International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

ANALYSIS OF FACTORS AFFECTING FIRE SAFETY MANAGEMENT OF RESIDENTIAL BUILDING: A CASE STUDY

Chirag Gautami[1], Dr. Mayuri Prajapati[2], Ronak Khurana[3]

[1]ME Scholar, Department of Civil Engineering, SNPIT & RC Umrakh, Gujarat, India
[2]Assistant Professor, Department of Civil Engineering, SNPIT & RC Umrakh, Gujarat, India
[3] Assistant Professor, Department of Civil Engineering, SNPIT & RC Umrakh, Gujarat, India

---

Abstract - *The present study develops an approach to integrate fire safety assessment and decision making using the important index (IMPI) and analytical hierarchy process (AHP) method. Methods used includes; physical observations, document review and questionnaire interviews. The study finding shows at solving fire protection measures of high-rise residential building and provide some practical value, assessment of fire safety and establishment of precautionary emergency program. The approach can be used to help to reduce the probability of fire occurrence and severity of possible consequences during the fire hazard. The investigation provides the application of Delphi method for determining the 32 factors causes of fire and 25 factors fire protection measures ranking by important index (IMPI) method for causes of fire along with analytical hierarchy process (AHP) for fire protection measures. Overall results show top 10 cause of fire along with fire protection measures of high-rise residential building which are useful to understand for precautions of fire scenario.*

Key Words: **Fire Safety Management, Residential building, high-rise building, Causes of fire, Fire Protection Measures, Multi-criteria Decision Making (MCDM)**

1. INTRODUCTION

Fire safety is one of the most significant concerns in the due to its vital role for the survival of human beings and protection of properties. With the development of urban economy, high-rise buildings and super high-rise buildings become more erection because of high population density and land price. Nowadays in our country high-rise buildings develop into the direction of modernization, maximization and multi-functions, so it becomes more difficult to put out fires from outside and defecate than one that takes place in ordinary constructions considering the high floors, complex functions and miscellaneous devices. Certain it tends to cause great economical loss and personnel casualty accidents easily.

The fireproof of high-rise building is still a worldwide difficult problem. Consequently, it is of paramount significance to understand the characteristics of combustible materials, causes of fire, and high-risk areas to ignition in residential facilities. This study has two objectives. The first is to identify the causes of fire in high-rise residential building and requirements for providing the minimum level of safety, hence, mitigate the risk of fire occurrence. The second objective is to conduct a case study to demonstrate the compliance level of a sample residential facility with their applicable fire safety protection measures requirements.

2. OBJECTIVE

a. To find out the main factors causes of fire in high-rise residential building.
b. To identify the fire safety protection measures in high-rise residential building.
c. To develop fire safety index and fire safety establishment.

3. SOURCES OF CAUSES OF FIRE AND FIRE PROTECTION MEASURES IN RESIDENTIAL BUILDING

For identify the factors responsible for fire safety management, a literature review is conducted in which several work of the researchers has been examining and the critical factors are taken which was common in most of the research papers. Further, the selected factors are again classified with in their applicable or desired categories.

Total 37 numbers of factors of causes of fire and 38 numbers of factors of fire protection measures are identified by literature study and these factors are classified into six and five categories respectively.

4. RESEARCH METHODOLOGY

For achieving aim of this paper, three approaches are used; first one is Delphi method which is used to identify most appropriate factors affecting fire safety management which includes causes of fire and fire protection measures of residential buildings respectively; second method important index (IMPI) method which is used to find out the relative importance of causes of fire in residential building; third method analytical hierarchy method which is used to

calculate the relative importance of the main group and co-factor under each group.

4.1 Delphi Method

The Delphi technique was originally proposed based on people's conjecture, judgment, and inspiration but gradually took the academic form. A questionnaire survey was designed and analysis performed using the Delphi method. The Delphi process generally consists of three rounds of survey questionnaires. In the first round, experts respond to a broad question, while each additional round builds upon the responses collected from previous rounds. The process is terminated when consensus is reached.

