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Performance-based Fire Safety Design for Existing Small-scale Hospitals

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Abstract

The new era of National Health Insurance in 2000 has had a significant impact on the management and operation of small-scale hospitals. In response to social needs, and in order to survive under the new insurance system, some small-scale hospitals have transformed or established new Respiratory Care Wards by using existing hospital space. According to the 2009 statistics released by Department of Health, Executive Yuan, there are a total of 307 small-scale medical institutes which provide services under 99 beds. Compared with other large-scale medical centers and general hospitals, small-scale hospitals cannot properly deal with safety management and response to emergency evacuation due to lack of facilities, equipment and human resources. Therefore, small-scale hospitals face a major challenge in emergency response once a fire has occurred. As a result of such a situation, this study has focused mainly on Respiratory Care Wards (RCW) where patients are unable to evacuate. It hopes to analyse the safety management, and emergency response in small-scale hospitals by means of understanding the space characteristics and fire risk. Through on-site surveys, we can understand the fire risk, space features, patient characteristics, facilities and equipment. With reference to the related regulations of hospital emergency management and response, we will propose some fire safety engineering approaches, such as refuge areas in horizontal evacuation and so-called “besieged zones” for “defense-in-place”, etc., to provide some alternative measures to improve fire safety for those small-scale hospitals.

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1. Introduction

Because of scientific and technological progress and advances in medical science, the phase of “Demographic transition” has been continuing since the mid 1980s in Taiwan, i.e. the proportion of aged people is increasing. An aging society with a lower birth rate leads to a population with an inverted pyramid structure. The shortage of social nursing care will be the main problem for an aged society in the near future. According to the statistics of the Ministry of the Interior, Taiwanese people over the age of 65 account for 7% of the total population, reaching the

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threshold for an aging society. The Council for Economic Planning and Development, Executive Yuan, also points out that Taiwan's population over the age of 65 was 2.4 million people or 10.5% of total population in 2009. It shows that Taiwan is on the way from “aging society” toward “aged society”*. The council estimates the population in Taiwan will be one-fifth of the elderly in 2025 and the elderly rate of population in Taiwan will reach 29.8% in 2050. [1] These statistics reveal Taiwan will face rising medical problems caused by the aging population and low birth rate. These problems will also impact on current public health and thus medical systems. How to enhance community chronic care and long term nursing care will be one of the most important challenges to the current system. In response to social needs, local small-scale hospitals transformed into elderly welfare facilities will be a growing trend in the near future.

In addition, a health insurance system has been in place since 1995 and was expanded into the National Health Insurance scheme in 2000. The new system has significantly impacted the management and operation of small-scale hospitals because of insurance subsidies and changes in patient medical care. In response to social needs, and in order to survive under this new insurance system, some small-scale hospitals have transformed and established Respiratory Care Wards (RCW) and kidney dialysis facilities by utilising existing hospital space. Notably some hospitals have retrofitted existing spaces with new medical equipment such as oxygen supply systems for patients who are not movable. According to the 2009 statistics released by the Department of Health, Executive Yuan, there are a total of 307 small-scale medical institutes which provide services under 99 beds. Among these, there are 115 institutes offering RCW services and 90 kidney dialysis. Compared with other large-scale medical centres and general hospitals, small-scale hospitals cannot properly deal with safety management and response to emergency evacuation due to lack of facilities, equipment and human resources. Therefore, small-scale hospitals face a major challenge in emergency response once a fire has occurred.

In the light of these trends, this study focuses on existing small-scale hospitals which take care of immovable patients; reviews the fire safety problems in these buildings and proposes some fire safety engineering approaches, such as refuge areas in horizontal evacuation and so-called “besieged zones” for “defense-in-place”, etc., to provide some alternative measures to improve fire safety for these small-scale hospitals.

2. Fire safety problems in existing small-scale hospitals

According to the statistics of the Unusual Incident Report System (UIRS) which has been installed by the Taiwan Joint Commission on Hospital Accreditation and sponsored by the Department of Health, Executive Yuan, there has been a total of 181 fires occurring in hospitals during the past five years, as shown in Figure 1 (i.e. about 36 hospital fires per year on average). This figure is far higher than the fire authority statistics. The main reason is the difference in the benchmark standard and judgment method. UIRS encourages voluntary notification and is accessed by any employee in a hospital. The fire authority statistics, however, are based on fire service intervention in the incidents. If the incident has been contained by hospital staff, and the fire authorities not informed, the incident records will not be collected by fire authorities. From the point view of fire problems, UIRS provides the more realistic description of such problems in Taiwan.

