. on the day of the student experiment, and refer to the actual safe evacuation plan. In the simulation, 500 people on the first floor, 320 people on the second and third floors, the maximum capacity of the experimental building was set to 1,140, the population density of the geometric training area was set to 1.39㎡/person, and 5.57㎡/person in other areas.

4. EXPERIMENTAL METHODS

4.1 Architectural modeling

First, according to the university experimental building design floor plan (see Figure 2), we combine all layers of cover in the two-dimensional view of Pathfinder as shown in Figure 3 to construct the entire 3D structure frame of the simulation model.

4.2 Character modeling

The hypothetical conditions of fire emergency evacuation simulation for college experiment building personnel are as follows:

Evacuees are arranged according to the maximum number of people on each floor of the experimental building, and the shoulder width of the person is 50. 0 cm, average height 1. 7 m, the rest are normal default settings.

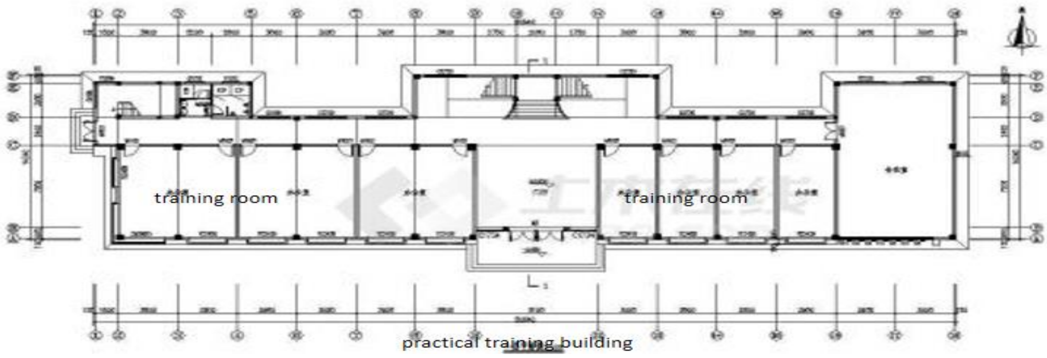


Fig. 2. Experimental Motion Floor Plan

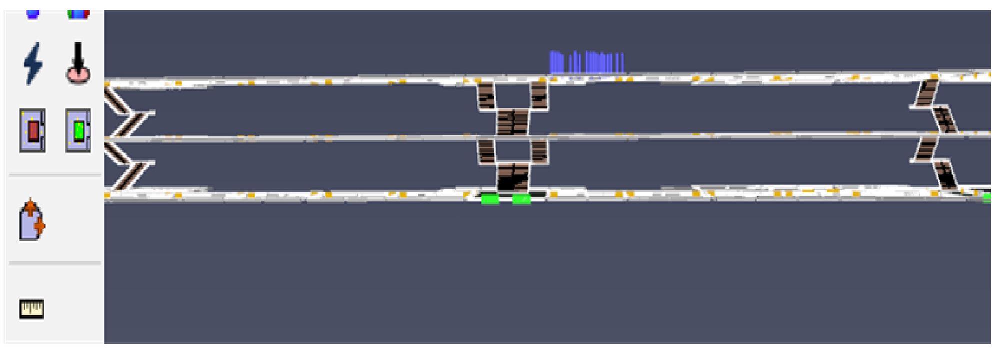


Fig. 3. Experimental Building Personnel Escape Model

Ignore individual differences and assume that their consciousness is clear and their ability to act is normal. The proportion of personnel is distributed among young men 40%, young women 40%, and middle-aged and old people 20%[5]. Because the experimental building is not a high-rise building, there is no fire elevator when evacuating, so the characters can only escape from the door and stairs when evacuating and cannot use ordinary elevators.

The average daily walking speed of a person is 1. 2m/s, the average evacuation speed during evacuation is 2m/s, and the response acceleration time and duration of personnel are set, and the characters in the region are randomly distributed, and the personnel behavior mode is adopted.

Individuals vary according to gender and age, and according to the "human body size of Chinese adults" (GB/T10000-1988), only employees and students in the experimental building are the subjects, not outsiders, and the related parameters of each evacuation personnel are shown in Table 1.

