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Utilizing a hybrid fuzzy DEMATEL-ANP-Delphi approach for identifying and prioritizing construction cost overruns in project management

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Abstract

Construction projects are frequently associated with a high incidence of cost overruns. To address this issue, the present study adopts a descriptive and survey-based approach to identify and rank the factors that contribute to construction costs. The study's statistical population comprises ten expert specialists, and the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) with Analytical Network Process (ANP) (DANP) technique is utilized to evaluate the research factors. Additionally, the fuzzy DANP and Delphi methods are employed to rank the essential dimensions and criteria of the research. The study's findings reveal that environmental factors are the primary cause of construction cost overruns, followed by managerial factors and legal and administrative factors, respectively. Dynamic conditions often result in unpredictable challenges for environmental factors, making them a critical driver of construction cost overruns. Therefore, environmental factors play a significant role in contributing to construction cost overruns.

Keywords: construction management, fuzzy Delphi, fuzzy DANP, environmental aspects, ranking
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1 Introduction

The construction industry is recognized as one of the most dynamic and complex industries in modern society, and its fluctuations significantly affect many other sectors, particularly those directly associated with it [2]. Given the limited time and specific cost framework of construction projects, effective planning and supervision are crucial. However, cost overruns and delays are common occurrences in this industry due to various interacting factors that vary from place to place [9]. Therefore, identifying the factors that contribute to cost and time overruns is critical, as some factors may have a substantial impact on others [17]. By clarifying the causes of cost overruns, better decision-making strategies, and effective planning and organization can be implemented [16]. Conversely, construction cost overruns may lead to industrial disputes between the employer, contractor, and consultant [6]. In multi-dimensional projects,

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scheduling and budget allocation become even more complicated [7]. Furthermore, financial pressures on the employer may result in incorrect decisions and resource waste, which then transfer pressure to the contractor and project agents, disrupting the project's progress [12]. Although cost overruns occur less frequently than time overruns, the latter may result from the former. The success of a construction project is measured by its adherence to the initial cost and time estimates. Recent research has focused on evaluating the factors that contribute to construction cost overruns. Poor contract management, inexperienced labourers, delayed plan approval, and improper maintenance of materials and equipment are among the factors that contribute to construction cost overruns, as reported by Amri and Marey-Pérez [4].

Nyoni [14] highlights that imprecise material cost estimations and the lack of regular progress reports are significant contributors to construction cost overruns in Zimbabwe. Similarly, Memon et al. [13] report that poor communication among parties, delayed governmental permissions, and a lack of technical personnel are the primary factors leading to cost overruns in the Pakistani construction industry. Hence, proper monitoring and system control can significantly improve the situation. Moreover, taking into account the stability of environmental components can lead to a more sustainable cost evaluation. For instance, Leśniak and Zima [12] investigate the impact of neighbouring geographical situations and material quality on the development of construction projects. Sen et al. [18] categorize the factors contributing to construction cost overruns into four groups: design, customer, contractor, and environment.

Kanchana and Sukumaran [10] identified several hidden factors that contribute to cost overruns in construction projects, including redesigns mandated by project owners, contractor-related problems, and frequent changes to provisions and permits. In a similar vein, Seyedebrahimi et al. [19] explored the cost of residential construction projects in Yazd city using documentary and survey methods. The researchers applied a hierarchical analysis technique to the collected data and identified the factors that influence the cost of such projects.

In another study, Obianyo et al. [15] employed a fuzzy logic soft computing technique to assess the cost overrun variables of construction projects. They collected survey responses from construction industry professionals and experts and identified the factors contributing to cost overruns, which were then arranged in a questionnaire format based on a review of relevant literature and a comprehensive investigation. The researchers found that cost overruns occur due to the underestimation of actual costs during cost budgeting, and the fuzzy logic model exhibited superior forecasting accuracy when compared to the actual results.

Similarly, Zafar et al. [22] investigated time overrun risk variables in highway projects in the FATA area of Pakistan, which is afflicted by terrorism, using a questionnaire survey. They applied a fuzzy synthetic evaluation modelling technique to the collected data and identified stakeholder interference and security threats as the most important factor groupings, followed by incompetent contractors and underproductive workers, ineffective project planning and contractual arrangements, shortages of construction materials, and force majeure. The researchers suggested that major time overrun risk indicators could be used to develop a decision support system to control risks and enhance the performance of highway projects in countries affected by terrorism.

