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MODELING A MULTI-CRITERIA DECISION SUPPORT SYSTEM FOR PREQUALIFICATION ASSESSMENT OF CONSTRUCTION CONTRACTORS USING CRITIC AND EDAS MODELS

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Research paper

***Abstract**: Contractor prequalification assessment in the construction industry is an essential part of the project development process because contractors play a pivotal role in the extension of projects and resources. The main objective of the present study is comprised prequalification assessment for classifying contractors by applied the EDAS method for recognizing the contractors' potential before competitive tendering and obtaining bids. First, an inclusive, detailed list of 56 sub-factors under 5 main factors for project prequalification was compiled following a thorough literature review, and review of contractors by experts of Bandar Imam Khomeini municipality who already have done projects with contractors. Second, used the CRITIC method for obtained the weighing and importance of each factor. Third, classified the contractors by applied the EDAS system for recognizing the contractors' potential before competitive tendering and obtaining bids. Finally, the prequalification assessment process was developed to obtaining the rank of each contractor and help the stakeholders to select the right contractors. The effectiveness of the present approach was tested by applying it to a case study of the prequalification assessment of four construction companies' in Bandar Imam Khomeini municipality, Khuzestan, Iran. It is worth mentioning that the prequalification assessment by the proposed approach is approved by the project stakeholders and is consistent with their expectations. It can be concluded that based on relevant ranking and weighing of companies that procedure can be extended to the same studies in this regard, and the contribution of the present study is to propose a support system for prequalification and identification of contractors' ability, before assigning projects to companies for success in projects.*

***Keywords:** Support system, Contractor Prequalification, MCDM, CRITIC, EDAS*

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1. Introduction

Construction plays a key role in any economy; henceforth, it is important to push forward and support the construction industry for developing the countries suffering from under development. The gross output of the construction industry is the value of all the buildings and works produced by the industry in a given period of time, normally a year. In the world as a whole, it is probably about 10 percent of Gross National Product (Xu et al., 2020). In most developing economies around the world, the construction industry plays a significant role in the economy and can be hailed by the government as a platform to stimulate national economic transformation towards the status of a developed country (Mat Isa et al., 2015). In the concern of developing the countries, the construction industry is typically the alarm for financial growth and the main producer of skilled occupations. Important challenges in presentation, productivity, labor, and sustainability contains undermined industry reliability and growth. Despite extensive studies, the development of the industry has shown slow progress. It is almost certain that the existing construction studies have contributed a lot to sympathetic the major causes and consequences of construction issues. Therefore, poor presentation in construction developments remains a worldwide marvel (Yap et al., 2019).

The construction industry in Iran is challenged with other glitches such as unpredictability in the cost of material, wobbliness in production and investment laws and guidelines, the frailty of transportation infrastructure, international sanctions etc. Furthermore, the selection of suitable contractors also is a major crisis for the entire world and majorly for Iran construction industries (Poloie et al., 2012). Construction Contractors play an important part in any construction projects, for the successful or unsuccessful release of projects, that's why contractor selection is the most critical decision for project. The selection process should embrace the investigation of contractors' potential to deliver a service of an acceptable standard, on time, and budget (Topcu, 2004).

Khuzestan province is the major oil-producing region of Iran, and is also one of the wealthiest provinces in Iran. Khuzestan ranks third among Iran's provinces in GDP. The highest construction budget in the whole country was allocated to Khuzestan, Iran in 2019. The government construction budget was $ 226,732,000 for the Khuzestan province in 2019. The municipality's construction budget of Khuzestan province allocated around $ 125,224,000 in 2019 in Khuzestan province, Iran. According to the interview of the mayor of Bandar Imam Khomeini, 350 active construction projects were running there in 2017. One of the main functions of the Plan and Budget Organization (PBO) is to take the assessment of Iranian Contractors, Considering criteria and capacity qualifying in five grade terms of throughput and from large to small ranked as follows, contractors ranking from level one to level five. Numerous factors are influential in determining the rank and grade of a contracting company. Educational and work records of the board members and staff of the company, work records of the company, the status of financial accounts, etc.

Therefore, this paper tries to make a support system for the prequalification of contractors within the enterprise, that an organization or client can recognize the potential of the contractor before competitive tendering and obtaining bids. Prequalification is an important part of the process of finding the right contractor for the project. Therefore, this research attempts to make certain distinctions and classification between contractors, which are at the same level. Based on the author's point of view, there is a difference between the contractor who has five years'

experience with that who has only one-year experience where both of them are in the same rank; thus offering a particular classification between contractors who are at the same rank is requirement. The necessity in the system for the prequalification assessment of construction contractors (Iran) gets back to the lack of relevant study comprising of the need to put the required qualifications in a frame for the identification of contractors' ability, before assigning projects to companies. Therefore, our efforts were focused to propose a support system for the assessment of construction contractors. Success in any construction project majorly depends on choosing the right contractors, contractor prequalification is a process that is widely used to select responsible and competent contractors to perform the construction contract and provide the desired results with minimal damage, because potential contractors are measured and judged according to a set of common criteria, the contractor's prequalification can be considered as a multi-criteria decision issue (Nieto-Morote & Ruz-Vila, 2012). The present study focuses on exploring support system for the prequalification assessment of contractors by offering a review of literature to identifying the various assessment criteria of construction contractor. First, various assessment criteria of construction contractor are identified from available literature and categorized to secure the five prominently used performance measures of a firm, namely: general information, financial aspect, technical and equipment information, management information, professional Experience information of companies in the framework of a questionnaire. Developing a frame for contractors' prequalification assessment through MCDM practices is an essential step for project owner's for recognizing the potential of construction contractors to address their variable future needs. Few studies discuss how prequalification assessments are essential for sustaining the competitive advantage of a construction project as a whole, and no proper classifications and guidelines exist to classify contractors holding the same rank. Hence, this study focuses on:

i. Identifying various construction contractor assessment criteria from the existing literature.
ii. Recognizing the contractors' potential before the tender process.
iii. Classifying contractors, which are holding the same rank.

