Doi:

Identifying and Ranking Human and Instrumental Resource Monitoring Criteria Firefighting and Effective Rescue and Relief in Controlling the Risk of Accidents in Construction Projects in Tehran

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Abstract

INTRODUCTION: Every year, a number of citizens, especially workers, lose their lives or are injured in fires, and many assets are destroyed by fires. In fact, the dimensions of these losses are also increasing with urban and industrial development. The purpose of this research is to identify and rank the supervisory and instrumental criteria of firefighting and rescue in controlling the risk of accidents in construction projects in Tehran.

METHODS: In this applied-descriptive research, library and questionnaire methods were used and then the main criteria were prioritized using the Analytic Network Process (ANP) technique. About 10 construction experts (mass builders) in Tehran were selected and studied based on available sampling.

FINDINGS: In this research, in the first stage, based on the opinions of experts, 42 sub-criteria were screened and selected as appropriate sub-criteria, and in the second stage, the main research criteria were prioritized.

CONCLUSION: Based on the results, the criteria of "safe emergency evacuation instructions", "appropriate and sufficient emergency exits", "management of electrical equipment", and "safe emergency evacuation instructions" with normalized weights showed that the sub-criteria of "gas welding and flame cutting work must be performed by skilled workers", "adequate emergency lighting", "prevention of generator overheating", and finally "location of emergency signs" are in the first priority.

Keywords: Risk; Fire; Construction projects; Tehran city.

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Introduction

Every year, several citizens and workers lose their lives or suffer injuries due to fire incidents. In addition, billions of tomans of national assets are lost due to fires. The scale of these damages increases with urban and industrial development, as issues such as urban population growth and the increase in construction projects can raise the risk of fire hazards. Therefore, fire safety is one of the critical concerns in the design and implementation process of construction projects (1).

Due to the scope and diversity of activities and hazards, construction operations rank high among accident-prone activities (2).

Fire is one of the most significant issues affecting the three domains of safety, health, and the environment, and it can endanger the assets and health of workers in construction projects in a short time. Fire and explosion incidents in industries and both small and large projects cause numerous financial, human, and environmental damages annually in various countries around the world, including Iran. According to global fire statistics published by the Center of Fire Statistics World Fire Statistics, an average of 2,946,040 fire incidents, 23,127 fire-related deaths, and 70,270 fire-related injuries occur annually worldwide. Unfortunately, significant fires have been recorded in the history of Tehran City and its projects, resulting in extensive human casualties and financial losses (3).

This indicates that construction projects, like completed buildings, are at high risk of fire. Most workplace fire incidents occur due to the large number of flammable materials on construction

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sites, technical defects, and inadequate worker training during operations such as welding, cutting, and drilling during construction, as well as the absence of fire prevention and control systems (8). In this regard, risk identification is a rational method for examining hazards, which allows for the recognition of various dangers such as fire, and their potential impacts on individuals, materials, equipment, and the environment. Through this process, highly valuable data is obtained to support decision-making related to reducing fire hazards, improving the environment around hazardous facilities, emergency planning, acceptable risk levels, inspection and maintenance policies, and more (9).

Given the high number of construction projects in Tehran and the increasing statistics of fire incidents, finding strategies to control fire risks in these projects is essential and unavoidable. Moreover, considering the continuous population growth in Tehran and the need to initiate more construction projects, it is evident that failure to address fire risk control in these projects will result in exponential growth in such incidents in the coming years, imposing substantial costs and damages on the citizens and the city. Therefore, this study aims to contribute by identifying and ranking fire risk factors in construction projects in Tehran.

In the construct validity section, the construction experts (mass builders) in Tehran constitute the statistical population of the present study, selected using convenience sampling. The population comprises 10 individuals, all of whom have experience supervising buildings and are members of the Engineering Organization.

Based on the population size, 10 questionnaires were distributed, and the analyses were conducted based on the data collected from these 10 questionnaires.