Lastly, Alekhya et al. [3] examined the most significant cost overrun drivers in the Indian construction sector through a case study of the Hyderabad Metro Rail project. The researchers identified land acquisition issues, social and cultural issues, contractor financial difficulties, and fluctuations in material costs as the top five reasons for cost overruns in the project.

In summary, these studies shed light on the various factors that contribute to cost and time overruns in construction projects, providing valuable insights for practitioners and policymakers seeking to improve project performance and mitigate risks.

Thakur [21] conducted an assessment of risk variables associated with cost overruns and delays in bridge construction. A fuzzy inference system was used to calculate risk indices based on a questionnaire survey, and a risk management strategy was developed to mitigate the identified risk factors. The study also proposed the development of a neuro-fuzzy-based prediction model using the collected risk indices as weighting elements. Islam et al. [8] proposed a modified fuzzy group decision-making method for evaluating cost overrun risks in different phases of power plant projects. The study aims to improve the accuracy of project budgeting and contingency allocation decisions while enhancing risk evaluation. Afzal et al. [1] focused on the subjective risk assessment techniques used in construction management to address cost overruns, highlighting the importance of analyzing the relationship between complexity and risk elements. Sharma and Goyal [20] suggested the use of a value-based model to calculate the magnitude of risk factors, addressing ambiguity, uncertainty, and individual perceptions of complex building project issues. The top ten reasons for cost overruns in the Indian construction industry, including material price fluctuations, inaccurate time and cost estimates, and design changes, were identified. This study aims to establish a comprehensive scheme for the construction cost overrun problem by investigating the impact of managerial, legal, and environmental factors on construction costs. The fuzzy DANP technique is used to evaluate the research factors, and fuzzy DANP and Delphi methodologies are used to rank the essential dimensions and criteria of the research. Through a descriptive and survey approach, this study identifies and ranks the effective factors on construction costs using ten expert specialists as the statistical population.

2 Research methods

The current study adopts a rigorous mixed-methods approach, which seamlessly integrates both qualitative and quantitative methods for data analysis. In the qualitative phase, the study employs the fuzzy Delphi method, which is a well-recognized approach for achieving expert consensus on complex issues. The method enables the identification and validation of the research factors by extracting expert opinions through a series of rounds of questionnaires and feedback sessions. This approach ensures that the research factors identified in the study are reliable and valid, as they are based on the collective wisdom of domain experts.

In the subsequent quantitative phase, the study employs the fuzzy DEMATEL technique to evaluate the research factors, which allows for the exploration of the interrelationships among the factors. This technique provides a means of analyzing complex relationships among factors and provides a basis for further analysis. To rank the main research dimensions and their respective criteria, the study uses a combination of fuzzy DANP and Delphi methodologies. This combination of methods enables the researchers to identify and prioritize the most critical factors that affect construction cost overruns.

To present the results of the study comprehensively, Table 1 presents the linguistic expressions denoting the triangular fuzzy values assigned to each criterion by the experts, representing their judgments on the criterion's validity. These linguistic expressions enable the researchers to deal with the imprecise and uncertain data that often arise in the construction domain. Moreover, the use of fuzzy logic and triangular fuzzy numbers in the study facilitates the representation of expert opinions more realistically and accurately.

The combination of qualitative and quantitative methods employed in the study enables a more comprehensive analysis of the research factors, their interrelationships, and the relative importance of each criterion. This approach provides a more accurate understanding of the complex nature of construction cost overruns and offers valuable insights for practitioners and policymakers. The rigorous approach and comprehensive results of the study make a significant contribution to the literature on construction cost overruns and provide a useful guide for researchers and practitioners working in this field.

Table 1: Linguistic expressions of the fuzzy values

Linguistic expressions	**Delphi fuzzy value**
Very low	(0,0,0.25)
Low	(0,0.25,0.5)
Medium	(0.25,0.5,0.75)
High	(0.5,0.75,1)
Very High	(0.75,1,1)

3 Results and discussion

In this section, first, the fuzzy Delphi technique is employed to approve the most effective criteria included in the primary dimensions, which are managerial, legal and administrative, and environmental. Then, the fuzzy DANP approach helps to rank the approved criteria.