The most important message from this research is prequalification of contractors within the enterprise, that an organization or client can recognize the potential of the contractor before the tender process. Contractor selection is a critical activity that plays a major role in the success of the projects؛ and prequalification is an important part of the contractor selection process of finding the right contractor for the project.

2. Literature review

Awad & Fayek (2012) recognized and categorized the most significant assessment factors that guarantee applicants and brokers considerations when assessing a particular construction project for runway purposes. They used many data collection methods such as interviews, questionnaires, and interacting meetings, with highly experienced experts, which were conducted to compile a comprehensive and detailed list of the evaluation criteria. For solution methodology, they used fuzzy logic and expert systems mutual to grow a decision support system for applying in contractor and project assessment. They asserted that the strategic system could

assist contractors to self-assess and to recognize areas for promotion to better get an attachment for construction projects.

Ng (2001) demonstrated the performance and presentation of the method by analyzing with the theoretical system, which is called case-based reasoning System that can help expert and decision-makers to additional reliable, prompt decisions for the contractor's prequalification dimension and offer as a new case for formulating factors for the contractor's prequalification for expert judgment. Experimental results show that the satisfied and the case-based reasoning System is appropriate for modeling the scope of the contractor's prequalification. El-Sawalhi et al., (2007) established a state-of-the-art system for prequalification based on combining the merits of the AHP, Neural Network, and Genetic Algorithm in one consolidated model, which is able to overcome the limitations of the published system. They used this method in the Gaza Strip and West Bank and all sub-criteria will be tested via an email questionnaire to reach a consensus for achieving that prequalification that is suitable to be adopted. The proposed Genetic-Neural Network model will overcome most of the disadvantages of published models, particularly the accuracy of the model outputs and the prediction of the contractor's performance. Nieto-Morote and Ruz-Vila, (2012) researched a case study for the rehabilitation project of a building at the University Polytechnic of Cartagena is presented to illustrate the use of the proposed model and linguistic assessment or exact assessment of the performance of the contractors on qualitative or quantitative criterion, respectively, they suggested system provides a systematic scaffold for contractor assessment in a Fuzzy environment that can be easily extended to the analysis of other classification problems in project management. Kishore et al., (2020) developed a framework for construction subcontractor's selection, they used AHP and SAW method for Analyzing data, in a real case study in Iran Khuzestan's presence, for collecting quantitative data from main contractors and Subcontractors applied a prequalification assessment, finally, the result showed the priority in subcontractors' selection as Hejrat Manesh Izeh (i), Khesht Sazan Karoun (ii), Yeganeh saze omid (iii), Sakht karan Moongasht (iv), Darya Sanat Khavarmianeh (v), Omran mehragane Yosef (vi) respectively. Jafari (2013) investigated the central aims of prequalification to recognize an array of appropriate contractors that are required for post-qualification steps and further considerations, proposed a novel contractor prequalification model with the goal of deciding this issue, he used quality function deployment to involve the 'voice of the project owners' through the prequalification of contractors in the construction projects, this model employs the quality function placement system and reflects the project owner's needs and the contractor's abilities, used a numerical example and found that the thought of the project goals or the project owner's needs and prospects can influence contractor prequalification.

Khosrowshahi (1999) suggested the artificial neural network as the most suitable technique to grade contractors, because of its competence to process the noisy data, and thus reliable for building a non-linear association among the score of the individual criterion and its impact on the decision to be made. Ka Chi Lam and Yu, (2011) developed a novel technique for contractor prequalification, which is called the multiple kernel learning method, Hence, the capability of the multiple kernel learning method was compared with support vector machine models through a case study, From the outcome, it has been shown that both method perform well in classification, and multiple kernel-learning model is better than support vector machine models.

Sönmez et al., (2002) investigated a contractor prequalification problem to show how the evidential reasoning approach can overcome this issue; used the Dumpster-Shafer theory to obtain partial evidence for an acceptable conclusion, finally the proposed method, the evidential reasoning approach, makes the concept of degree of belief. Sacks and Harel (2006) proposed an economical game theory approach for understanding the behavior of subcontractors in assigning resources to projects and the influences on workflow constancy applied in gaming theory. The study asserted that impractical scheduling and over-commitments of subcontractors in manifold projects jeopardize the relations between the supervisors or managers and the subcontractors and thus, achieving success in projects. Finally suggested into thought subcontractors' behaviors across organizational, social, and technical aspects as pre-qualification criteria in instruction to control possible achievement goals in projects. Banaitiene and Banaitis, (2006) studied on the criteria employed for contractor selection and assessment of bid Tender offer in Lithuania and abroad, which analyzes issues related to the evaluation of contractors' qualifications, the data was collected from the questionnaire survey, the outcomes presented that the proposals are based on experts' estimates of the weight of contractors' evaluation criteria. Finally, the finding indicated three main weights of contractor evaluation criteria such as (i) Bid price (ii) Legal activity (iii) Contractor adequacy.

Kukoyi et al., (2021) determined the prequalification of selecting construction project contractors using Health and safety criteria Cronbach's alpha was used to test the reliability of the questionnaire used for data collection, the results show that health and safety is not a clients' goal or a project value hence, health and safety are not viewed as a vital pre-qualification criterion for contractor selection.

