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Decision support system based on BWM for Analyzing success factors affecting the quality in the Iraqi construction projects

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ABSTRACT

Creating a balance between cost, time, and quality in construction projects is always expected. It is possible to have a project with excellent quality and minimal cost, but at the expense of time, or vice versa. The goal of this paper is to discover, evaluate and prioritize the factors that most influence the desired construction projects' level of quality (success factors) in Iraq. Over a comprehensive review of literature, 11 potential quality-related factors were found to fall into the following five categories: client, contractor, design, materials, and project related factors. These factors' significance was determined using fuzzy Best Worst Method (BWM). Result shows the most three significant success factors influencing quality in the construction projects were related to contractor, client, and designer. These factors were financial competence of contractor, technical capability of client, and designer suitable selection with weights (30.84%, 15.58%, and 10.05%) respectively. These results conclude that maximization of the success factors will guarantee that the building sector achieves its quality objectives.

Keywords: Quality, BWM, projects Management, MCDM, Construction Management

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1. Introduction

Construction works acting a crucial role in the economic growth of nations. The fundamental principle is to maintain quality in the construction sector for achieving continuous improvement, enhanced budget performance, and increasing productivity [1]. The quality-affecting factors in the execution of construction projects are essential topics that should be studied [2]. Construction projects have an inclusion of a large number of contributors including the owner, designer, contractor, and various specialists from industries relating to construction. Each one of those members includes in realizing quality in building projects. The triangle of project management containing project cost, time, and quality. construction projects' success heavily relies on quality, which is one of the triple constraints [3]. Quality gives the owner and contractor a tool to make sure the targeted outcomes are attained to build high-quality and long-life projects. There are various factors that could impact the construction projects' quality during the design and execution stages of the project. To ensure that the project is designed and built with the goals of reaching the intended quality, these factors and how they affect the quality of the completed project should be understood by the owner agency of project, consultant, and contractor organization [4]. The examination of many criteria and a number of constraints are regularly used to inform the procedure for making decisions and the selection of the best alternative. Multi-Criteria Decision-Making (MCDM) is a phrase that is used to describe making decisions that considers many factors. The BWM has substantially improved its standing in the field of MCDM over the last several years as a model that delivers accurate and useful results for the best possible decision-making [5]. Rezaei [6] established the BWM to overawed certain weaknesses of the AHP method, that firstly concern a lot of comparisons in criteria pairings. The BWM suggests that the best and worst criteria should serve as benchmarks for pairwise comparisons with other criteria [7]. Criteria weight assignment is an imperative part of every MCDM problem. Addressing this significant component, the multi-criteria BWM is employed in this study to calculate each criterion interval weight to fuse more information into the decision-making process. In the past decades, lists of crucial factors affecting how well construction projects succeed in terms of quality have been determined by numerous scholars and they determined its importance using various methods. For instance, Rauzana et. al. [2] conducted research using descriptive analysis to recognize the elements that have emotional impact on the performance's quality in building projects in Banda Aceh in relations to costs, tools, labors, and materials. Madhushan et. al. [3] identified and critically assessed factors that have an impact on a building project's quality. The responses gathered and the index of relative important were used to determine the importance of those factors that were found. JHA and IYER [8] examined the causes of the poor quality in Indian building projects to recommend potential corrective approaches. The factors that influence the projects' quality performance were discovered. Based on statistical evaluation of survey results on the factors, two separate groups of factors emerged (success and failure). Abu El-Maaty et. al. [4] determined the most significant determinants of quality performance using fuzzy triangle approach. Mokwena [3] examined the elements touching the application of quality management practices in building projects. This study used a quantitative methodology for data collection. Ayibiowu et.al. [9] used a literature analysis and questionnaire survey to to determine the primary reasons of low quality project delivery in the Nigerian building construction industry. Oni et. al. [10] evaluated the elements touching practices of managing quality on constructing places of building. a practical sampling method was used in this study. Raphael [11] used a closed-ended questionnaire to analyze the precarious elements touching quality implementation of building projects supported by the government in Tanzania. Hijazi [12] recognized the key factors that have a negative effect on the quality performance of building projects, discussed their relative importance, and offered suggestions for how to achieve good quality performance in such projects. Sheikh [13] talked about the major factors affecting the building process quality. In Pakistan's building stage of the life cycle of construction, projects were used to rank the factors using the additional artificial grey relational analysis approach and the conventional relative importance index. Sheikh et. al. [14] conducted another study in Pakistan with the goal of identifying, quantifying, and analyzing the essential elements that have an influence on the quality of implementing building projects throughout the design phase. The Grey Absolute Decision Analysis (GADA) and Relative Importance Index (RII) were applied to score the elements. Azman [15] identified and ranked the key success elements persuading construction projects' level of quality using IBS. The most significant difficulty facing projects worldwide, and in Iraq in particular, is quality improvement. This problem results from a number of intricate factors. Thus, it is imperative to identify the quality factors. Therefore, this paper aims to determine and critically assess elements touching the quality of a construction project in Iraq by using decision making model.