3.1 Results of the fuzzy Delphi method

Denote n and m, respectively, as the number of the criteria and the number of experts. A fuzzy value $\tilde{\tau}_{ij}$. It is defined by the j^{th} expert to validate the i^{th} criterion as:

$$\tilde{\tau}_{ij} = (a_{ij}, b_{ij}, c_{ij}), \quad i = 1, ..., n, \quad j = 1, ..., m, \tag{3.1}$$

in which, a_{ij}, b_{ij} and c_{ij} respectively are the lower, medium, and upper parameters of the fuzzy value $\tilde{\tau}_{ij}$. Denote the de-fuzzy average value $\bar{\tau}_i$ of each criterion i (see Table 2) as

$$\bar{\tau}_i = \frac{a_i + b_i + c_i}{3}, \tag{3.2}$$

in which, a_i, b_i and c_i Are the arithmetic mean of the m experts' views on the i^{th} criterion,

$$\begin{cases} a_i = \sum_j \frac{a_{ij}}{m}, \\ b_i = \sum_j \frac{b_{ij}}{m}, \\ c_i = \sum_j \frac{c_{ij}}{m}. \end{cases} \tag{3.3}$$

According to the experts' decisions, the criterion is not approved if the de-fuzzy average of a criterion is less than 0.5. Table 2 indicates the fuzzy and the de-fuzzy average value of each criterion as well as the approval status of the criteria. Moreover, the approved criteria by the experts' views are coded in Table 2. The effective factors on the construction cost overrun are extracted from the literature.

Table 2: The results of the fuzzy Delphi method

Dimensions	**Criteria**	**Fuzzy average**	**De-fuzzy average**	**Status**	**Code**
Managerial (A)	Employing a capable designer and consultant	(0.4,0.63,0.88)	0.633	Approved	A_1
	Employing a professional contractor	(0.53,0.75,0.93)	0.733	Approved	A_2
	The payment strategy	(0.45,0.68,0.88)	0.667	Approved	A_3
	Services purchasing (Water, electricity, etc.)	(0.28,0.48,0.73)	0.492	Rejected	–
	Procurement of machinery and equipment	(0.45,0.7,0.93)	0.692	Approved	A_4
	Proper communication with consultant and contractor	(0.23,0.43,0.68)	0.442	Rejected	–
	Accurate computation of the required materials	(0.5,0.75,0.9)	0.717	Approved	A_5
	Design the digital 3D model with precise cost estimation	(0.48,0.73,0.93)	0.708	Approved	A_6
	Investigating the reports provided by the contractor's supervisor	(0.25,0.48,0.7)	0.475	Rejected	–
	Effective and timely decision making	(0.48,0.73,0.9)	0.700	Approved	A_7
Legal and Administrative (B)	Insurance scheme	(0.45,0.7,0.88)	0.675	Approved	B_1
	Tax payment procedure	(0.23,0.43,0.68)	0.442	Rejected	–
	Banking facilities program	(0.4,0.65,0.85)	0.633	Approved	B_2
	Added value schedule	(0.25,0.45,0.7)	0.467	Rejected	–
	Municipality licensing and standards	(0.48,0.73,0.93)	0.708	Approved	B_3
	Contract type	(0.43,0.68,0.85)	0.650	Approved	B_4
	Required licenses from the society of engineers	(0.53,0.78,0.98)	0.758	Approved	B_5
	Employees certifications preparation	(0.23,0.45,0.7)	0.458	Rejected	–
	Holding and judging the tenders	(0.45,0.7,0.9)	0.683	Approved	B_6
	Preparing instructional courses for the staff	(0.45,0.7,0.9)	0.683	Approved	B_7
Environmental (C)	Environmental and geographical conditions	(0.53,0.78,0.88)	0.758	Approved	C_1
	Land market local value	(0.45,0.7,0.88)	0.675	Approved	C_2
	Possible recycling of manufacturing wastes	(0.23,0.45,0.7)	0.458	Rejected	–
	Strength of materials	(0.25,0.45,0.7)	0.467	Rejected	–
	Material costs	(0.55,0.8,0.98)	0.775	Approved	C_3
	Supply Chain of materials	(0.48,0.73,0.93)	0.708	Approved	C_4
	Loading and unloading materials	(0.2,0.38,0.63)	0.400	Rejected	–
	Warehousing and optimal maintenance of materials	(0.53,0.78,0.98)	0.758	Approved	C_5
	Workstation and labors	(0.20.40.753)	0.458	Rejected	–
	Modern communication facilities for staffs	(0.48,0.73,0.93)	0.708	Approved	C_7

