ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR

CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

A COMPARATIVE STUDY OF FIRE RISK ASSESSMENT AND SAFETY MEASURES IN SOME MULTI-STOREY BUILDINGS OF LAHORE

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Abstract
Many fire incidents happen in multi-storey buildings of Lahore that result in huge life, economic, environmental and infrastructure loss. The study is mainly carried out to undertake a fire risk assessment to determine fire risk and to analyze that into what extend selected multi-storey buildings are at risk. For fire risk assessment and checking the safety measures, surveys are made to four multi- storey buildings namely, Hafeez Center, Ali Tower, Century Tower and Garden Heights. The2se multi-storey buildings are selected because they have already experienced fire incidents. Random sampling technique is use to visually analyze the multi-storey buildings. Analytical Hierarchy Process (AHP) is used for fire risk assessment by prioritizing criteria in form of weights using Saaty Scale (1-9). The relative importance of factors over one factor to another is obtained by comparing the factors with each other. The length of the pairwise matrix is equivalent to the number of criteria used in decision making process. A 6×6 matrix is used having 6 criteria. These 6 criteria are selected by reviewing literature and by brainstorming. From AHP, we conclude that Century Tower is at high risk in comparison to other multi- storey buildings. The result obtained is that the early warning system, fire safety arrangements, area accessibility and building material in Ali Tower contributes equally about 17% of the fire risk, which gives higher risk in case of fire among all the factors. The Awareness of localities and structure of the building contribute 13% of the fire risk.

Keywords: Fire risk assessment, multi-storey buildings, Lahore, fire incidents, life loss, economic loss, infrastructure damage, safety measures, Analytical Hierarchy Process (AHP), building materials.

1. Introduction
Fire is a recognized critical safety issue that is being faced by developing countries including Pakistan. There are number of fire incidents that happen in the multi-storey buildings of Lahore. The number of incidents of fire in Lahore is recorded 18528 from past five years (2016-2020), which has increased in commercial plazas, industrial entities, with we organized

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CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

structural design but lack proper fire safety measures is more vulnerable to fire incident, than those buildings that are built in unplanned area but with proper fire safety measures. It is necessary to highlight the main causes of the fire that result in infrastructure, environmental and severe life loss. Four multi-storey buildings Hafeez Center, Ali Tower, Century Tower and Garden Heights are selected because they have already experienced fire incident. Analytical Hierarchy Process (AHP) is used for fire risk assessment and safety measures, by prioritizing criteria in form of weights using Saaty Scale (1-9). Survey was carried out at these buildings to assess the structure of the building, safety measures, building material used, area accessibility of the building, and fire-fighting equipment. Multi-storey buildings that are selected for research meet all the by-laws of multi-storey building mentioned in Building Codes of Pakistan and also in Lahore Development Authority (LDA) Revised By-laws for multi-storey buildings

2. Material and Methods

The research methodology of this study comprises physical surveys of selected commercial buildings, fill out the questionnaires, and analysis by applying the Analytic Hierarchy Process (AHP) to show individual and aggregate existing problems of the survey buildings. Questionnaire is based on the general information of the respondent and some technical information about the provision of the emergence exit door, stairs, alarms and fire extinguishers, etc. in commercial plazas in accordance with design standards Fire Emergency Services 2020. The sample size of 133 was chosen by researchers to gather information about each multi-storey building. The technique used for sampling was Simple Random Sampling as it is the purest form of probability sampling. The people fill the questionnaire from the selected scale of 1 to 9 where 1 being the lowest and 9 being the highest as we are doing this by Analytical Hierarchy Process. Two questionnaires were designed; one questionnaire was designed to check the prioritization matrix for people's perceptions filled by the researchers. The questionnaire is designed to check the fulfillment of minimum standards required for achieving the fire safety measures that can be used by everyone including persons with disabilities. The second questionnaire was designed to be filled by the respondents with and without disability of the buildings to collect general information from them about the problems they face due to the absence of accessibility standards and to gain information about the existing features available in all facilities like fire safety arrangements, accessibility, and building structure.

AHP helps in the decomposition of the decision-making problem into a hierarchy. In the assessment, comparisons are done pairwise which is used to provide individual evaluation from the set of factors. According to the importance of two elements, they may be equally important, moderately important, strongly important, very important or extremely important, comparison is done accordingly. The importance of elements is expressed in terms of absolute values which are taken on the scale of 1 to 9. A square matrix is developed after assigning values to all the factors from the pairwise comparison. This matrix determines the weights of each factor. These weights vary according to the importance level of the element, causing fire in the multi-storey building. When the solution is normalized into one unique solution, the perception of importance of respective factors which can cause fire risk is obtained. AHP Hierarchy process develops flexible ways of analyzing the risk (Mohammad A. Mustafa, 1991). Fire risk assessment process is described in different steps below:

3. Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a decomposition multiple-attribute decision making (MADM) method. It was developed by Saaty (1990), who proposed a method that can represent human decision-making process and help to achieve better judgments based on hierarchy, pair-wise comparisons, judgment scales, allocation of criteria weights and

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CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

selection of the best alternative from a finite number of variants by calculation of their utility functions (Jiří Franeka, 2014). It stands out from other decision-making techniques as it quantifies criteria and options that traditionally are difficult to measure with hard numbers. AHP helps decision-makers find one that best suits their values and their understanding of the problem. AHP is done in three basic steps:

i. Problem structuring
ii. Priority calculation
iii. Consistency check (optional but recommended)

3.1.Problem Structuring

As the name suggests, in AHP, we use a hierarchy structure to break down the problem. In this research, we use three levels that are, goals at the top then criteria that we select for assessment and finally alternative that shows which multi-storey building is at high, moderate, and low risk. It is dividing and conquer system that is shown in figure 3.3

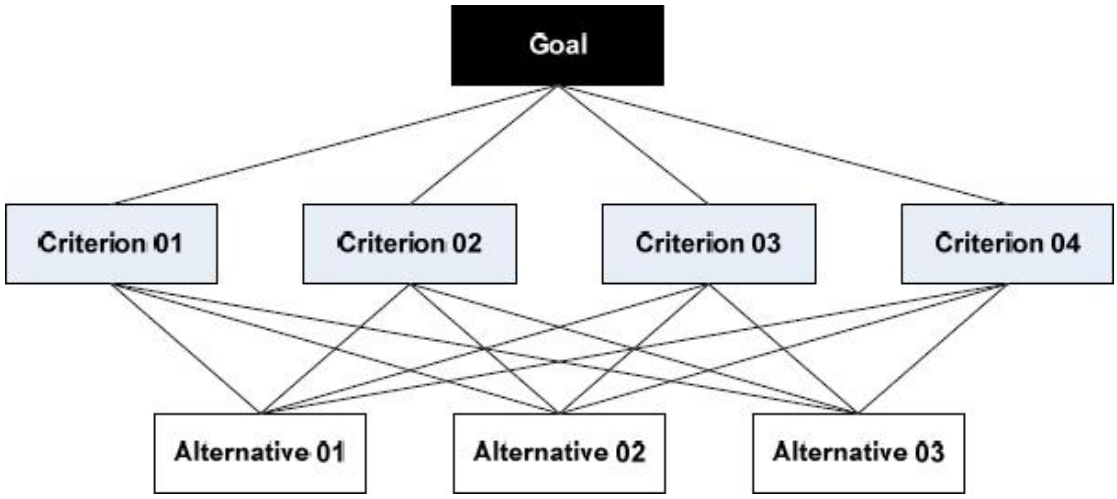
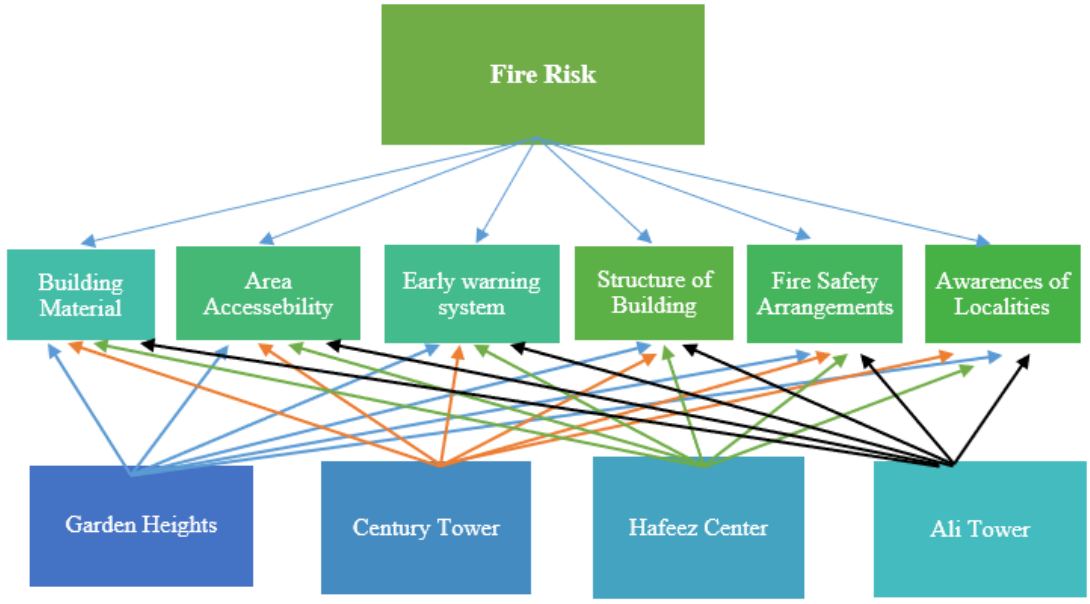


Figure 1. Problem Structuring

(Source: Prepared by Researcher)

Figure 2. AHP hierarchy of Fire risk assessment and Safety Measures



ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

(Source: Prepared by Researcher)

So, it is a tree-like diagram that starts from the root node and we keep on dividing.

3.2. Priority Calculation

Two types of prioritizing calculations are done that area:

1. Criteria priorities
2. Alternative priorities

First, criteria are prioritized with respect to alternatives then all the alternatives are prioritized with one criterion. In this way comparison between different criteria with respect to each alternative is done (shown in table 3.2), similarly, all the alternatives are compared with each criterion (shown in table 3.3). In this way, final criteria are obtaining that mainly causing a fire risk. Also, it concludes with alternative i.e., multi-storey building is at high risk. 4 criteria wise comparison are done in which all the factors such as structure of building, building material, fire safety arrangements, early warning system, area accessibility and awareness of locality are compared. 6 alternative wise comparison are made in which Hafeez Center, Ali Tower, Century Tower and Garden Heights are compared.