As mentioned above, in order to survive under the new insurance system, some small-scale hospitals have been transformed and now provide RCWs, kidney dialysis, and nursing care services by using existing hospital space. Some of the following problems regarding fire safety will arise for these existing small-scale hospitals.

*The United Nations definition of an ageing society - one in which more than 7% of the population is over the age of 65, aged society for more than 14%, and super-aged society for more than 20%

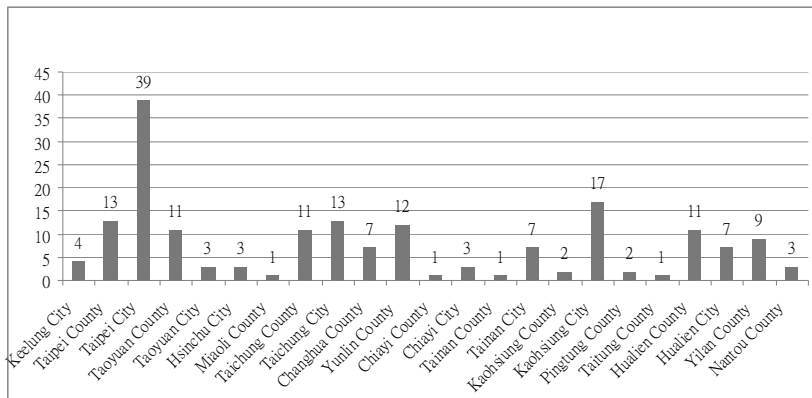


Figure 1 - the geographical distribution of hospital fires in Taiwan (2005–2009)

2.1. The relaxations of the latest regulations for existing hospitals cause fire safety loopholes

Environmental security should keep abreast of the times and legality cannot stand for safety. In particular, those regulations which are crucial to life safety and property protection should be up-to-date and strictly adhered to. For example, the hospitals established before the Medical Act went in effect in November 24, 1986, may have been allowed partial relaxation of fire safety requirements. These include all the partition walls, walkways, walls, floors and ceilings, which originally required fire resistant level and now may have legal relaxation. Although, the Construction and Planning Agency, Ministry of the Interior, proposed “The Improvement approaches on Fire Protection Facilities and Fire Safety Equipment for Original Legal Buildings” in 2007 to require different improvement items in existing hospitals based on their license dates as shown in Table 1. [2] However, under the consideration of continuous operation, expense, capital allocation etc., the mandatory requirements still could not be carried out up to now.

Table 1. the improving items of fire protection and evacuation facilities in hospitals

Items	Approaches	License dates	Compartmentation	Internal Wall	Lining Materials	Exits in Ground Floor	Exits except Ground Floor	Corridors	Stairs	Safety Stairs	Roof Refuge Platform	Emergency Access
		Before 1974.2.16	Based on area, occupancy, and vertical penetration to decide	△	○	△	×		Based on the distance, platform width · turning radius to decide	△	×	△
		1974.02.17-1996.04.18		△	○	☆	×			△	×	☆
		1996.04.19 - 2003.12.31		☆	○	☆	×	☆		△	×	☆
		After 2003.01.01		☆	○	☆	×	☆		△	×	☆
○ improved by current regulations / ☆ improved by original regulations / △ specific requirements / × no need for improvement												

2.2. The changes in patients' mobility make the emergency evacuation more difficult.

The transformed small-scale hospitals set up chronic respiratory care beds, most of which come from an adjustment of the existing acute beds. Although the acute patients have poor mobility, they are conscious when an

emergency happens. Most of acute patients can evacuate by themselves or with others' assistance including wheelchair or escort. Chronic respiratory patients have to rely on oxygen supply tubes and they are usually unconscious and therefore immovable. The concept of horizontal evacuation under emergency situations is the primary approach in general hospitals. However, the basic strategy for fire evacuation of respiratory care patients is to secure them in the same place instead of horizontal evacuation. However, if there are specific countermeasures, such as an adjoining compartments, sub-compartments, small portable oxygen cylinders and regular evacuation routes, the strategy of horizontal evacuation can be considered.

2.3. Shortage of internal nursing staff reduces the capability of an emergency response

The other important problem of small-scale hospitals for long term care hospitals is the shortage of nursing staff. Based on the requirements of RCW nursing staff released by the Bureau of National Health Insurance, the manpower level is one for six respiratory care patients. With an eight-hour shift and daily rest, one nursing staff should take care of over 15 to 20 patients. They are busy people and have many duties such as sputum suction, turning patients, sponge bathing patients, administering injections, distributing and applying other medicines and writing nursing reports etc. It is very difficult to evacuate all the respiratory care patients once a fire has occurred.

