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Providing Optimal Decision-Making Function for Efficient Selection of A Contractor Using PSO Algorithm in MAPNA

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Abstract

Careful decision-making to select contractors to manage a project is one of the most important factors in the success and efficiency of a project. It is such that extracting a decision function from the set of factors influencing the selection of contractors can play an important role in improving project performance; therefore, providing a decision function is the main goal of this research. In this paper, the decision model is estimated in the form of linear and exponential equations using the Particle Swarm Optimization Algorithm (PSO) technique. The superior function is selected through the selection of the best estimation model based on the selection criteria of the competing function. Then, it is attempted to predict the values of the decision function. In this paper, for the optimal decision making function, a function of contractors' technical capability, contractors' behavioral capability, company capacity and facilities and project outsourcing goals are considered. The research results show that the linear function explains the efficient selection of a contractor with higher accuracy. The optimal decision-making function shows that MAPNA managers place more emphasis on MAPNA's resources, facilities, and capabilities to efficiently select a contractor. It can also be predicted that in future selections, managers will focus on the ability of MAPNA to

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cooperate with the contractor, and based on this, MAPNA group subsidiaries will be given priority in the selection.

Keywords: Efficient Contractor Selection, Particle Swarm Optimization Algorithm (PSO), Decision Function.
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1. Introduction

Today, different countries have proposed different methods for referring work to a contractor, and there are different models for optimal selection of contractors. In recent years, much attention has been paid to the issue of selecting the right contractor. Selecting the right contractor can involve many quantitative and qualitative factors. A good contractor will help the company grow in the long term and will be an important element in the success of business components [1]. Today's highly competitive markets force companies to respond quickly and accurately to the needs of customers in order to maintain and improve their position in their markets through their customers' satisfaction [2]. Supplier selection is one of the challenges for companies operating in a competitive market. In Europe, this has been the focus of managers to improve supply chain performance and organizational performance [3]. As competition intensifies, the top companies in the market are trying to create a standard and practical model for selecting suppliers so that they can better ensure the performance of the supply chain. Some companies and organizations use the lowest cost criterion to select a supplier in the tender, while this criterion alone cannot guarantee the quality and success of the project. In such circumstances, the role of suppliers and related issues in the supply chain become very important [4]. The main gap in previous surveys in selecting suppliers has been the focus solely on the factors influencing them and their rankings, but in this study the main effort is to use a practical model in selecting suppliers in the MAPNA Company.

The Particle Swarm Optimization (PSO) algorithm was first introduced by Kennedy and Eberhart in 1995, inspired by the behavior of birds and fishes, which is physiologically based on social influences and learning. In this algorithm, members follow a simple behavior, but the result is the discovery of optimal areas in the search space. Practically, the PSO algorithm is one of the best ways to optimize problems; therefore, this algorithm can be used to simulate different models of functions and also to predict the variable process.

This paper aimed to investigate and predict the process of improving the success of the project in MAPNA Company using the criteria affecting the efficient selection of the contractor. They were used with PSO to simulate the decision function in linear and exponential forms. Then, using the performance evaluation criteria of the competing models, the best model was selected and used to predict the success of the project based on the efficient selection of the contractor.

Based on this, a brief overview of the research literature with two orientations of the studies conducted in the field of contractor selection and also mentioning some studies performed using PSO algorithm is first discussed. Then, the theoretical foundations are presented in both of the above areas. After that, the steps of estimation and results and selection of the superior model are described. Finally, a conclusion is made by presenting the prediction results based on the superior model.

2. Literature review

2.1. Contractor selection

In order to get acquainted with the background of the research, studies, such as Taghvaei et al. [5], are referred. They evaluated and ranked suppliers using a hybrid approach of Kano and fuzzy

TOPSIS methods. The results of this study can be used to improve the performance of companies to evaluate supplier selection. Sarayloo et al. [6] evaluated the selection and ranking of suppliers using Delphi technique, hierarchical analysis and Taguchi loss function. Hosseinpour et al. [7] used data envelopment analysis approach and hierarchical analysis in the selection of suppliers. Hasani Derakhshandeh [8] conducted a study entitled "multi-criteria decision making to select the best supplier".