Acheamfour et al., (2019) declared that contractors' prequalification models that considered clients' objectives only focused on cost, time, and quality as criteria for selection. Furthermore, associating the lowest bidder with a satisfactory project outcome is not the best act. Duarte and Sousa, (2020) Developed a simple and fast supply chain partner prequalification process, which agrees to a questionnaire, an automatic assessment, and a classification method, used the prequalification questionnaire and the questionnaire consists of grouped questions, the main achievement was the managers' lack of familiarity with analysis and improvement techniques, the difficulty of defining quality. Landy et al., (2020) figuring out the service quality factors that are considered more important in the construction sector, the procedure was documental and based on a review of articles obtained from major scientific databases, the result shows that in all cases, the traditional models of service quality were used as guidelines to explain and adapt to specific contexts, overall, the results indicate a generalized conservative approach that characterizes this sector. Acheamfour et al., (2019) investigated the impact of contractors prequalification on construction project delivery with empirical arguments and has given some recommendations regarding success in construction project delivery performance in terms of time and quality in the adoption of due process, not minding the cost of the project, the contractual qualification building projects' time delays, finances the fund's credentials and project characteristics and cost increases are closely linked to contractors' qualifications criteria. Patil et al., (2020) evaluated five criteria along with their sub criteria for contractor prequalification, such as technical considerations, management considerations, financial considerations, reputation

considerations and health, safety and environmental considerations, figuring out the top three causes of inadequate contractor prequalification, the outcome shows serves as the fundamental for further experiential studies on contractor prequalification criteria. (Adedokun, 2020) identified the significant factors for the selection of contractors in construction projects, for data collection used 120 questionnaire surveys adopted, observed that capital bid, financial status, experience, the experience of technical personnel, and client-contractor relationship are the most important sub-factors for contractors' prequalification. (Khoso et al., 2020) investigated the most suitable criteria for the pre-qualification process for Pakistan construction projects, data collection gathered through interviews and floating several questionnaires, for data analysis applied computer software, observed that the most important factors are experience and past performance, financial stability, personnel capabilities, equipment capabilities, and managerial capabilities.

Doloi (2009) studied prequalification criteria in contractor selection and impacts of contractor selection on project success, selected criteria (43 cases) for evaluating project performance through multiple linear regression models, applied a questionnaire survey and expert opinion to data collection. Jaskowski et al., (2010) based on the questionnaire survey tried to find the right contractor in the prequalification step, applied an example that illustrates this approach to determine criteria weights for bidder assessment, the findings passed through the pairwise comparison, AHP weighing system, and Fuzzy set theory with the emergency of pertinent outcomes in the assay. The outcomes demonstrated that the offered fuzzy AHP method is superior to the classic AHP in terms of developed excellence of criteria prioritization. Rashvand et al., (2015) developed a comprehensive contractor assessment system that directly addresses the contractor's abilities and practices as a critical element at the prequalification stage, analyzed data based on an analytic network project model, the results showed that this model evaluated scores that are the effectiveness of a contractor's management ability. K C Lam et al., (2000) introduced a model to support contractor prequalification selection using artificial neural networks.

The prequalification assessment of the contractor has been done via an extension of the multi-kernel learning model based on the questionnaire. The following step verified results via sensitivity analysis of a few decision support systems that were actually algorithms measurement (Ka Chi Lam & Yu, 2011).

Korytárová et al., (2015) completed the research based on 345 tenders for public works contracts in the Czech Republic and compared the results with the projects in Poland from 2013-2014, the data collected from official databases; the significant differences appeared in two areas of professional experiences and economic and financial qualifications. A study used the support vector regression model to select the contractor with relevant results for 250 virtual contractors. Awad and Fayek (2012) Used questionnaires, face-to-face and individual interviews, and interacting group meetings, with highly experienced experts for contractor selection. Therefore, 38 alternatives and 32 prequalification cases were chosen to configure the dimensions of the decision-making system with an accuracy of up to 84.0%, and developed a new pre-qualification method using a quality function deployment technique based on availability and requirements of the project and contractor. Attar et al., (2013) Proposed a method to support vector machine that has been based on the forecast of a contractor's deviation from a client's objectives, for analyzing the

system, Contractor prequalification for two hundred and fifty contractors was solved, they believe that the suggested system had a great generalization in linear, nonlinear, noisy, and inductive environments. The results showed that support vector machines could reliably perform even with a small amount of training data. Contractors' pre-qualification models that considered clients' objectives only focused on cost, time, and quality as criteria for selection; Furthermore, associating the lowest bidder with a satisfactory project outcome is not the best practice, Insights on various prequalification criteria can have positive impacts on projects (Acheamfour et al., 2019). Chen et al., (2021) Proposed an integrated subjective-goal approach to calculate criterion weights and to put into effect an ELECTRE III-based method that incorporates that consists of HFLTS opportunity distributions, which permit treating the indetermination, imprecision, and uncertainty embedded in value determinations of alternative-criterion selections whilst comparing bids. Prasetia and Imaroh (2020) Developed an approach for carrying out an evaluation of the contractor's selection/providers in the upstream oil and gas industry with the goal of enforcing green supply chain management with the AHP method, the result shows that the two most important criteria are environmental criteria and health and safety criteria. Marović et al., (2021) Developed an analytic hierarchy process (AHP) together with PROMETHEE for Selecting the Optimal Contractor, the result of their synergy were proposed that: (i) allows the incorporation of opposing stakeholders' demands; (ii) increases the transparency of decision-making and the consistency of the decision-making process; (iii) enhances the legitimacy of the outcome. Kukoyi et al., (2021) Determining the reasons for clients contending with contractors that are not committed to health and safety, using a questionnaire for data collection, and Mean scores for data analysis, finally provided information on influence clients to have to respect health and safety as a prequalification criterion and towards construction workers' health and safety. Dehmourdi et al., (2021) Studied the impact of the crisis in construction projects, using the CRITIC method to the weighting of crisis factors and WASPAS method to find out the most influential crisis factors and made a case study of "Khuzestan province (Iran), finally, observed that most influential crisis factors in the Khuzestan construction industry are the economic crisis, followed by the market and real estate. Okifitriana Latief (2021) developed the Quality Management System (QMS) for the Construction Services Procurement Process to Improve the Quality of Contractor Performance in universities Indonesia, used the survey, and statistical analysis for data analysis, and finally developed a Quality Management System for the construction services procurement process in universities Indonesia. Afshar et al., (2017) proposed a practical prequalification technique for contractor assessment that uses interval type-2 fuzzy sets to report both linguistic imprecision and differences of opinions, they solve a numerical example has been presented to exemplify how the prequalification technique is carried out using type-1 and type-2 fuzzy sets. Associating the outcomes shows the effect of preserving the erraticism of the evidence in the chain of reasoning. The contractor prequalification assessment is a screening instrument by the in-charge staff, client, and project supervisor based on a certain and defined framework where lots of criteria and factors are allocated to be processed by a variety of MCDM models (Russell & Skibniewski, 1988). Topcu (2004) provided a new framework based on the MCDM models for the construction contractor and suggested to the Turkish public sector, the system suggested that three key goals have been produced for

