A Bidding Assessment Framework using CRITIC and MABAC Methods

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ABSTRACT

The bidding process is instrumental for contractors and ensures work continuity and company survival. Even if the decision made to proceed with work contracting is confirmed, bidding preparation is one of the main factors effecting profit percentage. A bidding system must be built with high flexibility in order to be widely applicable and able to deal with data diversity. This paper introduces a new application of MABAC and CRITIC methods to cope with this need. The assessment framework consists of multi-attributive border approximation area comparison and criteria importance through inter-criteria correlation. A comparison made between the results gained from the proposed framework and the conventional process reveals a major difference in preference results.

Keywords-MABAC; CRITIC; MARCOS; bidding process; bidders; decision support techniques

I. INTRODUCTION

Ensuring execution confirmation and project delivery are main targets of any contractor. Many organizations may be focused on the bid with the lowest price which can ultimately delay the delivery procedure. Price-led bidder analysis may pose risks and uncertainty which may lead to conflicts [1] which can be caused by errors in tender documents or submitted bid, inaccurate cost estimations, misjudgment on site and/or market conditions, and optimistic construction procedure [2]. The bidding process is a complicated stage for all project stakeholders. The bid preparation effort is worthless if the contract is assigned to another company, so, the bidder often considers all efforts and works during the bidding stage [3]. According to the standard documents of bidder's prequalification applied by the Iraqi Ministry of Planning, the bidder's evaluation consists from legal eligibility, non-completed previous contract commitment, execution and financial eligibility, and experience. All the main categories have subcategories with details needed to be clarified by the bidder [4]. Nationality, conflicts of interest, involvement in UN black list, and country eligibility according to UN and Iraqi laws are listed in the first category. The second one consists from non-completed contracts by the contractor and unresolved and previous legal disputes. The third category has two subcategories, which are financial abilities, and average annual income. The subcategories of the fourth category are general and specialized experience for a period from five to ten years. All these requirements are applicable to the bidder either if it is a single company or a corporate trust [5]. Governments often use Multi Criteria Decision Making (MCDM) methods to evaluate bidders [6-11].

II. THE BIDDING PROCESS

The main goal of project owners is to execute the project complying with specified cost, time, and quality. A cornerstone of this achievement is optimizing contractor selection. The bidding process needs to be designed accurately to guarantee this goal [12]. Some of the considered bidding qualification criteria can be:

- Overall price: With the bidders attempting to win work continuity, the first applicable choice to make an attractive bid is lowering the bid price to the maximum level. Bid price is one of the main constrains of all project stakeholders to make any decision [13]. The owner in general may not target the lowest bid in order to avoid taking a considerable risk of project failure due to improper contractor selection.

- Timing of the projects: the project duration needs to be optimized to the minimum level. When the project execution period is minimized, easier construction procedure with lower risk is adopted. Both owner and contractor expenditures will be reduced due to lower indirect costs [14].
- Number of similar executed works: Contractor's past experience reflects its ability to complete the project.
- Specialized machines and equipment: Some projects are based on machinery availability. Furthermore, machinery availability may indicate contractor's financial ability.
- Contractor budget allocated for the project.
- Workforce nationality: Some government regulations oblige the companies to provide a certain amount of local nationality workforce.
- Annual company income.
- Specialized and trained staff.

The conventional bidding process requirements may vary. In general, bidders may need to pass a prequalification system that is similar to a check list. The prequalification stage may be summarized to legal, financial, and execution ability, non-completed contracts, and past experience. So, all other issues (except bid price) have no weights to assess the bidders. The conventional bidding process does not encourage innovation to make better solution and services. Top management cannot avoid favoritism, bias, and potential outcome skewness. The traditional method may suffer from information asymmetry, bid rigging, or errors [15].

The proposed technique provides some advantages like comprehensive evaluation, robust ranking, weighted factors, transparency, and high level of integrity.