Table 1. Status of Personnel

	Shoulder width/cm	Speed m · s	Number of people	Total numberof people
Male employees	43	1.19	16	1140
Female employees	39	1.13	15	
Boys	45	1.21	609	
Female students	38	1.15	500	

4.3 Scenario modeling

A scenario simulation is conducted for each person's location, safety door opening and closing, and stair evacuation route setting, and the scenario setting is as follows.

Table 2. Configuration of Scenario

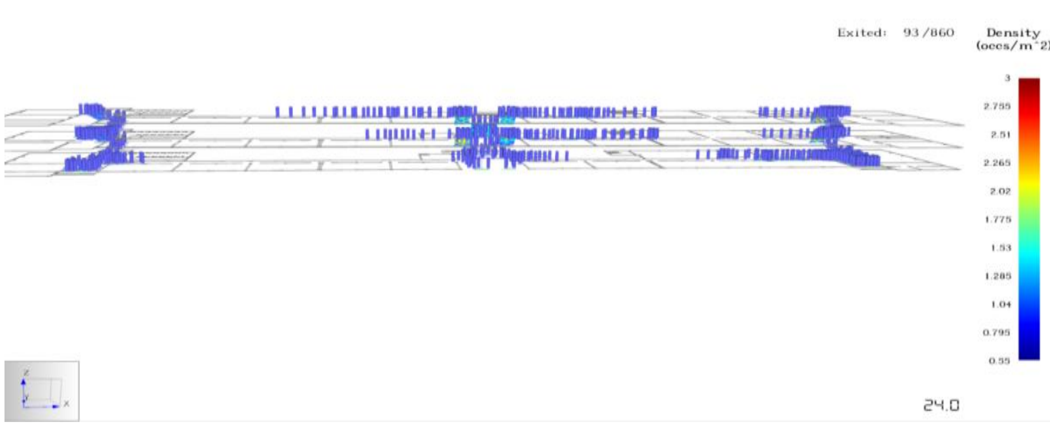
a playbook	Changing Device Layouts	Add Escalator	Stairs emergency exit width optimization
Scenario 1	Transverse	Add an escalator between the 3rd and 1st floors	Changing the width of the stairs
Scenario 2	set vertically	The escalator on the left between the 3rd floor and the 1st floor	Changing the width of the safety outlet
Scenario 3	mixed arrangement	The left and right stairs between the 3rd and 1st floors	Change stairs and emergency exits at the same time

5. EVACUATION SIMULATION ANALYSIS

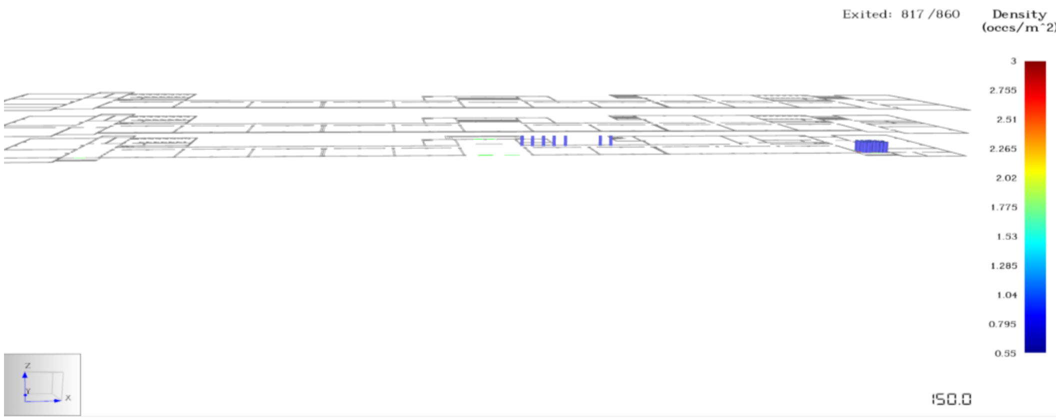
5.1 Initial Simulation

The emergency evacuation route is determined according to the existing construction and manpower conditions of the experimental building[6]. When evacuation begins, evacuation personnel on the first floor can choose a nearby evacuation route and exit through the southern and eastern safety gates. Evacuation personnel on the second floor can evacuate to the first floor by selecting the southern stairs, the eastern stairs, and the intermediate stairs, and then select a nearby safety door to evacuate. The last evacuation personnel on the third floor will move from the southern stairs to the second floor, select a route, and then evacuate to the first floor.