To emphasize greater field experience, at least 5 years of professional experience in the building construction industry was kept as one of the criteria for the selection of experts. Based on existing literature reviews and interviews with 12 experts in the first round of the survey under the Delphi process, six major attributes and their sub attributes were selected. In the second round of the survey, the findings of the first round of interviews were presented to the experts. Experts were asked to evaluate the importance of the attributes on a seven-point scale.

4.2 Important Index (IMPI) Method

In this technique, for each cause/factor two questions should be asked: What is the frequency of occurrence for this cause? And what is the degree of severity of this cause? Both frequency of occurrence and severity were categorized on a four-point scale. Frequency of occurrence is categorized as follows: always, often, sometimes and rarely (on 4 to 1-point scale). Similarly, degree of severity was categorized as follows: extreme, great, moderate and little (on 4 to l point scale).

Frequency index: A formula is used to rank causes of delay based on frequency of occurrence as identified by the participants.

Frequency Index (F.I.) (%) = $\sum$ a (n/N) * 100/4

Where, a is the constant expressing weighting given to each response (ranges from 1 for rarely up to 4 for always), n is the frequency of the responses, and N is total number of responses.

Severity index: A formula is used to rank causes of delay based on severity as indicated by the participants.

Severity Index (S.I.)(%)= $\sum$ a (n/N) * 100/4

Where a is the constant expressing weighting given to each response (ranges from I for little up to 4 for severe), n is the frequency of the responses, and N is total number of responses.

Importance index: The importance index of each cause is calculated as a function of both frequency and severity indices, as follows:

Importance Index (IMP.I.)(%) = [F.I.(%)* S.I. (%)]/100

4.3 Analytical Hierarchy Process (AHP) Method

The AHP is a theory of measurement through pair-wise comparisons and relies on the judgements of experts to derive priority scales (Saaty, 2008). AHP develops priorities among all the criteria and sub-criteria within each level of the hierarchy. Accordingly, AHP method received considerable attention among decision makers and has demonstrated its applicability in different fields, such as maintenance policy selection.

Responses received from respondents are analyzed using AHP. All the respondents have provided their input of pairwise comparison of criteria measured in Satty's scale on 1-3-5-7-9. Responses of each respondent, for criteria and sub-criteria, are entered into a matrix, thus nine matrices for each respondent is prepared (one for main criteria and eight for sub- criteria). The geometric mean of all thirty respondents for each category i.e main criteria and sub-criteria is calculated and one master sheet having one matrix for main criteria and eight matrices for sub-criteria is prepared. This matrix is solved using steps 1 to 8 mentioned in the following paragraph.

5. DATA ANALYSIS

5.1 Data Analysis by Delphi Method

By using Delphi technique, there are 32 factors causes of fire and 25 factors fire protection measures of residential building identified as show in table 5.1 and table 5.2 respectively.

Table -5.1: Lists of Factors Causes of Fire in Residential Building analyzed by Delphi method

Sr. No.	Group	Factors
1.	Causes of fire due to equipment (Cooking, Heating & Electrical)	Gas splitter
		Flammable oils and grease
		Cooker & Pots or pan over hotness
		Chimney
		Fire place smoke channel
		Heater
		Heating appliances
		Air conditioner
		Lamb-bulb
		Microwave-oven
		Fridge-freezer

2.	Human Error	Bad house keeping
		Electrical installation deficiency
		Heat producing equipment on
		Plugging too many things in same extension cord
		Device interruption
		Careless smoking and throwing cigarette buds
3.	Flammable liquid	Fuels
		Thinner
		Adhesives
		Paints and other raw materials
		Lighting candle on flammable material
4.	Electrical and lighting	Old/ defective wiring
		Overload circuits
		Loose connections
		Faulty fuses
		Imbalance electrical loads
5.	Cease/ expired fire safety system	Poor inspection
		Less hydrant system equipment (sprinkler & extinguisher)
		Not properly assign instruction of sign board and equipment
6.	Inadequate design	Mean of egress (escape routes)
		Fire doors/ exit closer