3.2.1. Technique for Priority Calculations

3.2.1.1.Pairwise Comparison

It is an easier and more accurate way to do a comparison between only two elements and indicate the importance than by comparing all the elements at once. It is evaluated by using a fundamental Saaty scale of 1-9.

Table 1. Saaty Scale

DEGREE OF IMPORTANCE	DEFINITION
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

(Source: Satty, 1990)

3.2.1.2.Conversion Verbal Scale to Numeric Scale

The questionnaires and responses that we record are converted by assigning the value of the fundamental scale by Saaty. 1 is given for equal importance.

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

3.2.1.3.Comparisons Are Collected in Matrix

All the comparison is done in form of a matrix. Different matrixes are made for both criteria and alternatives. In the comparison matrix, all the comparisons are taken positively. When one criteria or alternative is compared with itself we give a number 1. In the matrix, reciprocals are made, which means, that the upper triangle is the reverse of the lower triangle. The number of necessary comparisons for each comparison matrix is n^2-n/ 2, where n is a number of elements. As the value of n increases the number of comparisons also increases. All the comparisons are done on Excel to calculate the criteria and alternative priorities.

3.3. Consistency Check

This is done to check the inconsistency in the comparison. Inconsistency is the result of human effort. In case when many elements are compared with each other, inconsistency may appear.

Validate and calibrate the evaluation procedure. Validity indicates the procedure measures what it is designed to measure. An evaluation procedure cannot be proven valid. Instead, evidence is collected either to support or refute validity.

When a sufficient amount of data supporting validity is amassed, the procedure is declared to be valid. If evaluation includes a norm or acceptable level, then the procedure must also be measured. Consistency is checked by using the value of lambda max that is obtained by formula:

Consistency index = λ_{max}-n / n-1

Consistency Ratio= consistency index / Random Index

The value of the consistency ratio must be less than or equal to 0.1 if the C.I is greater than 0.1 then there is some inconsistency because of human error.

3.3.1.1.Random Index

Random index is the globally used index table that is used for the consistency check (Rao, 2007) . Consistency ratio is obtained by dividing consistency index with random index. As per the number of criteria use, value is used from random index. For criteria wise consistency check, 1.24 is use because 6 factors are compared with each other. Whereas, for alternative wise comparison, as we compare four alternatives, 0.90 value is use. Radom Index is shown in Table 3.4.

Table 2. Random Index

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.5

(Source: Rao,2007)

Table 3. Criteria Based Pairwise Comparison

PAIRWISE COMPARISON – CRITERIA WISE						
Criteria	**Structure of Building**	**Building Material**	**Early Warning System**	**Area Accessibility**	**Fire Safety Arrangements**	**Awareness of Localities**
Structure of Building	1	-	-	-	-	-
Building Material	-	1	-	-	-	-
Early	-	-	1	-	-	-

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Warning System						
Area Accessibility	-	-	-	1	-	-
Fire Safety Arrangements	-	-	-	-	1	-
Awareness of Localities	-	-	-	-	-	1

(Source: Generated by researcher)

Table 4. Alternative Based Pairwise Comparison

PAIRWISE COMPARISON-ALTERNATIVE WISE				
Alternative	**Hafeez Center**	**Ali Tower**	**Century Tower**	**Garden Heights**
Hafeez Center	1	-	-	-
Ali Tower	-	1	-	-
Century Tower	-	-	1	-
Garden Heights	-	-	-	1

(Source: Generated by researcher)

4. Overview of Case Study Area

For the research, four multi-storey buildings of Lahore area selected as cases study namely:

- Hafeez Center
- Garden Height Plaza
- Ali Tower
- Century Tower

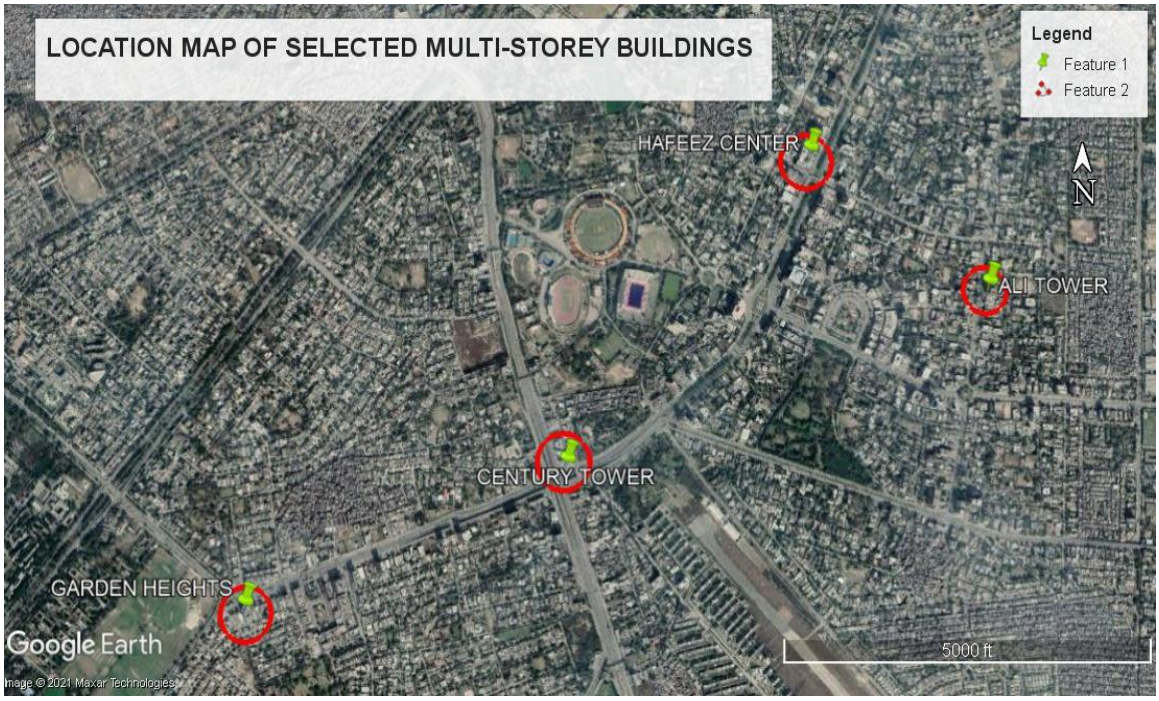
Survey was carried out at these buildings to assess the structure of the building, safety measures, building material used, area accessibility of the building, and fire-fighting equipment. Multi-storey buildings that are selected for research meet all the by-laws of multi-storey building mentioned in Building Codes of Pakistan and also in Lahore Development Authority (LDA) Revised By-laws for multi-storey buildings.

4.1. Location Map of Selected Multi-Storey Buildings of Lahore

Here is the location map of the selected multi-storey buildings of Lahore for research work.

Figure 3. Location Map of Selected Multi-Storey Buildings of Lahore

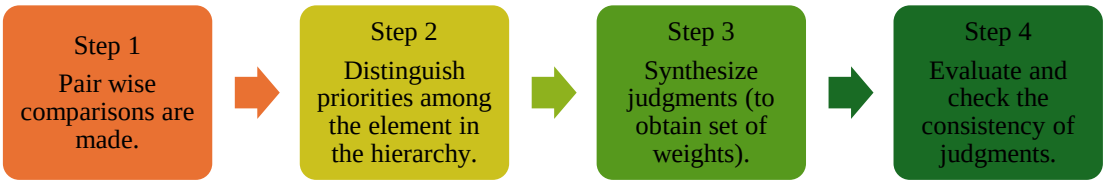
ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)



5. Fire Risk Assessment Calculated By AHP

AHP helps in the decomposition of the decision-making problem into a hierarchy. In the assessment, comparisons are done pairwise which is used to provide individual evaluation from the set of factors. According to the importance of two elements, they may be equally important, moderately important, strongly important, very important or extremely important, comparison is done accordingly. The importance of elements is expressed in terms of absolute values which is taken on the scale of 1 to 9. A square matrix is developed after assigning values to all the factors from the pairwise comparison. This matrix determines the weights of each factor. These weights vary according to the importance level of the element, causing fire in the multi-storey building. When the solution is normalized into one unique solution, the perception of importance of respective factors which can cause fire risk is obtained. AHP Hierarchy process develops flexible ways of analyzing the risk (Mohammad A. Mustafa, 1991). Fire risk assessment process is described in different steps below:

Figure 4. Fire Risk Assessment Process Using Analytical Hierarchy Process (AHP)



(Source: Generated by researcher in 2021)

The factors are compared according to their relative importance which contributes to risk of fire in selected multi-storey buildings.

Table 5. Scale of Relative Importance for Pair Wise Comparison in Fire Risk Assessment

DEGREE OF IMPORTANCE	DEFINITION
1	Equal importance
2	Weak

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

(Source: Saaty, 1990)

Fire Risk Assessment Analysis of Hafeez Center Using AHP Process

5.1.Pair Wise Comparison of Criteria

A priority matrix is developed for the selected criteria's whose absolute values are assigned from the survey conducted and from professional opinions and by using Saaty's Scale. (See Appendix 1). The relative importance of factors over one factor to another is obtained by comparing the factors with each other. The length of the pairwise matrix is equivalent to the number of criteria used in decision making process. A 6×6 matrix is used having 6 criteria. These 6 criteria are selected by reviewing literature and by brainstorming. Each criteria are given an absolute value according to the degree of importance in Saaty's Scale. (See table 2)

Table 6. Pair wise comparison of criteria of Hafeez Center

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities
Structure of Building	1	0.333333	0.2	0.5	0.125	0.1111111
Building Material	3	1	0.2	1	1	0.3333333
Early Warning System	5	5	1	3	1	3
Area Accessibility	2	1	0.33333	1	2	1
Fire Safety Arrangements	8	1	1	0.5	1	0.3333333
Awareness of Localities	9	3	0.33333	1	3	1
SUM	28	11.33333	3.066666	7	8.125	5.7777777

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pairwise Comparison

The matrix is then normalized into weightages which shows the likeliness of the criteria contributes in increasing the fire risk. The weightages of the criteria show which factor is more prone to fire or are vulnerable, which will contribute more in increasing the fire risk.

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Normalized pairwise matrix is calculated by dividing all the elements of the pair wise matrix column by the sum of each column. For example, each element of column (structure of the building) is divided by the sum value of 28. All the 6 criteria columns are normalized according to the example given above.