III. THE MABAC METHOD

The Multi-Attributive Border Approximation area Comparison (MABAC) method was firstly introduced in 2015 [16]. This method can be used to analyze trade competitiveness [17], green supply chain management [18], risk management [19], automotive brake materials [20], enhancement of machine key parameters [21], etc. MABAC approach mainly consists of calculating the distance from the border approximation area and the difference between distances [22, 23]. The main steps of this method are:

The input data can be unified in a matrix form:

$$X = \begin{pmatrix} M_{11} & M_{12} & \dots & M_{1j} \\ M_{21} & & & \vdots \\ \vdots & & & \vdots \\ M_{i1} & \dots & \dots & M_{ij} \end{pmatrix}_{i\times j} \quad (1)$$

where M_{ij} is an element of i^{th} alternative and j^{th} attribute.

The alternatives have their own weights which can be entered manually by the end user or can be calculated depending on the data using the CRITIC algorithm.

Data regularization process needs to be performed according to the attribute behavior [24]. Equation (2) will be adopted if the alternative is negative and (3) if it is positive:

$$M_{ij}^{*} = \frac{M_{ij} - M_i^{+}}{M_i^{-} - M_i^{+}} \quad (2)$$

$$M_{ij}^{*} = \frac{M_{ij} - M_i^{-}}{M_i^{+} - M_i^{-}} \quad (3)$$

where M_{ij}^{*} is the regularized element of the i^{th} alternative and j^{th} attribute, M_i^{+} is the maximum value of (M_1, M_2, ……, M_i), and M_i^{-} is the minimum value of (M_1, M_2, ……, M_i).

The next step is applying attribute weights that can be calculated with the CRITIC method or entered by the end user:

$$M'_{ij} = W_j + M_{ij}^{*} W_j \quad (4)$$

The border approximation area matrix values of the attributes can be obtained by:

$$B_j = \left(\prod_1^i M'_{ij} \right)^{\frac{1}{i}} \quad (5)$$

The distance between each weighted alternative according each respective attribute, and the border approximate area can be found with:

$$D_{ij} = M'_{ij} - B_j \quad (6)$$

The summation of the distances of each alternative will be used for the overall rating of the alternatives and the higher algebraic value of distance summation of the alternatives will point the first choice while the other alternatives will be ranked in a descending order [25]:

$$R_i = \sum_1^j D_{ij} \quad (7)$$

IV. THE CRITIC METHOD

The Criteria Importance Through Intercriteria Correlation (CRITIC) is an objective weighting method and has a variety of applications. This method deals with numerical data only, and the independency of attributes can be neglected [26]. The method can be summarized in the following steps:

Firstly, the data will be regularized according to (2) and (3). The second step is calculation of attributes correlation coefficients by (8).

$$CC_{jk} = \frac{\sum_{i=1}^{E} (M_{ij} - \bar{M}_j)(M_{ik} - \bar{M}_k)}{\sqrt{\sum_{i=1}^{E} (M_{ij} - \bar{M}_j)^2 \sum_{i=1}^{E} (M_{ik} - \bar{M}_k)^2}} \quad (8)$$

where CC_{jk} is the correlation coefficient between the j^{th} and the k^{th} attribute, $\overline{M_j}$, and $\overline{M_k}$ represent the average of attributes j and k.

The next step is calculating attributes' standard deviations, and the C_j index according to:

$$\sigma_j = \sqrt{\frac{1}{(F-1)} \sum_{j=1}^{F} \left(M_{ij} - M_j\right)^2} \quad (9)$$

$$C_j = \sigma_j \sum_{k=1}^{F} (1 - C_{jk}) \quad (10)$$

The attribute weights are determined by:

$$W_j = \frac{C_j}{\sum_{j=1}^{F} C_j} \quad (11)$$

V. DATA PROCESSING

In order to apply the proposed model, real data from a governmental project at Babil governorate in the health sector were collected with the main objective of assessing the provided offers as shown in Table I. The variance of bidder input data related to the ideal solution is shown in Figure 1. The data in Table I would make bidder 2 win the bidding, if the conventional bidding system was adopted.

The factors shown in Table I are:

- F1: Bid Price ($).
- F2: Project Time (days).
- F3: No. of similar executed works.
- F4: No. of current contracts.
- F5: No. of native workers.
- F6: Annual income ($).