Jain et al. [9] looked for factors influencing optimal selection of suppliers with a multi-criteria TOPSIS decision-making approach and hierarchical analysis. Fikri et al. [10] designed the integrated AHP-based decision support system to select suppliers in the automotive industry. El Mokadem [11] categorized supplier selection criteria according to lean or agile production strategies. In this study, the main focus of the researcher was to identify the criteria that affect the choice of suppliers. Identified criteria for selecting suppliers, including quality, delivery, plant capabilities, services, management, technology, finance, flexibility, reputation, research and development, were among the important criteria in selecting suppliers. In a study of the organization's resource planning systems, six criteria of customer service, reliability, coherence, financial factors, security, and service level monitoring were identified [12].

Some of the important criteria that are considered for outsourcing decisions are: economic situation, resources, strategies, risks, management and quality [13]. Another study proposed 7 criteria of experience, economic factors, product quality, supplier efficiency, technical and development skills, and compliance to select a supplier [14].

The criteria used in this study are derived from the study of Karbakhsh et al. [18], who have identified the effective factors in the selection of contractors using the grounded theory approach. The criteria identified in this study are classified into four groups of technical capabilities of contractors, the behavioral capabilities of contractors, the capacity and resources of the company, and the goals of outsourcing that have been identified as effective criteria in selecting contractors. The results are evaluated in each group and finally the calculations show that the highest rank is related to the behavioral capability of contractors with a weight of 0.313. The technical capability of contractors (0.256) is ranked second, capacity and resources of the mother company (0.218) is in the third place, and the outsourcing goals of the project (0.212) are in the fourth place.

2.2. PSO Algorithm

Nowadays, with regard to the growing number of issues and the importance of speeding up achieving the response, other classic methods do not solve many problems because the search space increases exponentially and classic methods are not cost-effective. Due to the above considerations, random search algorithms are more used to solve optimization problems and the use of evolutionary algorithms and heuristic search algorithms has grown significantly in recent years.

PSO algorithm is one of the most powerful and popular algorithms for optimization, which is mostly used because of its relatively high convergence speed. This algorithm, despite its short lifespan, has been able to surpass older algorithms, such as the genetic algorithm, in many applications, and is considered as the first choice. Regarding domestic studies, PSO algorithm has been rarely used in the field of economics-related issues. The only study in this area is the study of Emami Meybodi et al. [16], who solved two forms of nonlinear energy demand equations using PSO algorithm using the macro indices of economics. The results of this study showed that the secondary form provides better results in viewing the data and with a higher correlation coefficient, it can be used in projects in the Iranian energy sector.

3. Research methodology

In this type of selection process, there are M different criteria and N decision makers, in which each person scores each of the criteria. So for each of the decision-makers' total points, a selection point is obtained. The efficient selection of contractor is also the end result of evaluating the selection criteria. Analysis of the results of various decisions of decision makers can be done by various methods. In this study, PSO algorithm was used to achieve the optimal function of the results of the decision makers. This research is a continuation of the previous research of the authors, which has led to the achievement of the efficient contractor selection model, and uses its results for the new study. Thus, as noted in the literature, a context that can analyze variables affecting contractor selection is derived from the results of past research. These variables include contractors' behavioral capability, contractors' technical capability, parent company's capacity and resources, and project outsourcing goals. Also, each of these variables has sub-criteria that facilitate the scoring process of decision makers, which is shown in Table 1.

Table 1: Decision-making components and criteria for efficient selection of contractor

Components	Weight	Criteria	Criteria weight in components	Final weight of criteria	Inconsistency rate
contractors' technical capability	0.256	Contractor commitment	0.308	0.078	0.008
		Contractor experience	0.342	0.087	
		Contractor compatibility	0.209	0.053	
		Contractor trust	0.211	0.054	
outsourcing goals	0.212	Project outsourcing value added	0.299	0.063	2*2 matrix is always consistent
		Project efficiency	0.304	0.064	
company's capacity and resources	0.218	Employer resources	0.327	0.071	2*2 matrix is always consistent
		The ability of cooperation between company and contractor	0.304	0.066	
contractors' behavioral capability	0.313	Financial capability of contractors	0.409	0.128	0.001
		Management skills of contractors	0.249	0.077	
		Source capability of contractors	0.391	0.122	
		Innovative capability of contractors	0.211	0.066	

The conceptual model of the research is also shown in Figure 1.

