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A ranking system for fire safety performance of student housing facilities

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ABSTRACT

For old/existing buildings, detailed fire risk assessments based on current codes and standards may result in unrealistic conclusions. Hence, it is desired that more holistic approaches are employed such as safety ranking systems. This paper seeks to propose a Fire Safety Ranking System (SH-FSRS) for student housing facilities. A review of published literature and code requirements formed the basis for the identification of the required fire safety attributes. These attributes were grouped into three criteria: building characteristics; fire safety systems; and management and maintenance. Professional experts have been consulted for pairwise comparisons to derive the weights for these criteria and attributes through the Analytical Hierarchy Process (AHP). The study has also presented the implementation of the developed SH-FSRS on a case study. A conglomerate of student housing facilities was grouped into four architectural models, and their fire safety rankings were presented. Model D facilities ranked first (final score 81%), model B facilities ranked second (final score 69%), model A facilities ranked third (59%) and Model C facilities ranked fourth (final score 55%). Finally, recommendations were provided to improve the fire safety performance of these facilities.

1. Introduction

Student housing is considered as a high risk facility where fires can quickly rage out of control in the absence of appropriate and sufficient control and suppression systems (Sanni-Anibire and Hassanain, 2015). The International Building Code (IBC, 2012) describes student housing facilities as dormitories containing more than two sleeping units, or dwelling units, where the occupants are primarily permanent in nature. For students, campus life represents a period of independence and an opportunity for juvenile indulgence, which is a potential threat to their personal safety. Fire risk in a student housing facility can be attributed to the large number of students potentially exposed at one location, the fuel load that exists in the student rooms, and the design configuration of the student housing facility (Sanni-Anibire and Hassanain, 2015). Though, the occurrence of campus fires is relatively rare; however, when it occurs, it leaves devastating consequences that can last forever, changing lives of not only individuals but families and communities (Mowrer, 1999). Thus the provision of fire safety programs that include prevention, detection, and suppression to ensure a high level of fire safety in student housing facilities is a matter of priority.

Fire risks are addressed through risk assessment techniques (Manchester and Bardos, 2004). The objective of such assessments is to reduce the risk to life and property (Ramachandran, 1999). A variety of fire safety risk assessment approaches already predominate. They could be classified as qualitative, quantitative, or a hybrid of both (Amaratunga et al., 2002; Nystedt, 2001). Examples include approaches based on safety checklist/code assessments (Hassanain and Hafeez, 2005; Hassanain, 2008), real life evacuation drills (Chen et al., 2013; Cuesta and Gwynne, 2016; Huo et al., 2016), computer aided evacuation simulations (Lo et al., 2005; Tashrifullahi and Hassanain, 2013; Ding and Weng, 2016), fire safety ranking techniques (Chow, 2002; Zhao et al., 2004; Chen et al., 2012), statistical and probabilistic models (Khorasani et al., 2014), and a hybrid of these approaches (Klüpfel et al., 2003; Copping, 2004; Yuan et al., 2009; Ulriksen and Dederichs, 2014; Sanni-Anibire and Hassanain, 2015).

Some of the established risk assessment approaches could be expensive and labor-intensive processes due to the level of information that may be required. Also, the fire protection measures of existing buildings may vary with the requirements stipulated by ever changing codes and standards. Thus, existing/old buildings assessed based on the requirements of current standards may result into unacceptable levels of safety performance (Lo and Cheng, 2003). Ranking techniques however, provide the specific advantage of being cost effective and efficient in the absence of

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sufficient data for detailed risk assessments (Watts, 2016). A ranking technique for high-rise nonresidential buildings in Hong Kong was proposed by Chow (2002). Also Chow and Lui (2002) proposed a fire safety ranking system for karaoke establishments in Hong Kong. Despite the need to continuously ensure satisfactory safety performance of student housing facilities, few studies have however been carried out (Mowrer, 1999; Hassanain, 2008; Argueta et al., 2009; Sanni-Anibire and Hassanain, 2015). Furthermore, a comprehensive survey of literature reveals that there is an absence of research studies on the use of fire safety ranking approaches in student housing facilities. Thus, the main objective of this study is to develop a fire safety ranking system for student housing facilities and demonstrate its application through a case study. The case study selected for this research is a conglomerate of student housing facilities in one of the university campuses in the Eastern Province of Saudi Arabia. It is hoped that the proposed fire safety ranking system will provide a cost-effective, yet valuable approach in the assessment of student housing facilities by the concerned facilities' managers, university administrators and housing departments.