Table -5.2: Lists of Factors Fire Protection Measures in Residential Building analyzed by Delphi method

Sr. No.	Group	Factors
1.	Active protection system	Alarm
		Fire extinguishers
		Siamese connection
		Smoke control, detection & Disposal
		Sprinkler
2.	Fire prevention management building	Inform and maintain of fire evacuation in building
		Detail fire emergency plan
		Coordinates fire drills through building manager
		Arrange fire drills in every 3 months
		Regular inspection & maintenance of hydrant system
3.	Protect fire spread	Fire blanket provide in kitchen
		Verified combustible construction & fire resisting
		appropriate signs of firefighting equipment and emergency telephone
		well managed storage of hazardous substances
		Place extinguisher close to fire hazards to decreased risk
4.	Rescue Facility	Adequate escape routes leads directly as possible to safe place
		Appropriate fire door sign at eye level
		Minimum width of escape corridor >=1.2m
		Ensure door aren't wedged or held open
		Maintain safety escape routes
5.	Fire safety, notice and warning	Maintain necessary sign & notice
		Emergency lights linked to fire alarm system
		Auto dialer device
		Capacity of emergency lighting from 1-3 hrs
		Mean of warning clearly heard

5.2 Data Analysis by Important Index (IMPI) Method

Important index (IMPI) method which is used to find out the relative importance of causes of fire in residential building. The identification of factors is as shown in table 5.3.

Table -5.3: Frequency Analysis by IMPI Techniques for Causes of Fire in Residential Building

Total factor	IMPI Value	Rank
Gas splitter	81.68	1
Flammable oils & grease	35.50	11
Cooker & pots/ pan over hotness	19.16	23
Chimney	7.69	32
Fire place smoke channel	12.61	25
Heater	34.58	12
Heating appliances	51.26	9
Air conditioner	42.12	10
Lamb-bulb	12.61	26
Microwave/ oven	9.65	29

Fridge/ freezer	24.82	17
Bad house keeping	81.61	2
Electrical installation deficiency	60.21	6
Heat producing equipment on	30.51	13
Plugging too many things in same extension cord	25.05	15
Device interruption	22.19	21
Careless smoking & throwing cigarettes	23.85	18
Fuels	23.44	20
Thinner	10.26	28
Adhesives	8.65	31
Paints and other raw materials	11.95	27
Lighting candle on flammable materials	25.02	16
Old/ defective wiring	80.64	3
Overload circuits	54.23	8
Loose connections	25.63	14
Faulty fuses	23.69	19
Imbalanced electrical loads	9.32	30
Poor inspection	21.27	22
Less hydrant system & equipment (sprinkler & extinguisher)	56.45	7
Not properly assign instruction of sign board and equipment	14.89	24
Mean of egress (escape routes)	77.40	4
Fire doors/ exit closer	64.18	5

5.3 Data Analysis by AHP Method

AHP is used to determine the relative importance of the main group and the co-factors corresponding to particular group.

Table -5.4: Prioritize of Main Attributes

Main Attributes	Eigenvalue	Rank	CR Value for Combined Matrix
Active protection system	0.3282	1	0.0984
Fire safety, notice & warning	0.3071	5	
Rescue facility	0.1809	4	
Fire prevention management building	0.1145	2	
Protect spread fire	0.0691	3	

The relative importance and the ranking of the main attributes is shown in Table 5.4.

Table -5.5: Prioritize of Active Protection System

Main Attributes	Eigenvalue	Rank	CR Value for Combined Matrix
Sprinkler	0.2773	5	0.0971
Alarm	0.2662	1	
Siamese Connection	0.2305	3	
Fire extinguisher	0.1426	2	
Smoke Control, Detection & Disposal	0.0832	4	

The relative importance and the ranking of the Active protection system is shown in Table 5.5.

