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# Estimation of the Evacuation Time Depending on the Optimization of the Exits of a Commercial Building

**J. Anjum[1], M. S. Islam[2]**

[1]Department of Civil Engineering, RUET, Bangladesh (jerinanjumce17@gmail.coml)
[2]Department of Civil Engineering, RUET, Bangladesh (islam94001@yahoo.com)

**Abstract**

Natural catastrophes are unforeseen occurrences, making it challenging to predict them. With a high percentage of fatalities and extensive damage, earthquakes are the most destructive natural disasters. It is a potential occurrence that could bring destruction and fatalities at any time. Because the exit doors cannot be opened, numerous were injured during previous seismic disasters while attempting to leave the premises. By adjusting the number of widths and optimizing exits in both fixed and random placements in response to unanticipated events, the primary goal of this study is to achieve the quickest evacuation time among the various scenarios. In this paper, the number of exits, including additional fire stairs, is also analyzed together with the evacuation times for different occupant orientations. The evacuation time is calculated using Pathfinder with 3D designed commercial building. This software's steering mode closely replicates human behavior also. Here, the evacuation time is calculated under six different circumstances. Following the results analysis, a comparison between the performances of the various situations can be done, and the ideal solution is taken into consideration to ensure the safety of the most people.

***Keywords:*** *Natural Catastrophes; Evacuation Time; Fire Stair; Occupant Orientation; Commercial Building.*

## 1 Introduction

The vulnerability of emerging nations to disasters increases with population growth and urbanization in megacities. So to mitigate losses building safety has long been one of the most important foundations of building construction processes, despite the current focus on the energy crisis and green technology in the construction and building industry (Mirzei-Zohan et al., 2023). Managing the timely evacuation of high-rise public buildings during an emergency is one of the issues for safety control because of the inherent threats to human life (Xiong et al., 2017). Developing nations are more susceptible to catastrophes as a result of population increase and urbanization in megacities. The most important parameters for a safe and effective evacuation process very much dependent on the behavior of the population during the evacuation (Miao, 2011). Due to the nature of the incident, as well as other factors like financial constraints and implicit hazards, the evacuation process cannot be easily tested experimentally. In recent years, numerical solutions for the environment and human behavior have been incorporated in order to find an optimized design for building evacuation (Zimi et al., 2022).

Recently, numerous researcher work has been done on emergency response systems and building evacuation. In several research, the evacuation process' 3D simulations were analyzed to determine the appropriate design framework. Zahid Imtiaz et al. referred variation of evacuation time with the change of occupants age and the number of occupants (Zahid et al., 2022). Suhana Rahman Choiti et al. focused on Spatial Analysis of RMG factory building with respect to escape route used during an emergency evacuation (Choiti et al., 2018). Anvari et al. used the MassMotion program in order to examine performance measures such as mean total evacuation times, standard deviations, maximum evacuation times, and lowest evacuation times during fast evacuation of people on trains (Anvari et al., 2017). In order to generate a fire emergency scenario, Lorusso et al. developed a specialized platform. They then tested their platform by simulating a fire emergency in an existent schoo (Lorusso et al., 2022). An integrated building evacuation simulation with multi-criteria decision-making was created by Marzouk and Mohamed (Marzouk and Mohamed, 2019). Their emphasis is on the integrated system and they recommended include specific human behavior to generate a more realistic approach. The Behavioural Modification Approach, an underutilized potential with a significant knowledge gap in evacuation dynamics, serves as the primary driving force behind this study's attempt to address the challenge of accounting for human cognitive-related factors that may affect the efficiency of evacuation (Haghani et al., 2020). Aleksandrov et al. AnyLogic to simulate an emergency evacuation from the building during a crisis and evaluated the evacuation time while taking into account many useful aspects which established a new technique to identify the best evacuation plans in tall buildings (Aleksandrov et al., 2019). Their approach takes into account the stochastic character of human behavior, simulating the unpredictability in human decision-making, and egress component capabilities. Liu, Jacques, Liu et al. make the assumption that the evacuation begins after the earthquake's vibration subsides (Liu et al., 2016). The evacuation simulation model's behavior during a vibrating building's evacuation is not taken into account by this assumption.

In this work, the evacuation model of a commercial building is proposed and simulated using Pathfinder as a simulation tool. A commercial building with dimension of 130*120 square feet has been designed and observed the quickest evacuation. The evacuation time is simulated under different conditions like varying number of exits, different occupant orientations. The paper is organized as follows. Section 2 presents the design model of a commercial building with floor plan. Section 3 describes the simulation results of the evacuation scenario in respect of different criteria with reliable discussions of the associated work. And finally section 4 concludes the paper.