assortments as cost, time, and quality, they asserted this model can be used as a decision support system by the project owners in order to recognize the most appropriate contractor that will be given the contract. Nassar and Hosny (2013) 294 projects passed through the prequalification assessment for contractor selection in UAE, the MCDM models of the AHP and Fuzzy algorithm used to categorize the companies for the projects pertain to quantitative and qualitative measures.

Keshavarz Ghorabaee et al., (2015) proposed a new approach for the EDAS, in the suggested approach of the system; according to positive and negative distances from the mean solution to evaluate the options, to prove the performance of the proposed method in the Multi-Criteria Cataloguing issue, it is mentionable for better understanding they used a mutual example, asserted that the proposed method could be used for multi-criteria decision-making problems, associated the proposed method with VIKOR, TOPSIS, SAW, and COPRAS as a numerical example. They observed that the suggested method is steady at dissimilar weights and is consistent with other methods. Kazan and Ozdemir (2014) studied financial ratios of economical statements of the fourteen-large scale conglomerates, which traded on ISE, used the CRITIC Weights method to calculate nineteen criteria over three periods (2009-2011), and found their financial ratio weights. Then among multi-criteria decision-making methods, the TOPSIS method was employed to measure and evaluate the performances of 14 large-scale ISE-listed conglomerates.

Kahraman et al., (2017) suggested that the intuitive fuzzy EDAS method used to evaluate the options for selecting a solid waste disposal site; Comparative analysis and sensitivity are also included. Sensitivity analysis is also given to show how strong decisions are made intuitively through fuzzy EDAS. Liang et al., (2018) evaluated a case of the cleaner production performance for four gold mines is provided to explain the application of the proposed method, first determined the comprehensive criteria weights obtained from the combined criteria weights extended SWARA model, a systematic comparison analysis with other existent methods is conducted to reveal the advantages of our method, in the last phases obtaining the ranking orders results indicate that the integrated EDAS-ELECTRE method is suitable and effective for gold mines to evaluate their cleaner production performance, and has important reference values for the cleaner production management and operation. Adalı and Işık (2017) evaluated four contract builder options using the CRITIC method and MAUT methods. For achieving the importance of criteria used CRITIC method, while the complete ranking of the contract builder options obtained using MAUT, and then the output it is important to work with the right contract manufacturer to gain a competitive advantage, they believe CRITIC and MAUT solve the problems of selecting a contractor for a textile company.

Žižović et al., (2020) Proposed a new method in modifying the (CRITIC) method, which waterfalls underneath objective methods for decisive factors weight constants, by presenting a new procedure of combination of weight constant values in the CRITIC-M method, a more complete sympathetic of data in the initial decision matrix was made possible, foremost to additional objective values of weight constants, Therefore, the relations between information in the initial decision matrix are obtainable in a more objective solution. Maheshwari et al., (2021) developed a finite element model for a ventilated brake disc is developed to numerically simulate the fatigue life and axial deflection, for data analyses and compare the various design parameter combinations, multi-criteria decision-making such as ARAS, EDAS, COPRAS, FEA, MCDM and TOPSIS are used. Applied TOPSIS to optimize process

parameters of the vibration-assisted turning process; also investigated EDAS method in a broad range of technological systems to engineering problems. (Ghorabaee et al., 2018).

Mousavi-Nasab and Sotoudeh-Anvari (2017) reviewed application of MCDM techniques including EDAS in the field of material selection. Similarly, COPRAS (Complex Proportional Assessment) is an advanced MCDM methodology, which is based on the evaluation of alternatives to the solution of the problem proportionately. Zavadskas et al., (2019) introduced a new technique based on EDAS in the Minkowski space (EDAS-M), which was the modified extension of conventional EDAS approach. To develop the proposed plan, they used CRITIC method for obtaining the objective criteria weights, applied seven unusual methods for comparing their plan to validate the efficiency and effectiveness of the proposed method. Developed the Fuzzy evaluation based on distance from average Solution (Fuzzy EDAS) method for resolving the air-handling unit and the heating, ventilating and air conditioning system and its supplier collection problem for a green multifunctional shopping center project located in Russia, sensitivity analysis was approved out to show the constancy of the consequences (Polat & Bayhan, 2020).

The foremost aim for the applied EDAS method is to allow both the calculating the criteria weights and ranking the alternatives in a simple and easy way. If other MCDM methods such as COPRAS, fuzzy ARAS, VIKOR, MOORA, were chosen, they should have been integrated with the criteria weighting methods such as AHP, which would complicate the problem (Stević et al., 2018).