2.4. Medical pipelines break fire compartments which provides a means for fire and smoke to spread

In order to transform the type of Respiratory Care Wards, small scale hospitals have to install related medical facilities. Furthermore, the original electricity and water pipelines should be adjusted. Additional oxygen storage should be installed and the oxygen pipelines should be laid throughout the whole building. Those pipelines penetrate the compartment. Such retrofits are just submitted to the approval of the health authority for the purpose of applying for health insurance and are not supervised by building control authorities. Such a situation always causes the fire resistant lining materials to be hard to identify, and compartments are broken by pipeline penetration without seals. All medical equipment runs 24 hours a day and 7 days a week with high a demand for electricity, which increases the risk of fire.

2.5. Current building codes and fire codes cannot provide sufficient protection.

Even the latest building codes and fire codes which regulate fire safety in hospitals from the point view of general patients cannot take into account the requirements of immovable patients such as those in respiratory care and on kidney dialysis. These patients who require life support systems like an oxygen supply or dialysis machine. The space requirements for accessibility should be higher than general hospitals. However, in most existing small-scale hospitals in Taiwan, non fire resistant stairs provide a means for a chimney effect for smoke diffusion instead of vertical evacuation. Also, beds cannot make smooth turns because of narrow corridors increasing the difficulties of horizontal evacuation. Therefore, the specific principles and prescriptive requirements of fire safety for hospital occupancies such as HTM 05 [3] and BS 9999 [4] adopted in the UK are essential in Taiwan.

3. General fire safety principles for small-scale hospitals

To improve Fire safety in small-scale hospitals shall be approached different from large-scale hospital buildings. The nature of large-scale hospital operation means that the nursing staff ratio is relatively high and the building is occupied at all hours with better prevention and precaution measures. With the very dependent or immovable patients, the fire safety precaution for small-scale hospital has to be tailored made. Each of the fire safety elements in term of fire resisting construction, fire fighting access, fire protection system, and fire safety management is described briefly below. The means of escape should be in harmony with the floor plan and will be different case by case. The case study will illustrate in next section.

3.1. Fire resisting construction

Basically, buildings in Taiwan including hospitals with a floor area of more than 1500 m² should be subdivided into compartment floors, walls, ceilings and fire doors with a medium duration (60 minutes) fire resistance. Every compartment should be limited to a maximum area of 1500 m². In addition, every upper storey and every lower storey should form a separate compartment. Every floor should be a compartment floor with a medium duration (60 minutes) fire-resistance. However, the floor area of existing small-scale hospitals are commonly less than 1500 m² without any fire rating and smoke proof construction, and vertical penetrations such as stairs and pipe shafts cannot form floors with separate compartments independently. To solve these deficiencies and for the progressive horizontal evacuation, the sub-compartment and besieged zone approaches are proposed in the next section. This is the most important factor in completing the horizontal evacuation strategy. In addition, the surface finish applied to walls and ceilings can contribute to the spread of a fire. With hospitals being a relatively vulnerable space, materials with low surface spread of flame should also be considered.

3.2. Fire fighting access

The fire safety strategy of a hospital with RCW is to ensure fires can be extinguished effectively and quickly by the nursing staff. In the worst case scenario, fire fighting and rescue will have to be conducted by the fire brigade. Adequate and efficient emergency access should be arranged in a sub-compartment or besieged zone beside the road, over 4 meters, to enable fire aerial ladders to gain access to the building.

3.3. Fire protection systems

As part of the fire safety strategy for hospitals, it is desirable to enable early detection for a fire so that it can be suppressed by an automatic suppression system or by trained personnel. Unfortunately, most of the existing small scale hospitals do not have automatic suppression systems such as sprinklers. Therefore, the initial fire fighting must rely on on-duty nursing staff. If the fire cannot be dealt with immediately, all nursing staff in hospitals must be alerted by smoke detection system at once in order to initiate the first stage of horizontal evacuation to the adjoining sub-compartment or besieged zone.

3.4. Fire safety management

For a small scale hospital with RCW, it is imperative to have trained nursing staff to react appropriately in the event of a fire. The provision of an adequate number of nursing staff who have received effective fire safety training is the best first line of defense against a fire. These trained staff can deal with a fire immediately on the spot. The staff should have also received training in the methods of patient evacuation to cope with the sub-compartment and besieged zone design.