## 2 Research methodology

The flowchart of the proposed study is shown in fig. 1. The first step entails a plan of designing a 3D building and then by varying different parameters simulation results are examined and expected outcome is recorded. Different case study is observed during the simulation which is presented in table 1. There may be a major source of uncertainty for the results obtained when dealing with building evacuation (Mirzaei-Zhan et al., 2023). So to deal with this specific condition has been set up which is shown in table 1.

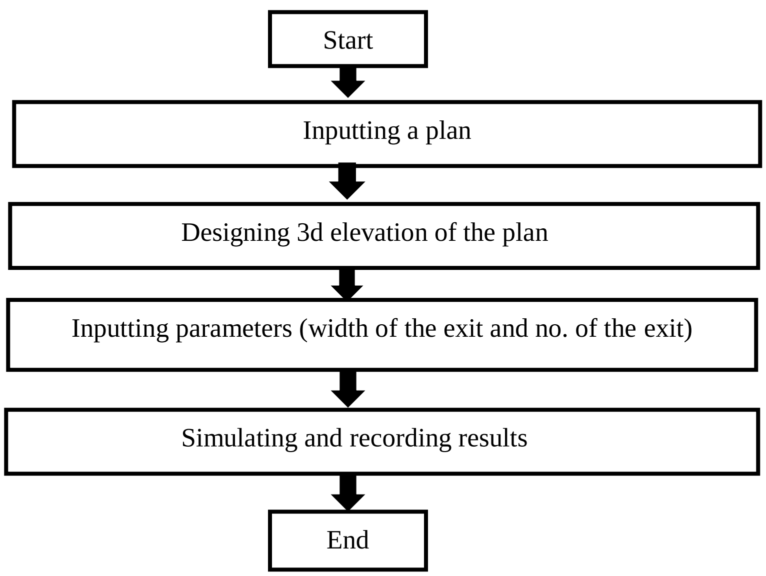



Figure 1. Research methodology flowchart presented in this study.

Figure 2(a) illustrates pathfinder's 3D perspective of the building, which has six storied and building area of 15600 and total floor area of 93600 square feet, and figure 2(b) is the plan of the structure, which has two staircases. Moreover, different cases with specific condition shown in table 1 has been set to evaluate the total scenario of this study. In case 1 width of the exit is varied while keeping others parameter constant, case 2 presents the model when location of the exit is varied keeping others parameter constant and case 3 relates the condition while two parameters was varied to observe evaluation time.

Table 1. Six different conditions which will be used in this simulation.

| Case | Condition | Width of the exit | Location of the exit | Time | People |
|---|---|---|---|---|---|
| Case 1 | 1 | Variable | Fixed | Fixed | Findings |
| | 2 | Variable | Fixed | Findings | Fixed |
| Case 2 | 3 | Fixed | Variable | Fixed | Findings |
| | 4 | Fixed | Variable | Findings | Fixed |
| Case 3 | normal | Variable | Variable | Fixed | Findings |
| | obstacle | Variable | Variable | Findings | Fixed |

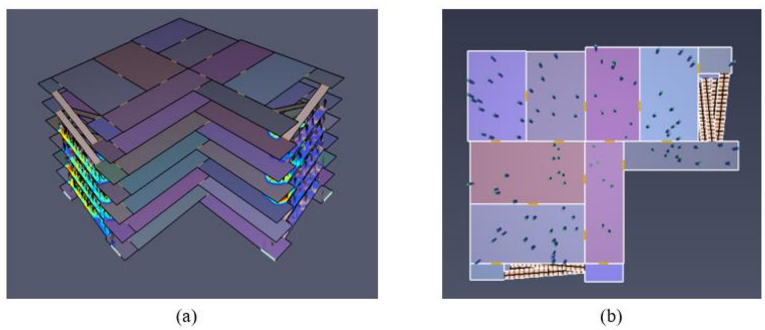


Figure 2. (a) 3D design of the building and (b) floor plan of the building.

## 3 Simulation results & discussion

The behaviors of this simulation are obtained by using Pathfinder as a tool under three different cases in respect of six different conditions. The main goal of this study is to optimize the evacuation model of a building. The simulation based results of first case when width of the exit was changed in respect of other parameters is shown in fig. 3. Fig.