Methods

Given that the main objective of this study is to identify and rank supervisory and operational criteria for effective fire extinguishing and rescue tools in controlling the risk of construction project accidents in the Tehran metropolis, the research is classified as applied in terms of purpose. Moreover, as it utilizes both library study methods and field methods such as questionnaires, the study is considered descriptive-survey in nature and methodology. To prioritize the criteria, the Analytic Network Process (ANP) technique has been employed. The structure of the initial (unweighted) super matrix model in ANP is as follows:

$$\mathbf{W}= \begin{matrix} \text{Objective} \\ \text{Main criteria} \\ \text{Options} \end{matrix} \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{pmatrix}$$

Figure 1: Structure of the initial (unweighted) supermatrix

After normalization, the weighted average of each row will be calculated. The following formula is used for normalization without software:

$$r_{ij} = \frac{\bar{a}_{ij}}{\sum_{i=1}^{m} a_{ij}}$$

In this formula, rij is the normalized element corresponding to element aij in the initial supermatrix.

The pairwise comparison matrix is multiplied by the "relative weight" column vector. The new vector obtained this way is called the weighted sum vector; The elements of the weighted sum vector are divided by the relative priority vector, and the resulting vector is called the consistency vector. And the average of the elements in the consistency vector yields λmax. The consistency index is defined as follows: Where n is the number of available options in the problem. Often, instead of calculating λmax, the approximate method of the geometric mean is used.

$$CI = \frac{\lambda_{\max} - n}{n-1} \qquad L = \frac{1}{n}\left[\sum_{i=1}^{n} (AW_i / W_i)\right]$$

Parameter L is the approximate value of λmax; Vector AWi is the result of multiplying the pairwise comparison matrix of the criteria by the priority vector (eigenvector) and Vector Wi is the same priority vector or eigenvector of the criteria.

Table 1: Random Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	.52	.88	1.10	1.24	1.34	1.40	1.44	1.48	1.51	1.53	1.55	1.57	1.58

Therefore, after calculating AWi, it is sufficient to divide each element of this vector by the corresponding element in vector Wi, and then sum the obtained values. Dividing the total by the number of criteria (n) yields the value L. The random index is extracted in Table 1.

Findings

In this study, to rank the final sub-criteria, the Delphi technique was first used for screening, followed by multi-criteria decision-making models and the ANP model. To determine the relationships between the main variables, the DEMATEL technique was employed. For the final ranking of strategies, the TOPSIS method was used. For data analysis, Excel, SPSS, and Super Decisions software were utilized.

Designing the ANP Model

According to the research objective, based on the identified criteria and sub-criteria, the appropriate Analytic Network Process model was designed using Super Decisions software.

Table 2: Symbols used for criteria and sub-criteria

Criterion	Criterion Symbol	Sub-criterion	Sub-criterion Symbol
Monitoring the enforcement of regulations	C1	Enforcement of smoking prohibition	S11
		Gas welding and flame cutting are carried out by skilled workers	S12
Firefighting and rescue equipment	C2	Accessibility for emergency vehicles	S21
		Prevention of section blockage	S22
		Provision of fire escape stairs	S23
		Installation of smoke vents	S24
		Construction of proper stairways	S25
		Lobby ventilation	S26
Availability of adequate emergency exits	C3	Sufficient emergency lighting	S31
		Appropriate width of escape routes	S32
		Sufficient number of exits	S33
		Provision of exit signs	S34
		Adequate travel distance	S35
Storage method for flammable and hazardous materials	C4	Waste removal	S41
		Storage of flammable liquids in sealed appropriate containers	S42
		Provision of proper fire extinguishers near doors and hazardous goods	S43
Electrical equipment management	C5	Prevention of overheating in excavators	S51
		Prevention of overheating in generators	S52
		Overheating of rollers	S53
		Insulation and protection of electrical wiring	S54
		Use of grounding (earth) wire	S55
Fire-resistant materials used on construction site	C6	Use of fire-resistant construction materials	S61
		Size of storage compartments for flammable materials	S62
Existing firefighting facilities and equipment	C7	Audio-visual alarm systems	S71
		Presence of fire alarms	S72
		Availability of fire blankets	S73
		Presence of fire hydrant risers	S74
		Fixed electric fire pumps	S75
		Hose reels	S76
		Periodic inspections	S77
		Portable fire extinguishers on each floor and site office	S78
		Fire precautions in flammable liquids storage areas	S79
		Sprinkler system	S710
Availability of safe emergency evacuation procedures	C8	Evacuation training for on-site staff	S81
		Proper placement of emergency signs	S82
		Evacuation awareness among residents and staff	S83
Site environmental conditions during a fire	C9	Risk of extreme heat	S91
		Risk of irritating gases	S92
		Risk of smoke	S93
		Risk of toxic gases	S94
Workers' safety behavior	C10	Staff readiness to evacuate during fire	S101
		Achievable rate of evacuation	S102