TABLE I. BIDDER ASSESSMENT DATA

	F1	F2	F3	F4	F5	F6
Bidder 1	9,550,000,000	720	5	10	75	60,500,000,000
Bidder 2	9,400,000,000	735	4	8	125	80,000,000,000
Bidder 3	10,000,000,000	700	5	4	90	100,500,000,000
Bidder 4	10,500,000,000	750	4	6	50	50,000,000,000

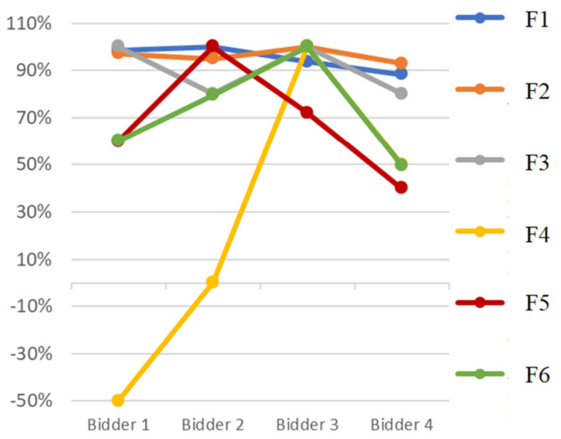

Fig. 1. Bidder input data related to the ideal solution.

The first part is related to the MABAC method (Tables II to IX) and the EDAS method.

The end user can enter his own criteria weights or use the CRITIC method to calculate them. Is matrix is formulated from the collected data to make processing easier. The calculations are shown in Tables II-V. The correlation coefficients between the attributes (P_{jk}) according to (8) are shown in Table II. Table III shows the factor standard deviations according to (9). Factors conflicts calculation according to (10) are shown in Table IV, and factor weights are finalized with (11) and are shown in Table V.

The second stage of data processing is applying MABAC equations on the weighted matrix. The first stage is detecting ideal and anti-ideal solutions as shown in Table VI. The normalized weighted data matrix is shown in Table VII and Figure 2. Border area matrix calculations are shown in Table VIII. Table IX shows the distances from the border area. The final results are shown in Table X and illustrate the total distance from the border area and the final alternatives ranking.

TABLE II. CORRELATION COEFFICIENTS BETWEEN THE ATTRIBUTES (P_{jk})

	F1	F2	F3	F4	F5	F6
F1	1	0.29717	0.20386	-0.63820	0.79359	0.30818
F2	0.29717	1	0.87846	0.27198	0.27371	0.79033
F3	0.20386	0.87846	1	0	-0.09206	0.40152
F4	-0.63820	0.27198	0	1	-0.12351	0.52131
F5	0.79359	0.27371	-0.09206	0.52131	1	0.64267
F6	0.30818	0.79033	0.40152	0.52131	0.64267	1

TABLE III. STANDARD DEVIATION

	F1	F2	F3	F4	F5	F6
σi	0.45055	0.42720	0.57735	0.43033	0.41811	0.44134

TABLE IV. FACTOR CONFLICTS

	F1	F2	F3	F4	F5	F6
F1	0	0.70283	0.79614	1.63820	0.20641	0.69182
F2	0.70283	0	0.12154	0.72802	0.72629	0.20967
F3	0.79614	0.12154	0	1	1.09206	0.59848
F4	1.63820	0.72802	1	0	1.12351	0.47869
F5	0.20641	0.72629	1.09206	0.47869	0	0.35733
F6	0.69182	0.20967	0.59848	0.47869	0.35733	0

TABLE V. FACTOR WEIGHTS

	F1	F2	F3	F4	F5	F6
W_j	19.51%	11.40%	22.35%	19.96%	15.72%	11.06%

TABLE VI. IDEAL AND ANTI-IDEAL SOLUTIONS

	F1	F2	F3	F4	F5	F6
R+	10,500,000,000	750	5	10	125	100,500,000,000
R-	9,400,000,000	700	4	4	50	50,000,000,000

TABLE VII. NORMALIZED WEIGHTED MATRIX

	F1	F2	F3	F4	F5	F6
B1	0.343281818	0.23808	0.4296	0.186	0.168533	0.168867327
B2	0.3684	0.19344	0.2148	0.248	0.2528	0.222849505
B3	0.267927273	0.2976	0.4296	0.372	0.193813	0.2796
B4	0.1842	0.1488	0.2148	0.31	0.1264	0.1398