3. Methodology

The solution methodology applied for the present study is the CRITIC method for obtaining the importance and influence of contractor assessment factors and the EDAS system for recognizing the contractors' potential before competitive tendering and obtaining bids. A questionnaire was designed to collect the initial matrix of data. To determine the weight of each criterion used as per the weighing system of CRITIC concerning the variables. The members who participated to complete the assessment program were those who were in close connection with the contractor and supervisors of the project, around 4 members. In the present case study, four construction companies including Daghigh Koshan Sepahan, Hejrat Manesh Eizeh, Hemat Talash, and Omran Mehran Mongasht were assessed to get the contractor prequalification ranking levels. In addition, the contractors participated in tendering the project and evaluated in the Bandar Imam Khomeini municipality, Khuzestan, Iran. For obtaining the importance of each sub-factor using the CRITIC method and for classifying and ranking of the contractors by applying the EDAS system for recognizing the contractors' potential before competitive tendering and obtaining bids. The studied contractors are from the same competence ranking (rank 5) obtained from in-charge the Plan and Budget Organization (PBO) of Iran. Previous performance evaluation completed by staff who have related information with these companies in ways such as the director of the technical department, Supervisor Engineer, Resident Engineer, and Consultant Engineer. The sub-factors and main factors of assessment comprising the general ability, financial ability, technical and

equipment ability, management ability, and professional experience of companies consists of 56 cases in this regard.

Many studies have analyzed construction contractor assessment in terms of their advantages and have produced conceptual frameworks. However, in Iran scenario, additional research is needed to identify the potential of contractors who in the same rank, before competitive tendering and obtaining bids. This study proposes to:

i. Identify the essential contractors prequalification assessment factors from existing literature;
ii. Conduct a questionnaire-based survey from Bandar Imam Khomeini municipality, Khuzestan, Iran experts to identify the importance of each factor;
iii. Conduct a second questionnaire-based survey with the same experts as respondents to obtain the potential of the four contractor;
iv. Apply CRITIC system to find the total grade of the each factor;
v. Identify the rank and potential of each contractor through EDAS method.

3.1. CRITIC Method

The MCDM models have always been associated with two factors and issues, one is the weighting of criteria and the other is the ranking of options. These two categories are complementary to each other, sometimes by one method and sometimes by a combination of methods. In this method, the data are analyzed based on the degree of interference and conflict between the factors or criteria. CRITIC method of processing causes the role of each factor to be applied correctly in the results of the calculations. In the CRITIC method, for each evaluation criterion, there is a range of variations of the measured values between the pixels (options), which are expressed in the form of a membership function. Each of the components formed for the criteria used has statistical parameters such as standard deviation. These parameters represent the degree of difference in the relevant standard values. The CRITIC method steps 1 to 3 as follows:

Step 1: The decision matrix X is formed, it shows the performance of different alternatives with respect to various criteria.

$$X = \begin{bmatrix} x_{11} & x_{11} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

Step 2: Decision matrix is normalized data using the equation 1:

$$r_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (2)$$

r_{ij} - Normalized performance value

X_{ij} - Each sub-factors number

Step 3: While determining the criteria weights, both standard deviation of the criterion and its correlation between other criteria are included.

$$C_j = \sigma_j \sum_{j=1}^{n} (1 - r_j) \quad (3)$$

C_j - Quantity of information contained

σ_j - Standard deviation

For determine the importance of each sub-factor used equation number 3.

$$W_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \quad (4)$$

3.2. EDAS Method

The EDAS method is the best solution is the distance from the average solution. This method does not need to calculate the positive and negative ideals, but consider two criteria for evaluating the desirability of options; the first is a positive distance from the mean (PDA) and the second is a negative distance from the mean (NDA). These measures can show the difference between each option and the median solution. Options are evaluated according to higher PDA values and lower NDA values. Higher PDA values or lower NDA values indicate that the option is better (Keshavarz Ghorabaee et al., 2015).

Step 1: Select the most important criteria that describe alternatives.

Step 2: Construct the decision-making matrix (X), shown as follows

Where Xij denotes the performance value of ith alternative on jth criterion.

Step 3: Determine the average solution according to all criteria, shown as follows:

$$AV = [AVJ]1 \times M \quad (5)$$

Where,

$$AVj = \frac{\sum_{i=1}^{n} xij}{N} \quad (6)$$

Step 4: Calculate the positive distance from average (PDA) and the negative distance from average (NDA) matrixes according to the type of criteria (benefit and cost), shown as follows:

If jth criterion is beneficial

$$PDA = \left([PDA_{ij}\, n \times m]\right) \quad (7)$$

$$NDA = \left([NDA_{ij}\, n \times m]\right) \quad (8)$$

And if jth criterion is non-beneficial,

$$PDA_{ij} = \frac{\mathbf{MAX}(0,(Xij - AV\ j))}{AV\ j} \quad (9)$$

$$NDA_{ij} = \frac{\mathbf{MAX}(0,(AV\ j - Xij))}{AV\ j} \quad (10)$$

Where PDA_{ij} and NDA_{ij} denote the positive and negative distances of ith alternative from an average solution in terms of jth criterion, respectively.

Step 5: Determine the weighted sum of PDA and the weighted sum of NDA for all alternatives, shown as follows:

$$SP_i = \sum_{j=1}^{m} Wj\ PDA_{ij} \tag{11}$$

$$SN_i = \sum_{j=1}^{m} Wj\ NDA_{ij} \tag{12}$$

Where Wj is the weight of jth criterion.