Table 3: Priority Determination of Sub-criteria under Monitoring the Enforcement of Regulations

	Smoking Prohibition Enforcement	Gas Welding & Flame Cutting by Skilled Workers	Geometric Mean	Eigenvector
Smoking Prohibition Enforcement	1	0.827	0.909	0.453
Gas Welding & Flame Cutting by Skilled Workers	1.210	1	1.100	0.547

Since the views of more than one expert were considered in this study, the geometric mean technique was used to calculate the final priority rankings of expert opinions. The geometric mean helps incorporate the judgment of each member while assessing the group consensus for each pairwise comparison. The geometric mean is the most appropriate mathematical rule for aggregating judgments in ANP because it preserves the reciprocal property of the pairwise comparison matrix.

Priority Determination Based on Goal (W21)

To begin the analysis, the main criteria were compared in pairs concerning the goal. For this, a group of experts was consulted. Using the geometric mean and normalization of the resulting values, the eigenvector was calculated.

Based on the resulting eigenvector: The criterion "Availability of safe emergency evacuation procedures" with a normalized weight of 0.167 ranks first and the criterion "Electrical equipment management" with a normalized weight of 0.134 ranks second; The criterion "Fire-resistant materials used on construction site" with a normalized weight of 0.113 ranks third. The criterion "Site environmental conditions during a fire" with a normalized weight of 0.108 ranks fourth and the criterion "Firefighting and rescue equipment" with a normalized weight of 0.103 ranks fifth. The criterion "Availability of adequate emergency exits" with a normalized weight of 0.088 ranks sixth and the criterion "Existing firefighting facilities and equipment" with a normalized weight of 0.077 ranks seventh; the criterion "Storage method for flammable and hazardous materials" with a normalized weight of 0.072 ranks eighth. The criterion "Workers' safety behavior" with a normalized weight of 0.071 ranks ninth and the criterion "Monitoring the enforcement of regulations" with a normalized weight of 0.065 ranks last.

Pairwise comparison of sub-criteria

In the next step, the sub-criteria under each main criterion were compared pairwise. Due to space limitations, only two examples are presented below:

Prioritizing the sub-criteria for monitoring the implementation of laws

The calculations performed to prioritize the sub-criteria for monitoring the implementation of laws are presented in Table 3. Since this criterion consists of 2 sub-criteria, 1 pairwise comparison was performed. According to the resulting eigenvector: The sub-criterion "Gas welding and flame cutting carried out by skilled workers" with a normalized weight of 0.547 ranks first. The sub-criterion "Enforcement of smoking prohibition" with a normalized weight of 0.453 ranks second.

Priority Determination of Sub-criteria under "Firefighting and Rescue Equipment"

This criterion includes 6 sub-criteria, which results in 15 pairwise comparisons. The results are presented in Table 4 (not shown here due to brevity). Based on the obtained eigenvector: The sub-criterion "Preventing the blockage of sections" with a normalized weight of 0.230 is in the priority. The sub-criterion "Providing fire and rescue stairs" with a normalized weight of 0.193 is the second priority. The sub-criterion "Accessibility of emergency vehicles" with a normalized weight of 0.174 is the third priority and the sub-criterion "Building appropriate stairs" with a normalized weight of 0.160 is in the fourth priority. The sub-criterion "Lobby ventilation" with a normalized weight of 0.125 is the fifth priority and the sub-criterion "Installing smoke vents" with a normalized weight of 0.117 is in the last priority. The inconsistency rate of the comparisons made is 0.022, which is smaller than 0.1, and therefore the comparisons made can be trusted.