TABLE VIII. BORDER AREA MATRIX

	F1	F2	F3	F4	F5	F6
g	0.281073	0.212508	0.303773	0.270064	0.179742	0.195839

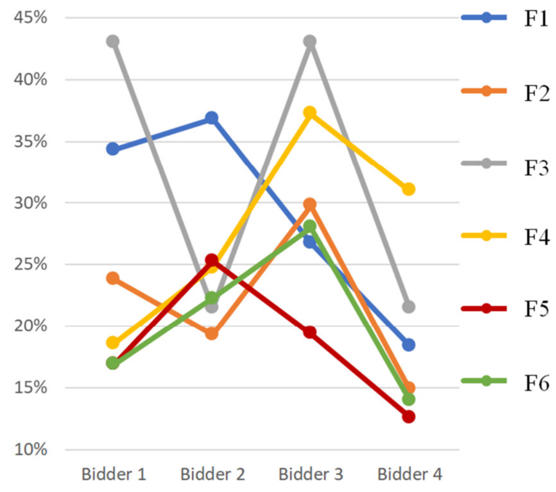

Fig. 2. Bidder weighted normalized data

TABLE IX. DISTANCE FROM BORDER AREA

	F1	F2	F3	F4	F5	F6
B1	0.062208	0.025572	0.125827	-0.08406	-0.01121	-0.026972
B2	0.087326	-0.01907	-0.08897	-0.02206	0.073058	0.027009
B3	-0.013145	0.085092	0.125827	0.101936	0.014072	0.083760
B4	-0.096873	-0.06371	-0.08897	0.039936	-0.05334	-0.0560395

TABLE X. TOTAL DISTANCE AND FINAL RANKING

	Total distance from border area	Rank
B1	0.091362	2
B2	0.057289	3
B3	0.397541	1
B4	-0.319	4

VI. RESULTS VALIDATION

The results gained from the proposed framework need to be validated with another MCDM system. Results validation process will be performed using Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS) [27]. Key features of this method are balancing criteria and finding compromise solution between alternatives, a structural approach due to its utility function, using of references value which are ideal and anti-ideal solution (IS and AIS, respectively). MARCOS method has been adopted to solve problems in supplier selection, sustainable development, transportation and logistics and other areas. MARCOS procedure will be explained and adopted on the collected data starting with detection of ideal and anti-ideal solution depending on criteria behavior as shown in Tables XI and XII. The next step is data normalization that needs is performed taking into consideration factor behavior as illustrated in (12) and (13) for the ideal and anti-ideal solutions as shown in Table XIII. Factor weights will be applied on data and solutions in order to calculate the summation of each bidder weighted data, as illustrated in Table XIV. The next step is calculating the alternatives benefit ratings according to (14) and (15). Then, the benefit function of the alternatives is calculated with (16) and (17). The ranking is conducted according to the final benefit function values, as shown in (18) and the results can be seen in Table XV.

TABLE XI. IDEAL AND ANTI-IDEAL SOLUTION

Positive criteria	Negative criteria
IS $= \max X_{ij}$	IS $= \min X_{ij}$
AIS $= \min X_{ij}$	AIS) $= \max X_{ij}$

$$M_{ij} = \frac{X_{ij}}{IS_j} \quad \text{for positive factors} \quad (12)$$

$$M_{ij} = \frac{IS_j}{X_{ij}} \quad \text{for negative factors} \quad (13)$$

$$k_i^- = \frac{\sum W_j \times X_{ij}}{\sum AIS_j} \quad \text{for negative factors} \quad (14)$$

$$k_i^+ = \frac{\sum W_j \times X_{ij}}{\sum IS_j} \quad \text{for positive factors} \quad (15)$$

$$f(k_i^-) = \frac{k_i^+}{k_i^+ + k_i^-} \quad (16)$$

$$f(k_i^+) = \frac{k_i^-}{k_i^+ + k_i^-} \quad (17)$$

$$f(K_i) = \frac{k_i^+ + k_i^-}{1 + \frac{1-f(k_i^+)}{f(k_i^+)} + \frac{1-f(k_i^-)}{f(k_i^-)}} \quad (18)$$