2. Material and method

This study's methodology is divided into three general stages.:

Stage1: Find the factors that affect the quality in construction projects in Iraq.
Stage 2: Establish the influence or weight of the decision-making group's members as well as the weights of the various factors.
Stage 3: specify the final rankings of the factors.

In the first stage, factors and sub factors are identified and established their categorized arrangement. Afterwards, the decision-making group's members are identified. In the second stage, weighing of the decision-makers or levels of impact in the means of decision are determined, using BWM to calculate the weights of the main factors for each decision-maker, and then by averaging each individual's weights, weights for groups are calculated. To derive the sub factors' local weights, the same process is used. It is feasible to determine the sub factors' global weights by calculating the local weights of the sub factors and the main factor weights. In the third stage, the final rankings of the factors are calculated.

The following are the BWM linear model's steps:
Step 1: Identify the group of factors.
The hierarchy of both key and secondary factors that was used in this paper is explained in Table 1.

Table 1. Hierarchy of the main and sub-factors

Main Factors	Code	Sub-Factors	Code
Client-related factors	MF 1	Timely decision Technical capability Monitoring and feedback	SF 1 SF 2 SF 3
Contractor-related factors	MF 2	Appropriate selection Past experiences Financial competence	SF 4 SF 5 SF 6
Design-related factors	MF 3	Clarity and completeness of drawings Compliance with code, specification, and standard Designer suitable selection	SF 7 SF 8 SF 9
Materials-related factors	MF 4	Timely material deliveries with suitable materials procurement and storage	SF 10
Project-related factors	MF 5	Clear scope and favorable political, social & economic environment	SF 11

Step 2. Based on the decision maker opinion, the best (the highest significant, the highest desired) , and the worst (the smallest significant, the smallest desired) factors are determined.
Step 3. Using a value between 1 and 9, identify the best factor's preferences relative to all other factors, and create the best to others factors. The components of this factor symbolized by *aBj*, denotes the significance of the best factor over factors *j*.
The meaning of the values 1-9: 1: equivalent importance, 2: roughly in the middle of equal and moderate, 3: slightly more significant than, 4: roughly in the middle of strong and moderate, 5: significantly more significant than, 6: Somewhere between strong and very strong, 7: extremely crucially more than, 8: somewhat in the middle of very strong and absolute, and 9: definitely more significant than.
Step 4. Create the others-to-worst factor by computing the preferences of all other elements over the worst element by means of an integer ranging from 1 to 9. The factors are symbolized by *ajW* that denotes the significance of factors *j* over the worst factor.

Step 5. Identify optimal weights ($w^*1, w^*2, \ldots, w^*n$) and ξ^{L*} by explaining the subsequent linear standard:

$$min\xi^L s.t. \left|\mathcal{W}_B - a_{Bj}\mathcal{W}_j\right| \leq \xi^L, for\ all\ j \left|\mathcal{W}_j - a_{jW}\mathcal{W}_W\right| \leq \xi^L\ , for\ all\ j \sum \mathcal{W}_j = 1 \mathcal{W}_j \geq 0, for\ all j \quad (1)$$

In the BWM's linear model, ξ^{L*} is seen as a measure of the reliability of pairwise contrasts: A number that is close to 0 indicates good consistency [6]. However, to effectively address the issue with consistency in this model, Liang et al. [16] recently established an approach called as a "input-based method" that is based on input data. In this method, the decision-maker receives instant feedback regarding her/his data consistency after identifying the preferences of the factors in the practice of best-to-others and others-to-worst factors. If the ratios of consistency are not within the acceptable threshold, the preferences must be changed before the model may be implemented.
Definition 3. The definition of ratio of input-based consistency is*:*

$$\mathrm{CR^I} = \mathrm{maxCR^I_j} \quad (2)$$

where:

$$CR_j^I = \begin{cases} \left|a_{Bj} \times a_{jW} - a_{BW}\right| & a_{BW} > 1 \\ \div & \\ a_{BW} \times a_{BW} - a_{BW} & a_{BW} = 1 \end{cases} \quad (3)$$

In the above relations, $CR^I{}_j$ is an indicator of the level of local consistency meant for the factor Cj in the relationships above, where CRI is the global input-based consistency ratio for all factors [16]. Table 2 of [17] contains the allowable thresholds for the ratio of input-based consistency in relation to the quantity of factors and the scale applied in the BWM.