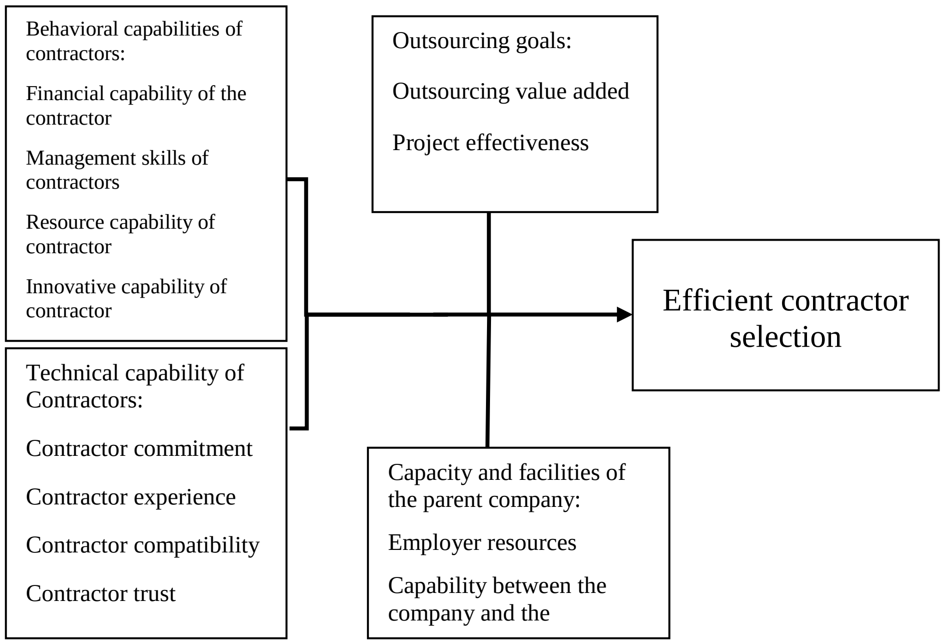

Figure 1: Conceptual model of efficient contractor selection

Based on the conceptual model, efficient contractor selection is a function of four variables, which are defined as follows:

$$Y_i = W_1 + W_2 + W_3 + W_4 \tag{3.1}$$

i = 1, 2, 3, (decision makers)
W1: Contractor behavioral capability (Financial capability, management skills, resource capability, and innovation capability)
W2: Contractor technical capability (contractor commitment, contractor experience, contractor compatibility, and contractor trust)
W3: Capacity and resources of the company (resources of the employer company and the cooperation capability between the company and the contractor)
W4: Project outsourcing goals (project outsourcing value added and project effectiveness)

3.1. Theoretical foundations of PSO algorithm

PSO algorithm is an optimization technique based on a population of primary responses. PSO is one of the most important and best algorithms introduced in the field of artificial intelligence. This technique was first designed and modeled by Kennedy and Eberhart in 1995 based on the social behavior of bird and fish groups.
In many cases, this method is similar to evolutionary computational techniques, such as genetic algorithms. In this method, the system starts working with a population of primary responses and tries to find the optimal response by moving these responses during successive iterations. In this algorithm, each particle represents a response that is randomly moving in the problem space. The change in the location of each particle in the search space is influenced by itself and its neighbors, so the position of other particles affects how the particle moves and searches. Each particle adjusts its position in the search space according to the best place it has ever been and the best place in its entire neighborhood. The initial position of each particle is randomly determined in the search space with a uniform distribution within the problem definition range.

Each particle is defined in a multidimensional way (depending on the nature of the problem) with two values of $x_i^d(t)$ and $v_i^d(t)$, which represent the spatial and speed positions corresponding to d^{th} dimension of i^{th} particle, respectively. Subsequently, the position of each particle is determined based on its own experience and that of its neighbors. If $x_i^d(t)$ is the position of the position of d^{th} dimension of particle i at time t, the next position of the particle is obtained from the sum of the position of the d^{th} dimension of the particle i at time and the speed of particle i. The particles are guided by the velocity vector. In the velocity vector, both the result of the social experience of the neighboring particles and the individual experience of each particle are involved. Each particle updates its speed with a linear combination of a personal component that represents the use of personal knowledge and experience, and a social component that reflects the experiences of neighbors. In the personal component, the best position of the particle that has been achieved so far, i.e. pbest, is considered, and in the social component, the best position that the whole particles have achieved, i.e. gbest, is considered.
To achieve the best response, each particle tries to change its position by using the following information and relationships:
Current position $x_{ij}(t)$, current speed $v_{ij}(t)$, distance between current position and pbest, and distance between current position and gbest. In this way, the speed of each particle changes according to the following relation:

$$v_{ij}(t+1) = w \cdot v_{ij}(t) + c_1 \cdot r_1 \left(\mathrm{pbest}_{ij}(t) - x_{ij}(t)\right) + c_2 \cdot r_2 \left(\mathrm{gbest}_j(t) - x_{ij}(t)\right) \tag{3.2}$$

