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Analyzing the Risk of Fire in a Hospital Complex by "Fire Risk Assessment Method for Engineering"(FRAME)

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ABSTRACT

Aims The occurrence of fire in residential buildings, commercial complexes and large and small industries cause physical, environmental and financial damages to many different communities. Fire safety in hospitals is sensitive and it is believed that the society takes the responsibility to care sick people. The goal of this study was to use Fire Risk Assessment Method for Engineering (FRAME) in a hospital complex environment and assess the level of fire risks.
Materials & Methods This descriptive study was conducted in Kashan Shahid Beheshti hospital in 2013. The FRAME is designed based on the empirical and scientific knowledge and experiment and have acceptable reliability for assessing the building fire risk. Excel software was used to calculate the risk level and finally fire risk (R) was calculated separately for different units.
Findings Calculated Rs were less than 1for health, autoclave, office of nursing and infection control units. R1s were greater than 1 for all units. R2s were less than 1 for office of nursing and infection control units.
Conclusion FRAME is an acceptable tool for assessing the risk of fire in buildings and the fire risk is high in Shahid Beheshti Hospital Complex of Kashan and damages can be intolerable in the case of fire.

Keywords Fires; Fire Extinguishing Systems; Risk Assessment; Hospitals; Risk Reduction Behavior

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Introduction

Rapid oxidation process at high temperatures with heated gas products and emission of visible and non-visible radiation is called fire [1, 2]. The occurrence of fire in residential buildings, commercial complexes and large and small industries cause physical, environmental and financial damages to many different communities. According to reports, half of the deaths caused by fire occur in buildings. In Australia, the annual number of deaths due to building fires is 4 people per one million. This amount is 15 per million in UK and 20 per million in US. For countries that are similar to Australia in terms of technology, the direct and indirect damaged caused by fire in buildings is 0.72% of total Gross Domestic Product (about 200 million dollars) [3]. More hazard of fire in buildings show the minimum safety aspects of fire fighting systems and is mainly due to low benefits of providing maximum safety [4]. In general, there are three main methods of fire safety design in buildings including Standard Method, Fire Safety Engineering Design Methods and Escape from danger-risk-based design methodology [5, 6].

Johnson *et al.* approve the need for the audit method based on risk assessment as a tool for selection of fire safety engineering methods. They also approve the selected choice for safety with the use of risk assessment in a cost-effectiveness case study [7]. Chu *et al.* offer a framework for decision making based on different methods of fire safety risk assessment for individuals and use the fault tree analysis method to assess the risk of fire [8]. National Society of Canada (NRC) has prepared a computer model of risk assessment and cost of the fire. This model can assess the expected risk of fire and the protection costs and damages resulting from a fire in buildings [9].

In industry, different studies have used different methods for assessment of the fire risk [2, 10-12] Wei *et al.*applied semi-quantitative technique of LOPA (Layer of Protection Analysis) at hydroxylamine production unit to estimate the chemical reactive risks, determining the probability of failures and the severity of consequences of scenarios [13].

In 2014, Parvini *et al.* assessed the fire and explosion risk at Azad-Shahr CNG refueling station by using Quantitative Risk Assessment (QRA) method. Their obtained results provided useful points and recommendations like the minimum safe distance from rupture center depending on such outcomes as overpressure, types of fire, or toxic release [14].

Fire Risk Assessment Method for Engineering (FRAME) is one of the most comprehensive, practical and transparent computational methods to assess the risk of fire in buildings. The main advantage of this method is that it calculates the risk of fire for three different modes; buildings and their contents (R), individuals (R1) and indoor activities (R2). To calculate the risk, three parameters are calculated; potential risk (P), the level of risk acceptance (A) and the level of protection (D). In this method, the result of the calculation of fire risk (R) is obtained as a number without unit (R=P/A*D)). Since the safety is relative, this number will always be greater than zero [15].

Today, fire safety is one of the great challenges facing designers and users of the health sector. Knowledge deficit, lack of exercise and excessive fixed equipment to patients make the importance of fire safety in accidents more obvious [16]. Fire safety in hospitals is so sensitive, morally and legally because many hospitals are controlled by national laws and regulations and it is believed that the society takes the responsibility to care sick people. For this reason, if patients or employees are harmed by the external factors such as fire, this will have a direct reflection on the management quality of the health care system [17].