TABLE XII. IDEAL AND ANTI IDEAL SOLUTION

	F1	F2	F3	F4	F5	F6
IS	9,400,000,000	700	5	4	125	100,500,000,000
AIS	10,500,000,000	750	4	10	50	50,000,000,000

TABLE XIII. DATA NORMALIZATION

	F1	F2	F3	F4	F5	F6
B1	0.9843	0.9722	1.0000	0.4000	0.6000	0.6020
B2	1.0000	0.9524	0.8000	0.5000	1.0000	0.7960
B3	0.9400	1.0000	1.0000	1.0000	0.7200	1.0000
B4	0.8952	0.9333	0.8000	0.6667	0.4000	0.4975
IS.	0.895	0.933	1	0.4	1	1
AIS	1	1	0.8	1	0.4	0.4975

TABLE XIV. WEIGHTED NORMALIZED DATA

	F1	F2	F3	F4	F5	F6
B1	0.1813	0.1446	0.2148	0.0744	0.0758	0.0841
B2	0.1842	0.1417	0.1718	0.0930	0.1264	0.1112
B3	0.1731	0.1488	0.2148	0.1860	0.0910	0.1398
B4	0.1649	0.1388	0.1718	0.1240	0.0505	0.0695
IS	0.1649	0.1388	0.2148	0.0744	0.1264	0.1398
AIS	0.1842	0.1488	0.1718	0.1860	0.0505	0.0695

TABLE XV. BENEFIT FUNCTION, FINAL BENEFIT FUNCTION AND RANKING

	$f(k_i^-)$	$f(k_i^+)$	$f(K_i)$	Rank
B1	0.485561	0.514439	0.618678	3
B2	0.485561	0.514439	0.66119	2
B3	0.485561	0.514439	0.761049	1
B4	0.485561	0.514439	0.574433	4

As shown in the above tables, the best and worst choice are the same for MABAC and MARCOS methods but there is a difference for B1 and B2 bidders due to the assessment function of each method. MABAC deals with alternatives like regions and measuring distance to border approximation area, while MARCOS's key feature is balancing criteria and finding a compromise solution between alternatives depending on utility function and its relation to IS and AIS. As a conclusion, MABAC provides a clear distinction of alternatives unlike MARCOS which provides mores comprehensiveness. Both methods are effective and selecting between them may depend on the decision problem, complexity, and decision maker requirements.

VII. CONCLUSION

One of the most vital roles in project execution is selecting the proper contractor who is capable of delivering the project in an optimum way. The conventional bidding process generally focuses on bidding price and the other factors are not affecting the bidder selection. Even if the owner adopts a bidder prequalification system, it will work like a tick option.

The CRITIC – MABAC framework is a technique applicable for bid offer evaluation. The difference in bidder performance and abilities needs to be evaluated and used to justify contractor selection. Depending on owner organization policy, evaluation factors need to be specified clearly to the bidders and should be allowed to change according to the project field. CRITIC method may be used to determine factor weights depending on the input data. This method provides a dynamic variation of factor weights, consideration of contrast data, impartiality basis, and conjunction ability to work with other methods.

The results of the proposed framework recommend the third bidder in the considered case, who had the third higher bid price with more than 6.4% difference from the lowest price and more than 19% by criteria weight. This can be justified due to the minimum execution time, the higher number of executed projects by the bidder, and its higher annual income. According to the given data, the second and first bidder with the lowest bid prices would be selected if the conventional bidding system was adopted. The selected contractor by the proposed framework provides more reliable execution with less delay, less claims, and project termination risks.

Future work can be done regarding the comparison of the proposed framework with other methods, other case studies, and consideration of more data types.

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