Evacuation time analysis of high-rise building by Using Pathfinder case study: Residential Occupancy

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Abstract. This research involves the study of evacuation time for a high-rise and extra-large building in Bangkok, which has 41 stories. The height of building is 143.7 meters and the building have usage area of 31,898 square meters. The objectives of this research are the estimate time of the building evacuation. The building occupant load of 2,461 persons was estimated according to NFPA 101 Life Safety Code. The simulation via Pathfinder was carried out for 4 cases; Case 1 fire in resident room on the 13th floor is to ensure that the type fires most likely to occur, Case 2 fire in lounge at the 35th floor that a large number of occupants in a large area and Case 3, 4 from case 1 and case 2 the exit stair at the inside is not available. The building evacuation times are 2,321 seconds, 2,410.8 seconds, 2,736.3 seconds, and 2,841.8 seconds respectively. In the case where only one exit stair is available, the building evacuation time may be increase because of the congestions at the exit stair.

1. Introduction
At present, Residence in Bangkok (Thailand) is a high-rise building, due to the land prices is increase and to make it worth the investment, according to National Fire Protection Association 101 (NFPA 101, Life Safety Code), The most important thing about High-rise building with sleeping area is life safety of the residents. The analysed of evacuation time should be the first priority in building design. In the past, Evacuation time was calculated by hydraulic calculation method refer to International standard (NFPA 101) but there was some problems. The Hydraulic calculation had many human errors and not accurate with real situation. Now Pathfinder Program, is developed for simulate evacuation time, is lower human error and more accurate than hydraulic calculation.

Definition of high-rise buildings that a person may enter or use, with a height of 23 meters or more. Measuring the height of the building is measured from the ground level of construction to the deck floor. For a gable or hip building, measure from the ground level that is constructed to the top of the top wall [1].

2. Model capabilities and modelling studies

2.1. Model building
Pathfinder is an emulation simulation program. The display is graphical. This allows users to design both in 2 and 3 dimensions for results analysis with motion simulation divided into 2 operating modes:
Steering Mode and SFPE Mode, the use of Steering Mode will be the most practical use that is, imitating human behaviour and movement. In SFPE mode use based on the theory, assumptions, and calculations by hand as defined in the SFPE manual, this mode is controlled by the flow rate through the gate or through the density of the population. Which is allowed to infiltrate and do not have to try to evade. [2]. A Condominium building has 41 floors. The height from the ground is 143.7 meters, with a total area of 31,898 square meters, show on figure 1.

![Figure 1. High-rise condominium building model.](image)

2.2. Simulation setting

1. This simulation has 2,461 people in the building. Occupant load factor is based on the NFPA 101, Life Safety Code [3].

2. The user profile of the building is divided into equal proportions, such as children, teenagers, middle-aged, elderly including male and female, etc. [4]

3. Behaviour model has been set to “Steering” mode; jam velocity is 0.25 m/s; control the speed threshold at which occupants are recorded as being jammed at the exit [5].

4. According to NFPA 101 the simulated scenarios are as follows:
   - Case 1, Fire in resident room on the 13th floor is to ensure that the type fires most likely to occur.
   - Case 2, Fire in the lounge at the 35th floor that a large number of occupants in a large area.
   - Case 3 from case 1 the exit stair 2 is not available.
   - Case 4 from case 2 the exit stair 2 is not available.

3. Simulation result

3.1. Simulation result
Case 1: Evacuation times 2,321.0 seconds.
Figure 2. Simulation result of case 1.

Case 2: Evacuation times 2,410.8 seconds.

Figure 3. Simulation result of case 2.

Case 3: Evacuation times 2,736.3 seconds.

Figure 4. Simulation result of case 3.
Case 4: Evacuation times 2,841.8 seconds.

Figure 5. Simulation result of case 4.

4. Results and discussions

Figure 6. Summary simulation result.

The evacuation time consists of 4 parts; Time from fire ignition to detection (Time to Notification), Time from detection to notification of occupants of a fire emergency (Reaction Time), Time from notification (or cue reception) until evacuation commences (Pre-evacuation Time) and Time from the start of purposive evacuation movement until safety is reached (Travel or Movement Time). The first 3 parts are Delay time or Pre-evacuation Time.

