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A REVIEW OF FIRE RISK ASSESSMENT TOOLS IN COMPARTMENT

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ABSTRACT

Fires in confined space, such as enclosure in buildings, ships or planes are called compartment and categorized as unwanted fire. Fire resulted in property loss, human injury and fatality as well as negative impacts towards environment. The numbers of fire cases keep increasingly from year to year and become human concerns regardless fire engineer, fire fighter, policy makers and academicians as well. Fire engineers had found one way to reduce the occurrence by determine whether such a potential exist by undertaking a fire risk assessment of the building or facility. The main goal of fire risk assessment is to identify and characterize the fire risks of concern and provide information for the appropriate fire risk management decision. The search of relevant publications was performed mainly through international bibliographic database and science search engine as well as by examining citations from other authors. The relevant features of currently available tools of risk assessment approach are described. As a conclusion, various tools for risk assessment in compartment has their own convergence and divergence, nonetheless the owners of building/design and fire engineer can choose based on their needs and capabilities as the focus not on hazards identification only but towards method to reduce or prevent the fire risk from occurs.

Key words: fire risk assessment, tools, hazard identification, probability analysis, consequence analysis, risk quantification.

1. INTRODUCTION

Fires in confined space, such as enclosure in buildings, ships, or planes are called compartment. Quantitative risk assessment (QRA) is required in identification and assessment of major risk early in the project life cycle to avoid expensive remedial cost during the life of the project. Fire risk assessment involves four main steps: hazard identification, consequence assessment, probability calculation and finally risk quantification. After hazard have been identified, frequency analysis or/and consequence analysis should be carried out before evaluation of risk can be done.

The value or outcome from these analyses will be calculated to get the risk level; either risk is acceptable or unacceptable. If the risk is acceptable, it shows that fire safety is adequately installed and the building is safe to be occupied. If the risk in unacceptable, it shows that fire safety is inadequately installed and the building is very risky to live in. Therefore, the risks identified should be reduced by taking all the instruction, recommendation, and suggestion from the fire safety personnel to ensure all identified risk are eliminated or reduces at acceptance level. Fire risk assessment process mostly used based on British Standard Institute in document PD-7974-7:2003: Application of fire safety engineering principles to the design of buildings, as in Figure-1.

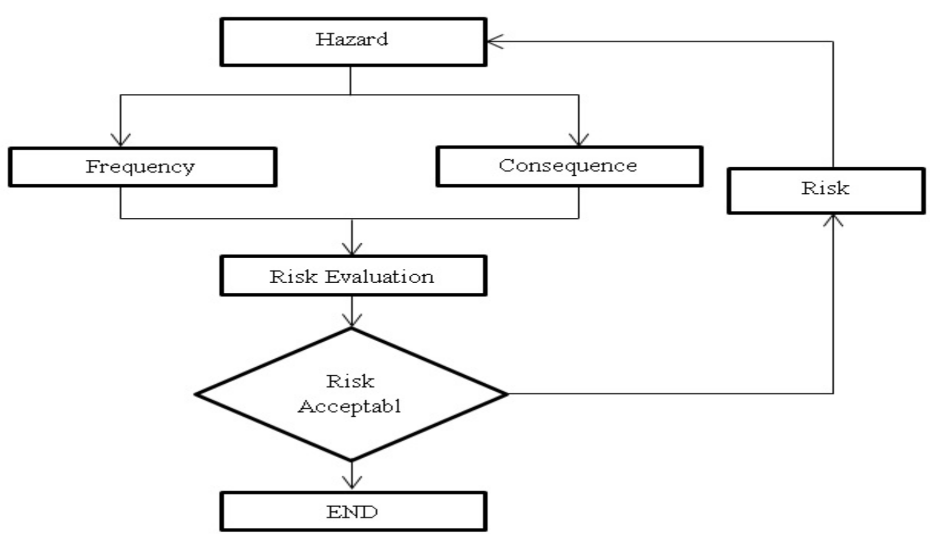

Figure-1. General approaches to probabilistic fire risk assessment (BSi, 2003).

