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Fire Risk Analysis using Scenario Clusters in a Maritime University

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Abstract: Fire hazards and situations that may cause firesare better understood when risk analysis can be carried out to quantify the probabilities of fire occurring. The objective of this paper is to analyze and evaluate the fire safety measures in a maritime university to determine whether appropriate measures, polices and fire management systems are being put in place.A scenario cluster approach is designed as a preliminary study for advanced risk analysis where data are gathered using questionnaires, interviews and inspection of targeted buildings in the university community. Findings from an illustrative example reveals the state of fire safety of the university community thereby providing available information for effective decision making process in line with the fire safety management system put in place.

Keywords: Fire management system, fire risk analysis, & fire scenario clusters

I. INTRODUCTION

Fire is a rapid, self-sustaining oxidation process accompanied by the evolution of heat and light in varying intensities [1]. The most common fuels that causes fires are flammable gases used for cooking, furniture, clothing, and solvents used in our daily activities (kerosene, gasoline, and combustible dusts) [1]. Fire, one of the several disasters, is a major threat to life and property in every society and affects the physical and social phenomenon in a typical maritime university community [2, 3].The causes of fire are categorized into domestic, industrial, vehicular, institutional, electrical, commercial, bush, etc., and these fires accounts for 41% of the total number of incidents in most developing countries [4, 5]. From 1993-2015, a total of 86.4 million fire incidents have caused more than one million fire deaths, and total annual loss from global fire hazard accounts for about 1 per cent of the world GDP (approximately US$857.9bn [GDP]) [6,7].On an average, 3.8 million fires caused 44,300 fire deaths every year in both developed and developing countries across the globe [6].In developing countries like Ghana, fire incidents have become a regular occurrence, with thousands of lives and millions of dollars lost every year causing panic in communities thereby generating discussions relating to politics, sabotage, misfortune, etc. [5]. The Ghana national fire service recorded 5531 fire outbreaks in 2018, compared with a total of 4544 fire outbreaks in 2017, amounting to a cost of property damage of GHC28.87million and GHC36.28million in 2018 and 2017 respectively [8].Fire safety management is fundamental in every society or organization and involves both a risk assessment and risk treatment stage [7]. Fire risk assessment in buildings comprises of three steps i.e. fire risk identification, fire risk analysis, and fire risk evaluation [8]. Fire risk identification is the systematic process to understand how, when, and why a fire could happen [9, 10].Traditional fire prevention approaches have been used in societies and maritime university communities in responding to fire threats such as putting in place a fire department intervention, insurance, building regulations, fire hazards education, and controls on the use of materials and products in buildings [11, 12]. Major challenges in the use of traditional approaches in a developing nations are poor performance, functional reliability, and high cost of fire control installations [7]. Another approach used in fire management system in a maritime university community is a prescriptive approach of ensuring fire safety is well integrated with the actual building design process with the main goal of obtaining fire safety regulatory bodies approval [7]. Unlike current fire safety improvement strategies, which focus only on improving fire protection features in buildings (i.e. managing impact of fire hazard), the fire scenario cluster approach provides a framework for university community to access both its preventive and management of fire hazard [11]. In this paper, fire scenario clusters are used to perform fire risk analysis in a typical maritime university community with an overall objective of recommending appropriate fire safety measures for decision making and safety management planning.

II. LITERATURE REVIEW

Several studies have been conducted by researchers around the world to find out the causes of fire outbreaks. Fire risk assessment has been developed in identifying geographic information system technologies where forest fires plays a vital role in landscape transformation [13, 14]. Research on integrating geospatial information into fire risk assessment has also been carried out with the main aim of identifying the most relevant components associated with fire occurrence [15]. In 2008, researchers further carried out an estimation of fuel

moisture content from satellite images in the context of risk assessment [16]. Also, performance base risk assessment in buildings have played an integral role in understanding traditional prescriptive fire risk assessment methods in line with object-oriented simulation using zone model [17, 18]. Researchers further modeled human behavior within a fire risk assessment using Monte-Carlo model highlighting the need for fire risk analysis [19].Other domains in which fire risk assessment has been applied include in field management, commercial buildings, monitoring vegetable biomass, and under coal development [20, 21, 22, 23, &24]. The U.S. fire administration reported a total of 371,500 fire outbreaks in 2017 resulting in 2,695 deaths, 10,825 injuries, and $7,797,000,000 dollar loss [25].

The occurrences of fire outbreaks may include the following; carelessness, violation of standard codes of building, lack of knowledge on safety measures, and inadequate training [4]. Another leading cause of fire outbreak based on statistics from United States fire administration (USFA) in residential and non-residential buildings is cooking [26]. From the survey conducted by USFA, it was found out that an average of 188,800 cooking fires were registered in residential buildings and these fires resulted in an estimated annual average of 195 deaths, 3,800 injuries and $463 million in property loss from 2014 to 2016. In Ghana, it was found out that the mortality rate increased as a result of fire incidents from 2007 to 2013 where 379 people were recorded dead in 5489 fire incidents across Ghana for the year 2013 with a property loss worth more than GHC25 million [27].Several sources of fire in buildings could be direct or indirect which contribute to fire hazard; and in the event of a fire, there is a significant risk to life, structure, property, and environment from the initial development stages of fire itself [28, 7]. Although fire is one of the major disasters registered around the world, through proper and effective management, fire can be prevented or minimized.Fire safety management used in the reduction of potential fire harm and damage to properties has been subject of research as organizations seek ways of implementing best fit approaches [29, 30]. Fire safety includes the prevention of fire, flames and smoke from spreading and the understanding of how to improve the chances of a successful fire evacuation [31].