Step 6: Normalize the values of SP and SN for all alternatives, shown as follows:

$$NSP_i = \frac{SP_i}{MAX_i(SP_i)} \tag{13}$$

$$NSN_i = 1 - \frac{SN_i}{MAX_i(NS_i)} \tag{14}$$

Step 7: Calculate the appraisal score (AS) for all alternatives, shown as follows:

$$ASI = \frac{1}{2}\ (NSP_i + NSN_i) \tag{15}$$

4. Results and discussion

Contractor prequalification assessment in the construction industry is an essential part of the project development process because contractors play a pivotal role in the extension of projects and resources.

Table 1. Sub criteria of general information

Sub criteria		CRITIC	Daghigh Koshan	Hejrat Manesh	Hemat Talash	Omran Mehran
Sub criteria of general information		weight	Appraisal Score (AS)			
1	Follow The extent of rules and regulations	0.0163	0.719	0.507	0.878	0.719
2	Follow The extent of standard and specification	0.0163	0.629	0.507	0.548	0.2057
3	Completeness of documents of firm	0.0163	0.629	0.169	0.125	0.360
4	Quality of documents plans and drawings	0.0133	0.527	0.098	0.477	0.587
5	Use the value engineering	0.0163	0.822	0.615	0.175	0.240
6	Observance the health, safety, environment, and energy	0.0163	0.822	0.120	0.292	0.144

7	Observance of rules	0.0163	0.091	0.676	0.878	0.205
8	Environmental, labor and social security	0.0157	0.325	0.334	0.590	0.197
9	Stability of board members and specialist staff	0.0163	0.476	0.094	0.585	0.449

Prequalification is an important part of the process of selecting the right contractor for the project. Whereas multiple criteria may contribute to prequalification measures, it is important to identify the essential assessment criteria. Based on the on the present case study the following results are determined. Table 1 shows the criteria of general information, appraisal score of each contractor, and total CRITIC score of each criteria. According to result of CRITIC method, the importance of most criteria in general information section almost match with each other.

Table 2. Sub criteria of financial information

Sub criteria		CRITIC	Daghigh Koshan	Hejrat Manesh	Hemat Talash	Omran Mehran
Sub criteria of financial information		weight	Appraisal Score (AS)			
1	Financial position of the contractor	0.0163	0.339	1.000	0.702	0.450
2	The liquidity of contractor	0.0232	0.130	0.172	0.624	0.292
3	Total assets of contractor	0.0163	0.091	0.604	0.798	0.206
4	Securities other than shares	0.0133	0.075	0.415	0.358	0.588
5	Timely payment of wages of employees, agents, and subcontractors	0.0199	0.580	0.206	0.000	0.175
6	Insurance to all facilities, equipment, and personnel against possible accidents	0.0163	0.476	0.348	0.439	0.540
7	Shares and equity contractors in the bourse	0.0157	0.604	0.162	0.211	0.628
8	Insurance technical provisions in the site of the contractor	0.0163	0.646	0.121	0.293	0.360
9	Macroeconomic and financial developments in of contractor experience account	0.0163	0.476	0.716	0.251	0.000
10	Balance sheet vulnerabilities of	0.0173	0.667	0.538	0.266	0.218

	contractor					
11	Capital ratios of contractor	0.0163	0.494	0.508	0.251	0.000
12	Standalone bank credit ratings which contractor has account	0.0227	0.127	0.484	0.610	0.333

From the Table 2 it is observed the criteria of financial information, appraisal score of each contractor, and total CRITIC score of each criteria. It is observed that the liquidity of contractor (sub criteria number 2) has most influential in this section.

Table 3. Sub criteria of technical and equipment information

Sub criteria		CRITIC	Daghigh Koshan	Hejrat Manesh	Hemat Talash	Omran Mehran
Sub criteria of technical and equipment information		weight	Appraisal Score (AS)			
1	Site preparation	0.0163	0.494	0.508	0.702	0.450
2	Site amenities	0.0186	0.386	0.000	0.625	0.234
3	Transportation facilities contractor	0.0232	0.130	0.687	0.416	0.205
4	Provide communication and access ways	0.0227	0.000	0.705	0.610	0.714
5	Status of site technical office	0.0227	0.229	0.588	0.174	1.000
6	Quality of specifications standards	0.0163	0.091	0.121	0.251	0.514
7	Using new technology	0.0227	1.000	0.588	0.348	0.000
8	Quality and quantity of construction machines	0.0163	0.339	0.423	0.000	0.240
9	Quality and quantity materials control	0.0163	0.629	0.423	0.251	0.450
10	Quality operation in mechanical	0.0163	0.091	0.716	0.549	0.144
11	Quality operation in electrical	0.0163	0.548	0.508	0.798	0.000
12	Contractor performance in laboratory	0.0157	0.457	0.116	0.422	0.432
13	Take timely action for shortage and problems	0.0163	0.494	0.325	0.439	0.540
14	Provide timely report	0.0327	0.987	0.484	0.878	0.960
15	Provisional hand-	0.0173	0.436	0.179	0.000	0.255

	over timely					
16	Having suitable and sufficient equipment and machinery to carry out construction	0.0173	0.097	0.370	0.532	0.477

From the Table 3 it is noted the criteria of technical and equipment information, appraisal score of each contractor, and total CRITIC score of each criteria. From the Table 4 it is observed the criteria of management information, appraisal score of each contractor, and total CRITIC score of each criteria.