Table 7. Normalized Pair wise Comparison

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities
Structure of Building	0.0357142	0.0294117	0.0652173	0.0714285	0.0153846	0.0192307
Building Material	0.1071428	0.0882352	0.0652173	0.1428571	0.1230769	0.0576923
Early Warning System	0.1785714	0.4411764	0.3260869	0.4285714	0.1230769	0.5192307
Area Accessibility	0.0714285	0.0882352	0.1086956	0.1428571	0.2461538	0.1730769
Fire Safety Arrangements	0.2857142	0.0882352	0.3260869	0.0714285	0.1230769	0.0576923
Awareness of Localities	0.3214285	0.2647058	0.1086956	0.1428571	0.3692307	0.1730769

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

After gaining Normalized values of each criteria, weights are generated by obtaining the average of each criteria.

Table 9. Weights generated from Normalized Pair wise comparison

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities	Weights
Structure of Building	0.03571	0.02941	0.06521	0.071428	0.015384	0.019230	0.0393
Building Material	0.10714	0.08823	0.06521	0.142857	0.123079	0.057692	0.0973
Early Warning System	0.17857	0.44117	0.32608	0.428571	0.123079	0.519230	0.3361
Area Accessibility	0.07142	0.08823	0.10869	0.142857	0.246153	0.173076	0.1384
Fire Safety Arrangements	0.28571	0.08823	0.32608	0.071428	0.123076	0.057692	0.1587
Awareness of Localities	0.32142	0.26470	0.10869	0.142857	0.369230	0.173076	0.2299

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

SUM OF WEIGHTS	1

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The sum of the weights is 1 which means that the values calculated for the consistency check are accurate.

Consistency Check

By using the Pair wise comparison matrix which is not normalized the consistency of the matrix is checked. Each value of the column is multiplied by the criteria value. For example, the row of structure of the building having a value 1 is multiplied by the weighted value of 0.0393979. All the other column wise values are multiplied just like the above example. After multiplication, the weighted sum value is calculated by taking the sum of each value in the row. For example, the row of building material criteria values is summed up and give the value of 0.656567.

Table 10. Calculation of Weighted Sum after Normalization

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities	Weighted Sum
Weights	0.03939	0.0973	0.33611	0.138407	0.158705	0.229999	
Structure of Building	1	0.3333	0.2	0.5	0.125	0.111111	0.25367
Building Material	3	1	0.2	1	1	0.333333	0.65656
Early Warning System	5	5	1	3	1	3	2.28388
Area Accessibility	2	1	0.33333	1	2	1	0.97402
Fire Safety Arrangements	8	1	1	0.5	1	0.333333	1.05324
Awareness of Localities	9	3	0.33333	1	3	1	1.60325

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The ratio of weighted sum value and criteria weights of each row give a value that is nearest to the number of criteria selected 6. The value of Λ_{max} is obtained by the average values of Lambda Λ.

- **Consistency Index:**

Consistency Index is calculated by using formula:

Consistency Index = $(\Lambda_{max} - n) / n-1$,

Where n is the number of criteria

Consistency Index = $(\Lambda_{max} - 6) / 6-1$

Consistency Index = (6.770205 - 6) / 5

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Consistency Index = -0.8716

- **Consistency Ratio:**

By using Consistency Index C.I and Random Index R.I consistency ratio is calculated. The random index for n equal to 6 is 1.24.

Consistency Ratio = Consistency Index C.I / Random Index R.I

Consistency Ratio = -0.8716 / 1.24

Consistency Ratio = -0.7029

Table 11. Consistency Check After Normalized Pair Wise Matrix

Weighted Sum	**Weights**	Λ_{max} =WEIGHTED SUM/WEIGHTS	**Consistency Index**	**Consistency Ratio**
0.253676	0.039397	6.438822		
0.656567	0.097370	6.742997		
2.283887	0.336118	6.794876		
0.974024	0.138407	7.037345	-0.8716	-0.7029
1.053248	0.158705	6.636487		
1.603255	0.229999	6.970703		
Λ_{max}		**6.770205**		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The consistency ratio obtained using AHP process should be equal or less than 0.1. Here the consistency of Hafeez Center is -0.7029 which shows the calculated assessment of the building is accurate.

Fire Risk Assessment Analysis of Garden Heights Using AHP Process

Pair Wise Comparison

A priority matrix is developed for the selected criteria's whose absolute values are assigned from the survey conducted and from professional opinions and by using Saaty's Scale. (See Appendix 1). A 6×6 matrix is used having 6 criteria. These 6 criteria are selected by reviewing literature and by brainstorming. Each criteria are given an absolute value according to the degree of importance in Saaty's Scale. (See table 2)

Table 12. Pair Wise comparison of criteria of Garden Heights Plaza

CRITERIA	**Structure of Building**	**Building Material**	**Early Warning System**	**Area Accessibil-ity**	**Fire Safety Arrangem e-nts**	**Awaren-ess of Localities**
Structure of Building	1.0000	2.0000	2.0000	1.0000	3.0000	1.0000
Building Material	0.5000	1.0000	2.0000	4.0000	5.0000	3.0000
Early Warning System	0.5000	0.5000	1.0000	2.0000	1.0000	3.0000
Area Accessibility	1.0000	0.2500	0.5000	1.0000	6.0000	2.0000
Fire Safety Arrangem	0.3333	0.2000	1.0000	0.1667	1.0000	2.0000

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ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

ents						
Awareness of Localities	1.0000	0.3333	0.3333	0.5000	0.5000	1.0000
SUM	**4.3333**	**4.2833**	**6.8333**	**8.6667**	**16.5000**	**12.0000**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pairwise Comparison

The matrix is then normalized into weightages which shows the likeliness of the criteria contributes in increasing the fire risk. Normalized pairwise matrix is calculated by dividing all the elements of the pair wise matrix column by the sum of each column. For example, each element of column (structure of the building) is divided by the sum value of 4.33. All the 6 criteria columns are normalized according to this.

Table 13. Normalized Pair wise Comparison

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities
Structure of Building	0.2308	**0.4669**	0.2927	0.1154	0.1818	0.0833
Building Material	0.1154	0.2335	0.2927	0.4615	0.3030	0.2500
Early Warning System	0.1154	0.1167	0.1463	0.2308	0.0606	0.2500
Area Accessibility	0.2308	0.0584	0.0732	0.1154	0.3636	0.1667
Fire Safety Arrangements	0.0769	0.0467	0.1463	0.0192	0.0606	0.1667
Awareness of Localities	0.2308	0.0778	0.0488	0.0577	0.0303	0.0833

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

Table 14. Weights Generated from Normalized Pair Wise Comparison

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awaren-ess of Localities	W
Structure of Building	0.2307692	**0.46692**	0.292682	0.11538	0.18181818	0.083333	0.2
Building Material	0.1153846	0.23346	0.292682	0.46153	0.30303030	0.25	0.2
Early Warning	0.1153846	0.11673	0.146341	0.2307	0.06060606	0.25	0.1

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

System							
Area Accessibility	0.2307692	0.05836	0.073170	0.11538	0.36363636	0.16666	0.1
Fire Safety Arrangements	0.0769230	0.04669	0.146341	0.36363	0.06060606	0.166666	0.0994
Awareness of Localities	0.2307692	0.07782	0.048780	0.0576	0.03030303	0.083333	0.0881
SUM OF WEIGHTS							1.0

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

After gaining Normalized values of each criteria, weights are generated by obtaining the average of each criteria. The sum of the weights is 1 which means that the values calculated for the consistency check are accurate.

Consistency Check

By using the Pair wise comparison matrix which is not normalized the consistency of the matrix is checked. Each value of the column is multiplied by the criteria value. For example, the row of structure of the building having a value 1 is multiplied by the weighted value of 0.228485726. All the other column wise values are multiplied just like the above example. After multiplication, the weighted sum value is calculated by taking the sum of each value in the row. For example, the row of building material criteria values is summed up and give the value of 2.06359531.

Table 15. Calculations of Weighted Sum after Normalization

Criteria	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities	Weighted Sum
Weights	0.228485	0.276016	0.153305	0.167998	0.086076	0.0881	
Structure of Building	1	2	2	1	3	1	1.60147
Building Material	0.5	1	2	4	5	3	2.06359
Early Warning System	0.5	0.5	1	2	1	3	1.09198
Area Accessibility	1	0.25	0.5	1	6	2	1.23483
Fire Safety Arrangements	0.33333333	0.2	1	0.1666666	1	2	0.57498
Awareness of Localities	1	0.333333	0.333333	0.5	0.5	1	0.58674

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The ratio of weighted sum value and criteria weights of each row give a value that is nearest to the number of criteria selected 6. The value of Λ_{max} is obtained by the average values of Lambda Λ.

- **Consistency Index:**

Consistency Index is calculated by using formula:

Consistency Index = (Λ_{max} - n) / n-1,

Where n is the number of criteria

Consistency Index = (Λ_{max} - 6) / 6-1

Consistency Index = (6.8766667 - 6) / 5

Consistency Index = 0.1

- **Consistency Ratio:**

By using Consistency Index C.I and Random Index R.I consistency ratio is calculated. The random index for n equal to 6 is 1.24.

Consistency Ratio = Consistency Index C.I / Random Index R.I

Consistency Ratio = 0.1 / 1.24

Consistency Ratio = 0.141

Table 16. Consistency checks after Normalized Pair Wise Matrix

Weighted Sum	**Weights**	**Λ_{max}** =WEIGHTED SUM/WEIGHTS	**Consistency Index:**	**Consistency Ratio:**
1.601475586	0.228485726	7.009083726		
2.063599531	0.276016557	7.476361397		
1.091980887	0.153305481	6.122908311		
1.234835278	0.167998894	7.350258359	0.1	0.14
0.574980425	0.086076774	6.679855651		
0.586747474	0.088116567	6.658764567		
Λ_{max}		6.8766667		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The Consistency Ratio obtained using AHP process should be equal to or less than 0.1. Here the consistency of Garden Heights Plaza is 0.1 which shows the calculated assessment of the building is accurate.

Criteria Wise Fire Risk Assessment Analysis of Ali Tower Using AHP Process

Pair Wise Comparison

A priority matrix is developed for the selected criteria's whose absolute values are assigned from the survey conducted and from professional opinions and by using Saaty's Scale. (See Appendix 1). The relative importance of factors over one factor to another is obtained by comparing the factors with each other.

The length of the pairwise matrix is equivalent to the number of criteria used in decision making process. A 6×6 matrix is used having 6 criteria. These 6 criteria are selected by reviewing literature and by brainstorming.