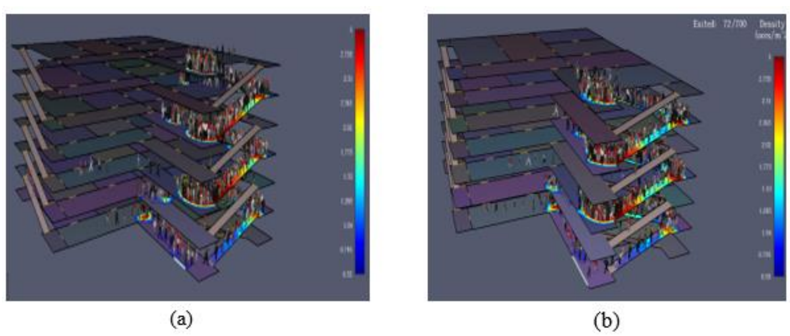


Figure 3. (a) Simulation results of case 1 (width=10ft) and (b) Simulation results case 1 (width=20ft).

3(a) shows when the width was kept at 10 ft. and and the placement was kept close to the staircase. So the other staircase was not used correctly, and all traffic attempted to descend via the specific one staircase. The density was quite high at the stairwell, which takes total 457 sec to exit the building. The condition in fig. 3(b) is similar to the previous one, but the width of the exit has been extended to 20 feet, and the density of inhabitants is significantly lower than in the previous one.As the Number of residents in each condition is comparable, the graph depicts the difference in evacuation time which is shown in fig. 4.

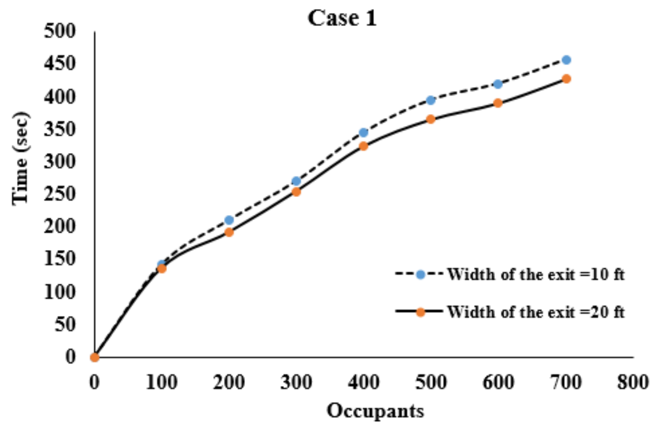
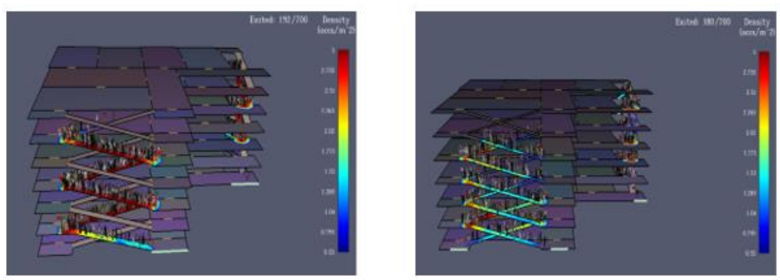



Figure 4. Evacuation time with respect to number of occupants for case 1.

The second case is observed by varying the location of the exit which is shown in fig. 5. In the breadth of the exit has been specified at 40 feet and that distance is eventually divided as 20 feet in two separate positions with an evacuation duration of 339 seconds which is studied in fig. 5(a). In fig. 5(b) a total width of 40 feet and dividing the width into four pieces at four separate positions resulting in a total width of 10 feet is studied and the anticipated evacuation time is 200 seconds



(a) (b)

Figure 5. (a) Simulation results of case 2 ( location of exit=2 places) and (b) Simulation results of case 2( location of exit=4 places).

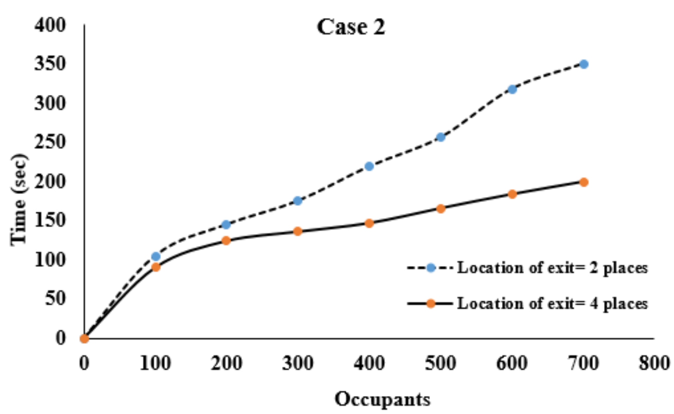
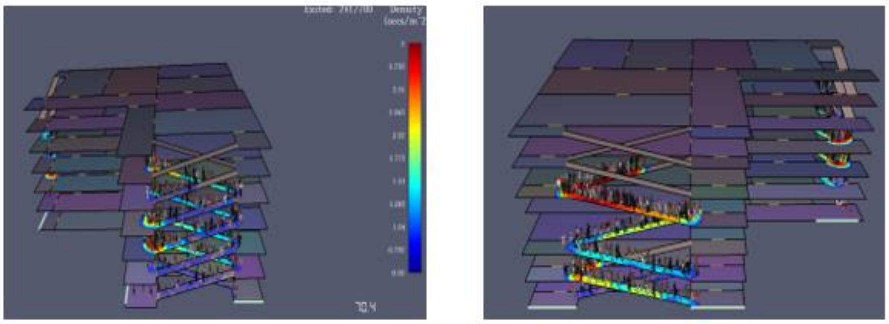



Figure 6. Evacuation time with respect to number of occupants for case 2.