After checking the evacuation route of the personnel, the investigation found that the north emergency exit on the first floor was actually a passage to transport the experimental equipment, and under normal circumstances, it was not allowed to enter without an employee. Therefore, depending on the actual situation, there are two scenario settings for the preliminary simulation. One was that the north safety door continued to close, and the other was responded by the employee, which opened the north safety door in 8 seconds.



(a) 24s



(b)150s

Fig. 4. 2 personnel evacon speed

The total evacuation time in Scenario 1 was 422.5 seconds. The following is used as the basis for the analysis of several key moments in the evacuation process in various scenarios. As a result of the analysis, the number of evacuation personnel is distributed at 0 seconds and the number of evacuation personnel is basically concentrated at the entrance and exit of the stairs at 24 seconds, and the density of evacuation personnel in the stairwell is about 2.75 to 3 people/㎡[7]. As shown in Figure 4, the maximum congestion time is 0 to 150 seconds, and the maximum evacuation rate at the southern gate is 2-2.5 people/s, the remaining doors are 1-2 people/s, indicating the second state until the evacuation is completed at 150 seconds. Close to 150 seconds, the eastern safety door is used the fastest, and the northeastern safety door is stopped at 250 seconds, reducing the usage rate of other inquiries. Then, the simulation of Scenario 2 was conducted, and when the number of people began to evacuate, the experimental workers opened the northern emergency exit in 8 seconds of the reaction, and the total evacuation time was 420.5 seconds.

When each door in Nario 2 was used, the simulation results showed that the total evacuation time was reduced by only 2 seconds compared to scenario 1 after opening the safety evacuation door in the north. As shown in Figure 5, the safety door in the north is very underutilized compared to the other door, and although there is one more safety door leading out, only a small part of it is chosen and has less impact on the overall evacuation process, because it has a habit of escaping to a familiar exit. Therefore, the entire safety evacuation process of the experimental building requires improvement and optimization design to identify the cause of the blockage and establish countermeasures.

6. OPTIMIZATION SIMULATION

6.1 Changing the layout of experimental equipment

In order to analyze the effect of equipment layout on safety evacuation time, the total safety evacuation time was 419.3 s, which was only 1.23 s less than the initial simulation.There was no significant change in the north side security gate, but the utilization of the other gates after the change changed slightly compared to the initial and changed time periods of 100s to 150s.At the same time, it was found that the safety exit on the northeast side was reduced because the experimental machine was changed horizontally.The fan-shaped local congestion has become a "S" congestion, which makes evacuees crowded at the northeast exit and very close to the experimental machine, which hinders the evacuation of the personnel and may also collide with the experimental equipment.Therefore, it can be concluded that changing the orientation of the experimental machine on the first floor of the experimental building has little effect on the overall evacuation time.

6.2 Add Escalators

To understand the relationship between safe evacuation routes and total evacuation time, this simulation adds an escalator directly between the third and first floors, and the change plan is shown in Figure.

According to the simulation results, adding a third-floor escalator to the first floor can significantly shorten the total evacuation time by 293.0 seconds. Between 0 and 150 seconds, evacuees used each safety door more evenly and quickly evacuated. It is explained that increasing the number of evacuation routes and emergency exits can effectively achieve an evacuation effect, so it is effective if the evacuation layer directly increases the path and exit. As shown in Figure 7, it can be seen that the utilization rate of the escalator is higher than that of the stairs on the first and second floors, the passage on the third and first floors increases, the waiting time on the third floor is significantly reduced, the population density of the stairs to the south and east decreases, and the evacuation time is significantly reduced.