Table 2. Acceptable limits for the ratio of input-based consistency [16]

scale	Factors Number						
	3	4	5	6	7	8	9
3	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
4	0.1121	0.1529	0.1898	0.2206	0.2527	0.2577	0.2683
5	0.1354	0.1994	0.2306	0.2546	0.2716	0.2844	0.2960
6	0.1330	0.1990	0.2643	0.3044	0.3144	0.3221	0.3262
7	0.1294	0.2457	0.2819	0.3029	0.3144	0.3251	0.3403
8	0.1309	0.2521	0.2958	0.3154	0.3408	0.3620	0.3657
9	0.1359	0.2681	0.3062	0.3337	0.3517	0.3620	0.3662

3. Results and discussion

A questionnaire survey was used to gather decision-makers' opinions with the purpose of conclude the factors' weights. The preferences of the main factors (MF1 to MF5) and sub-factors (SF1 to SF4) and (SF5 to SF9) were provided by each of the three decision-makers separately (See Tables 3-6). Inconsistency of the input data was computed based on equation (3). Inconsistent statistics are depicted by red numbers. Referring to Saaty and et al. [18], the decision-makers or specialists for making assessments of preferences using methods based on pairwise comparison does not follow statistical guidelines for sample size; rather, they are chosen based on their experience, information and other factors. In fact, if the expert is knowledgeable in a field, the presence of others who might not be as competent will skew his judgment. The experts may also be given weights, which would make the decisions of judges with higher weights more significant than judges with lower weights [18].

Table 3. Main factors' best-to-others and others-to-worst

Decision-Maker	The best factor preference over others						
	Best Factor	MF 1	MF 2	MF 3	MF 4	MF 5	
DM 1	MF 2	2	1	4	6	8	
DM 2	MF 2	3	1	3	8	6	
DM 3	MF 2	2	1	5	8	7	
	Worst Factor	**Other factors preference over the worst one**					
DM 1	MF 4	7	6	6	1	3	
DM 2	MF 4	6	7	7	1	3	
DM 3	MF 4	8	6	4	1	3	
DM 1	CR^I_j	0.2667	0.0000	0.6000	0.0000	0.6000	Threshold 0.3062
DM 2		0.1786	0.0179	0.2321	0.0000	0.1786	
DM 3		0.1429	0.0357	0.2143	0.0000	0.2321	

Table 4. Sub-factors' best-to-others and others-to-worst (SF1-SF3)

Decision Maker	The best factor preference over others				
	Best Factor	SF 1	SF 2	SF 3	
DM 1	SF 2	2	1	4	
DM 2	SF 2	3	1	6	
DM 3	SF 2	3	1	7	
	Worst Factor	**Other factors preference over the worst one**			
DM 1	SF 3	2	3	1	
DM 2	SF 3	3	5	1	
DM 3	SF 3	3	3	1	
DM 1	CR^I_j	0.0000	0.08333	0.0000	Threshold 0.1359
DM 2		0.1000	0.0333	0.0000	
DM 3		0.0476	0.0952	0.0000	

Table 5. Sub-factors' best-to-others and others-to-worst (SF4-SF6)

Decision Maker	**The best factor preference over others**				
	Best Factor	SF 4	SF 5	SF 6	
DM 1	SF 6	6	3	1	
DM 2	SF 6	7	4	1	
DM 3	SF 6	8	4	1	
	Worst Factor	**Other factors preference over the worst one**			
DM 1	SF 4	1	3	7	
DM 2	SF 4	1	2	7	
DM 3	SF 4	1	3	6	
DM 1	CR^I_j	0.0000	0.1000	0.0333	Threshold 0.1359
DM 2		0.0000	0.0238	0.0000	
DM 3		0.0000	0.0714	0.0357	

Table 6. Sub-factors' best-to-others and others-to-worst (SF7-SF9)

Decision Maker	**The best factor preference over others**				
	Best Factor	SF 7	SF 8	SF 9	
DM 1	SF 9	7	3	1	
DM 2	SF 9	8	4	1	
DM 3	SF 9	7	4	1	
	Worst Factor	**Other factors preference over the worst one**			
DM 1	SF 7	1	3	8	
DM 2	SF 7	1	3	6	
DM 3	SF 7	1	3	6	
DM 1	CR^I_j	0.0000	0.0476	0.0238	Threshold 0.1359
DM 2		0.0000	0.0952	0.0476	
DM 3		0.0000	0.1190	0.0238	

Before loading the input data into the BWM model, inconsistent data should be corrected. Thus, referring to makers of decision, inconsistencies in the data were therefore reviewed with them and the appropriate corrections were made. Tables 7 provide an illustration of the results.

