Fire evacuation and patient assistance simulation in a large hospital building

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Abstract. This research studied the fire evacuation simulation and patient assistance who were unable to help themselves out of a hospital building. The studied building is a high and large building as Thai law which was 10\textsuperscript{th} floors on 90,842.18 square meters and able to accommodate 4,017 occupants that calculated by the NFPA 101 standard which simulated from 3 evacuation cases. The experiment result found that all people can be moved out from the building within 3,048 seconds, 2,931 seconds, and 2,958.3 seconds respectively which didn’t over than the standard as High Building Controlled under Thai Law. The reason that time-limited needed as 1 hour when transferred the people out of the building because enhance the safety of people, especially critically ill patients. Thus, the researchers suggested more channels of evacuation through the elevators by testing for 2 situations. The result of 2 situations showed that this method can be decreased the fire evacuation frill time as 2,073 seconds and 1,979.5 seconds respectively.

1. Introduction
The conflagration is the unexpected event which causes to the loss of life and asset. Especially, the burning of high or large building \[1\] that there are high, large area, used by a lot of users, and complex building pattern \[2\] are the factors cause difficult and slow in the way of moving people out of the building.

Thus, the researcher has studied the fire evacuation of the large hospital to investigate the escape behavior of people who stuck in the building and analyze the capability of fire exit route in the building. The reasons of this study are the fire evacuation from the hospital building does not control by factors about the size of building and number of people in the building, but also related to the category and character of building users \[3\]. Moreover, the building users contain general users who can move out of the building by themselves and building users who need someone to move them out. However, the fire evacuation from hospital building might still be delay because of the way of transferring patients out from the building need to use the time to prepare \[4\].

2. Model building
The simulation of building and fire evacuation from the large hospital building is created by Pathfinder program which is the simulation program about the human movement to find the exit that
can define the evacuation behavior of building occupants by showing the result on both 2 and 3 dimensions [5].

And in this study, the study of fire evacuation time out of the building compared with the law governing large buildings and high-rise buildings in Thailand [6] that determine buildings with sizes from 10,000 square meters or more is a large building And buildings with a height from the ground ranging from 23 meters or more is a high-rise building. The building that is considered a high-rise building must be able to evacuate the building users within 1 hour.

2.1. Model building

The researcher has created the hospital building simulation by importing the file of 2 dimensions building (.dwg file) of Auto CAD program to Pathfinder program. The hospital building that we study is the high and large building as Thai law [6] and just finished constructing as 10th floors building (including the basement and deck), height from the ground as 43.49 meters, total area as 90,842.16 square meters, and also consist of 6 fire exit stair and 1 ramp fire escape as shown in figure 1 and figure 2.

![Figure 1. Model of a large hospital.](image1)

![Figure 2. Fire exit stair and ramp of hospital building.](image2)

2.2. Simulation settings

Set the building occupants as 4,017 occupants which are calculated through NFPA 101 [7] standard and define the category of user by speediness, evacuation behavior, and the preparing time of evacuation [4] as shown in table 1.

| Profile               | Occupant (person) | Speed (m/s) | Behaviors                          |
|-----------------------|-------------------|-------------|-----------------------------------|
| Assistant team        | 236               | 1.35        | - Assist                           |
|                       |                   |             | - Wait110s (Preparation time)      |
|                       |                   |             | - Go to exit                       |
| General staff         | 464               | 1.35        | - Go to exit                       |
| Visitor               | 1428              | 1.20        | - Go to exit                       |
| Out-Patient           | 1429              | 0.95        | - Go to exit                       |
| In-Patient            | 325               | 0.95        | - Go to exit                       |
| Critically ill patient| 135               | 0.4         | - Wait for Assistant              |
|                       |                   |             | - Wait110s (Preparation time)      |
|                       |                   |             | - Go to exit                       |

The critically ill patients are defined to transfer by hospital bed which support by assistance evacuation team and can be divided the type of hospital bed as table 2.

| Type of bed | Size of bed (m.) | Assistant Request / bed (person) |
|-------------|------------------|----------------------------------|
| Adult Bed   | 0.9×2×1          | 2                                |
| Baby Bed    | 0.5×0.9×0.88     | 1                                |
101 adult hospital beds which contain by emergency department’s bed at 1st floor as 13 beds, operating and childbirth department’s bed at 4th floor as 45 beds, ICU’s bed at 5th floor as 43 beds, newborn baby’s bed as 34 beds which consist by 10 baby’s beds at childbirth department and other 24 beds at ICU department. 