Determining the priority of the sub-criteria for the existence of appropriate and sufficient emergency exits

The calculations performed to determine the priority of the sub-criteria for the existence of appropriate and sufficient emergency exits are presented in the table. Since this criterion consists of 5 sub-criteria, 10 pairwise comparisons were performed. Based on the eigenvector, the results are as follows: The sub-criteria for "adequate emergency lighting" with a normalized weight of 0.232 is the priority. The sub-criteria for "adequate width of escape routes" with a normalized weight of 0.214 is the second priority; the sub-criteria for "adequate distance for movement" with a normalized weight of 0.203 is the third priority. The sub-criteria for "sufficient number of exits" with a normalized weight of 0.189 is in the fourth priority. And the sub-criteria for "providing exit signs" with a normalized weight of 0.162 is the last priority. The inconsistency rate of the comparisons made was 0.017, which is smaller than 0.1, and therefore the comparisons made can be trusted.

Table 4: Prioritization of Sub-Criteria Related to Firefighting and Rescue Equipment

Criteria	Emergency Vehicle Access	Avoiding Section Blockage	Provision of Fire and Rescue Staircases	Installation of Smoke Vents	Construction of Appropriate Stairs	Lobby Ventilation	Geometric Mean	Eigenvector
Emergency Vehicle Access	1	1.243	0.908	1.506	0.754	1.186	1.072	0.174
Avoiding Section Blockage	0.804	1	1.631	2.713	1.420	1.631	1.421	0.230
Provision of Fire and Rescue Staircases	1.101	0.613	1	1.813	1.414	1.661	1.193	0.193
Installation of Smoke Vents	0.664	0.369	0.552	1	0.827	1.296	0.725	0.117
Construction of Appropriate Stairs	1.327	0.707	0.707	1.209	1	1.161	0.988	0.160
Lobby Ventilation	0.843	0.613	0.602	0.772	0.861	1	0.769	0.125

Prioritizing the sub-criteria for storing flammable and hazardous materials

The calculations performed to prioritize the sub-criteria for storing flammable and hazardous materials are presented in Table 7. Since this criterion consists of 3 sub-criteria, 3 pairwise comparisons were performed. Based on the eigenvector, the results were obtained as follows: The sub-criteria "Garbage cleaning" with a normalized weight of 0.539 is the first priority. The sub-criteria "Keeping flammable liquids in a suitable closed container" with a normalized weight of 0.235 is the second priority. And the sub-criteria "Providing a suitable fire extinguisher near the door and dangerous goods" with a normalized weight of 0.226 is the last priority. The inconsistency rate of the comparisons made was 0.017, which is smaller than 0.1, and therefore the comparisons made can be trusted.

Prioritizing the sub-criteria of electrical equipment management

The calculations performed to prioritize the sub-criteria of electrical equipment management are presented in the table. Since this criterion consists of 5 sub-criteria, 10 pairwise comparisons were performed. Based on the eigenvector, the results were obtained as follows: The sub-criteria "Prevention of generator overheating" with a normalized weight of 0.249 is in the first priority. The sub-criteria "Insulation and protection of electrical wiring" with a normalized weight of 0.205 is the second priority.

The sub-criteria "Roller overheating" with a normalized weight of 0.202 is in the third priority. The sub-criterion "Preventing the excavator from overheating" with a normalized weight of 0.177 is the fourth priority.

The sub-criterion "Using an earth wire" with a normalized weight of 0.166 is in the last priority. The inconsistency rate of the comparisons made is 0.087, which is smaller than 0.1, and therefore the comparisons made can be trusted. Determining the priority of the sub-criteria for the resistance of materials used in the construction site. The calculations performed to determine the priority of the sub-criteria for the resistance of materials used in the construction site are presented in Table 9. Since this criterion consists of 2 sub-criterions, 1 pairwise comparison has been performed. Based on the eigenvector, the results are obtained as follows: The sub-criterion "Size of flammable material storage compartments" with a normalized weight of 0.547 is in the first priority. The sub-criterion "Use of fire-resistant building materials" with a normalized weight of 0.453 is the last priority.