Table -5.6: Prioritize of Fire Prevention Management Building

Main Attributes	Eigenvalue	Rank	CR Value for Combined Matrix
Detail Fire Emergency Plan	0.4465	2	0.0950
Regular Inspection & Maintenance of Fire Damper & Hydrant System	0.2613	5	
Inform & Maintain of Fire Evacuation in Building	0.1494	1	
Coordinates Fire Drills Through Building Manager	0.0731	4	
Fire Awareness Training & Drills	0.0694	3	

The relative importance and the ranking of the fire prevention management building attributes is shown in Table 5.6.

Table -5.7: Prioritize of Protect Fire Spread

Main Attributes	Eigenvalue	Rank	CR Value for Combined Matrix
Place Extinguisher to Fire Hazards to decreased Risk	0.3189	5	0.0589
Verified Combustible Construction & Fire resisting	0.2476	2	
Appropriate Sign of Firefighting Equipment & Emergency Telephone	0.2021	3	

Well Manage Storage of Hazardous Material	0.1834	4	
Fire Blanket Provide in Kitchen	0.0477	1	

The relative importance and the ranking of the protect fire spread attributes is shown in Table 5.7.

Table -5.8: Prioritize of Rescue Facility

Main Attributes	Eigenvalue	Rank	CR Value for Combined Matrix
Adequate escape routes leads directly as possible to safe place	0.3316	1	0.0988
Minimum width of escape corridor >=1.5 m	0.2891	3	
Maintain safety escape routes	0.2199	5	
Appropriate fire door sign at eye level	0.0988	2	
Ensure door aren't wedged or held open	0.0604	4	

The relative importance and the ranking of the rescue facility attributes is shown in Table 5.8.

Table -5.9: Prioritize of Fire Safety, Notice and Warning

Main Attributes	Eigenvalue	Rank	CR Value For Combined Matrix
Mean of warning clearly heard	0.3469	5	0.0647
Auto dialer device	0.2221	3	
Emergency lights linked to fire alarm system	0.1207	2	
Maintain necessary sign & notice	0.0961	1	
Emergency light capacity from 1-3 hrs	0.0267	4	

The relative importance and the ranking of the fire safety, notice and warning attributes is shown in Table 5.9.

In the final stage, the summarized weights of all attributes are obtained by multiplying the weight of the main attributes by the corresponding weight of sub-attributes. Rank is classified into two categories, first is based on the main criteria and the second one is based on the sub-attributes. By attaining sub attributes of any main attributes, significant improvement can be seen in the main criteria, and that leads to enhancement in the overall fire protection measures of fire safety management in residential building Final rankings are as below.

Table -5.10: Final Prioritize of Fire Protection Measures

Sr No	Main Attributes	Sub Attributes	Summarized Weight	Rank
1	Active Protection System	Alarm	0.0140	7
2		Fire Extinguisher	0.0262	16
3		Siamese Connection	0.0162	10
4		Smoke Control, Detection & Disposal	0.0449	20
5		Sprinkler	0.0135	6
6	Fire Prevention Management Building	Inform & Maintain of Fire Evacuation in Building	0.0245	15
7		Detail Fire Emergency Plan	0.0082	1
8		Fire Awareness Training & Drills	0.0526	22
9		Coordinates Fire Drills Through Building Manager	0.0499	21
10		Regular Inspection & Maintenance of Fire Damper & Hydrant System	0.0140	8
11	Protect Spread Fire	Fire Blanket Provide in Kitchen	0.0474	24
12		Verified Combustible Construction & Fire resisting	0.0092	9
13		Appropriate Sign of Firefighting Equipment & Emergency	0.0112	13