Zarei *et al.* have evaluated the fire and explosion risk for a hydrogen production industry and have revealed that jet fire caused by a full bore rupture in desulphurization reactor has the highest fatality (26 people). A full bore rupture in reformer unit can lead to the most dangerous flash fire. So that people at distance up 130m from placing leakage and affected area 1505m^2 were exposed to concentration of 61120ppm and all people would be killed. The most dangerous vapor cloud explosion caused by hydrogen purification absorbers, so that distances up to 60m from absorbers location all people would be killed and all equipment and buildings will be completely destroyed [18]. Golmohamadi *et al.* have evaluated the fire risk for a chemical industry in which mean value of risk in units is 115.45 and research and development (R & D) and sparse part store units have the highest and lowest risk values, respectively [19]

Mahdinia *et al.* have evaluated the fire risk for activities, buildings and individuals in 12 sections of a hospital in Qom, Iran, and have reported the fire risk levels unacceptable in all sections, so minimum acceptable safety level have not provided. The fire risk level could be reduced if there were a perfect relief and rescue plan in the hospital [20].

The building area and number of patients in Hospital Complexes are high and in the case of fire may lead to irreparable damages. The goal of this study was to use FRAME in a hospital complex environment and assess the level of fire risks.

Materials & Methods

This descriptive study was conducted in Kashan Shahid Beheshti hospital in 2013 and all (39 units) of it was studied using FRAME.

The FRAME is designed based on the empirical and scientific knowledge and experiment and have acceptable reliability for assessing the building fire risk [15]. There are two modes for making decision about risk; if R≤1, this means that the protective measures and the level of risk acceptance level is equal to or greater than the potential risks and the level of risk is acceptable. In other words, the studied environment is satisfactory in terms of the fire safety. If R>1, it represents that the potential risk is at a higher level of the product of protection level and acceptance level and the conducted safety measures are not adequate [15, 16]. Data was collected by referring to the study units and using evaluation method checklist. The checklist consists of 55 questions in different aspects such as building position, length, width, and area units, number of people, number of exiting road, number of trained personnel in firefighting, firefighting systems types, firefighting materials and etc. [15]. The data collected regarding to the type via observation, interview with relevant persons or authorities or referring to the documents.

Due to the multiplicity and complexity of the relationships used in the risk assessment and lengthy calculations, Excel software was used to calculate the risk level and finally fire risk (R) was calculated separately for different units. Then by comparing R and the other factors, the safety status of the building has been determined in relation to the risk of fire according to acceptable level [15, 16].

Figure 1) Level of the risk of fire for the building (R), individuals (R1) and activities (R2) in Shahid Beheshti Hospital Complex of Kashan, Iran using FRAME

Row	Unit	R	R1	R2
1	CCU1	14.028	52.364	6.186
2	CCU2	7.603	22.797	10.767
3	CSR	6.147	53.180	15.671
4	ICU1	3.290	14.851	4.284
5	ICU2	2.465	8.519	3.564
6	ICU3	3.616	22.205	4.394
7	ICU OH	7.026	13.556	9.314
8	Operating Room	3.020	31.809	5.364
9	autoclave	0.735	2.266	4.183
10	Laboratory	4.552	7.089	6.421
11	Kitchen	2.774	10.573	35.772
12	Pediatrics	38.232	74.481	21.831
13	Central Warehouse	2.127	5.026	5.347
14	Endoscopy	1.205	2.256	2.565
15	Angiography	1.205	4.940	2.792
16	Emergency Trauma	2.044	4.529	2.510
17	internal Emergency	3.694	5.658	21.486
18	Hygiene	0.788	3.985	1.062
19	Pavilion	1.362	3.614	1.890
20	Before Surgery & Post Cat	2.441	4.394	3.054
21	Surgery For Men1	5.816	31.292	7.070
22	Surgery For Men2	6.367	57.406	7.254
23	Surgery For Men3	7.855	33.446	6.814
24	Outpatient & Hospitalization Pharmacy	1.513	5.577	6.633
25	Clinic 1&2	3.423	6.281	2.936
26	Nursing Office	0.670	2.369	0.835
27	Dialysis	1.129	4.746	3.012
28	Radiology	2.485	2.298	7.550
29	Chemotherapy	1.093	2.760	2.894
30	Medical1	2.394	6.075	10.907
31	Medical2	5.691	14.524	15.769
32	Medical3	1.736	4.786	2.430
33	Medical4	2.487	7.864	4.160
34	Infectious Ward	2.335	7.451	4.006
35	Shop	1.426	5.777	1.921
36	Library	1.621	5.387	2.580
37	Infection Control	0.351	2.906	0.387
38	Neurology	3.129	13.91	4.912
39	Trauma Research Center	1.025	2.570	1.357