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Each criteria are given an absolute value according to the degree of importance in Saaty's Scale. (See table 2)

Table 17. Priority Wise Comparison Matrix of Ali Tower

CRITERIA	Structure of Building	Building Material	Area accessibility	early warning system	Fire Safety Arrangements	Awareness of Localities
Structure of Building	1	2	3	0.2	0.333333333	1
Building Material	0.5	1	1	0.333333333	0.25	1
Area Accessibility	0.333333333	1	1	0.166666667	0.333333333	0.2
Early Warning System	5	3	6	1	3	1
Fire Safety Arrangements	3	4	3	0.333333333	1	2
Awareness of Localities	1	1	5	1	0.5	1
SUM	10.83333333	12	19	3.033333333	5.416666667	6.2

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pairwise Comparison

The matrix is then normalized into weightages which shows the likeliness of the criteria contributes in increasing the fire risk. The weightages of the criteria show which factor is more prone to fire or are vulnerable, which will contribute more in increasing the fire risk.

Normalized pairwise matrix is calculated by dividing all the elements of the pair wise matrix column by the sum of each column. For example, each element of column (structure of the building) is divided by the sum value of 10.833.

Table 18. Normalized Pair-wise Comparison of criteria

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities
Structure of Building	0.092307692	0.166666667	0.157894737	0.065934066	0.061538462	0.161290323
Building Material	0.046153846	0.083333333	0.052631579	0.109890011	0.046153846	0.161290323
Early Warning System	0.030769231	0.083333333	0.052631579	0.054945055	0.061538462	0.032258065
Area Accessibility	0.461538462	0.25	0.315789474	0.329670033	0.553846154	0.161290323
Fire Safety Arrangeme	0.276923077	0.333333333	0.157894737	0.109890011	0.184615385	0.322580645

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

nts						
Awareness of Localities	0.092307692	0.083333333	0.263157895	0.32967033	0.092307692	0.161290323

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

After gaining Normalized values of each criteria, weights are generated by obtaining the average of each criteria.

Table 19. Normalized Pair wise criteria weights.

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities	Weights
Structure of Building	0.09230	**0.1666666**	0.1578947	0.0659340	0.061538462	0.161290	0.1176053
Building Material	0.04615	0.0833333	0.0526317	0.10989011	0.046153846	0.161290	0.0832421
Early Warning System	0.030769	0.083333	0.052631	0.05494505	0.061538462	0.03225	0.0525792
Area Accessibility	0.465384	0.25	0.315789	0.32967033	0.553846154	0.16129	0.3453557
Fire Safety Arrangements	0.276923	0.333333	0.15789	0.10989011	0.184615385	0.322580	0.2308728
Awareness of Localities	0.092307	0.0833333	0.2631578	0.32967033	0.092307692	0.16129	0.1703445
SUM OF WEIGHTS							1

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The sum of the weights is 1 which means that the values calculated for the consistency check are accurate.

Consistency Check

By using the Pair wise comparison matrix which is not normalized the consistency of the matrix is checked. Each value of the column is multiplied by the criteria value. For example, the row of structure of the building having a value 1 is multiplied by the weighted value of 0.11760532. All the other column wise values are multiplied just like the above example.

After multiplication, the weighted sum value is calculated by taking the sum of each value in the row. For example, the row of building material criteria values is summed up and give the value of 0.53780.

Table 20. Weighted Sum Of the criteria

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities	Weighted Sum

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Weights	0.11760	0.0832	0.05257	0.345357	0.2308728	0.170344	
Structure of Building	1	2	3	0.2	0.3333333	1	0.75820
Building Material	0.5	1	1	0.333333	0.25	1	0.53780
Early Warning System	0.33333	1	1	0.166666	0.333333	0.2	0.34360
Area Accessibility	5	3	6	1	3	1	2.36154
Fire Safety Arrangements	3	4	3	0.333333	1	2	1.53020
Awareness of Localities	1	1	5	1	0.5	1	1.09488

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The ratio of weighted sum value and criteria weights of each row give a value that is nearest to the number of criteria selected 6. The value of Λ_{max} is obtained by the average values of Lambda Λ.

- **Consistency Index:**

Consistency Index is calculated by using formula:

Consistency Index = (Λ_{max} - n) / n-1,

Where n is the number of criteria

Consistency Index = (Λ_{max} - 6) / 6-1

Consistency Index = (**6.5560264** - 6) / 5

Consistency Index = -0.907329

- **Consistency Ratio:**

By using Consistency Index C.I and Random Index R.I consistency ratio is calculated. The random index for n equal to 6 is 1.24.

Consistency Ratio = Consistency Index C.I / Random Index R.I

Consistency Ratio = -0.907329 / 1.24

Consistency Ratio = -0.731717

Table 21. Consistency Check of criteria in Ali Tower using AHP process

Weighted Sum	**Weights**	**Λ_{max} =WEIGHTED SUM/WEIGHTS**	**Consistency Index**	**Consistency Ratio**
0.758200861	0.117605324	6.446994349	-0.907329	-0.731717
0.537805484	0.083242173	6.460733366		
0.343609069	0.052579287	6.535065167		
2.361547842	0.34535579	6.838014328		
1.530203093	0.230872881	6.627903135		
1.094880709	0.170344544	6.427448054		
Λ_{max}		**6.5560264**		

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The Consistency Ratio obtained using AHP process should be equal to or less than 0.1. Here the consistency of Ali Tower is -0.731 which shows the calculated assessment of the building is accurate.

5.2. Criteria Wise Fire Risk Assessment Analysis of Century Tower Using AHP Process

Pair Wise Comparison

A priority matrix is developed for the selected criteria's whose absolute values are assigned from the survey conducted and from professional opinions and by using Saaty's Scale. (See Appendix 1). The relative importance of factors over one factor to another is obtained by comparing the factors with each other. The length of the pairwise matrix is equivalent to the number of criteria used in decision making process. A 6×6 matrix is used having 6 criteria. These 6 criteria are selected by reviewing literature and by brainstorming. Each criteria are given an absolute value according to the degree of importance in Saaty's Scale. (See table 2)

Table 22. Priority-Matrix of Century Tower

CRITERIA	Structure of Building	Building Material	Area Accessibili-ty	Early Warning System	Fire Safety Arrangements	Awareness of Localities
Structure of Building	1	5	3	0.5	0.333333333	1
Building Material	0.2	1	0.5	0.3333333	1	0.5
Area Accessibility	0.3333333	2	1	2	0.333333333	1
Early Warning System	2	3	0.5	1	1	3
Fire Safety Arrangements	3	1	3	1	1	2
Awareness of Localities	1	2	1	0.33333333	0.5	1
SUM	7.533333 3	14	9	5.166666	4.166666667	8.5

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pairwise Comparison

The matrix is then normalized into weightages which shows the likeliness of the criteria contributes in increasing the fire risk. The weightages of the criteria show which factor is more prone to fire or are vulnerable, which will contribute more in increasing the fire risk. Normalized pairwise matrix is calculated by dividing all the elements of the pair wise matrix column by the sum of each column. For example, each element of column (structure of the building) is divided by the sum value of 7.3333. All the 6 criteria columns are normalized according to this.

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Table 23. Normalized Pair-wise Comparison

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessibility	Fire Safety Arrangements	Awareness of Localities
Structure of Building	0.132743363	**0.357142857**	0.333333333	0.096774194	0.08	0.117647059
Building Material	0.026548673	0.071428571	0.055555556	0.064516129	0.24	0.058823529
Early Warning System	0.044247788	0.142857143	0.111111111	0.387096774	0.08	0.117647059
Area Accessibility	0.265486726	0.214285714	0.055555556	0.193548387	0.24	0.352941176
Fire Safety Arrangements	0.398230088	0.071428571	0.333333333	0.193548387	0.24	0.235294118
Awareness of Localities	0.132743363	0.142857143	0.111111111	0.064516129	0.12	0.117647059

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

After gaining Normalized values of each criterion, weights are generated by obtaining the average of each criterion.

Table 24. Normalized Pair wise criteria weights.

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Access-ibility	Fire Safety Arrangements	Awar-eness of Local it-ies	W
Structure of Building	0.132743	0.35714	0.333333	0.09677	0.08	0.1176	0.18627
Building Material	0.026548	0.07142	0.055555	0.06451	0.24	0.0588	0.08614
Early Warning System	0.044247	0.14285	0.111111	0.38709	0.08	0.1176	0.14715
Area Accessibility	0.265486	0.21428	0.055555	0.19354	0.24	0.3529	0.22030
Fire Safety Arrangements	0.39823	0.07142	0.33333	0.19354	0.24	0.2352	0.24530
Awareness of Localities	0.13274	0.14285	0.1111111	0.06451	0.12	0.117	0.1148

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

SUM OF WEIGHTS	1

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The sum of the weights is 1 which means that the values calculated for the consistency check are accurate.

Consistency Check

By using the Pair wise comparison matrix which is not normalized the consistency of the matrix is checked. Each value of the column is multiplied by the criteria value. For example, the row of structure of the building having a value 1 is multiplied by the weighted value of 0.186273468. All the other column wise values are multiplied just like the above example.

After multiplication, the weighted sum value is calculated by taking the sum of each value in the row. For example, the row of building material criteria values is summed up and give the value of 0.573126385.

Table 25. Consistency Of the criteria

CRITERIA	Structure of Building	Building Material	Early Warning System	Area Accessi-bility	Fire Safety Arrangeme-nts	Aware-ness of Localit-ies	Weighted Sum
Weights	0.1862734	0.086145	0.14715997	0.220302	0.24530575	0.11481246	
Structure of Building	1	5	3	0.5	0.333333333	1	1.3652
Building Material	0.2	1	0.5	0.3333	1	0.5	0.5731263
Early Warning System	0.3333333	2	1	2	0.333333333	1	1.0187288
Area Accessibility	2	3	0.5	1	1	3	1.5146
Fire Safety Arrangements	3	1	3	1	1	2	1.7816
Awareness of Localities	1	2	1	0.333333	0.5	1	0.8166239

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The ratio of weighted sum value and criteria weights of each row give a value that is nearest to the number of criteria selected 6. The value of Λ_{max} is obtained by the average values of Lambda Λ.