Prioritizing the sub-criteria of existing fire-fighting equipment and facilities

The calculations performed to prioritize the sub-criteria of existing fire-fighting equipment and facilities are presented in Table 4-12. Since this criterion consists of 10 sub-criterions, 45 pairwise comparisons have been performed. Based on the eigenvector, the following results were obtained: The sub-criterion “Portable fire extinguishers on each floor and site office” with a normalized weight of 0.156 is in the first priority. The sub-criterion “Fire-resistant fixed fire pump with electricity” with a normalized weight of 0.143 is in the second priority. The sub-criterion “Provision of flammable liquids at the storage site” with a normalized weight of 0.1249 is the third priority. The sub-criterion “Existence of hose reel” with a normalized weight of 0.1247 is in the fourth priority.

The sub-criterion “Sprinkler system” with a normalized weight of 0.088 is in the fifth priority. The sub-criterion “Existence of fire alarm” with a normalized weight of 0.082 is the sixth priority. The sub-criterion “Periodic inspection” with a normalized weight of 0.078 is in the seventh priority. The sub-criterion “Existence of fire hydrant riser” with a normalized weight of 0.074 is in the eighth priority. The sub-criterion “Existence of fire blankets” with a normalized weight of 0.068 is the ninth priority. The sub-criterion “Audio-visual advisory systems” with a normalized weight of 0.062 is the last priority. The inconsistency rate of the comparisons made was 0.054, which is less than 0.1, and therefore the comparisons made can be trusted.

Determining the priority of the sub-criteria for the existence of safe emergency evacuation instructions

According to the calculations made to determine the priority of the sub-criteria for the existence of safe emergency evacuation instructions, since this criterion consists of 3 sub-criteria, 3 pairwise comparisons have been made. Based on the obtained eigenvector, the sub-criteria “Location of emergency signs” with a normalized weight of 0.437 is in first priority.

The sub-criteria “Evacuation knowledge of residents and employees” with a normalized weight of 0.334 is in second priority. The sub-criteria “Evacuation training for employees on site” with a normalized weight of 0.230 is in last priority. The inconsistency rate of the comparisons made was 0.062, which is smaller than 0.1, and therefore the comparisons made can be trusted.

Determining the priority of the sub-criteria of the site's environmental conditions during the fire

According to the calculations made to determine the priority of the sub-criteria, since this criterion consists of 4 sub-criteria, 6 pairwise comparisons have been made. Based on the obtained eigenvector, the sub-criteria “Risks of smoke” with a normalized weight of 0.297 is in the first priority. The sub-criteria “Risks of toxic gases” with a normalized weight of 0.272 is in the second priority. The sub-criteria “Risks of irritant gases” with a normalized weight of 0.258 is the third priority. The sub-criteria “Risks of excessive heat” with a normalized weight of 0.173 is the last priority. The inconsistency rate of the comparisons made was 0.014, which is smaller than 0.1, and therefore the comparisons made can be trusted. Determining the priority of the sub-criteria of workers' safety behaviors. The calculations performed to determine the priority of the sub-criteria of workers' safety behaviors are presented in Table 13. Since this criterion consists of 2 sub-criteria, 1 pairwise comparison was performed. Based on the obtained eigenvector, the sub-criteria “Readiness of employees on site for evacuation in case of fire” with a normalized weight of 0.625 is in the first priority. The sub-criteria “Achievable rate of movement” with a normalized weight of 0.375 is the last priority.

Step 4: Displaying the map of network relationships.