3.2 Fuzzy DANP approach

The implementation of the fuzzy Delphi approach in Table 2 confirms the primary significant factors contributing to the construction cost overrun. The ensuing steps elucidate the essential process for prioritizing the endorsed criteria as outlined by Chiu et al. [5].

3.2.1 Calculation of the direct communication fuzzy matrix ($\tilde{z}$)

In this step, the impact of the criterion on the criterion is determined by a pairwise comparison performed by the experts using Table 1. The arithmetic mean of the expert's views is then taken to compute the direct communication matrix with triangular fuzzy entries as follows:

$$\tilde{z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^3 \oplus \ldots \oplus \tilde{x}^m}{m}, \tag{3.4}$$

in which $\oplus$ is the fuzzy summation, m is the number of experts and $\tilde{x}^i$ is the pairwise comparison matrix corresponding to the i^{th} expert.

3.2.2 Normalize the direct communication matrix

The components of the mean matrix $\tilde{z}$ are the fuzzy values with lower, medium, and upper elements defined as $\tilde{z}_{ij} = (l_{ij}, m_{ij}, u_{ij})$. Denote r as:

$$r = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} u_{ij} \right). \tag{3.5}$$

The normalized mean matrix $\tilde{H}$ is then computed by dividing all of the entries of $\tilde{z}$ by r from:

$$\tilde{H} = \frac{\tilde{z}}{r}. \tag{3.6}$$

3.2.3 Calculation of the fuzzy total-influential matrix ($\tilde{T}_c$)

In this step, the total influential fuzzy matrix $\tilde{T}_c$ is obtained by computing the summation of the successive exponents of the normalized mean matrix $\tilde{H}$ As:

$$\tilde{T}_c = \lim_{k \to +\infty} (\tilde{H}^1 \oplus \tilde{H}^2 \oplus ... \oplus \tilde{H}^k) \tag{3.7}$$

Denote the n-dimensional matrices H_l, H_m and H_u as respectively the lower, middle, and upper fuzzy values of the $\tilde{H}$ Matrix. Moreover, denote the lower, middle, and upper fuzzy values of $\tilde{T}_c$ matrix as T_l, T_m and T_u. Then:

$$\begin{aligned} T_l &= H_l \times (I - H_l)^{-1}, \\ T_m &= H_m \times (I - H_m)^{-1}, \\ T_u &= H_u \times (I - H_u)^{-1}, \end{aligned} \tag{3.8}$$

holds, in which, $I_{n \times n}$ is the identity matrix.

3.2.4 The total influential matrix of the primary dimensions

The total influence matrix $\tilde{T}_c$ Pertains to the criteria included in each primary dimension A, B, and C. Hence, the $\tilde{T}_c$ the matrix contains several blocks. Each block includes the criteria that correspond to two of the primary dimensions. The total influence of each primary dimension on the other ones is investigated by constructing $\tilde{T}_D$ matrix. This matrix is obtained by computing the mean value of the entries of each block of $\tilde{T}_c$. The total influential matrix $\tilde{T}_D$ is presented in Table 3.

Table 3: Total influential fuzzy matrix $\tilde{T}_D$.