4. Case study

In small-scale hospitals, particularly in patient-access areas, the immediate and total evacuation of the building in the event of fire may not be possible or available. Patients with restricted mobility, such as those who use breathing apparatus and are confined to bed cannot move easily, particularly on stairways. Therefore, the concept of horizontal evacuation in emergency situations is the primary approach adopted in small-scale hospitals. The basic strategy for fire evacuation of those very dependent patients is to move them on their bed to a safer area on the same floor. Two cases to improve non-compartment spaces and create safer areas for existing small-scale hospitals will demonstrated as below.

4.1. A sub-compartment approach for a two-stair RCW floor

The floor area of most existing small-scale hospitals in Taiwan is usually less than 1500 m². Those hospitals are not required to have a floor fire compartment and adopt open RCW for convenient daily care. For such kinds of hospital with two or above general stairs, every non-compartment floor can be divided into at least two sub-compartments by compartment walls or metal rolling gates with a short duration fire-resistance. The sub-

compartment is not greater than 750 m², which shortens the time of horizontal evacuation. In addition, to prevent the “chimney effect” through general stairs, the confined space of staircases with fire rated walls and doors is necessary for vertical pathways. As shown in Figure 2, as part of the progressive horizontal evacuation, sub-compartments should be separated from each other with fire rated and smoke proof construction.



Fig. 2. non-compartment floor (left) can be improved by two sub-compartments with a fire rated metal rolling gate (right)

4.2. A besieged zone approach for a one-stair RCW floor.

Some of the older buildings only have one stair. To provide solutions based on fire safety engineering, a besieged zone approach is proposed to improve the care environment. A besieged zone is the compartment and/or space which is separated from the original fire compartment on the same floor. The space always presents the construction of a higher standard structure and the area of sticker fire protection function, albeit with relatively high retrofit expenses. As shown in Figure 3, non-compartment floors with a single stair can be a besieged space. The space area should consider accommodating all respiratory care patients in the same floor. The life support systems, such as the oxygen supply system, in the besieged zone should also be taken into account.

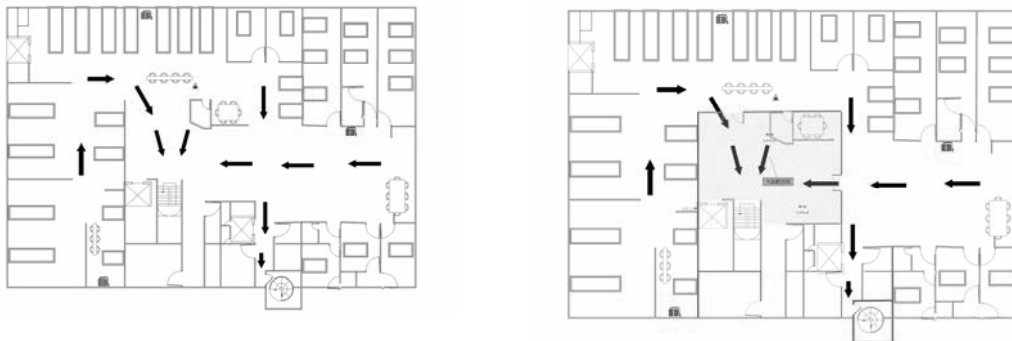


Figure 3 non-compartment floor with a single stair (left) can be a besieged space for further assistance of vertical evacuation (right)

No matter what solution we adopt, there are three main stages for emergency evacuation in the improved care environment:

- Stage 1- the segmentation of sub-compartments or besieged zones must completely be formed.
- Stage 2- horizontal evacuation from the sub-compartment where the fire originates to an adjoining safer sub-compartment or a besieged zone.
- Stage 3– waiting outside assistance for vertical evacuation to a lower floor substantially remote from the floor of origin of the fire (at least 2 floors below the fire floor), or to the outside if needed.

The principle of evacuating patients from an area affected by fire through a fire-resistant barrier to an adjoining area on the same floor is to protect the respiratory care patients from the immediate dangers of fire and smoke. This is known as progressive horizontal evacuation as achieved via Stage 1 and Stage 2 described above. As part of the progressive horizontal evacuation strategy, the compartment is essential and is required to provide shielding for sufficient time before patients are given assistance to evacuate further if necessary. In Stage 3 evacuation, egress staircases will be utilized. The egress staircases, as usual, would be provided with fire resistant construction to prevent migration of fire and smoke. All stairways to areas that provide sleeping accommodation or contain dependent or very high dependency patients should be designed to permit the evacuation of patients on mattresses.