		Telephone		
14		Well Manage Storage of Hazardous Material	0.0124	14
15		Place Extinguisher to Fire Hazards to decreased Risk	0.0071	4
16	**Rescue Facility**	Adequate escape routes leads directly as possible to safe place	0.0115	3
17		Appropriate fire door sign at eye level	0.0385	18
18		Minimum width of escape corridor >=1.5 m	0.0131	5
19		Ensure door aren't wedged or held open	0.0629	23
20		Maintain safety escape routes	0.0173	12
21	**Fire Safety, Notice and Warning**	Maintain necessary sign & notice	0.0259	19
22		Emergency lights linked to fire alarm system	0.0206	17
23		Auto dialler device	0.0112	11
24		Emergency light capacity from 1-3 hrs	0.0932	25
25		Mean of warning clearly heard	0.0072	2

6. CONCLUSION

An effectively implemented fire safety management ensures total safety to buildings. Residential facilities are known to be high-risk type of buildings to fire occurrence. Fire safety in residential facilities should be maintained in an appropriate level to safeguard the life of occupants and protect properties. This paper helps to assess the provision of fire protection measures for mitigation the risk of cases of fire. The study concludes with the development of risk analysis checklist and protection measures checklist which includes 32 factors causes of fire and 25 factors fire protection measures which is verified as acceptable or adequate by field survey of firefighters. The specific findings of research study shows that residential building satisfy overall fire safety for this case study.

Moreover, this study mainly focus on most effective measures are impact in high-rise residential buildings which includes the hazardous factors and protection measures. The top 10 factors causes of fire and protection measures which are concluded by analysis are:

Causes of Fire:

i. Gas splitter
ii. Bad housekeeping
iii. Old/ defective wiring
iv. Mean of egress (escape routes)
v. Fire doors/ exit closer
vi. Electrical installation deficiency
vii. Less hydrant system & equipment (sprinkler & extinguisher)
viii. Overload circuits
ix. Heating appliances
x. Air conditioner

Fire Protection Measures:

i. Detail Fire Emergency Plan
ii. Mean of warning clearly heard
iii. Adequate escape routes leads directly as possible to safe place
iv. Place Extinguisher to Fire Hazards to decreased Risk
v. Minimum width of escape corridor >=1.5 m
vi. Sprinkler
vii. Alarm
viii. Regular Inspection & Maintenance of Fire Damper & Hydrant System
ix. Verified Combustible Construction & Fire resisting
x. Siamese Connection

REFERENCES

[1] Hamida, Mohammad B., and Mohammad A. Hassanain. "Fire safety in the built-environment: a case study in a residential facility." Architecture Civil Engineering Environment 12, no. 2 (2019).

[2] Estrada-Lugo, Hector Diego, Marco de Angelis, and Edoardo Patelli. "Probabilistic risk assessment of fire occurrence in residential buildings: Application to the Grenfell Tower." (2019).

[3] Ouache, Rachid, Rajeev Ruparathna, Rehan Sadiq, and Kasun Hewage. "Fire Risk Assessment Model for Residential Buildings Using Bow-tie Method." (2018).

[4] Vidyadharan, Ayush, Joji John, Cherish Thomas, and Bikarama Prasad Yadav. "Fire Safety Management in India: A Review." In Advances in Fire and Process Safety, pp. 171-181. Springer, Singapore, 2018.

[5] Xin, Jing, and Chongfu Huang. "Fire risk analysis of residential buildings based on scenario clusters and its

application in fire risk management." Fire Safety Journal 62 (2013): 72-78.

[6] Liu, Xiuyu, Hao Zhang, and Qingming Zhu. "Factor analysis of high-rise building fires reasons and fire protection measures." Procedia Engineering 45 (2012): 643-648.

[7] Wong, Kelvin Hon-leung, and Da-yong Xie. "Fire safety management strategy of complex developments." Procedia engineering 71 (2014): 410-420.