$\tilde{T}_D$	**A**	**B**	**C**
A	(0.042,0.117,0.249)	(0.047,0.118,0.228)	(0.051,0.124,0.236)
B	(0.042,0.115,0.243)	(0.04,0.105,0.209)	(0.047,0.116,0.223)
C	(0.045,0.123,0.262)	(0.048,0.12,0.235)	(0.046,0.118,0.233)

3.2.5 Calculation of the impact intensity and direction

Denote $\tilde{D}_i$ as the sum of the i^{th} row and $\tilde{R}_j$ as the sum of the j^{th} column of the $\tilde{T}_c$ matrix as

$$\tilde{D}_i = \left[\sum_{j=1}^{n} \tilde{T}_{ij} \right], \quad \tilde{D} = [\tilde{D}_1, ..., \tilde{D}_n]^T_{n \times 1}, \tag{3.9}$$

$$\tilde{R}_j = \left[\sum_{i=1}^{n} \tilde{T}_{ij} \right], \quad \tilde{R} = [\tilde{R}_1, ..., \tilde{R}_n]_{1 \times n}. \tag{3.10}$$

Then, the de-fuzzy vectors $D)_{n \times 1}$ and $R)_{1 \times n}$ are obtained by computing the arithmetic mean of $\tilde{D}$ and $\tilde{R}$. Define the impact intensity and the impact direction of the i^{th} criterion, respectively, by $D_i + R_i$ and $D_i - R_i$. The value of $D_i + R_i$ Predicates the interaction of the i^{th} criterion with the other criteria. Moreover, $D_i - R_i$ Describes the casual and effective behaviour of the i^{th} criterion. In this regard, if $D_i - R_i$ is positive, the i^{th} criterion significantly affects the other criteria, while it is mainly influenced by the other criteria in case of a negative value of $D_i - R_i$. The impact and direction intensity of the criteria and the primary dimensions are investigated respectively in Tables 4 and 5.

Table 4: Impact and direction intensity of the criteria.

	$\tilde{D}$	$\tilde{R}$	**D**	**R**	**D+R**	**D-R**
A_1	(0.273,0.751,1.601)	(0.284,0.86,1.984)	0.875	1.043	1.918	−0.168
A_2	(0.257,.766,1.715)	(0.3034,0.874,1.947)	0.913	1.042	1.954	−0.129
A_3	(0.332,0.909,1.889)	(0.285,0.831,1.817)	1.043	0.978	2.021	0.065
A_4	(0.315,0.828,1.675)	(0.295,0.785,1.607)	0.939	0.896	1.835	0.043
A_5	(0.299,0.875,1.94)	(0.277,0.746,1.493)	1.038	0.838	1.876	0.200
A_6	(0.316,0.855,1.788)	(0.269,0.723,1.44)	0.987	0.810	1.797	0.176
A_7	(0.255,0.741,1.577)	(0.333,0.906,1.898)	0.858	1.045	1.903	−0.187
B_1	(0.265,0.668,1.288)	(0.306,0.797,1.594)	0.741	0.899	1.64	−0.158
B_2	(0.327,0.839,1.66)	(0.348,0.865,1.658)	0.942	0.957	1.899	−0.015
B_3	(0.24,0.636,1.274)	(0.356,0.929,1.837)	0.717	1.041	1.757	−0.324
B_4	(0.263,0.706,1.459)	(0.302,0.798,1.641)	0.809	0.914	1.723	−0.105
B_5	(0.282,0.766,1.58)	(0.1830.496,1.027)	0.876	0.569	1.444	0.307
B_6	(0.339,0.848,1.64)	(0.233,0.624,1.267)	0.942	0.708	1.65	0.234
B_7	(0.244,0.667,1.363)	(0.233,0.619,1.241)	0.758	0.698	1.456	0.060
C_1	(0.292,0.726,1.373)	(0.29,0.751,1.525)	0.797	0.855	1.652	−0.059
C_2	(0.224,0.599,1.201)	(0.278,0.71,1.396)	0.674	0.795	1.469	−0.12
C_3	(0.283,0.748,1.502)	(0.313,0.787,1.526)	0.844	0.875	1.719	−0.031
C_4	(0.257,0.659,1.269)	(0.271,0.689,1.354)	0.728	0.772	1.500	−0.043
C_5	(0.279,0.71,1.42)	(0.238,0.637,1.264)	0.803	0.713	1.516	0.090
C_6	(0.308,0.801,1.615)	(0.254,0.669,1.314)	0.908	0.746	1.654	0.163