2. Fire safety ranking systems

A fire safety ranking system is also known as a fire risk ranking system, or fire safety evaluation/assessment system (Watts, 1995; Lo, 1999; Wong and Lau, 2007). It is a multi-criteria decision-making process in which the ranking of fire safety attributes is derived (Watts, 1997b; Lo, 1998; Chow, 2002). This involves the estimation of a relative fire risk through the analysis and scoring of risk parameters. Professional judgment and experience form the basis for the assignment of values to the parameters of passive and active fire safety features. Subsequently, these values are computed arithmetically to produce the safety index (Lo and Cheng, 2003). Fire safety ranking systems have been identified as a cost-effective way to evaluate the safety performance of existing buildings (Lo, 1999; Lo and Cheng, 2003; Watts, 2016). The objective of a fire safety ranking system is to assess the performance of various fire safety attributes of existing buildings and quantify the fire risk level. Fire risk levels derived for various buildings form the basis for prioritization of actions to be taken for improvement in the fire safety performance (Wong and Lau, 2007). Various methods have been proposed in developing fire safety ranking systems. This includes the direct point allocation, paired comparison (multiple regression models, explicit trade-offs) and equal/unit weighting (Zhao et al., 2004). Also, Liu et al. (2009) presented a fuzzy synthetic evaluation system for computing the fire risk ranking of buildings. Lo et al. (2005) also presented a reliability interval method for manipulating the weightings of attributes and a synthetic model on the basis of gray system theory. The Analytic Hierarchy Process (AHP), developed by Saaty (1980) has been adopted by Zhao et al. (2004) as a fire safety ranking evaluation approach for existing buildings. AHP is defined as an organized framework that solves complex interactions and interdependence among decision problems in a simple way (Saaty, 1980). It does this by breaking down complex, unstructured factors into attributes, arranging the attributes into a hierarchical order, assigning numerical values to subjective judgments of the relative importance of each attribute, and synthesizing the judgments to determine which attributes have the highest priority. AHP can also be described as a mathematical theory that employs pairwise comparison based on the judgments of industry experts. Such pairwise comparison establishes the extent to which an element dominates another with respect to a given attribute (Saaty, 2008). The AHP process is described by Zhao et al. (2004) as follows:

Step 1: Create a decision hierarchy by resolving the problem into a hierarchy of decision elements (attributes).
Step 2: Collect input by a pairwise comparison of the decision elements.
Step 3: Determine whether the input data satisfies a "Consistency Test". If it is not satisfactory, return to Step 2 and repeat the pairwise comparisons process.
Step 4: Calculate the relative weightings of the decision elements.
Step 5: Aggregate the weighted scores of each decision element and rank the decision alternatives.

AHP is one of the most widely used decision making models and it is well suited to fire risk ranking due to the ill-defined nature of the fire safety attributes (Watts, 1995). Also, AHP easily facilitates the qualitative comparison of fire safety criteria and attributes and its subsequent quantitative expression for prioritization/selection/ranking.

Fire safety ranking methods have been developed in many countries to assist the evaluation of the fire safety level of buildings. For instance, a Fire Safety Evaluation System (FSES) has been developed in the United States on the basis of fire risk ranking (NFPA l0lA, 1995). The FSES provides a multi-attribute approach to determine equivalencies to the NFPA l0l Life Safety Code (1994) for certain occupancies (Watts, 1997a). In addition, a Central Office Risk Assessment Method (COFRA) was developed in the United States (Parks et al., 1998). Furthermore, Nelson et al. (1984) developed a system for the fire safety evaluation of the national park service overnight accommodation. In Hong Kong, Chow and Lui (2002) proposed a Fire Safety Ranking System (FSRS) for karaoke establishments in Hong Kong. The FSRS deviated from the already established National Fire Protection Association-Fire Safety Evaluation System (NFPA-FSES) in its consideration for the interior finish. Also in Hong Kong, Chow (2002) proposed a ranking technique for high-rise nonresidential buildings EB-FSRS similar to NFPA-FSES, but with a different objective.

Fire safety ranking systems present a number of advantages such as its ease of use, cost effectiveness, and the ability to produce a rapid and simple estimate of relative fire risk (Lo, 1998). It also illustrates the amount of deviation in the safety performance of old buildings when compared to the requirements of current fire safety codes and standards (Chow, 2002). Fire safety ranking systems also facilitate prioritization and proper allocation of materials in the maintenance management and upgrading of the buildings safety systems (Watts and Kaplan, 2001). There are also disadvantages in the use of fire safety ranking systems. It requires a significant amount of time, is not a uniform system, and thus, may require a development of unique systems for different building classifications (Copping, 2002).

3. Research methodology

The methodology employed in this research can be summarily categorized into four stages as follows.

3.1. Literature review

This involved a general review of existing literature to provide the contextual background for the study. This entailed the review of published journal papers in the domain of fire safety management. Additionally, safety codes and standards, including the International Building Code (IBC, 2012) and International Fire Code (IFC, 2009) were reviewed to identify fire safety criteria and attributes for student housing facilities. The criteria thus identified are in three categories: building characteristics; fire safety systems; and