Moreover, the graph (fig. 6) presents the difference in evacuation for two different condition of fig 5. Therefore another case study is optimised under two conditions as follows; one is normal condition and the other is in a condition in which there remains obstacle ( one floor is remain disabled) in the evacuation process. The simulation based results is presented in fig. 7 where fig 7(a) indicates the normal condition and when there is no obstacle. The evacuation mechanism is fine and the density at the stair is pretty normal in which the exits are changeable and also close to the stairs making it simple to evacuate the space. Fig. 7(b) shows the results of the condition where obstacles has been taken granted. It depicts an obstructive condition in which, if a fire or other occurrence occurs that renders no exit point available through that path, the staircase becomes unusable, and full traffic is diverted to the other staircase, which is extremely difficult to handle, and many other negative conditions occur, causing occupants to be trapped in the building which is extremely hazardous to the safety of the residents. Finally, fig. 8 illustrates the difference between the evacuation time for this two conditions. The characteristic difference between the normal evacuation time and the evacuation time under obstacle condition where one floor is disabled is shown in fig. 8. The total evacuation time under normal state is found 235 seconds where 255 for obstacle state.



(a) (b)

Figure 7. (a) Simulation results of case 3 (normal condition) (b) Simulation results of case 3 (obstacle condition).

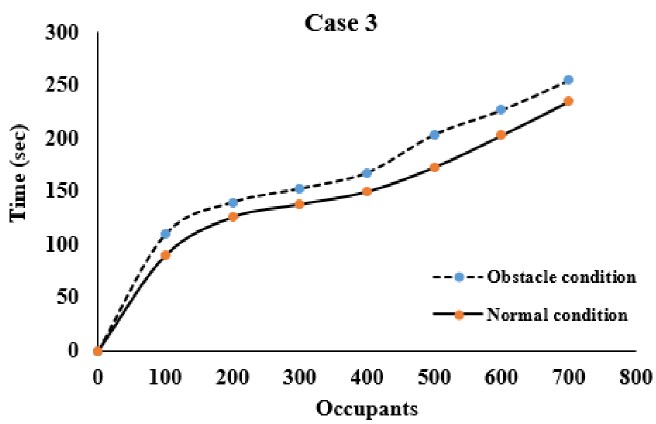



Figure 8. Evacuation time with respect to number of occupants for case 3.

According to previous study a dynamic indoor field model for emergency evacuation system was analyzed by Lovreglio et al. in which models had been constructed to predict exit choice based on four factors: the person's familiarity with their exit of choice, the number of individuals using various exits, the presence of smoke at specific exits, and the exit distance (Lovreglio et al.,2022). Zimi et al. developed a model to observe least evacuation time in where the old and children are placed in the bottom equally and then the middle aged and young are being placed (Zimi et al.,2022). A multi-criteria decision making approach for buildings evaluation was studied by Marzouk et al. that depends on criteria collected from prior existing models after they have been modified to suit the produced framework (Marzouk et al., 2019). On the other hand our proposed model has an applicability because the conditions under which the least evacuation time is measured is implementable for a commercial building. The reason why this paper differs from other studies is that it presents an adequate evaluation model that is expected to help reduce the risk in the time of a disaster. Because the shorter the evacuation time, the lower the damage caused by the disaster and our study represents this model. So, it can be an effective model for reducing losses during emergency situation. Moreover, exact placement of the exits is also studied which is also a great factor of evacuation process.

## 4 Conclusion

This paper presented an evacuation model of a building with significance of building exit points. The designed building was 130*120 square ft. There are six levels in this building with 700 occupants and we computed evacuation times in every feasible way to get out in the shortest amount of time. Because of the right orientation of the position, the least evacuated time had found 200 seconds reducing bad scenarios. Based on the study, we can infer that proper orientation of position of exits is vital for evacuation. The exit point should be located near the stairway because of the high density of people on the ground level. The width of the exit should be increased while designing the structures which thorough evacuation method should be used. Despite everything the behavior of the inmates has a significant impact; if they panic excessively, the evacuation procedure may be impeded.

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