- **Consistency Index:**

Consistency Index is calculated by using formula:

Consistency Index = $(\Lambda_{max} - n) / n-1$,

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Where n is the number of criteria
Consistency Index = (Λ_{max} - 6) / 6-1
Consistency Index = (**6.855** - 6) / 5
Consistency Index = 0.171

- **Consistency Ratio:**

By using Consistency Index C.I and Random Index R.I consistency ratio is calculated. The random index for n equal to 6 is 1.24.
Consistency Ratio = Consistency Index C.I / Random Index R.I
Consistency Ratio = -0.8290 / 1.24
Consistency Ratio = 0.1379
Table 26. Consistency Check using AHP process

Weighted Sum	**Weights**	**Λ_{max} =WEIGHTED SUM/WEIGHTS**	**Consistency Index**	**Consistency Ratio**
1.365212967	0.186273468	7.32907904		
0.573126385	0.08614541	6.653011312		
1.018728858	0.147159979	6.922594473		
1.514609232	0.220302927	6.8751208	0.171	0.1379
1.781679361	0.24530575	6.263096618		
0.816623917	0.114812467	7.112676309		
Λ_{max}		**6.8554**		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

The Consistency Ratio obtained using AHP process should be equal to or less than 0.1. Here the consistency of Century Tower is 0.1 which shows the calculated assessment of the building is accurate.

Alternative Priority Wise Fire Risk Assessment Analysis of Selected Multi-Storey Buildings Using AHP Process

Alternative Priority

In alternative priority, alternatives are compared with each criteria. 6 alternative priority matrix are made, as per our criteria, for all multi-storey buildings. The purpose of this comparison is that, it shows which multi-storey building will face fire incident because of selected criteria

4.17 Building Material
As per type of material present in building, all multi-storey buildings are prioritized.

Pair Wise Comparison

Table 27. Pairwise Comparison w.r.t Building Material

Alternative	**Hafeez Center**	**Ali Tower**	**Century Tower**	**Garden Heights**
Hafeez Center	1	3	2	4
Ali Tower	0.333333333	1	0.142857143	1
Century Tower	0.5	7	1	3
Garden Heights	0.25	1	0.333333333	1

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Sum	**2.083333333**	**12**	**3.476190476**	**9**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pair-Wise Comparison

Table 28. Normalized Pairwise Comparison w.r.t Building Material

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weights
Hafeez Center	0.48	0.25	0.57534246	0.444444444	0.43744672
Ali Tower	0.16	0.08333	0.04109589	0.111111111	0.09888508
Century Tower	0.24	0.58333	0.28767123	0.333333333	0.36108447
Garden Heights	0.12	0.08333	0.09589041	0.111111111	0.10258371
SUM OF WEIGHTS					**1**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

Table 29. Criterion Weights w.r.t Building Material

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weighted Sum
Weights	0.437446728	0.09888	0.36108447	0.102583714	
Hafeez Center	1	3	2	5	1.969189498
Ali Tower	0.333333333	1	0.2	1	0.419501268
Century Tower	0.5	5	1	7	1.792319254
Garden Heights	0.2	1	0.142857143	1	0.340541639

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Consistency Check

Table 30. Consistency Check of Building Material

Alternative	Weighted Sum	Weights	Λ_{max}	Consistency Index	Consistency Ratio
Hafeez Center	1.969189498	0.437447	4.501553		
Ali Tower	0.419501268	0.098885	4.242311		
Century Tower	1.792319254	0.361084	4.963712	**0.085602**	**0.095113**
Garden Heights	0.340541639	0.102584	3.319646		
			4.256805		

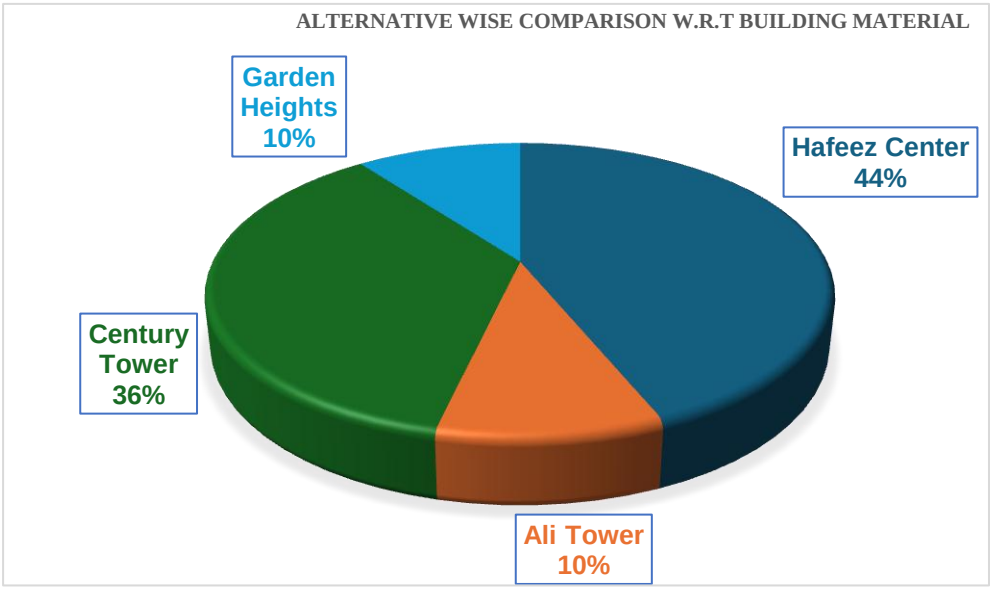
(Source: Generated by researcher using Microsoft Excel Stats in 2021)

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

5.3.Overall Comparison of case study area as Per Building Material

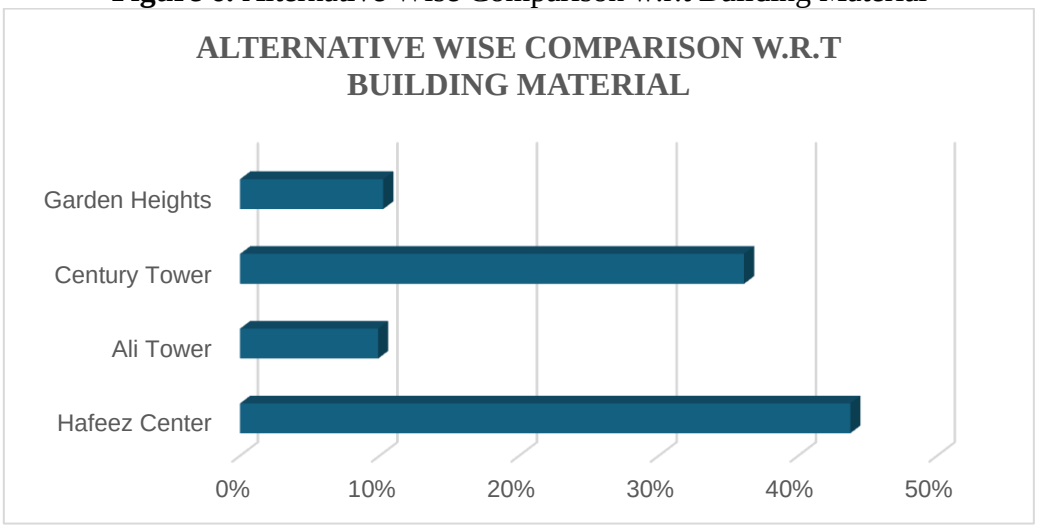
Building Material of Hafeez center is analyzed as poor among all other buildings. About 44% of this factor is contributing in fire risk among all other buildings. Garden Heights Plaza and Ali Tower are contributing equally 10% in the fire risk. Whereas Century Tower is also at fire risk due to the inadequate building material present there in the building. About 36% of among all other buildings Century Tower is at risk due to building material

Figure 5. Alternative Wise Comparison w.r.t Building Material



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 6. Alternative Wise Comparison w.r.t Building Material



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

5.3.1. Area Accessibility

Pair Wise Comparison

Table 30. Pair Wise Comparison w.r.t Area Accessibility

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Hafeez Center	1	0.333333	1	0.25
Ali Tower	3	1	2	1
Century Tower	1	0.5	1	2
Garden Heights	4	1	0.5	1
Sum	**9**	**1**	**4.5**	**4.25**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized pair-wise comparison

Table 31. Normalized Pairwise comparison w.r.t Area Accessibility

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weights
Hafeez Center	0.1111111	0.333333	0.2222222	0.0588235	0.1813725
Ali Tower	0.3333333	1	0.4444444	0.2352941	0.5032679
Century Tower	0.1111111	0.5	0.2222222	0.4705882	0.3259803
Garden Heights	0.4444444	1	0.1111111	0.2352941	0.4477124
SUM OF WEIGHTS					**1**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion weights

Table 32. Criterion Weights w.r.t Area Accessibility

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weighted Sum
Weights	0.181372549	0.503268	0.325980392	0.447712418	
Hafeez Center	1	0.333333	1	0.25	0.787037037
Ali Tower	3	1	2	1	2.147058824
Century Tower	1	0.5	1	2	1.654411765
Garden Heights	4	1	0.5	1	1.839460784

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Consistency Check

Table 33. Consistency Check w.r.t Area Accessibility

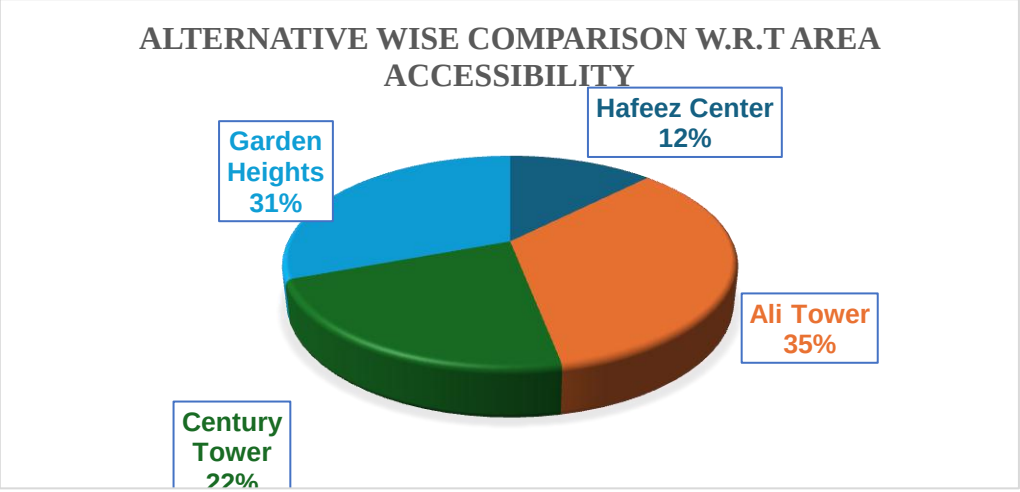
Alternative	Weighted Sum	Weights	Lambda	Consistency Index	Consistency Ratio
Hafeez Center	0.787037037	0.181372	4.33933933		
Ali Tower	2.147058824	0.503267	4.26623376		
Century Tower	1.654411765	0.3259803	5.07518797	**0.10911147**	**0.10567941**
Garden Heights	1.839460784	0.4477124	4.10857664		
Λ_{max}			**4.447334429**		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Overall Comparison as Area Accessibility

While area accessibility in Ali Tower contributes 35% in fire risk due to the tertiary road located along the building. While Hafeez center and Century Tower contributes 12% and 22% in causing fire risk. About 31% of fire risk analyzed in Garden Heights Plaza due to the lack area accessibility, as the building have only single entrance and one emergency exit way.