After the threshold intensity is determined, all the values of the T matrix that are smaller than the threshold are zero, meaning that the causal relationship is not considered. In this study, the threshold intensity is obtained as 0.58. Therefore, the pattern of meaningful relationships is as follows:

The sum of the elements of each row (D) indicates the degree of influence of that criterion on other criteria of the model. Accordingly, the criterion of monitoring the implementation of laws has the greatest influence. Workers' safety behaviors have the least influence. The sum of the elements of the column (R) for each factor indicates the degree of influence of that factor on other factors of the system. Accordingly, the criterion of electrical equipment management has a very high degree of influence. The criterion of existing fire extinguishing equipment and facilities also has the least influence on other criteria.

Table 6: Causal relationship pattern of the main criteria

Main Criterion	D	R	D+R	D−R
Monitoring the implementation of regulations	6.66	6.35	13.00	0.31
Firefighting and rescue tools	5.94	5.85	11.79	0.09
Availability of suitable and sufficient emergency exits	5.88	5.89	11.77	-0.01
Storage of flammable and hazardous materials	5.49	5.24	10.72	0.25
Management of electrical equipment	6.25	6.43	12.68	-0.18
Fire resistance of building materials	5.63	5.99	11.61	-0.36
Existing fire extinguishing equipment and facilities	5.72	5.23	10.95	0.49
Availability of safe evacuation instructions	5.68	5.29	10.97	0.39
Site conditions during a fire	5.62	5.72	11.34	-0.10
Workers' safety behavior	5.28	6.15	11.43	-0.87

Table 7: Final Prioritization of Sub-Criteria

Sub-Criterion	Code	Final Weight	Rank
Prohibition of smoking	S11	0.0450	6
Gas welding and flame cutting performed by skilled workers	S12	0.0544	3
Emergency vehicle access	S21	0.0173	27
Preventing area blockages	S22	0.0229	17
Provision of fire escape staircases	S23	0.0192	23
Installation of smoke vents	S24	0.0116	36
Construction of proper staircases	S25	0.0159	30
Lobby ventilation	S26	0.0124	35
Sufficient emergency lighting	S31	0.0235	14
Adequate width of escape routes	S32	0.0217	19
Sufficient number of exits	S33	0.0192	24
Exit signage	S34	0.0164	28
Suitable distance for movement	S35	0.0206	20
Waste removal	S41	0.0538	4
Storage of flammable liquids in appropriate sealed containers	S42	0.0235	15
Placement of appropriate fire extinguishers near doors and hazardous items	S43	0.0226	18
Preventing overheating of excavators	S51	0.0174	25
Preventing overheating of generators	S52	0.0245	13
Preventing overheating of rollers	S53	0.0199	22
Insulation and protection of electrical wiring	S54	0.0202	21
Use of grounding wires (earth wires)	S55	0.0163	29
Use of fire-resistant building materials	S61	0.0455	5
Proper size of storage compartments for flammable materials	S62	0.0549	2
Use of audiovisual alarm systems	S71	0.0063	42
Availability of fire alarms	S72	0.0083	38
Availability of fire blankets	S73	0.0069	41
Availability of fire hydrant risers	S74	0.0075	40
Fixed electric fire pump	S75	0.0145	32
Availability of hose reels	S76	0.0126	33
Periodic inspections	S77	0.0079	39
Portable fire extinguishers on each floor and office	S78	0.0158	31
Provision of fireproof storage in liquid storage areas	S79	0.0126	34
Sprinkler system	S710	0.0089	37
Evacuation training for on-site staff	S81	0.0230	16
Location of emergency signs	S82	0.0438	7
Evacuation knowledge among residents and workers	S83	0.0335	9
Hazards due to high heat	S91	0.0174	26
Hazards due to irritant gases	S92	0.0259	12
Hazards due to smoke	S93	0.0298	10
Hazards due to toxic gases	S94	0.0273	11
Staff preparedness for evacuation in fire emergencies	S101	0.0619	1
Achievable rate of movement	S102	0.0372	8

The horizontal vector (D + R) is the degree of influence and impact of the factor in question in the system. In other words, the higher the value of D + R of a factor, the more interaction that factor has with other factors in the system. Accordingly, the criterion for monitoring the implementation of laws has the most interaction with other criteria under study. The method of storing flammable and hazardous materials has the least interaction with other variables.