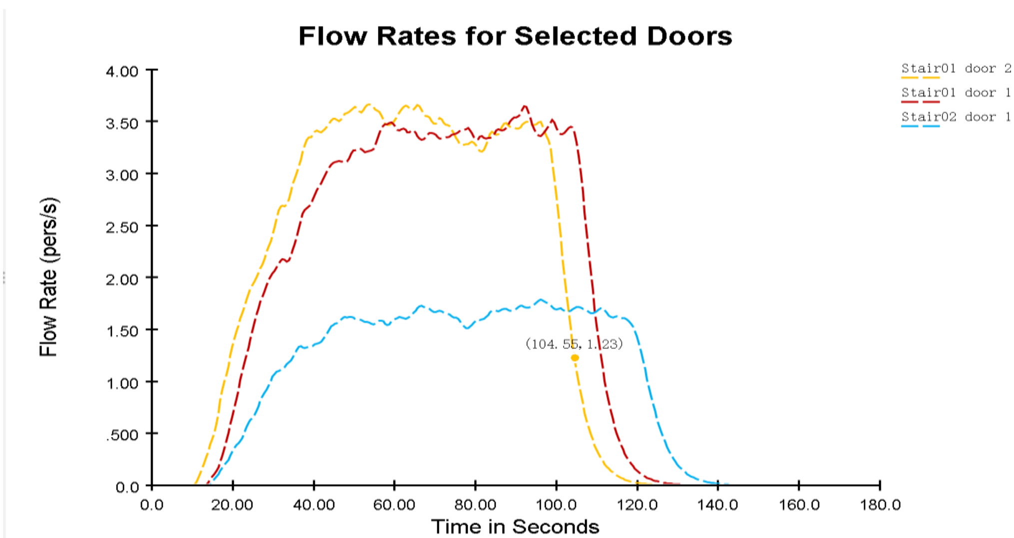


Fig. 5. Evacuation speed by safety door

Fig. 6. Experimental Equipment Placement Plot

6.3 Stairway, Emergency exit width optimization

In each simulation scenario, some reduced the total evacuation time, while others increased the total evacuation time. Overall, the concentration of stairs and emergency exits in each simulation situation is also a factor that hinders safe evacuation, and the northern safety door is underutilized, while the southern and eastern safety doors are prone to congestion. To alleviate congestion, the stairs and door sizes were optimized and then simulated, and the optimization of the stairs and door size is shown in Table 3.

Except that the use of safety doors in the north was extremely low due to the change of stairs and doors, the evacuation efficiency improved significantly. In the same period as the initial situation, the population density significantly eased and the number of evacuees increased significantly at the same time. The initial situation was that the east and south of the first floor were congested and the population density of emergency exits in the south was reduced. The population density of emergency exits 1 and 2 on the east side of the first floor was only 1.04 to 2.27 people/㎡, while the population density of emergency exits 1 and 2 on the east side of the first floor was less than 2.27 people/㎡. Therefore, the width of the stairs and safety doors is important to alleviate the emergency evacuation capacity and is effectively reflected in each method. Considering the current problems of the experiment, three optimization measures were simulated: replacing the equipment on the first floor of the experiment building horizontally, increasing the number of direct escalators from the third floor to the first floor, and changing the structure size of the stairs and safety doors. The total evacuation time optimized in the initial state after the simulation was 419.3 seconds, 293.0 seconds, and 305.5 seconds, respectively.

Table 3. Stairs and door changes

Name	The original size	New size
Northern emergency exit (m × m	2×1	2×2
Southern Emergency Exit (m × m)	2×1	2×2
Eastern Emergency Exit (m × m)	2×1.5	2×2
South staircase/meter	1.2	1.7
East staircase/meter	1.2	1.7
Middle staircase/mete	1	1

Fig. 7. Usage after Stair width change

7. A PLAN TO SECURE EVACUATION SAFETY

By comparing simulation scenarios 1, 2 and 3, the importance of safety statements can be clearly recognized[8]. In routine care, all safety evacuation ports must be opened and debris must not accumulate.

Since the side door of the experimental building has a certain effect on safe evacuation, it is necessary to have a dedicated personnel to open it in a timely manner in case of fire. At the same time, the reliability of various evacuation equipment is regularly checked to prevent accidents[9].

Comparing Scenario 1 with Scenario 3, it is essential to secure a wide passage of the evacuation passage because the evacuation time is significantly reduced if the width of the stairs and emergency exits changes at the same time as the number of evacuation personnel increases.

8. CONCLUSIONS

According to the actual conditions of the experimental building, reasonable design and modeling are carried out. In the initial situation, the spare door is always closed and the spare door is opened after reaction time. According to the comprehensive simulation scenario of the initial situation, the optimization scheme (increase of 3 floors to 1 escalator) is about 30.7% shorter than the total evacuation time of the initial scene. Combining theory and model, it can effectively simulate the potential evacuation problem of the experimental building, and provide supporting basis for the safety evacuation management of the experimental building.

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