Table 5: Casual relation pattern of the matrix $\tilde{T}_D$

	$\tilde{D}$	$\tilde{R}$	**D**	**R**	**D+R**	**D-R**
A	(0.14,0.3569,0.713)	(0.128,0.355,0.754)	0.404	0.413	0.817	−0.008
B	(0.155,0.155,0.155)	(0.136,0.343,0.673)	0.155	0.384	0.539	−0.229
C	(0.139,0.362,0.73)	(0.144,0.358,0.692)	0.410	0.398	0.808	0.012

3.2.6 Normalization of the total influential matrix of dimensions ($\tilde{T}_D^N$)

To normalize the $\tilde{T}_D$ matrix, three boundaries of the $\tilde{T}_D$ Matrix is reproduced by considering the lower, middle, and upper boundaries of the fuzzy entries of the $\tilde{T}_D$ Matrix. Then, the normalization is performed on each computed boundary matrix. To this end, each row is divided by the sum of the elements of the same row. Three boundary matrices are merged again to regenerate a fuzzy matrix. The normalized matrix $\tilde{T}_D^N$, is then constructed by transposing the result (see table 6).

Table 6: Normal matrix of total influence of dimensions $\tilde{T}_D^N$

$\tilde{T}_D^N$	**A**	**B**	**C**
A	(0.298,0.325,0.349)	(0.325,0.342,0.36)	(0.323,0.341,0.359)
B	(0.338,0.329,0.32)	(0.31,0.312,0.31)	(0.348,0.333,0.322)
C	(0.364,0.346,0.331)	(0.365,0.346,0.33)	(0.329,0.326,0.319)

3.2.7 Normalized total influential matrix and the un-weighted supermatrix

The $\tilde{T}_c$ matrix contains several blocks. To normalize the $\tilde{T}_c$ Matrix, each block is normalized separately. To this end, each row in a block is divided by the sum of the same row. The normalized $\tilde{T}_c^N$ matrix is constructed after the normalization of all the blocks. Finally, the transposition of the $\tilde{T}_c^N$ Matrix forms the un-weighted supper matrix S_u (see Figure 1).

3.2.8 The weighted supermatrix

The weighted supper matrix S_w is constructed by multiplying each element of the matrix $\tilde{T}_D^N$ by its corresponding block in the un-weighted supper matrix S_u.

3.2.9 Convergence of the weighted supermatrix

The super-weighted matrix is consecutively exponentiated by odd numbers until the entries of each row converge to a common value. Here, the super-weighted matrix converges after the 5th step.

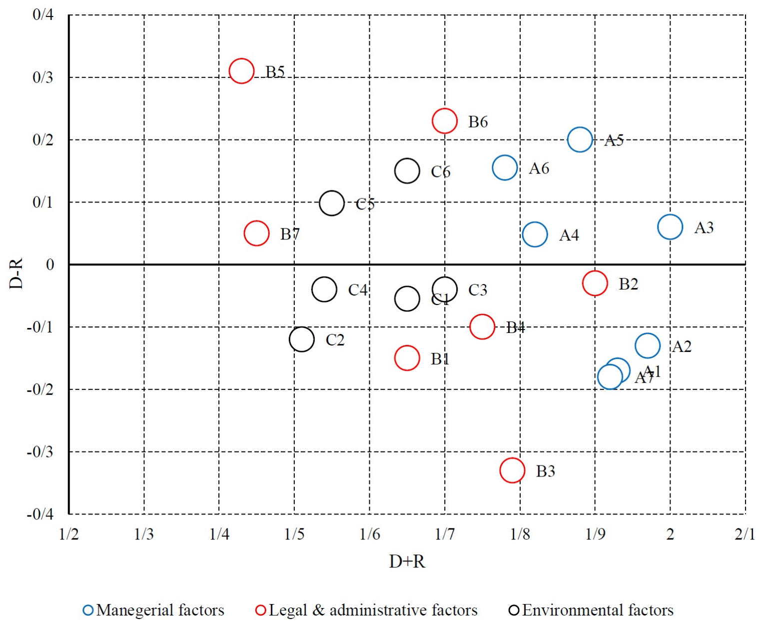

Figure 1: Causal diagram of criteria: Managerial factors, Legal and administrative factors, and Environmental factors.

