Performance – based life safety analysis of the hospital building

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Abstract. This study Performance – Based Life Safety Analysis of the Hospital Building reference NFPA 101, Life Safety Code. Four simulation scenarios were selected for this simulation. First, fire in a patient room; evacuation time is 2,847.3 seconds after the announcement. Second, fire in a storage room near the canteen; evacuation time is 3,014.5 seconds after the announcement. Third, from the first and second scenarios have a nonoperative fire alarm system which increases evacuation time that is 3,122.0 seconds and 3,235.8 seconds respectively. From simulation results shows that the first problem is the bottleneck at the fire escape door. It must be modified by expanding the door. And the second problem is the slow movement of the patient that has to solve the problem by having a staff to help evacuate.

1. Introduction

There are more than one thousand fires in global hospitals each year, and quite a lot of injured people in hospitals and health care facilities. Require to effective strategies for the safe evacuation of all hospital occupants in fire situations. This strategic planning for the migration process in the health care environment needs to be thoroughly considered. Most hospitals have large and complex building structures, including furniture and various portable equipment; therefore, there is great variability and dynamism in mean of egress. Wards have different uses (e.g. intensive care, outpatient clinics, etc.) and differences in the duties of staff to support these applications [1]. Inpatient wards in the high-rise hospital building, have the risk of fire occur. Because many occupants are in the building for a long time and different patient classifications (self-care to intensive care) [2]. Hospital emergency evacuation requires assistance for patients with reduced mobility. The extensive set of experiments to assess evacuation that has been helped using a stretcher, portable chair, evacuation chair, and life-saving pad. Then, the experimental data were used to predict the evacuation time for the entire hospital under the circumstances of personnel management and equipment assistance. In this research, study and analysed the fire escape route performance of the hospital building. Simulate the hospital building by Pathfinder program to simulate a fire situation and find the required safe egress time (RSET) by using the principles and theories in the setting program is based on the NFPA 101 (Life Safety Code) and actual suitability [3].
2. Model buildings and calculations

2.1. Model building
Pathfinder is an agent-based egress simulator that uses steering behaviors to model occupant motion. It consists of three modules: a graphical user interface, the simulator, and a 3D results viewer. Pathfinder provides two primary options for occupant motion: an SFPE mode and a steering mode [4]. The SFPE mode implements the concepts in the SFPE Handbook of Fire Protection Engineering [Nelson and Mowrer, 2002]. This is a flow model, where walking speeds are determined by occupant density within each room and flow through doors is controlled by door width. The steering mode is based on the idea of inverse steering behaviors. Steering behaviors were first presented in Craig Reynolds' paper "Steering Behaviors for Autonomous Characters" [Reynolds, 1999] and later refined into inverse steering behaviors in a paper by Heni Ben Amor [Amor et. al., 2006]. Pathfinder's steering mode allows more complex behaviors to naturally emerge as a by-product of the movement algorithms - eliminating the need for explicit door queues and density calculations [5]. The hospital building has a total area of 42,379 square meters, 72.2 height meters, 15 floors and 2 basements consisting of several business segments, including the SRT station, the Outpatient Department including I.C.U. and Inpatient Department on the upper floor of the building as shown in figure 1.

![Figure 1. Showing the usable area of the hospital building.](image)

2.2. Simulation setting
1. In this simulation, there are 4,100 Persons are involved. This number derived from the occupant load factor (m²/person) as defined in NFPA 101 [3]. Persons divided into three groups that staff, inpatient and outpatient.
2. Evacuation patterns of various groups.
   - The staff is designated as patient assistance for evacuation.
   - Outpatients can evacuate on their normal conditions.
   - Patients must be rescued by the staff with the bed or wheelchairs, etc.
3. The behaviors 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 [3].
4. Design fire scenarios base on NFPA 101. Four scenarios were selected for this simulation.
   - The idea behind design fire scenario 1 is to ensure that the types of fires most likely to occur in a given occupancy type that is, the statistically most significant scenarios are considered in the design analysis. Therefore, this building has 15 floors and 2 basements. From all of building have 8-story ward or 45 percent of the building, therefore, set a fire origin that is short circuit in ward at the 8th floor which is the middle floor of the building and the first floor of ward as shown in figure 2. To analyse that many patients and staff on the 9th floor and above will evacuate safely or not.
   - Design fire scenario 2, It addresses the concern regarding a fire starting in a normally unoccupied room and migrating into the space that potentially holds the greatest number of occupants in the
building. The fire origin is on the 5th floor, which had a storage room next to canteen. There was a lot of people which has both normal people and patients as shown in figure 3.

- Design fire scenario 3 and 4 addresses a set of conditions with a typical fire originating in the building with any one passive or active fire protection system or feature being ineffective. Examples include
  - Unprotected openings between floors or between fire walls or fire barrier walls
  - Failure of rated fire doors to close automatically
  - Shut-off of sprinkler system water supply
  - Non-operative fire alarm system
  - Inoperable smoke management system
  - Automatic smoke dampers blocked open.
Therefore, Scenario 3 and 4, from case 1 and 2, will require a delay of 300 seconds before starting to evacuate cause non-operative fire alarm system.

3. Simulation result and analysis

3.1. Simulation result

Figure 2. Enlarged picture of ward on the 8th floor.

Figure 3. Enlarged picture of canteen and storage room on the 5th floor.
**Figure 4.** Simulation results for case 1.

**Figure 5.** Simulation results for case 2.

**Figure 6.** Simulation results for case 3.
4. Results and discussion

Scenario 1, when a fire occurs at the ward, the assistant will evacuate the patient to the refuge area in phase evacuation. Normally, the assistant is less than the patient. Resulting in a lot of evacuation time. In the part of ICU room, it is made into a fire compartment and does not evacuate critically patients. Allowing time to evacuate 2,847.3 seconds as shown in figure 4.

Scenarios 2, fire occur near the fire escape 2. Therefore, the people on the 5th floor have to escape by using fire escape 1, causing the fire escape 1 to get a bottleneck at the door. And crowded inside the stairs. Allowing time to evacuate 3,014.5 seconds as shown in figure 5, evacuation time is greater than the first case 167.2 seconds.

Scenario 3, when the fire escape 2 was unavailable, allowing time to evacuate 3,122.0 seconds, the evacuation time increases from the first case 274.7 seconds. Because of a bottleneck at the fire door as shown in figure 6.

Scenario 4, when the fire escape 2 was unavailable, allowing time to evacuate 3,235.8 seconds as shown in figure 7, the evacuation time increases from the second case 221.3 seconds as shown in figure 8. Because of a bottleneck at the fire door.

5. Conclusions

Even though the fire escape has the correct width according to the standard but in the real evacuation, cannot support all the building user if evacuated simultaneously, should develop evacuation plans such
as phase evacuation.

The problem of the width of the exit door of the area that has many building users, there should be more than 1 exit.

Comparison of evacuation time for four scenarios was shown. Maximum evacuation time is scenario 4, this means that we may use this result to design available safe egress time (ASET). This simulation result can be used to find the fault location of the fire escape route to makes changes in the future.

Use the evacuation elevator to increase the evacuation method. And reduce evacuation time.

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