Findings

Shahid Beheshti Hospital was about 40,000m^2 and had 4 floors plus a basement, ground floor and 39 separated apartments with 475 beds. The Hospital Complex had old concrete and brick structures in the most sectors and it seemed that the safety principles and related facilities were not predicted and made at the construction time. The only available protection systems were fire capsules, powder and gas in all sectors under study and this equipment were enough in the most sectors, but there was no fire box and fire hose in the units. Except the Cardiac Intensive Care Unit and operating room sectors, there were no fire detection and alarm systems. The hospital was not connected automatically to any fire station for firefighting.

The lowest risk potential of buildings belonged to infection control sector and the most to angiography sector. The lowest level of risk acceptance of buildings was in the pediatric sector. Fire risk is unacceptable for building in most units (R1>1). Endoscopy unit showed the lowest risk potential of individuals and the lowest level of risk acceptance was in the "Surgery for Men 2" unit. The risk of activity in 95% of hospital sectors was higher than one and was unacceptable and in 5% of sectors, including infection control and nursing sectors, was less than one and was acceptable (Figure 1).

Discussion

In this study, the hospital was studied with 39 units using FRAME and the fire risk level was calculated separately for buildings, individuals and activities.

The lowest risk potential of buildings belonged to infection control sector which can be due to the low level of infrastructure in the infection control sector, less risky tools in making fire, and the location of this sector on the ground floor of the building. The lowest level of risk acceptance of buildings was in the pediatric sector. The presence of large number of sick children and relatives cause problems when leaving the danger zone. The long infrastructure also is an exacerbating factor. In other sectors, any major differences in the level of risk acceptance were detected due to the lack of any fire alarms. In a similar study by Mahdinia *et al.*, the similar result has been obtained. The maximum acceptable level of risk was in the infection control sector because of the alertness of people in this sector. Checking the values of protection level for buildings indicate that except the angiography sector that has the detection means, the remaining sectors have the minimum level of protection. This issue intensifies due to the lack of firebox [20]. In general, the risk of building and its contents were higher than one in 89% of the studied sectors. Despite the fact that the hospitals are placed in the low-risk environment group in terms of fire load [15, 21], still the building risk is higher than the acceptable area due to lack of considering the safety principles such as the exits, fire box, and the absence of fire alarm system in the most sectors.

The greatest risk potential of individuals was in ICU OH, mainly due to the low probability of access to and exit and high flammability equipment in this sector. Endoscopy showed the lowest potential of risk. The lowest level of risk acceptance is for the "Surgery in Men 2" which is also at the minimum level for the most parts. This is due to relationship between the fire spreading and evacuation time factor and also the unavailability of suitable exits. The level of protection was not much different in other sectors except the angiography and cardiac surgery sectors which have firefighting systems. According to the results obtained in all the sectors, the fire risk for individuals was higher than one and was unacceptable. This was due to the lack of safety principles and the absence of the fire box and fire alarm system. In a similar study by Mehdinia *et al.* in Arabnia Hospital in Qom, the similar result has been obtained and the risk level for individuals was more than one [20].

Fire risk for most units was unacceptable in the hospital. In a study by Jafari *et al.* in hydrogen manufacturing industry, fire risk for all units was unacceptable [22]. Also, based on the Jafari *et al.* findings in a hydrogen manufacturing industry, the fire risk is unacceptable and damages will be sever [23].

To reduce the risk associated with the activity, an acceptable level can be achieved with a better plan on emergency and resumption of activity in these conditions. Pourreza *et al.* reported the failure of protection and safety in laboratory and radiology sectors of Guilan University of Medical Sciences Hospitals due to the issues such as the lack of emergency exit ways, alarm systems, firefighting systems and personnel training [24].

Of limitations of this study was that the role of installing the controlling tools and systems in decreasing fire risk has not been studied. It is suggested that future studies investigate the role of corrective actions such as installing the fire detection and fighting systems in reducing the risk of fire in hospitals or other buildings.

Conclusion

FRAME is an acceptable tool for assessing the risk of fire in buildings and the fire risk is high in Shahid Beheshti Hospital Complex of Kashan and damages can be intolerable in the case of fire.

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