Table 4. Sub criteria of management information

	Sub criteria	CRITIC	Daghigh Koshan	Hejrat Manesh	Hemat Talash	Omran Mehran
Sub criteria of management information		weight	Appraisal Score (AS)			
1	Efficiency, accuracy and effectiveness planning of contractor's methods	0.0227	0.000	0.168	0.222	0.800
2	Performance and effectiveness of the contractor's methods for organization and control the project	0.0173	0.436	0.138	0.266	0.153
3	Performance and effectiveness of the contractor methods for quality and quality assurance	0.0163	0.411	0.348	0.702	0.450
4	Status of human resource management	0.0163	0.476	0.484	0.251	0.360
5	Stability in the organization and the executive team the contractor	0.0173	0.524	0.449	0.310	0.545
6	Coordination of contractor with covenants and other relevant factors	0.0157	0.000	0.487	0.527	0.197
7	Coordination of contractor with subcontractor	0.0163	0.091	0.121	0.293	0.851
8	Performance and abilities contractor project management	0.0227	0.127	0.392	0.976	0.333
9	Performance and abilities contractor site	0.0227	0.762	0.995	0.610	0.714

	management					
10	Methods of contractor procurement	0.0163	0.629	0.716	0.439	0.000
11	Performance of contractor program	0.0163	0.629	0.604	0.549	0.240

From Table 5 it is seen the criteria of professional experience information, appraisal score of each contractor, and total CRITIC score of each criteria. It is worth mentioning that the criteria number 7, (Good experience in previous works) was most influential in this section.

Table 5. Sub criteria of professional experience information

Sub criteria		CRITIC	Daghigh Koshan	Hejrat Manesh	Hemat Talash	Omran Mehran
Sub criteria of professional experience information		weight	Appraisal Score (AS)			
1	Executive experience in the field and field the desired work	0.0163	0.000	0.508	0.293	0.450
2	Classified documents and documentation of the work done in the previous project	0.0163	0.091	0.651	0.659	0.450
3	Native contractor or the project experience	0.0163	0.339	0.484	0.878	0.514
4	Creativity and Innovation in previous projects	0.0163	0.548	0.538	0.549	0.514
5	On-going communication and coordination with the client and monitoring devices	0.0163	0.494	0.282	0.176	0.654
6	Awards and appreciation official letters	0.0163	0.091	0.716	0.176	0.180
7	Good experience in previous works	0.0227	0.471	0.168	0.813	0.333
8	Quality of provided previously project	0.0186	0.104	0.482	1.000	0.615

The t-test and paired test statistical analysis confirmed no significant differences between both values of W for the AHP and CRITIC models. Figure 1 displays the comparison of the values of W of AHP and CRITIC. Figure 2 shows the sequence number diagram for both w values of the AHP and the CRITIC model. The Friedman test calculated the ranks for both W values as AHP (1.45) and CRITIC weighing system as 1.55 with a chi-square value of around 0.643. The distribution of weights of AHP was normal with a mean 0.02 and standard deviation 0.01 via a one-sample Kolmogorov-Smirnov test in the Null hypothesis (null hypothesis retained).

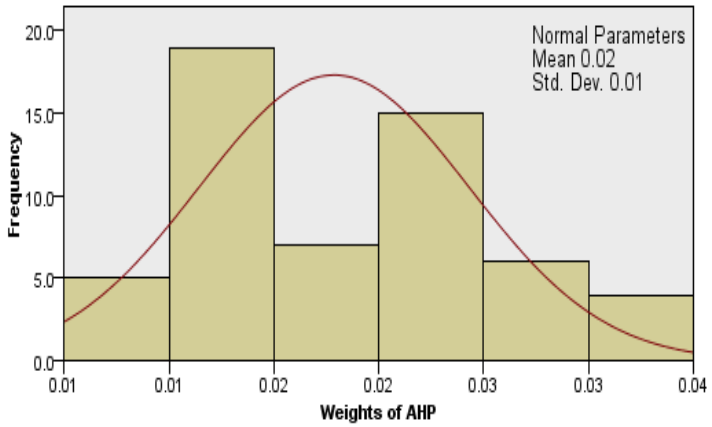

Figure 1. One-Sample Kolmogorov-Smirnov test.

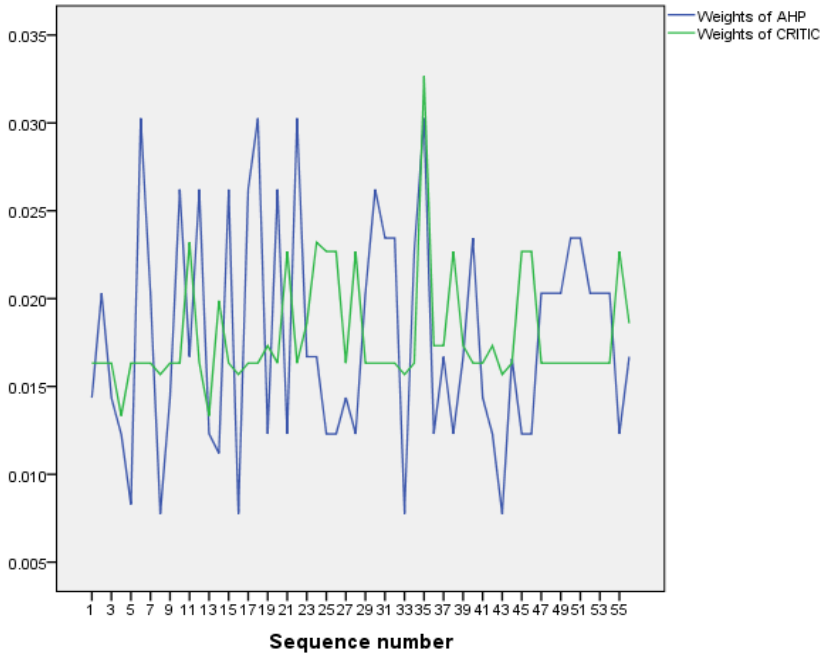

Figure 2. The sequence number diagram for both W values of AHP and CRITIC model

The sequence number diagram revealed that the expansion of W values does not follow a parallel trend but it is a linear development. The concept of a linear development refers to high overlapping between both w values when it goes to move with parallel lines. Figures 3 and 4 present the W values released in the ranking system of EDAS for both companies.