The main objective of fire safety, is to control and prevent ignition of fire from ignition sources such as building materials and contents [32]. Another objective of fire safety, is to control the development of fire which involves fire detection through the use of fire detectors (heat, smoke, and flame), control combustion,and limiting the rate of fire development and spread of fire [32].One of the critical causes of ineffective fire management is the lack of no specified policies on fire management [29]. As such, there is a need for specific fire management policies to ensure that life and properties are not affected by fire in a maritime university community. Fire policies are made to create fire awareness to occupants and users of a building to avoid mistakes that could cause a fire [33]. In risk management, it is important to first identify fire hazards, or risk factors, and their likelihood of occurrence [34, 35]. Risk management process involves two major parts, which are, risk assessment and risk treatment [35]. The risk treatment refers to the systematic process of improving existing risk control measures, the development of new risk control measures and the implementation of these measures to reduce fire risk [2]. Fire risk analysis enables fire risk management measures to be taken to improve the level of fire safety of buildings and also reduce the fire risk and subsequent damages [36].

There are numerous available techniques or models in literature used in fire risk analysis. A well-known approach used in studying events that can result in severe damage is the use of scenarios clusters which creates explicit relationships among events [37]. Scenario-based fire risk analysis refers to a specific environment, an already existing building or a design building, whose fire-induced consequences are the final output of the analysis in terms of severity/outcome measure [37]. The term scenario-based risk analysis predicts whether or not a set of events is bound to occur and also describes future events by setting up events that have a possibility of occurring using the present conditions [37]. Fire scenario starts before ignition and takes into account, the status of people and properties before fire ignition. Table 1 shows a column representing the time of a scenario – before ignition – while the five rows reflect the relevant particulars in a fire – for property (active vs. passive fire protection, where the latter includes potential fuels) – and effects of fire that affects the properties (i.e., smoke, toxicity, and odour) [37]. In this study, the scenario based fire risk analysis, identifies the consequences of fire in the community buildings by using a strategic step by step approach, highlighting all the building elements and the damaged heat induced failures that can trigger a greater fire impact. Furthermore, ranking these consequences as catastrophic, marginal or negligible, helps the identification of critical areas. The time of scenario before ignition looks at all possible fire protection system and the combustibility of the buildings, including the building layout, type of construction, and fire detector alarms. Stakeholder involvement is very critical at this stage, as most buildings in the university campus are old and the need for re-enforcement in line with safety standards is dependent on the input knowledge from fire building experts. The behavioral scenario, gives the university community an opportunity to train and model the behavior of students, staffs and visitors in case of any fire incident. This training must be in accordance with the fire management policy system in place. The maritime university trains sea going cadets on basic fire-fighting skills, and modeling this behavior

in the university campus remains crucial for students to develop deeper understanding onvarious fire scenario clusters.

Table 1: Typical fire scenario cluster analysis [37]

		Pre-ignition status	Fire situation		
			Ignition	Post-ignition status	Consequences
Property	Fire safety and protection systems	Detectors alarm Smoke control automatic extinguishing system	N/a	Activation Success/failure	Fire/heat induced Building element
	Building equipment combustible and other contents	Location/layout property use size/height Type of Construction Fire resistance	Item/material first Ignited Equipment involved Deficiency/failure	Combustion Heat transfer Thermal deformation Loss of stiffness Collapse	Damage heat/smoke/odour induced equipment/product

III. RESEARCH METHODOLOGY

Risk assessment entails defining hazards present in any situation in any premises and then determining the magnitude of the risks involved, taking into account any precautions already taken. The purpose of this section is to carry out a fire risk assessment based on scenario clusters by identifying fire hazards, identifying people at risk, assigning the risk category, commenting on existing fire safety systems and recording the findings. Fig. 1 shows a diagrammatic view of the scenario cluster based on fire protection adopted for this study. Scenario clusters designed in this study, are based on identified fire prevention and protection scenarios followed by a pattern from one stage to another to make the analysis easier.