Table 7. Revised best-to-others and others-to-worst for main factors.

Decision Maker	**The best factor preference over others**						
	Best Factor	MF 1	MF 2	MF 3	MF 4	MF 5	
DM 1	MF 2	2	1	5	6	6	
DM 2	MF 2	3	1	3	8	6	
DM 3	MF 2	2	1	5	8	7	
	Worst Factor	**Other factors preference over the worst one**					
DM 1	MF 4	7	6	3	1	2	
DM 2	MF 4	6	7	7	1	3	
DM 3	MF 4	8	6	4	1	3	
DM 1	CR^I_j	0.2667	0.0000	0.3000	0.0000	0.2000	Threshold 0.3062
DM 2		0.1786	0.0179	0.2321	0.0000	0.1786	
DM 3		0.1429	0.0357	0.2143	0.0000	0.2321	

To determine the optimal factor weights, a linear BWM model was used. This was accomplished by using the Excel program's "solver" add-in, which was made available on the https://bestworsmethod.com/2020 website, (retrieved on 1 January 2023). Figure 1 provides an illustration of how to use Excel Solver for main factors.

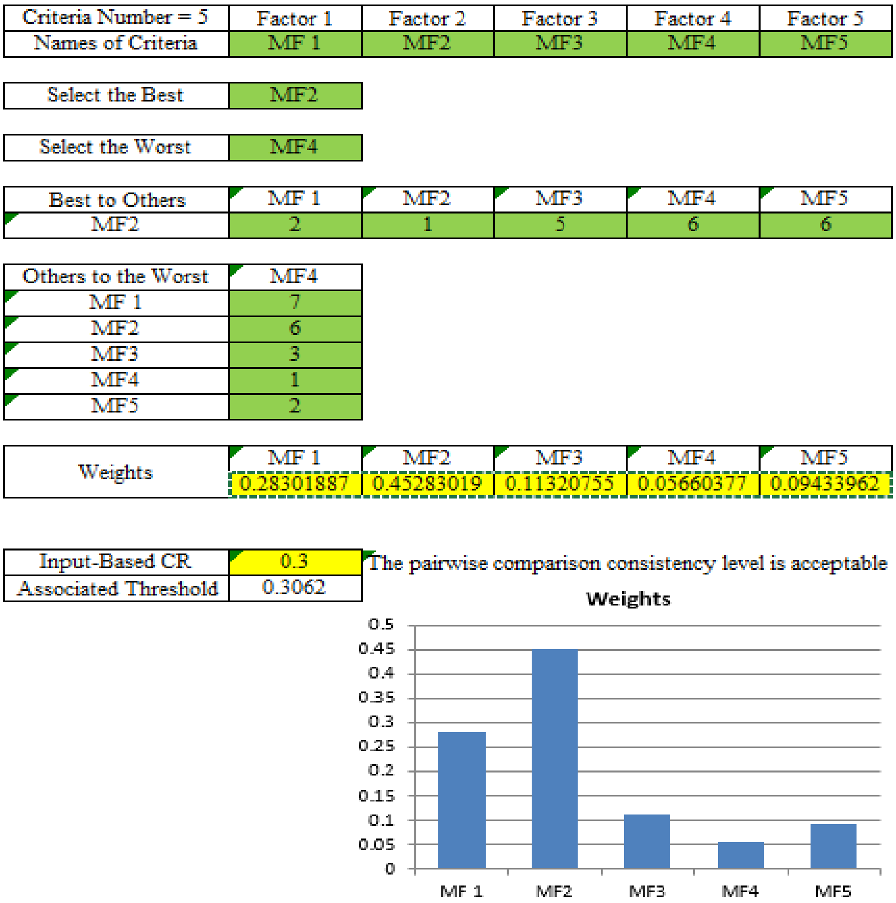

Figure 4. Excel's linear BWM solver model to establish the main factors' weights for the decision-maker 1.
* The CRi indicates the degree of reliability of the results; the lower the CRi, the better.

The integrated group weights are computed after determining the ideal weights of the factors for every maker of decision. Each decision-maker was given a weight to signify their level of significance or effect in the group for this purpose, and the averaging of weights of these separate factors as regarded as a group's average or integrated group weights. (see Tables 8-11).