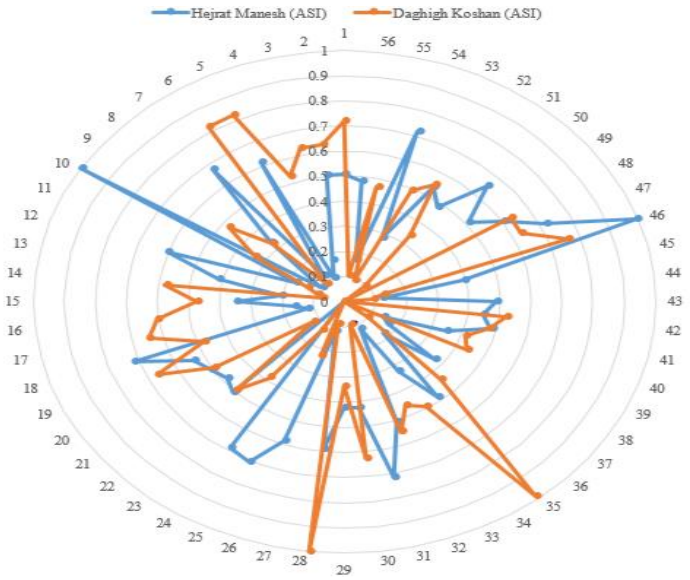

Figure 3. The W values released in the ranking system of EDAS for both companies

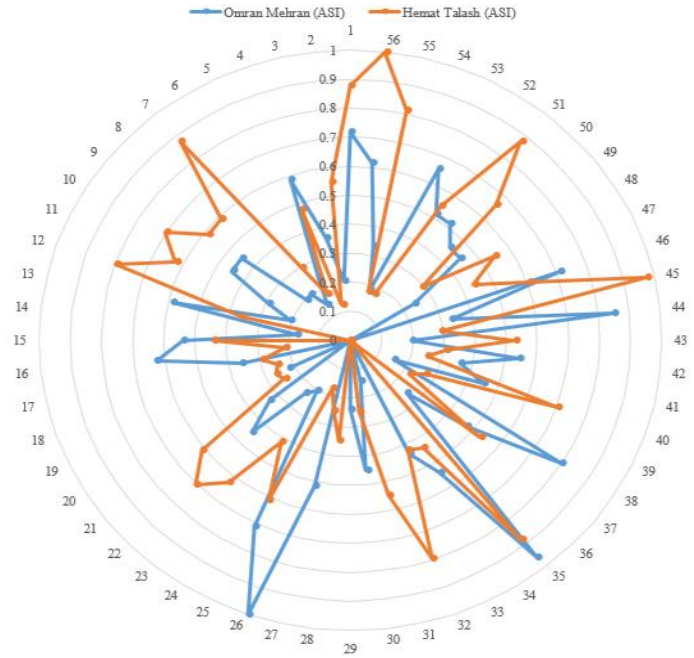

Figure 4. The W values released in the ranking system of EDAS for both companies

The findings of the EDAS model appeared in Table 6. The findings proved reasonable values in the ranking system with regard to this fact that the initial properties about companies were very close together. It needs to explain that the authors examined the various MCDM models to get the relevant response in this

regard. However, the propinquity between findings caused us to fail and we could not realize the ranks for the companies.

Table 6.The Final ranking of companies in the EDAS model

Company	Score	Rank values
Daghigh Koshan Sepahan	22.38356729	3
Hejrat Manesh Eizeh	23.86945084	2
HematTalash	26.03712557	1
Omran Mehran Mongasht	21.8705158	4

5. Conclusion

The MCDM models facilitated the differentiation of the ranks between variables, criteria, and alternatives. The weighing systems also help to sort out the criteria based on values. A questionnaire was used to collect the initial data of research and was processed in the EDAS and CRITIC systems; it can be used to collect various kinds of data for the same objective. An inclusive, detailed list of 56 sub-factors under 5 main factors for project prequalification was compiled following a thorough literature review, and review of contractors by experts of Bandar Imam Khomeini municipality who already have done projects with contractors, and then used the CRITIC method for obtained the weighing and importance of each factor and classified the contractors by applied the EDAS system for recognizing the contractors' potential before competitive tendering and obtaining bids. By the present research, it was attempted to rank four companies in order to conduct a prequalification assessment. An inclusive, detailed list of 56 sub-factors under 5 main factors for project prequalification was compiled following a thorough literature review, and review of contractors by 4 experts who already have done projects with contractors, and then using the CRITIC method for obtained the weighing of each factor and classifying contractors by applied the EDAS system for recognizing the contractors' potential before competitive tendering and obtaining bids. The present research proposed herein a new approach to prequalification that accounts for multiple criteria when assessing the best contractor. The proposed support system was developed to help the tender holder, owner or client, and stakeholders to select the right contractors, and to afford a systematic and organized approach to the multifaceted issues. The effectiveness of the present approach was tested by applying it to a case study of the prequalification assessment of four construction companies' in Bandar Imam Khomeini municipality, Khuzestan, Iran. It is worth mentioning that the prequalification assessment by the proposed approach is approved by the project stakeholders and is consistent with their expectations. Note that, albeit the proposed method is a generalized approach and can be applied to a variety of projects, applying more pragmatic cases to approve the proposed approach is complicated because of the limited accessibility of project sources, the requirement to more adjust boundaries. The contribution of the present study proposed as a support system for prequalification and identification of contractors' ability, before assigning projects to companies for success in projects. The future research orientation can be oriented towards developing new MCDM models, weighing systems, and expansion in the content of questionnaires.

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