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2. HAZARD IDENTIFICATION

For a fire to occur in compartment there must be a source of ignition, fuel and oxygen [1]. Identification of fire hazard is a crucial step in qualitative or quantitative fire risk assessment to identify possible fire scenario and to determine the fire risk in a building or compartment. Fire hazard may include combustible materials and ignition sources where the extent of fire hazard depends on a few factors. For combustible materials; the level of hazard depends on their ignitability, reaction, amount, orientation, location while for ignition sources; the level of hazard depends on frequency, ignition energy, temperature, numbers, timing, location, respectively (Ramachandran and Charters, 2011). In residential buildings the main locations of fires are in the kitchen, lounge room and bedroom cause by cooking fires and smoking materials [2]. It is useful to review statistical [3][4] and historical data [5][6][7] from comparable facilities as a starting point and move to other analytical technique such as what if analysis, fault tree and event tree analysis [8][9][10] if data is inadequate.

2.1. Design fire

Based on fire risk assessment flow chart (SFPE, 2006); the next step after identification of fire hazard is frequency and consequences analysis. Before proceeding to these analyses, the design fire scenario needs to be developed based on identified fire hazard. According to international and national guidance; Fire Safety Engineering-General Principle (ISO23932:2009), one of the major steps of fire safety engineering methodology towards fire safety design is the selection of design fire scenario (DFS). As discussed by [11], there are several approaches to establish design fire;

i) apply design fire provided by relevant design guide or standard,
ii) collect information data based on fire load density, ventilation and fire system and
iii) fire risk assessment on fire incident involving inventory and occupancy.

Considering first and third approach, there is currently no recognized standard that address design fires in wholesale premise and very limited data is available, respectively. Therefore, fire load density is relevant for design fire as supported by other studies [12] [13][14][15]. Fire load give you an idea how likely the fire severity and give value information for firefighter to identify the most vulnerable or dangerous area in fire building for fire service intervention. Different ignited fire load or fuels represent various fire scenario. Fire load is determined by carrying out fire load survey using different method including questionnaire, weighing, inventory, combination of weighing and inventory, and web-viewing [14]. Beside fire load entities, fire load densities, subsequent fire spread to adjacent combustible, influence of fire detectors and suppression as well as fire brigade can also being included in developing design fires [14] [16]. In order to determine design fire size, a full set of combustible heat release rate (HRR) database as a function of time should be developed (Peacock *et al*., 1994) by two ways; analysis and synthesis of experimental data or modelling and fire simulation [12].

3. FREQUENCY ANALYSIS

One of the challenges in assessing fire risk after fire hazard identification is to predict fire event's frequency since the fact that severe events not occurred all the time. Fire frequency is the number of times a fire occurs within a specific time interval and usually measured in fires per year per building or events per year per building. From statistical or historical information, the number of fires, location, property loss and injuries/casualties are obtained. The average value is calculated and the frequency of possible scenarios can be further deduced trough event tree analysis (ETA) or fault tree analysis (FTA), broke down from ignition to outcome into sub-events which occur frequently with meaningful data available. For both methods, commercial software is enabled nowadays to ease the users in terms of creating and calculating the frequency or reliability.

4. CONSEQUENCE ANALYSIS

The other component of Risk Assessment is consequence analysis that looks into an outcome of a scenario developed in fault tree or/and event tree respectively. Consequence analysis involves quantification of the likely loss/damage in terms of monies, business interruption or life safety [17] e.g. minor to serious. Nevertheless, in fire risk assessment only life risk and property risk are taken into consideration. A fire may result in anything from no damage/loss to catastrophic damage/loss based on the fire characteristic; heat, flame and smoke. Severity of fire event is assessed by consequence analysis where the ideal consequence analysis cover full range of possible fire events which is physically similar with the assessed system or building. Though the real event with real peoples in infinite period of time sounds not practical for ideal consequence analysis, there are a number of ways which is reasonable to assess event consequences (Ramachandran and Charters, 2011);