3.3 Ranking and computing the final weights

In this step, the criteria weights are perceived from the weighted supermatrix entries. The weights of the primary dimensions are obtained from the sum of the weights of its included criteria. The results are tabulated in Table 7.

Table 7: Final weights of the primary dimensions and the criteria.

Code	**A**	A_1	A_2	A_3	A_4	A_5	A_6	A_7
Final weight	0.336	0.0488	0.0499	0.0503	0.0466	0.0446	0.0433	0.0524
Code	**B**	B_1	B_2	B_3	B_4	B_5	B_6	B_7
Final weight	0.325	0.0503	0.0538	0.0598	0.0486	0.0319	0.0404	0.400
Code	**C**	C_1	C_2	C_3	C_4	C_5	C_6	
Final weight	0.339	0.0587	0.0557	0.0616	0.0547	0.053	0.0552	

According to Table 7, the environmental category receives the highest score, with a weight of 0.339. The managerial category then achieves second place with a weight of 0.336. Finally, the legal and administrative category stands at last place with a weight of 0.325 (see Figure 2)

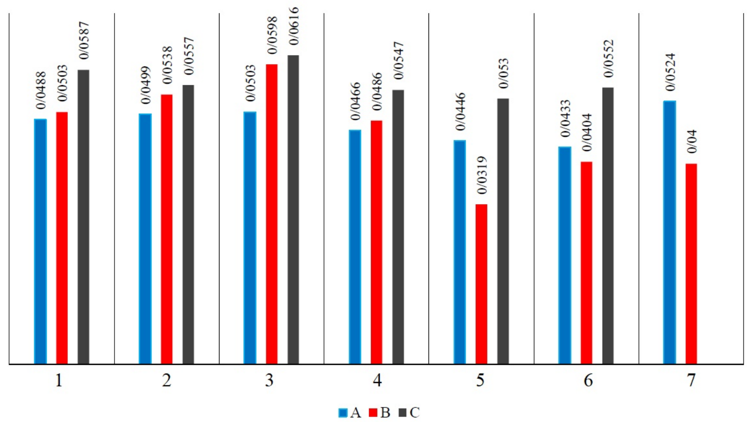

Figure 2: Final weights of the primary dimensions and the criteria.

The criterion "material costs" included in the environmental category ranks first among 20 criteria. Figures 3 and 4. illustrates the criteria rankings.

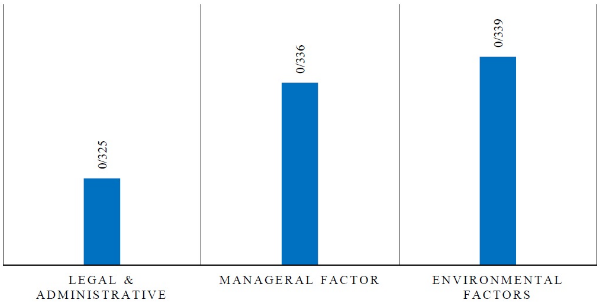

Figure 3: Weights of the main criteria

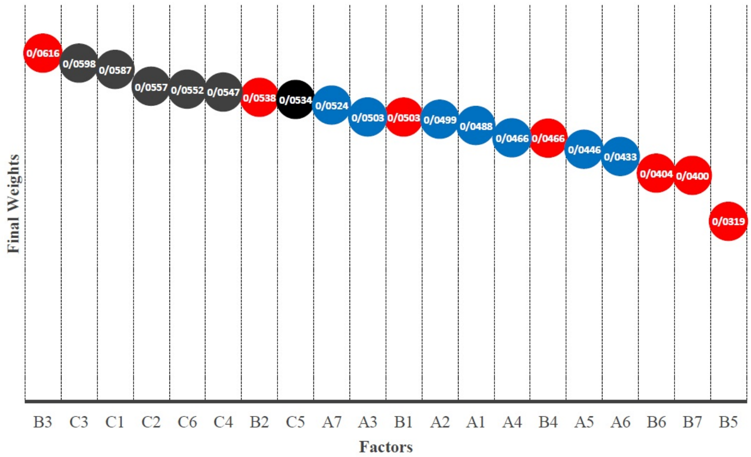

Figure 4: Final weights and ranking the criteria.