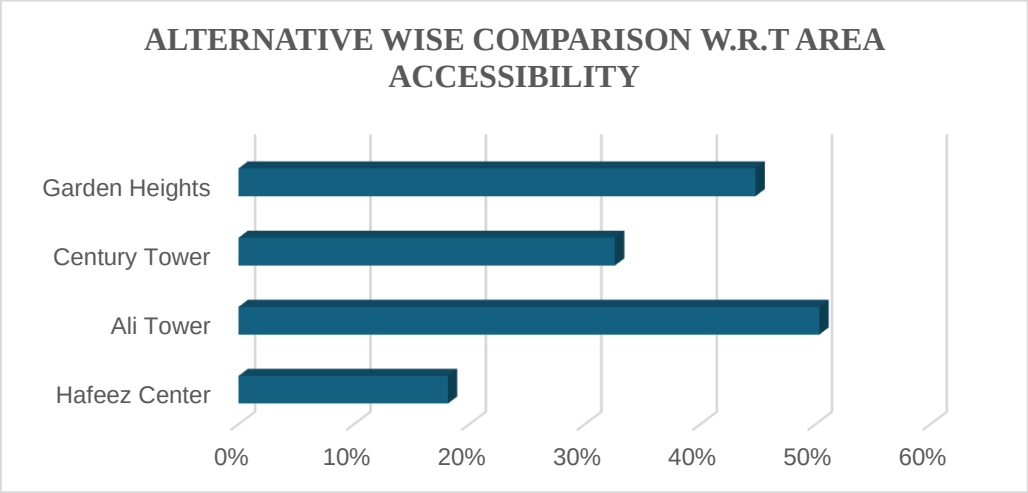
Figure 7 Alternative Wise Comparison w.r.t Area Accessibility



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 8. Alternative Wise Comparison w.r.t Area Accessibility

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

5.3.2. Fire Safety Arrangements

Pair Wise Comparison

Table 34. Pair Wise Comparison w.r.t Fire Safety Arrangements

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights
Hafeez Center	1	1	0.333333333	5
Ali Tower	1	1	0.2	1
Century Tower	3	5	1	3
Garden Heights	0.2	1	0.333333333	1
Sum	**5.2**	**8**	**1.866666667**	**10**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pair-Wise Comparison

Table 35. Normalized Pairwise comparison w.r.t Fire Safety Arrangements

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weights
Hafeez Center	0.192307692	0.125	0.178571429	0.5	0.24896978
Ali Tower	0.192307692	0.125	0.107142857	0.1	0.131112637
Century Tower	0.576923077	0.625	0.535714286	0.3	0.509409341
Garden Heights	0.038461538	0.125	0.178571429	0.1	0.110508242
SUM OF WEIGHTS					**1**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

Table 36. Criterion Weights w.r.t Fire Safety Arrangements

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weighted Sum
Hafeez Center	1	1	0.333333333	5	1.10242674

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Ali Tower	1	1	0.2	1	0.592472527
Century Tower	3	5	1	3	2.243406593
Garden Heights	0.2	1	0.333333333	1	0.461217949

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Consistency Check

Table 37. Consistency Check w.r.t Fire Safety Arrangements

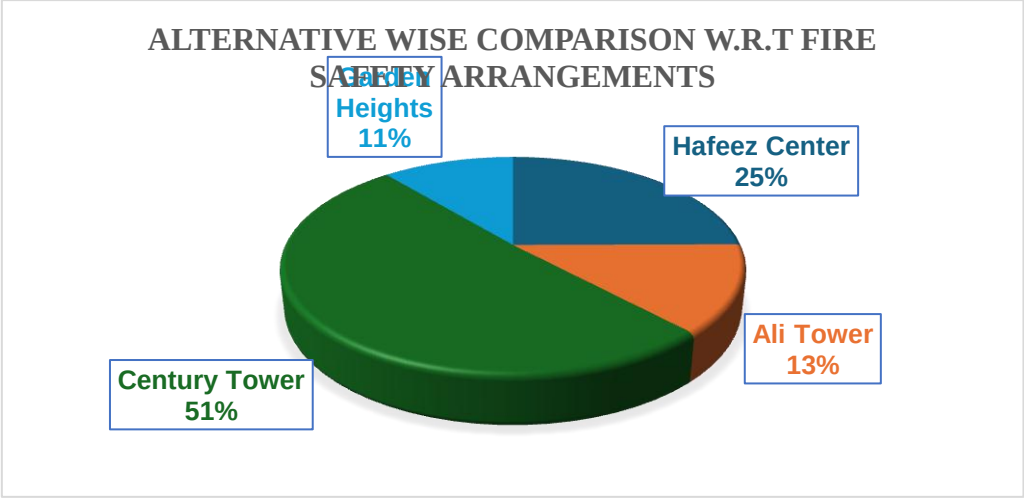
Alternative	Weighted Sum	Weights	Lambda	Consistency Index	Consistency Ratio
Hafeez Center	1.10242674	0.24896978	4.427954023	**0.10025**	**0.11139**
Ali Tower	0.592472527	0.131112637	4.518805657		
Century Tower	2.243406593	0.509409341	4.403936902		
Garden Heights	0.461217949	0.110508242	4.173606795		
Λ_{max}			**4.381075844**		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Overall Comparison as Per Fire Safety Arrangements

Century Tower is not fire-resistant building by under considering its fire safety measures. Due to the fact it contributes about 51% in the fire risk as compared to all other buildings. Hafeez Center is still under the process of renovation therefore fire safety measure contributes about 25% in fire risk. While safety measures of fire in Garden Heights and Ali Tower slightly contribute in fire risk.

Figure 9. Alternative Wise Comparison w.r.t. Fire Safety Arrangements

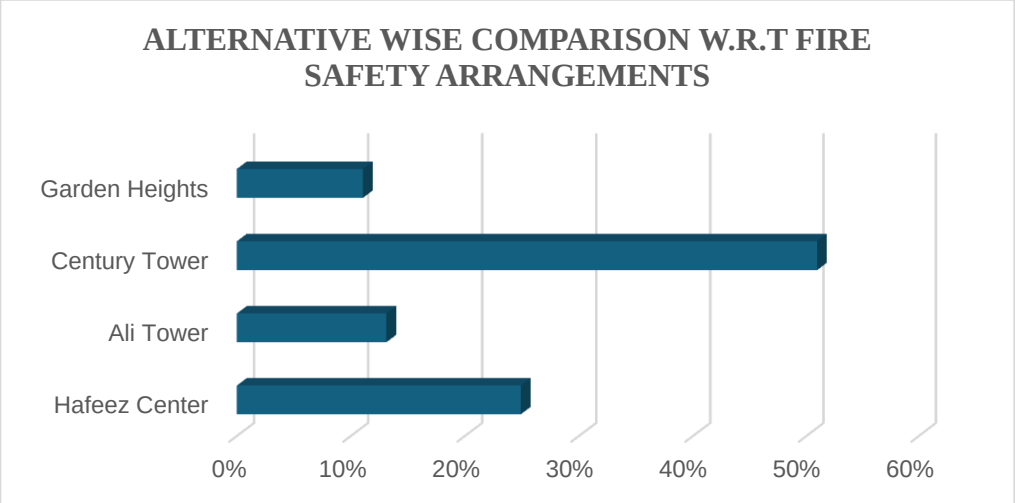


(Source: Generated by researcher using Microsoft Excel Stats in 2021)

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Figure 10. Alternative wise comparison w.r.t. Fire Safety Arrangements

(Source: Generated by researcher using Microsoft Excel Stats in 2021)



5.3.3. Awareness of Localities

Pair Wise Comparison

Table 38. Pair Wise Comparison w.r.t Awareness of Localities

Alternatives	Hafeez Center	Ali Tower	Century Tower	Garden Heights
Hafeez Center	1	2	0.333333333	1
Ali Tower	0.5	1	0.25	2
Century Tower	3	4	1	5
Garden Heights	1	0.5	0.2	1
Sum	**5.5**	**7.5**	**1.783333333**	**9**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Normalized Pair-Wise Comparison

Table 39. Normalized Pairwise comparison w.r.t Awareness of Localities

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weights
Hafeez Center	0.181818182	0.266667	0.186915888	0.111111111	0.186627962
Ali Tower	0.090909091	0.133333	0.140186916	0.222222222	0.146662891
Century Tower	0.545454545	0.533333	0.560747664	0.555555556	0.548772774
Garden Heights	0.181818182	0.066667	0.112149533	0.111111111	0.117936373
					1

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Criterion Weights

Table 40. Criterion Weights w.r.t Awareness of Localities

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weighted Sum
Hafeez Center	1	2	0.333333333	1	0.78081437
Ali Tower	0.5	1	0.25	2	0.61304281
Century Tower	3	4	1	5	2.28499008
Garden Heights	1	0.5	0.2	1	0.48760335

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Consistency Check`

Table 41. Consistency Check w.r.t Awareness of Localities

Alternative	Weighted Sum	Weights	Lambda	Consistency Index	Consistency Ratio
Hafeez Center	0.780814	0.186628	4.183802	**0.055202**	**0.061336**
Ali Tower	0.613043	0.146663	4.179945		
Century Tower	2.28499	0.548773	4.163818		
Garden Heights	0.48765	0.117936	4.13486		
Λ_{max}			**4.165606**		