The vertical vector (D - R) shows the power of influence of each factor. In general, if D - R is positive, the variable is considered a causal variable, and if it is negative, it is considered a causal variable. In this model, the criterion for monitoring the implementation of laws, fire extinguishing, and rescue tools, the method of storing flammable and hazardous materials, existing fire extinguishing equipment and facilities, the existence of safe emergency evacuation instructions, the causal variable and the existence of appropriate and sufficient emergency exits, the management of electrical equipment, the resistance of materials used in the construction site, and the environmental conditions of the site during a fire are the causal variables.

Final Prioritization of Sub-Criteria Using the ANP Technique

To determine the final prioritization of the model's sub-criteria using the ANP technique, the unweighted supermatrix, weighted supermatrix, and ultimately the limit supermatrix must be calculated. Therefore, the structure of the unweighted supermatrix can be observed in the final model design, which was created using Super Decisions software. (Table 7)

According to the performed calculations, the final weight of each sub-criterion in the model was determined using the ANP technique.

Based on the normalized weights: The sub-criterion "Achievable rate of displacement" with a normalized weight of 0.0619 is in first priority. The sub-criterion "Size of storage compartments for flammable materials" with a normalized weight of 0.0549 is ranked second. The sub-criterion "Gas welding and flame cutting should be done by skilled workers" with a normalized weight of 0.0544 is ranked third. And the sub-criterion "Waste cleanup" with a normalized weight of 0.0538 is ranked fourth. The sub-criterion "Use of fire-resistant construction materials" with a normalized weight of 0.0455 is ranked fifth. The sub-criterion "Implementation of smoking bans" with a normalized weight of 0.0451 is ranked sixth. The sub-criterion "Location of emergency signs" with a normalized weight of 0.0438 is ranked seventh. The sub-criterion "On-site staff preparedness for evacuation during fire" with a normalized weight of 0.0372 is ranked eighth. The sub-criterion "Evacuation knowledge of residents and employees" with a normalized weight of 0.0335 is ranked ninth. The sub-criterion "Hazards caused by smoke" with a normalized weight of 0.0298 is ranked tenth.

Discussion and Conclusion

This research was conducted to identify and rank the effective firefighting and rescue monitoring and instrumental criteria in controlling the risk of accidents in construction projects in the Tehran metropolis. To determine the final priority of the main criteria of the model, the initial (unbalanced) supermatrix, the balanced supermatrix, and finally the limit supermatrix was calculated using the ANP technique.

Based on the calculations and the limit supermatrix, it was determined that the sub-criterion "Achievable displacement rate" with a normalized weight of 0.0619 is the first priority, the sub-criterion "Size of flammable material storage compartments" with a normalized weight of 0.0549 is the second priority, the sub-criterion "Gas welding and flame cutting work should be performed by skilled workers" with a normalized weight of 0.0544 is the third priority, the sub-criterion "Gas cleaning" with a normalized weight of 0.0538 is the fourth priority, the sub-criterion "Use of fire-resistant building materials" with a normalized weight of 0.0455 is the fifth priority, the sub-criterion "Implementation of smoking ban" with a normalized weight of 0.0451 is the sixth priority, the sub-criterion "Location of emergency signs" with a normalized weight of 0.0438 is the seventh priority, the sub-criterion "Readiness of employees on site for evacuation in case of fire" with a normalized weight of 0.0372 is the first priority. Eighth, the sub-criterion "Knowledge of evacuation of residents and employees" with a normalized weight of 0.0335 is in the ninth priority and the sub-criterion "Risks of smoke" with a normalized weight of 0.0298 is in the tenth priority. In comparison with previous research, Sadeghian and Omidvar (4) presented a gas network fire risk model after an earthquake in a study on the assessment of gas network fire risk in various urban uses after an earthquake (case study: District 20 of Tehran) based on Monte Carlo simulation. Adeli Zadeh and Shobeiri (5) in an article entitled "Prioritization of fire risks in tall buildings using a combined FISM and FANP model" used the network analysis method to prioritize and weight the indicators, similar to the present study, with the difference that they conducted this analysis in a fuzzy space and taking into account the uncertainty of experts' opinions, and similar to the present study, safety management risk and safety instructions and electrical equipment management were introduced as the most important criteria.