Occupants of the building that can take care of themselves are designated to can be evacuated through every exit routes. The critically ill patients who need help from assistant team to move them from 4th and 5th floor are set to evacuate through ramp fire escape only, except the critically ill patients at emergency department at 1st floor that can be evacuated through every exit routes on 1st floor. 

Simulation of 3 scenario using steering mode [5] as follows.

Scenario 1: Evacuate every people out from the building through any existing fire exit routes as shown in figure 3.

Figure 3. Situation 1, Every fire exit routes are useable.

Figure 4. Situation 2, Fire exit stair no. 4 is unusable.

Scenario 2: The fire exit stair no. 4 is unusable because there are being on fire at fire pump room which located on the basement and causes the smoke to spread into fire exit stair no. 4 as shown in figure 4.

Scenario 3: 5 fire exit doors near emergency department on 1st floor is unusable because the car which delivered the patient is burned that make people in the building cannot use such fire exit as shown in figure 5.

Figure 5. Situation 3; 5 fire exit doors which located near emergency department on 1st floor is unusable.

3. Simulation result and analysis

3.1. Simulation result

From these 3 simulations, we found that the time of fire evacuation from the building is 3,048 seconds, 2,931 seconds, and 2,958.3 seconds respectively which does not over the limit as controlled by High Building Controlled under Thai Law that fix the time of evacuation as lower than 1 hours [6].
Figure 6. The number of building users in each period.

Furthermore, the researcher also found that the remaining building occupants who still stuck in the building are similar number among 3 simulations when the fire evacuation starts for 1,200 seconds as shown in figure 6. The last groups which move out from the building are critically ill patients and their assistance team which are aided from 4th floor and 5th floor as shown in figure 7. Since the building occupants can evacuate only one route that is ramp fire accompany with the physical factor which needs to be moved through the bed that makes the speed decrease. Moreover, the high of building also cause to slow movement of critical illness patients evacuation.

Figure 7. The last group of building occupants who remain in the building.

Figure 8. Increase the fire exit channel by using elevator to evacuate the critically ill patients.

3.2. Analysis of simulation result

Although these 3 simulations use the time to evacuate less than 1 hour as Thai Law controlled, we still need to concern about the safety of evacuation from the building, especially the critically ill patients and assistance team which have limitation about movement time. Besides, it can be an alternative channel when the ramp fire exit is unusable. Thus, the researcher has suggested the channel to evacuate from the building by adjusting the passenger elevator to be used as the fire escape elevator. Which according to the original drawing of this building, there are 9 passenger elevators that can be renovated into a fire escape elevator in the middle of the building as shown in figure 8.

In case of increasing the elevator channel to evacuate critically ill patients and assistance team by simulating as 2 Alternative as following:

Alternative 1: Set the assistance team to help the 4th floor critically ill patients by using the ramp fire escape and 5th floor critically ill patients by using elevator as shown in figure 9.
Figure 9. Evacuate the 4th floor critically ill patients by using the ramp fire escape and 5th floor critically ill patients by using elevator.

Figure 10. Evacuate the 4th and 5th floor critically ill patients by using elevator.

Alternative 2: Set the assistance team to help the 4th and 5th floor critically ill patients by using elevator as shown in figure 10.

The simulation result found that after increasing the fire exit by adjusting the passenger elevator to fire escape elevator for critically ill patients and assistance team, the time of evacuation from the building of 2 simulations are decreased to 2,073 seconds and 1,979.5 seconds respectively as shown in figure 11.

Figure 11. The fire evacuation time in each situation.

4. Results and discussion
From the fire escape route adjusting of large hospital building by improving the passenger elevator to be fire escape elevator, the experiment of 2 simulations found that they can decrease the time to evacuation from the building when compared with the simulation in Scenario 1, 2, and 3 as followings;

Alternative 1: Able to decrease the time of evacuation from Scenario 1, 2, and 3 as 31.98%, 29.27%, and 29.92% respectively.

Alternative 2: Able to decrease the time of evacuation from Scenario 1, 2, and 3 as 35.05%, 32.46%, and 33.08% respectively.

To sum up, the Alternative 2 use the least time to move out all occupants of the building.

5. Conclusion
The fire evacuation simulation from the large hospital building result found that we can move all people out from the building within 1 hour as the High Building Controlled under Thai Law.

The passenger elevator needs to be adjusted to apply as fire escape elevator to increase more evacuation channel for critically ill patients who cannot use the fire exit because they must be moved together with patient’s bed.

In case of using the elevator to escape the fire, users need to make sure that such elevators can be used safely when emergency events occur.

The fire emergency evacuation needs to be set clearly, prepare, train as well as the assistance team also need to be ready all the time to be more effective fire evacuation.
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