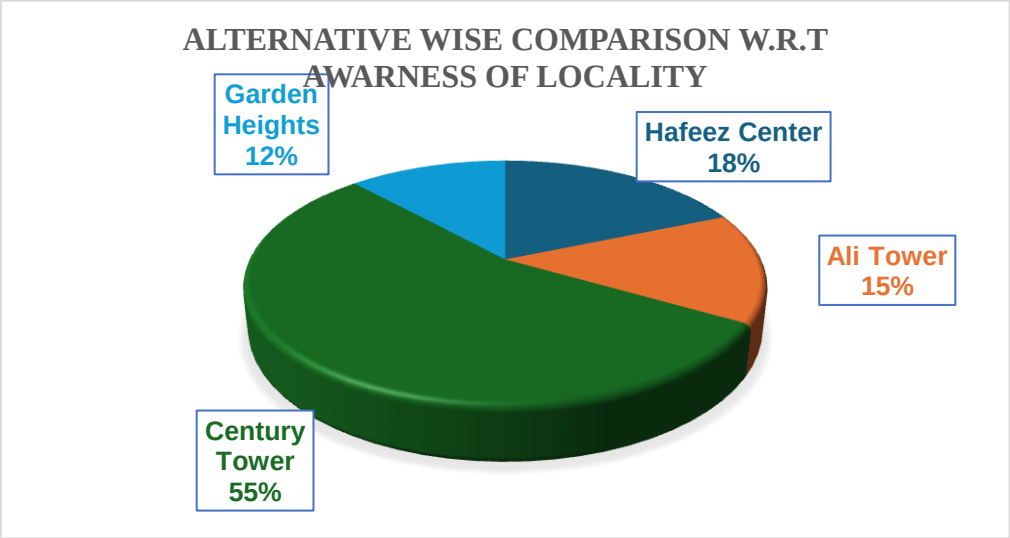
(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Overall Comparison as Per Awareness of Localities

The Awareness of localities contribute 55% of the fire risk in Century Tower, which is highest as compared to other buildings. Through analyzing Hafeez Center it is observed that awareness among people and staff is causing the building 18% at fire risk while in Ali Tower and Garden Heights it contributes 15% and 12%.

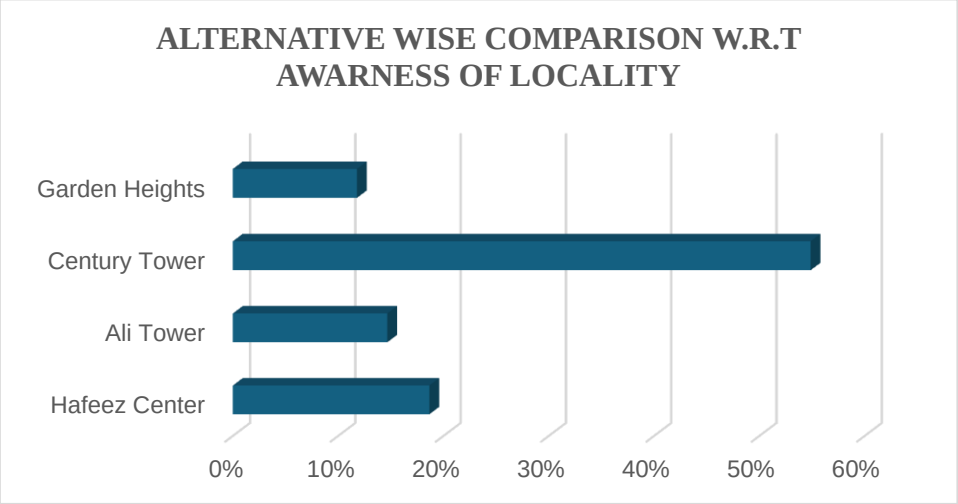
Figure 11. Alternative wise comparison w.r.t. Awareness of Localities

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 12. Alternative wise comparison w.r.t. Awareness of Localities



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

5.3.4. Early Warning System

Pair wise comparison

Table 42. Pair Wise Comparison w.r.t Early warning system

Alternatives	Hafeez Center	Ali Tower	Century Tower	Garden Heights
Hafeez Center	1	3	2	5
Ali Tower	0.333333333	1	0.2	1
Century Tower	0.5	5	1	7
Garden Heights	0.2	1	0.142857143	1
SUM	**2.033333333**	**10**	**3.342857143**	**14**

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Normalized pair wise comparison

Table 43. Normalized Pair wise comparison w.r.t Early warning system

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	WEIGHTS
Hafeez Center	0.491803279	0.3	0.598290598	0.357142857	0.43680918
Ali Tower	0.163934426	0.1	0.05982906	0.071428571	0.09879801
Century Tower	0.245901639	0.5	0.299145299	0.5	0.38626173
Garden Heights	0.098360656	0.1	0.042735043	0.071428571	0.07811067
SUM OF WEIGHTS					

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

Table 44. Criteria Weights w.r.t Early warning system

Alternative	Hafeez Center	Ali Tower	Century Tower	Garden Heights	Weighted Sum
Weights	0.436809184	0.098798	0.386261735	0.078131067	
Hafeez Center	1	3	2	5	1.896382033
Ali Tower	0.333333333	1	0.2	1	0.39978449
Century Tower	0.5	5	1	7	1.645573871
Garden Heights	0.2	1	0.142857143	1	0.319471166
					1.06530289

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Consistency Check

Table 45. Consistency Check w.r.t Early warning system

Alternative	WEIGHTED SUM	Weights	LAMDA	Consistency Index	Consistency Ratio
Hafeez Center	1.896382033	0.436809	4.341442682		
Ali Tower	0.39978449	0.098798	4.046483044		
Century Tower	1.645573871	0.386262	4.260255995	**0.061424591**	**0.068249545**
Garden Heights	0.319471166	0.078131	4.088913369		
Λ_{max}			**4.184273773**		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

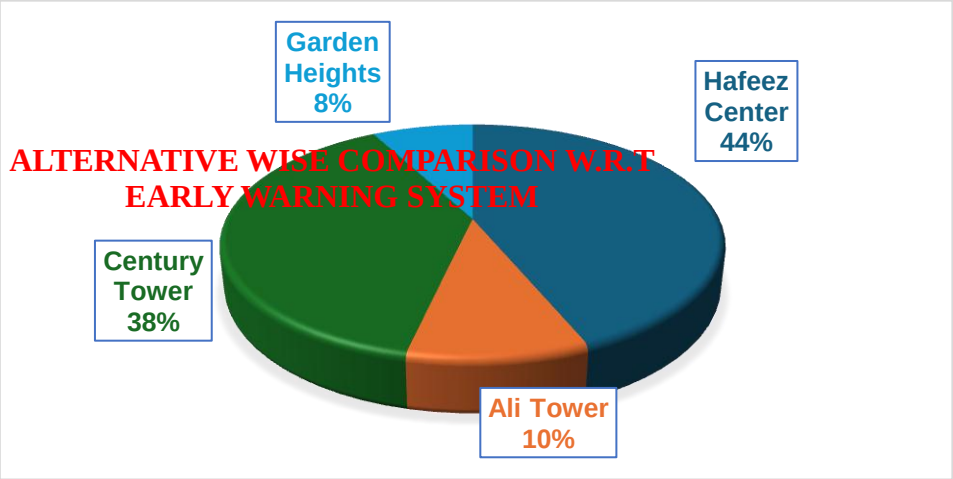
Overall Comparison as Per Early Warning System

From the above alternatives wise analysis of criteria of buildings, the result obtained are the Early warning system in Hafeez center contributes 44% of the fire risk, which gives higher risk in case of fire among all the factors while in Century Tower it contributes 38%, in Ali

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

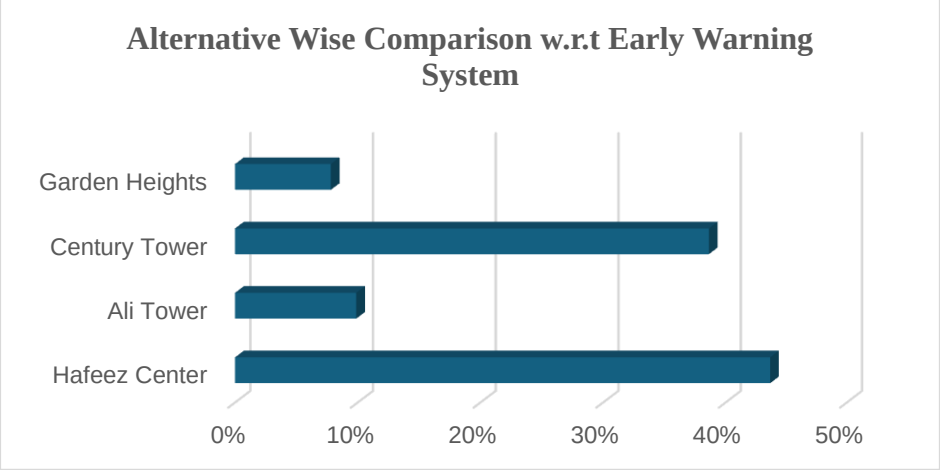
Tower it contributes 10% while the least contribution takes place in Garden heights Plaza about 8%.

Figure 13. Alternative wise comparison w.r.t Early Warning System



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 14. Alternative wise comparison w.r.t Early Warning System



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

5.3.5. Structure of the building

Pair wise comparison

Table 46. Pair Wise Comparison w.r.t Structure Of the building

CRITERIA	Hafeez Center	Ali Tower	Century Tower	Garden Heights
Hafeez Center	1	2	1	7
Ali Tower	0.2	1	1	1
Century Tower	1	1	1	3
Garden Heights	0.142857143	1	0.333333333	1
SUM	2.342857143	5	3.333333333	12

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Normalized pair wise comparison

Table 47. Normalized Pair wise comparison w.r.t Structure Of the building

CRITERIA	Hafeez Center	Ali Tower	Century Tower	Garden Heights	WEIGHTS
Hafeez Center	0.426829268	0.4	0.3	0.583333333	0.42754065
Ali Tower	0.085365854	0.2	0.3	0.083333333	0.167174797
Century Tower	0.426829268	0.2	0.3	0.25	0.294207317
Garden Heights	0.06097561	0.2	0.1	0.083333333	0.111077236
					1

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Criterion Weights

Table 48. Criteria Weights w.r.t Structure Of the building

CRITERIA	Hafeez Center	Ali Tower	Century Tower	Garden Heights	WEIGHTED SUM
Weights	0.42754065	0.167175	0.294207317	0.111077236	
Hafeez Center	1	2	1	7	1.833638211
Ali Tower	0.2	1	1	1	0.65796748
Century Tower	1	1	1	3	1.222154472
Garden Heights	0.142857143	1	0.333333333	1	0.437398374
					1.037789634