Case 1 Fire in resident room on the 13th floor is to ensure that the type fires most likely to occur. When a fire occurs on the 13th floor, a smoke detector detects the density of smoke (Time to Notification) and sends a signal to the Fire alarm. Until all people react (Reaction Time) takes about 60 seconds. After that, people on the 13th floor begin to evacuate (Pre-evacuation Time). After 120 seconds, the fire alarm will send a sandwich alarm (The floor where the fire occurred start alarm and setting time delay above 1 floor and below 1 floor, time not more than 180 seconds) to floor 14 and floor 12, and people from floor 14 and floor 12 start to evacuate, which the occupant inside the fire escape is not overcrowd. And evacuated quickly. After 180 seconds, fire alarms from level 15 upwards and level 11 downward start to evacuate and panic. From 240 seconds onwards, the people on the low level ran into the fire escape stairs impact into someone who had escaped from the upper level causing inside the fire escape stair 1 and 2 have overcrowd people and slower movement, show on figure 2.
From the incident, it takes time to evacuate to a place of safety. (Travel or Movement Time) 2321.0 seconds, which take the least evacuation time from a total of 4 cases.

Case 2 fire in lounge at the 35th floor that a large number of occupants in a large area. Delay Time is like Case 1. After 120 seconds, the fire alarm will send signals to the 36th and 34th floors from 36th and 34th floor. Start to evacuate, but due to the large number of people on the 35th floor, there was a bottleneck at the entrance to the fire escape causing the evacuation to be slow. After 180 seconds, fire alarms from Level 37 upwards and Level 34 downward start to evacuate, the people on the low level ran into the fire escape stairs impact into someone who had escaped from the upper level causing inside the fire escape stair 1 and 2 have overcrowd people and slower movement, show on figure 3, so it has Travel or Movement Time 2410.8 seconds, which is more than the case 1; 89.8 seconds

According to NFPA 101, the worst-case scenarios will be studied: at least 1 fire escape path is blocked or not available. Case 3 from case 1 the exit stair at the inside is not available. There will be bottlenecks at the entrance to every fire escape door and inside the fire escape stair will be overcrowded causing moves slowly, show on figure 4. Have the evacuation time of 2736.3 seconds, which is more than case 1; 415.3 seconds and more than case 2; 325.5 seconds.

Case 4 from case 2 the exit stair at the inside is not available. Like the case 3, the evacuation time is 2841.8 seconds, show on figure 5, which is more than the case 2; 431.0 seconds, which takes the most evacuation time from a total of 4 cases, show on figure 6.

5. Conclusion
Research studies on fire scenarios simulation and evacuation times. To sum up, Case 1 fire in resident room on the 13th floor is to ensure that the type fires most likely to occur, the people on the low level ran into the fire escape stairs impact into someone who had escaped from the upper level causing inside the fire escape stair 1 and 2 have overcrowd people and slower movement, the building evacuation times are 2321.0 seconds. Case 2 fire in lounge at the 35th floor that a large number of occupants in a large area, due to the large number of people on the 35th floor, there was a bottleneck at the entrance to the fire escape causing the evacuation to be slow, the building evacuation times are 2410.8 seconds. Case 3 from case 1 the exit stair 2 is not available, there will be bottlenecks at the entrance to every fire escape door and inside the fire escape staircase will be overcrowded causing moves slowly. Have the evacuation time of 2736.3 seconds, which is more than case 1; 415.3 seconds and more than case 2; 325.5 seconds. Case 4 from case 2 the exit stair 2 is not available, like the case 3, the evacuation time is 2841.8 seconds, which is more than the case 2; 431.0 seconds, which takes the most evacuation time from a total of 4 cases. From the simulation case 3 and 4, can be said that if at least one fire escape route is blocked or not available, the evacuation time will increase by approximately 420.0 seconds. The building evacuation time may be increase because of the congestions at the exit stair. In conclusion, scenarios and cause of the fire effect to evacuation time. However, we can use Pathfinder Program for simulation other scenarios to find evacuation time accord to local law and develop performance of mean of egress. For future work can use Pathfinder Program to simulation other building such as Hospital, Extra hazard factory and Office building etc.

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References
[1] E. Ronchi, D. Nilsson, Fire evacuation in high-rise buildings: a review of human behavior and modelling research (Fire Science Reviews, licensee Springer, 2013)
[2] Thunderhead Engineering, User Manual, Pathfinder, 2014
[3] NFPA, NFPA 101: Life Safety Code, National Fire Protection Association, 2018
[4] G. Grewolls, K. Grewolls, Sensitivity Analysis of Evacuation Simulations (SIMTEGO GmbH, Dynardo, 2014)
[5] Thunderhead Engineering, Technical Reference, Pathfinder, 2013