Masoudian et al. (6), in a study titled "Identifying, ranking and providing fire prevention solutions in high-risk places: A case study of Mashhad," like the present study, pointed out the need to consider evacuation routes in case of fire. Amiri and Asadi (7), in their study of fire risk assessment of Iranian passenger trains using the fuzzy-theoretic FMEA approach, concluded that the safety performance of the Iranian railway industry is at some known levels of fire risk in passenger trains. Lee et al. (10) conducted research on the topic of "Fire risk assessment of high-rise buildings under construction based on the theory of uncertain measurements" and, like the present study, used multi-criteria decision-making methods, but used the entropy method to weight the indicators. Fire extinguishing and rescue tools, the presence of appropriate and sufficient emergency exits, the method of storing flammable and hazardous materials, the management of electrical equipment, the resistance of materials used at the construction site, existing fire extinguishing equipment and facilities, the presence of safe emergency evacuation instructions, the environmental conditions of the site during a fire, and the safety behaviors of workers are among the effective criteria for fire risk in accidents in construction projects.

Compliance with Ethical Guidelines

There were no ethical considerations in this research.

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Author's Contributions

The research was conducted solely by the author.

Conflict of Interests

The authors declare no conflict of interest.

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References

1. Amini M. [Assessment of maximum possible losses in high-rise buildings fires using the LOPA method (case study of the Central Insurance Building of Iran) (Persian)]. [dissertation]: Islamic Azad University Central Tehran Branch. Tehran; 2018. 250p.
2. Jahangiri M, Sarebanzadeh K, Bashar O, Saleh Zade H. [Investigation risk perception, safety attitude and safety performance in supervisors of construction sites Shiraz-Iran (Persian)]. Iran J Ergon. 2013; 1 (2):10-18 Available from: http://journal.iehfs.ir/article-1-38-fa.html
3. Khakkar S, Ranjbarian M, Khodakarim S, Pouyakian M. [Fire risk assessment in commercial complexes in Tehran's 12th district and its relationship with structural features and their use (Persian)]. Journal of Occupational Health and Safety. 2010;10(3):273-289.
4. Sadeghian AR, Omidvar B. [Gas network fire risk assessment in different urban uses after the earthquake: a case study: district 20 of Tehran (Persian)]. Journal of Civil Engineering (Faculty of Engineering). 2015;27(1):17-34.
5. Adelizadeh, M, Shobeiri, SM. [Prioritizing fire risks in tall buildings using the combined FISM and FANP model (Persian)]. Journal of Safe City. 2018;1(4):75-100.
6. Masoudian M, Nosrati Karizek, A, Sepehri S. [Identification, ranking and presentation of fire prevention solutions in high-risk places: a case study of Mashhad (Persian)]. The 7th Scientific & Research Conference on the Development and Promotion of Architecture & Urbanism in Iran. Iran: Tehran, [23 Jan 2021] 2021. Available from: https://civilica.com/doc/1180344
7. Bolbol Amirin N, Asadi Lari A. [Fire risk assessment of Iranian passenger trains using the fuzzy FMEA-Gray theory approach (Persian)]. Journal of Transportation Engineering, 2010; 1(4): 27-38.
8. Başdemir H. A literature review of fire safety in construction sites. Gazi University Journal of Science Part B: Art Humanities Design and Planning. 2019;7(1): 199-209.
9. Hubbard, D.W. The failure of risk management: Why it's broken and how to fix it. John Wiley & Sons. 2nd Edition. 2020 https://doi.org/10.1002/9781119521914
10. Li W, Li H, Liu Y, Wang S, Pei X, Li Q. Fire risk assessment of high-rise buildings under construction based on unascertained measure theory. PLoS ONE. 2020;15(9): e0239166. https://doi.org/10.1371/journal.pone.0239166