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Consistency Check

Table 49. Consistency Check w.r.t Structure Of the building

WEIGHTED SUM	Weights	LAMDA	CONSISTENCY INDEX	CONSISTENCY RATIO
1.833638211	0.427541	4.288804	**0.026371206**	**0.02930134**
0.65796748	0.167175	3.935805		
1.222154472	0.294207	4.154059		
0.437398374	0.111077	3.937786		
1.037789634		4.079114		

(Source: Generated by researcher using Microsoft Excel Stats in 2021)

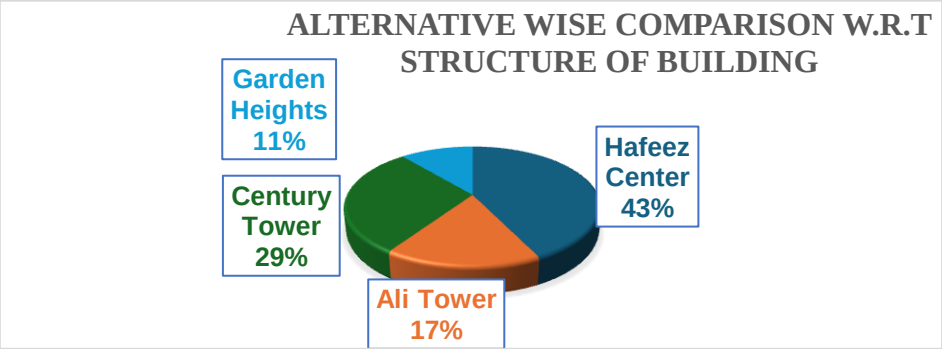
Overall Comparison as Per Structure of Building

As from the above analysis using AHP process it is analyzed that the structure of Hafeez center contributes 43% in the fire risk. Due to the recent fire incident occur in Hafez center 70% of the building is destroyed which is being still under renovation process. While Century

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

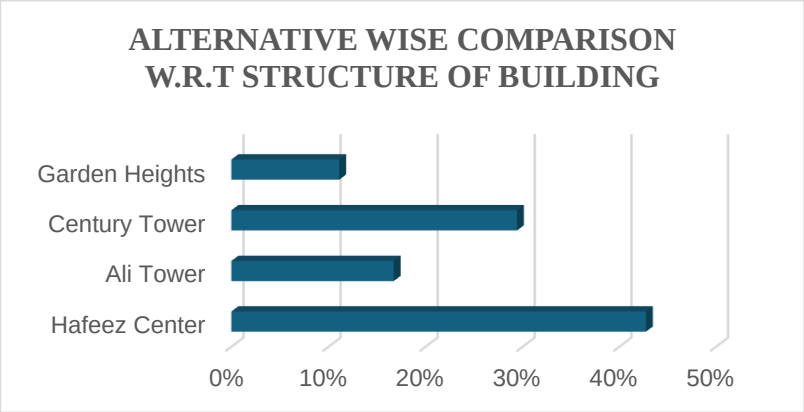
Tower contributes 29% and Ali Tower contributes 17% in fire risk. As Ali Tower is recently constructed and well-maintained building located on M.M.Alam Road. Garden Heights Plaza structure is about 11% contributing in fire risk as the building is well maintained and renovated after the fire incident.

Figure 15. Alternative wise comparison w.r.t Structure of the building



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 16. Alternative wise comparison w.r.t Structure of the building



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Comparison of Criteria of Four Multi-Storey Buildings of Lahore

All the weights obtained from the analyses using AHP are compared to assess which building is at risk as compared to others.

Table 50. Comparison of buildings w.r.t each other criteria

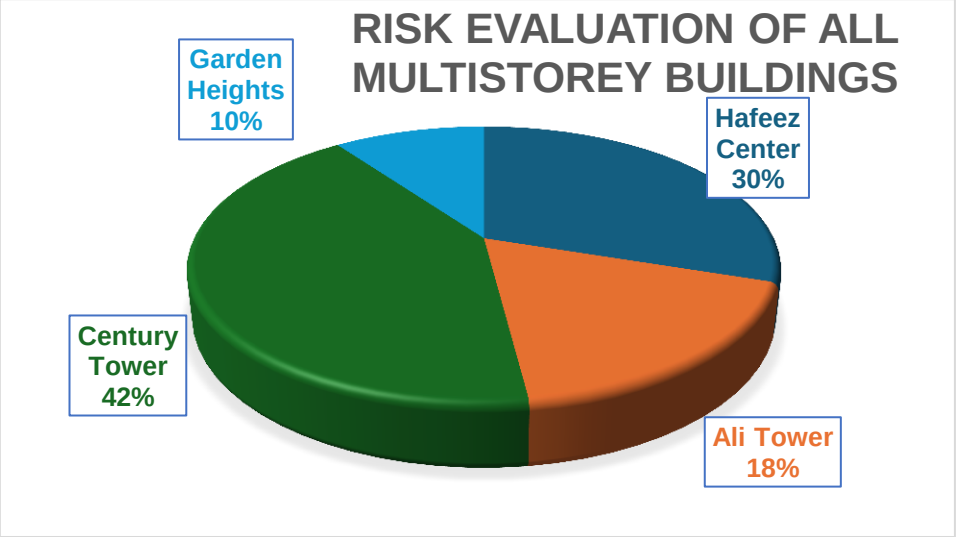
Criteria/ Alternative	Struct u-re of Buildin g	Buildin g Materi al	Area Accessibi li-ty	Fire Safety Arrangeme nts	Aware n-ess of Localit y	Early Warn-ing System	Average of Criteria	
Hafeez Center	0.4275 4	0.4374 4	0.181372	0.24896978	0.1866 27	0.4368 09	0.3	30%
Ali Tower	0.1671 7	0.0988 8	0.503267 9	0.131112637	0.1466 62	0.0987 98	0.2	18%
Century Tower	0.2942 0	0.3610 8	0.325980 3	0.509409341	0.5487 72	0.3862 61	0.4	42%

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Garden Heights	0.11107	0.10258	0.4477124	0.110508242	0.117936	0.078131	0.2	10%
							1	100 %

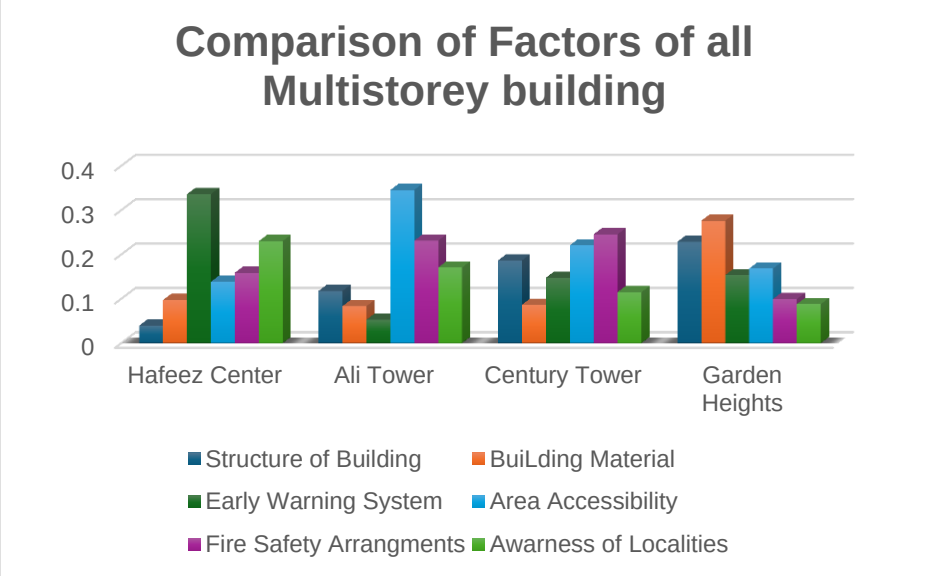
(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 17. Comparison of Multi-Storey Buildings Showing That Century Tower Is at Most Risk



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

Figure 18. Comparison of Factors of All Multi-Storey Buildings



(Source: Generated by researcher using Microsoft Excel Stats in 2021)

6. Conclusions

Construction of all four buildings are according to the Building By-Laws of LDA Building and Zoning Regulations (2019) is observed through field surveys. As mention in LDA

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

Building By-Laws, a building having four or more than four storey (38 feet height) is considered as multi-storey building. By conducting field surveys, analyses show that all the selected multistory buildings meet the criteria mentioned in Bylaws. By using Analytical Hierarchy Process (AHP), fire risk assessment of Hafeez center, Garden Heights Plaza, Ali Tower and Century Tower is done. After analyzing selected criteria and buildings by AHP process, it is concluded that Century Tower is at high risk of all selected multi-storey buildings. The results of analyses show that no fire resisting structures is used in the building design. As the building is used for multi-purpose such as offices/commercial centered, etc. inside of the building is much crowded. There are no evacuation strategies, no fire exits or fire alarms, just some fire extinguishers placed, in which most of them are not functional. Although once fire has occurred in Century Tower still authorities or Council members of the building have not taken the matter under serious consideration and no improvements have been made regarding fire safety measures. Council members of Hafeez Center and Century Tower are not aware about all the firefighting equipment's and early warning system. Therefore, both the buildings have lack of installation of firefighting equipment's and early warning system as per Building Codes of Pakistan of Fire Safety Provision 2016. Where as in Ali Tower and Garden Heights all the firefighting equipment's and early warning system are present and are functional. During the research study it is observed that most of the fire incidents occur due to short circuiting and lack of awareness of community and staff members' present in the building. At local level fire safety arrangements are serious while installation of building materials. It is observed that awareness of localities is low in Century Tower as it contributes about 55% of fire risk factor as compared to other whereas in Ali Tower and Hafeez center slightly more people aware about usage if firefighting equipment's and safety measures. During the field survey it is observed that security guards hired in the Century Tower and Garden Heights are not trained properly while Hafeez center and Ali tower staff and security guards/staff are trained by Rescue 1122 in different sessions.

Government department of emergency is taking initiative to aware community and staff members of the buildings about fire safety measures and management in case of fire incident. Results of field surveys of fire risk assessment show that among all the selected multi-storey buildings, the most recent fire incident happen in Hafeez center. Due to which renovation of the building is still under process but other selected multi-storey buildings are already renovated. Problem regarding area accessibility is observed in Ali Tower as it lies along tertiary road which result in increase in the chance of fire hazard. As fire tenders are not able to reach them on time then loss of lives and property would be greater and even there is risk that it would convert into disaster.

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.02 (2025)

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