Table 8. the weights of group for the main factors

Decision-Maker	**MF1**	**MF2**	**MF3**	**MF4**	**MF5**
DM 1	0.2830	0.4528	0.1132	0.0567	0.0943
DM 2	0.2032	0.4385	0.2032	0.0535	0.1016
DM 3	0.3004	0.4453	0.1202	0.0483	0.0858
Group average	0.2622	0.4455	0.1455	0.0528	0.0939

Table 9. the weights of group for the sub-factors SF 1-SF 3

Decision-Maker	**SF1**	**SF2**	**SF3**
DM 1	0.3077	0.5385	0.1538
DM 2	0.2444	0.6444	0.1111
DM 3	0.2800	0.6000	0.1200
Group average	0.2774	0.5943	0.1283

Table 10. the weights of group for the sub-factors SF 4-SF 6

Decision-Maker	**SF4**	**SF5**	**SF6**
DM 1	0.1000	0.24	0.66
DM 2	0.1000	0.1833	0.7167
DM 3	0.1000	0.2000	0.7000
Group average	0.1000	0.2078	0.6922

Table 11. the weights of group for the sub-factors SF 7-SF 9

Decision-Maker	**SF7**	**SF8**	**SF9**
DM 1	0.0896	0.2388	0.6716
DM 2	0.1000	0.2000	0.7000
DM 3	0.1000	0.2000	0.7000
Group average	0.0965	0.2129	0.6905

Each sub-factor global weights are found as shown in Table 12 by multiplying each sub-factor local weight by the relevant main factor weight.

Table 12. Weights and rankings of the main and sub factors on a local and global scale

Main factor	**Weight**	**Sub-factor**	**Local Weight**	**Global Weights**	**rank**
MF 1	0.2622	SF 1	0.2774	0.0727	6
		SF 2	0.5943	0.1558	2
		SF 3	0.1283	0.0336	9
MF 2	0.4455	SF 4	0.1000	0.0446	8
		SF 5	0.2078	0.0926	5
		SF 6	0.6922	0.3084	1
MF 3	0.1455	SF 7	0.0965	0.0140	11
		SF 8	0.2129	0.0310	10
		SF 9	0.6905	0.1005	3
MF4	0.0528	SF 10	1.0000	0.0528	7
MF5	0.0939	SF 11	1.0000	0.0939	4

Referring to Table 12 shows that SF 6 “financial competence of contractor”, SF 2“Technical capability of client”, and SF 9“designer suitable selection” respectively, from the decision-makers' perspectives, are the most significant factors. These factors sum up to roughly 0.50 in total weight.

the first ranking factor is “financial competence of contractor”. This shows the tendency with a contractor who has a sufficient financial competence before requesting for payments to complete substantial works. Those with high financial competence can work continuously, whereas those with low financial competence must wait for payments to be fulfilled before they can continue with the remaining work, resulting in time overruns. Financial stability of the contractor enables them to cover times of inactivity and avoid delays. Contractors with limited financial resources frequently provide tend to delivery low quality projects and frequently take longer than expected to complete them.

“Technical capability of client” is also among the most significant factor. To attain high quality performance, the employer should allow for appropriate moment. Additionally, clients need to be more dedicated to quality. Moreover, the designer must be talented to realize the employer's requirements and convert them into a pleasing and communicative design. Lack of suitable selection of designer is also a reason of quality shortcomings and delays of time.

4. Conclusion

Quality management is essential to the construction projects' success. There are several factors that contributed to the quality of construction projects. To recognize the numerous factors influencing the quality of construction projects, it is concluded that further study is necessary. This research provides a practical study about the factors of success influencing quality management involved in the building of the projects in Iraq and aims to evaluate and prioritize these factors. This research proposes a BWM method in order to take advantage of the strengths of this method. A comprehensive literature review was conducted and identify five main factors with eleven sub-factors. Then, the best and worst factors, as well as favorites for the best factor over all other factors and preferences for all other factors over the worst factor, were to be determined, using a number between 1 and 9, by the decision-maker. The relative weights of factors are determined using fuzzy BWM. A particularly effective technique for defining factor weights coefficients and multi-criteria decision-making is the BWM method. As a result, financial competence of contractor, technical capability of client", and designer suitable selection have been highlighted as a top three highest significant factors affecting the quality management in the Iraqi building projects. The findings of this research should offer a foundation for future studies that focuses and emphasizes more factors that directly relate to building quality management. The author would like to offer a number of things for the advancement of future study in a better path, including: Additional factors affecting quality management from different references can be included to conduct more thorough investigation, the number of decision-makers being increased, and then carry out additional study for the various regions, so that the significance of the differences in each region may be observed.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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