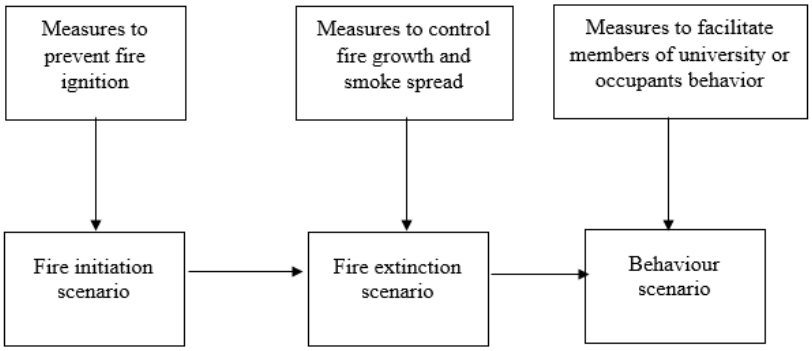

Fig. 1: Scenario cluster based on fire protection and prevention

The first phase is the fire initiation scenario which looked at steps put in place to minimize or avoid the university community of a fire, such as, the use of electrical insulation, proper fire trenches around target buildings, proper layouts and good housekeeping in the various infrastructures. Identifying risks, ensures that fuel products or highly flammable chemicals are readily detected. The second phase, is the fire automatic extinguish scenario which looked at measures put in place to control fire growth and smoke spread after fire initiation. Systems to minimize the fire spread may include, sound alarms and fire control mechanisms (smoke & heat detectors, sprinklers, sensitive electric breakers etc.). Lastly, a behavior scenario was developed that looked at the magnitude of the danger and addressed the actions of the population that could be impacted i.e., the number of people that could be exposed and the implications needed to define the general fire measures needed. Questionnaires and interviews were used for collecting data from respondents and inspections were used for collecting data on selected buildings. Questionnaire was administered online through Google forms. A checklist was formed to enable easy and efficient inspection in order to determine if the existing fire safety measures are adequate enough or in need of any improvements. The checklist consisted of the inspection of fire

alarms, fire reel systems, fire extinguishers, escape route length, protection of escape route, inspection of adequate fire signs and emergency lighting systems.

IV. ILLUSTRATIVE EXAMPLE

Inspections on fire safety policies, fire safety management and fire - fighting equipment were carried out on all buildings in the university community. By law, LI 1724, 2003 and LI 2249, 2016, a fire precaution (premises) regulations makes it mandatory for certain buildings to have fire certifications to meet the fire safety standards [38]. Inspections were focused on fire detection mechanisms, combustion control, ignition prevention and evacuation control. Inspections reveals that, the newly constructed buildings in the university campus are installed with fire alarms whilst the old buildings lack fire alarms. The combustible checklist showed the availability of fire extinguishers and fire hose reels throughout the university campus with fire extinguishers fitted in all buildings (located both inside and outside the buildings). Fire extinguishers were certified, and in good conditions (located in accessible places), whilst a good amount fire hoses and nozzles were in good conditions, with clear access. Also, the university community has good access roads to all the buildings to facilitate easy movement of people and fire service team during a fire outbreak. Again, electrical switch breakers and panels were located at accessible places within the buildings with exist signs well indicated. Furthermore, fire action posters were located around buildings to educate occupants in case of fire outbreaks. Assembly points were identified and located at acceptable distances from all buildings within the university community. The university has a fire safety policy in place and according to this policy, fire drills are conducted three to four times a semester including training during fire drills and education on fire evacuation plans.

In line with the fire scenario cluster developed for this study, and the inspections carried out, further data collected from the field were analyzed to determine the behavior of university community in case of a fire. A number of 52 respondents were received with age distribution as 22.9% representing 16 respondents within the age below 20, 64.3% representing 45 respondents within 21-30 age group, 10% representing 7 respondents within 31-40 age group, 1.4% representing 1 respondent within 41-50 and 1 representing 1.4% from age 51 and above age group. The educational background of respondents are as follows; 5.7% represents 4 respondents with basic education, 32.9% represents 23 respondents with secondary level, 60% represents 42 respondents with tertiary level and 8.6% represents 6 respondents with post first degree, 2.8% represents 2 respondents with other educational background which includes PhD and MSc. A total of 62 respondents listed examples of the causes of fire outbreaks such as faulty electrical wires, fault from electrical appliances and electrical systems, carrying out hot work near flammable materials, carelessness and ignorance, gas leakages and poor housekeeping. The key findings in this study reveals that, 34 respondents which represents 48.6% indicated the lack of adequate training on fire safety, with another 72 % indicating lack of awareness on the procedures when a fire alarm is sounded.

V. CONCLUSION

A maritime university trains students on fire - fighting skills necessary to work on board ships and this training needs to be part of the students' educational life on campus. In terms of fire safety management policies, the university management plays a major role in ensuring that all premises are equipped with fire safety equipment especially fire extinguishers. Although fire extinguishers are provided throughout identified buildings on campus, there is a lack of fire drills and general awareness among the university community on the causes of fire, fire drills &fire training. It is also important to improve on the fire detection mechanisms within the university campus in case of any fire emergencies. Scenario clusters developed in this study created targeted areas forfire risk analysis by providing a step by step methodology on identifying the level of fire safety in the university. The inspections and interviews conducted indicates that, the fire safety policies presently in place should be updated to meet the increase in the university population. The following recommendations are provided; (1) freshmen and women should be given special fire drills, (2) fire alarms should be installed in old buildings, and (3) voltage regulator be installed in all air conditioning units.

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