i. historical data
ii. disasters and near misses
iii. experiments and fire tests

iv. modelling

Historical data and disaster and near misses reported on consequences of previous fire events where the information might be useful if the reported cases are similar to the one being assessed. However, some of the events are not physically similar or not well reported thus the broad understanding of potential consequences are different and not well provided. Although experiments and fire tests provide much more relevant information of building or fire events consequences, they are usually large and expensive which only represent limited part of event progression that need extra observation to avoid error or repetition.

Due to uncertainty of historical data and highly costly for physical fire testing, fire computer modelling is a key element of consequence analysis in fire risk assessment. Literature had reported on the mathematical models to study the fire behaviour in compartment and for building fire analysis, a few models have been highlighted in three main approaches; simple calculation, zone and field models. Recently, computer fire models have been developed and improved to give more accurate and cost-effective prediction of fire consequences as previous computer fire model is expensive and time consuming. Available fire models generally include the capability to evaluate fire development and smoke movement as well as the time to reach critical damage thresholds and untenable condition (SFPE, 2006).

As reported by [18] , the models required to assess the consequences from fires have been identified as individual fire models, radiation model, overpressure model, smoke and toxicity models and human impact models. Survey done by Raymond Friedman in 1992 on computer models for fire and smoke had identified more than 70 computer models which address fire and smoke and further survey after 2003, more than 170 models have been detected (Olenick, 2015). The models are grouped in Zone (ARGOS, CFAST/FAST, B-Risk), Field (FDS, FIRE3D, FLUENT, FireFOAM), Detector Response (JET, G-JET), Fire Endurance (PhysibelVOLTRA, physibelBISTRA), and Miscellaneous (BlenderFDS, Building QRA, SMOKEVIEW, Pyrosim, Thermakin) models.

5. RISK EVALUATION

This phase involve quantification of risk level by combining the frequency and consequences of events. Once the level of risk has been quantified, it is necessary to decide about the level of risk whether tolerable or intolerable by comparing it with the risk from relevant prescriptive standard for life safety and what should be done to reduce intolerable risk (Ramachandran and Charters, 2011). The risk level can be used to help determine whether or not adequate controls are in places.

6. RISK REDUCTION

Fire risk analysis requires judgements about the probability of fire occurring and the consequences resulted. Therefore risk reduction consists of reducing the potential frequency and bringing down the hazard severity. In terms of quantitative risk assessment process, there are three main approaches to risk reduction (Ramachandran and Charters, 2011);

i) reduce the hazard
ii) reduce the frequency
iii) reduce the consequences

Used less hazard material and control of ignition sources are an example of reducing the fire hazard. According to [19], hazard reduction in a process plant focuses on the changing the process condition such as materials, temperature and pressure. The frequency of fire risk could be reducing by introduce additional mitigation measures or improving the reliability of existing measures. As reported from [20] in their study at large car parks where installation of smoke and heat control (SHC) system could reduce the temperature thus slower the fire spread from initially burning cars to neighbouring cars. Nevertheless, the former approaches are also helpful in reducing the consequences of the events.

7. CONCLUSIONS

In fire safety engineering, fire risk analysis is generally used to evaluate fire protection strategies and potential outcomes from fire events towards safety, property loss and environment. In Malaysia, fire risk assessment is totally new and appropriate measures should be taken to introduce this into current legislation. It may not critical to apply to low rise building, but high-rise building such as hotels, shopping complex, residential building such as apartments, condominium and others is needed. This review article is proposed to assist the fire risk analysis process with selected tools used widely in other countries. This full quantitative fire risk analysis can be modified in line with proposed changes in objective and the predicted level of fire risk evaluated. More importantly, the risk assessment procedure is used to help fire engineers and architecture on the enhanced measures at the design phase, while assist the owner and stakeholder to manage their building and facilities in a right way.

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