In addition, it is necessary to consider the use of lifts to evacuate RCW patients who would be unable to descend stairs without assistance. Escape lifts may provide an acceptable solution to a specific evacuation need, once the existing lifts fulfill the performance requirements. In addition, sufficient areas of the safe sub-compartment or besieged zone should be provided to accommodate those required to escape via the evacuation lift. The evacuation lift should also be operated only by staff who are trained to assist in the management of any fire evacuation. Firecode in the UK provides some recommendations for the use of evacuation lifts in hospitals. [5]

In the above two cases, each floor of the RCW facility is also subdivided by one or more smoke barriers designed to limit the passage of smoke from one area to another. If there is smoke or fire in one area, people can move across the smoke barrier, typically passing through self-closing, cross-corridor doors, into the sub-compartments or besieged zone that is protected from smoke. Such solutions offer very dependent patients a short response, horizontal evacuation in cases of fire.

For the “defend in place” principles to be effective, it is essential to maintain the integrity of fire and smoke barriers. For the fire safety manager in small-scale hospitals, this involves inspection and maintenance of doors and other openings in these barriers. It also involves inspection and maintenance of walls to avoid penetrations that would allow the passage of smoke or fire. On a practical level, one of the major challenges for many fire safety managers in those small-scale hospitals is to control penetrations created in smoke and fire barriers, typically above the ceiling in corridors. This can be achieved by personnel installing pipes, conduits, cables, and other items that need to run across the barriers as shown in Figure 4. Techniques are available to allow these items to pass through a barrier without harming its integrity. However, unauthorized penetrations continue to require careful surveillance to avoid to damage to the safe sub-compartment or besieged zone especially. Fire safety managers should be aware of the importance of this issue and make sure that any cable installation or similar activities under their control are conducted in compliance with performance requirements of defense in place.

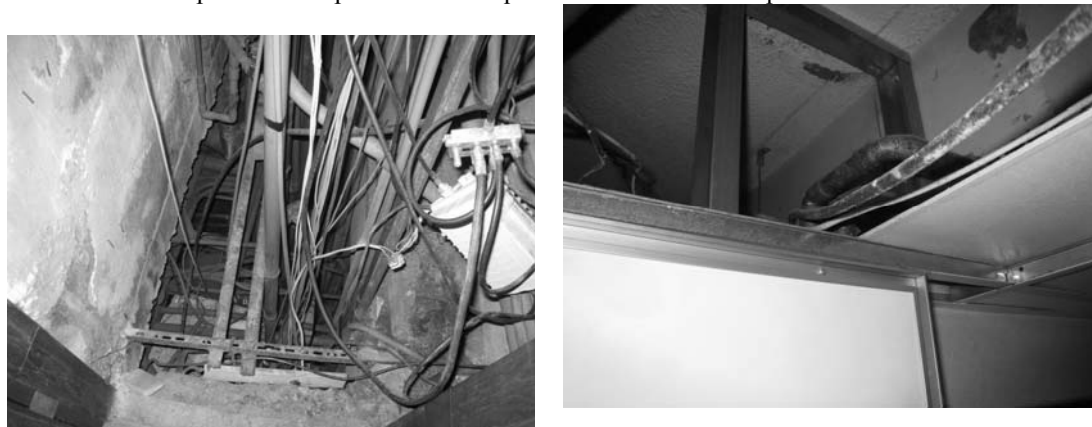


Fig. 4 lack of sealing in the pipeline shaft (left) and above-the-ceiling penetration of a smoke barrier (right).

5. Concluding Remarks

Fire safety design in an existing hospital represents a challenge for designers due to the higher risk occupancy profile and construction nature of the existing building. The general problems for existing small-scale hospitals and principles for fire safety design have been briefly discussed in this paper. Most principles are mainly referred to the recommendations given in international prescriptive guides such as the HTM 05 Fire Codes and BS 9999. However, prescriptive guidance is generic in nature and does not always provide sufficient flexibility, especially for special design features. A performance based approach is introduced as an alternative to address the overall fire safety level, allowing innovative design to be incorporated, such as the sub-compartment or besieged zone. The advanced engineering techniques available in recent years allow engineers to develop solutions taking into account evacuation, even smoke and fire behavior. With the use of appropriate fire protection systems and suitable fire safety management measures, the overall fire safety level of existing small-scale hospitals can be evaluated. Such an approach allows increased design flexibility, enables engineers to predict the level of safety and provides the ultimate solution in each improvement and thereby derives the most cost effective, sustainable and fire safe solution for existing small-scale hospitals.

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