4 Conclusion

The results in Section 3 indicate that the environmental category, with a total weight of 0.339, has the greatest role in the construction cost overrun, with a slight advantage compared to the managerial factors, which weight 0.336. Environmental factors are often facing huge fluctuations due to dynamic conditions. As a result, an insensible and unpredictable increase in costs is experienced. The criterion "material costs," included in the environmental category, achieves the highest influence on the cost overrun with a final weight of 0.616. The growth of the price of construction materials is influenced by local and seasonal changes, inflation, and banking interest. The above-mentioned elements clarify the dynamism of the environmental conditions. The results reported by Leśniak and Zima [12] and Nyoni [14] confirm the importance of the "material costs" factor in the environmental category. The criterion "Municipality licensing and standards" is included in the legal and administrative category, with a final weight of 0.598 in second place. Licensing fees include approval of building plans, approval of electrical and mechanical installation plans, and municipal tolls, which depend on the land size, gross building area, floor area ratio, number of parking spaces, local prices, and type of applications. These costs, which are occasionally updated, increase building costs exponentially. Similar results reported by Kanchana and Sukumaran [10], Memon et al. [13], and Sen et al. [18] rank this criterion as a practical principle factor in the construction cost overrun. With the final weight of 0.587, the third priority is offered to the "Environmental and geographical conditions" criterion under the Environmental category. Climatic conditions such as rain, humidity, temperature, and the daytime length may lead to the current cost increase or damage to the project equipment. Furthermore, the construction cost is affected if the transportation of the material, equipment, or personnel to the construction site is problematic due to possible traffic problems on major urban thoroughfares. Finally, the details of the establishment and equipment of the workstation may affect the environmental and geographical conditions. The results of the research performed by Leśniak and Zima [12] and Sen et al [18] confirm the importance of environmental and geographical conditions in construction cost overruns. The factor "Land market local value" in the environmental category is ranked 4th with a final weight of 0.557. The primary land price is defined by the responsible agencies, such as the municipality, property registration office, or tax office. The local land price increases over time mainly due to unbalanced supply and demand, the required cost of infrastructure development, and general inflation. Construction costs also increase in interaction with the increased real state value.

This fact is verified by the results achieved by Nyoni [14]. The factor "Modern communication facilities for staff" included in the environmental category, with a final weight of 0.552, has the 5th highest priority. Modern hardware and software facilities for communication may not be promising, specifically in developing countries. Because of their slower speed, traditional communication methods may increase construction costs.

With a final weight of 0.547, the criteria "supply chain of materials" in the environmental category stands in 6th place. The supply chain in the construction industry includes material, service, and equipment providers. The supply chain is the main cause of the construction cost overrun since its independent elements do not cooperate with integrity. An ideal situation is to establish integrated supply chain elements. These elements consist of construction material producer companies, construction and contracting companies, mass house building, consulting engineering companies, mechanical and electrical equipment manufacturers, importers and distributors, engineering offices, the Society of Engineers, municipalities, real estate, cooperative and mutual housing schemes, investment companies, securities and exchange organizations, the banking system, and finally, people as the main consumers and also the main investors and shareholders of this industry. A similar conclusion is made by Khalilzadeh and Mohammadi [11] on the importance of the supply chain's impact on the construction cost overrun. "Banking facilities program," with a computed weight of 0.538, is the 7th influential factor. This criterion is included in the main dimension, "legal and administrative." The expensive costs of purchasing or constructing residential buildings justify the citizens' demand for banking facilities to finance housing. Banking facilities are available with various interest rates and service charges. The interest rate is usually a combination of the real and inflation rates. Bank interest rates increase over time in developing countries due to the high inflation rate. The rising rate has a substantial impact on the increase in construction costs. The effect of the banking facility programs on the construction cost overrun is neglected in the literature. Finally, the criterion "Warehousing and optimal maintenance of materials," included in the environmental category, has the 8th priority (with a weight of 0.534). Improper organization of warehousing, a lack of classification, and improper transportation cause breakage, cracking, crushing, and damage to materials. It may also lead to the penetration of foreign materials, moisture, or pollution into the materials. These damages affect the construction cost. A similar result announced by Amri and Marey-Pérez [4] verifies the effect of proper warehousing and material maintenance.

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