In which, $v_{ij}(t)$ is the j^{th} dimension of each particle in t^{th} iteration, c_1 and c_2 are positive constants used for weighting of intrinsic and collective components and are called acceleration coefficients, r_1 and r_2 are random numbers with a distribution between zero and one $((r_{1i}(t), r_{2i}(t) \simeq u(0,1))$ that maintain the random property of the algorithm, and w is the inertial weight parameter.
The new position of each particle is obtained from the sum of the past position and the new velocity, which is determined by the following equation:

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \tag{3.3}$$

The flowchart of the PSO algorithm is shown in the following figure:

3.2. Simulation of the decision function

In this section, the variables affecting the decision making and linear and exponential expressions are first introduced, and then by expressing the results of estimation and using the evaluation criteria of competing models, the optimal model is presented for selection and forecasting results. The simulation of the decision function based on the variables affecting this function is considered as linear and exponential forms as follows:

$$\begin{aligned} Y &= \mathrm{W}_1\mathrm{X}_1 + \mathrm{W}_2\mathrm{X}_2 + \mathrm{W}_3\mathrm{X}_3 + \mathrm{W}_4\mathrm{X}_4 \\ Y &= \mathrm{W}_1\mathrm{X}_1^{z1} + \mathrm{W}_2\mathrm{X}_2^{z2} + \mathrm{W}_3\mathrm{X}_3^{z3} + \mathrm{W}_4\mathrm{X}_4^{z4} \end{aligned} \tag{3.4}$$

In these equations, wi is eight factors and X1, X2, X3, and X4 represent contractor behavioral capability, contractor technical capability, parent company resources and capacity, and outsourcing goals of the project, respectively.
The following are linear and exponential decisions simulated by PSO algorithm:
Linear function:

$$y = 0.229648X_1 + 0.139222X_2 + 0.355106X_3 - 0.181383X_4 + 1.1215 \tag{3.5}$$

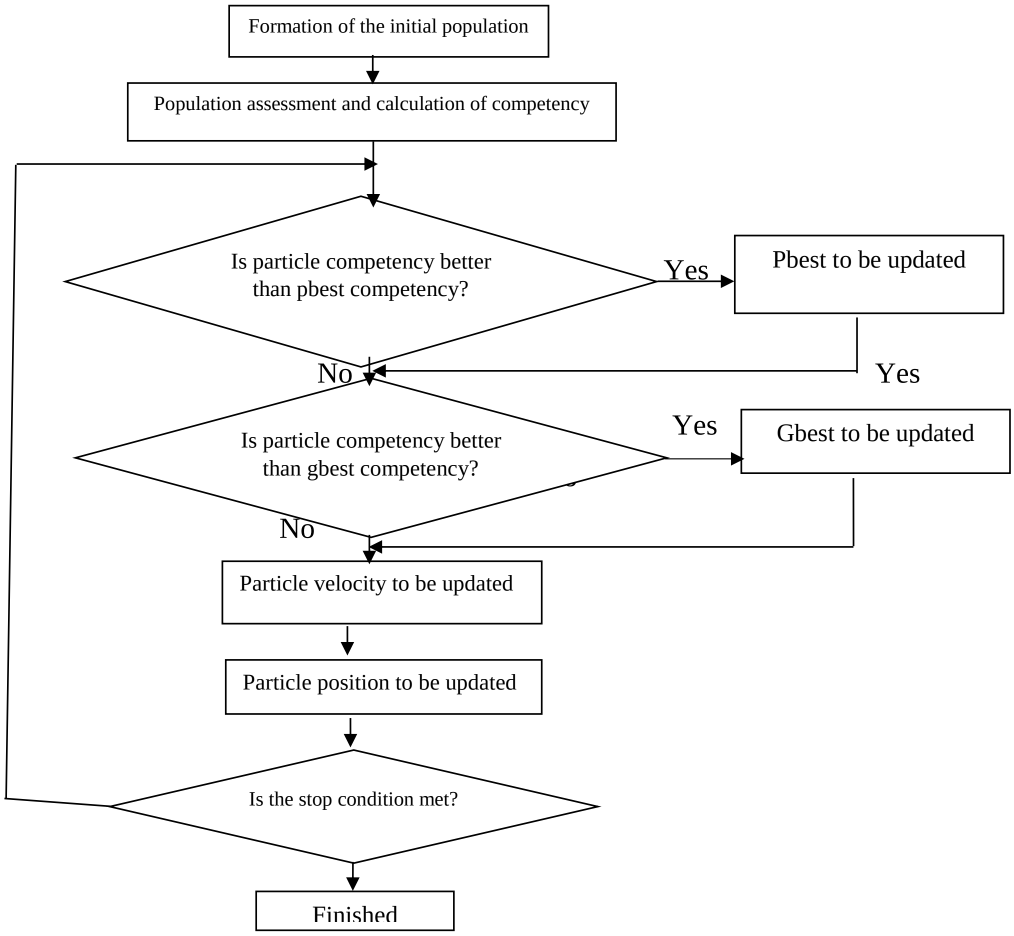

Figure 2: Conceptual model of efficient contractor selection

Exponential function:

$$y = 0.503852X_1^{0.672169} + 0.222829X_2^{0.739449} + 0.500515X_3^{0.710671} + 0.142158X_4^{0.386992} - 0.3257 \quad (3.6)$$

It should be noted that MATLAB software has been used for programming the PSO algorithm and the parameters specified in the algorithm are shown in the table below.

Table 2: Algorithm parameters

Parameter	Size
Particle size (n)	50
Inertia weight (w)	0.995
Maximum number of iterations (t)	1000

Evaluation of the performance of simulated functions in decision prediction was performed using four criteria of mean square error (MSE), root of mean square error (RMSE), mean absolute percent error (MAPE), and mean absolute error (MAE). These criteria are calculated as follows:
In the equations above, n is the number of observations.
The obtained results are presented in Table 3.

Table 3: Model evaluation and selection criteria

Criteria	Formula
MSE	$MSE = \frac{\sum_{i=1}^{n}(E_i^{observed} - E_i^{simulated})^2}{n}$
MAPE	$MAPE = \frac{\sum_{i=1}^{n}\left\lvert\frac{E_i^{observed} - E_i^{simulated}}{E_i^{observed}}\right\rvert}{n}$
MAE	$MAE = \frac{\sum_{i=1}^{n}\lvert E_i^{observed} - E_i^{simulated}\rvert}{n}$

Table 4: Evaluation of the performance of simulated functions

Criteria	Formula
MSE	$MSE = \frac{\sum_{i=1}^{n}(E_i^{observed} - E_i^{simulated})^2}{n}$
MAPE	$MAPE = \frac{\sum_{i=1}^{n}\left\lvert\frac{E_i^{observed} - E_i^{simulated}}{E_i^{observed}}\right\rvert}{n}$
MAE	$MAE = \frac{\sum_{i=1}^{n}\lvert E_i^{observed} - E_i^{simulated}\rvert}{n}$

According to Table 3, the results show that the linear decision-making function with lower MAE is more optimal than the exponential function and is considered as the optimal decision-making function for efficient contractor selection in MAPNA Company.

4. Conclusion

By obtaining the optimal decision-making function that has been in the process resulting from the views of MAPNA executives, the behavior of these managers in future choices can be predicted. MAPNA managers have placed more emphasis on some factors in deciding to select an efficient contractor. The most effective factors in the optimal function are determined by the effective coefficient of each factor in the optimal decision function. In this function, 0.35 for the capacity and resources of the employer company, 0.23 for the contractor behavioral capability, 0.18 for project outsourcing goals, and 0.14 is considered for the technical capability of the contractors. This function shows that in MAPNA Company, more emphasis is placed on the factor of employer resources and capacity to expect the contractor's performance. Thus, this shows that MAPNA managers' mentality for efficient contractor selection is based on micro-factors, such as employer resources and ability to cooperate between company and contractor. In the event of a loss in these micro-factors on the part of the employer (MAPNA), the expectation of the contractor's performance will be significantly reduced. In other words, the optimal function estimates that If MAPNA is more prepared to cooperate with contractor, the contractor will be closer to MAPNA's efficient selection. So it is easy to predict that MAPNA executives will prioritize contracting companies with stronger collaborative relationships, which are largely subsidiaries of the MAPNA Group, in deciding which contractor to choose. The contractor's behavioral ability is the second most important factor in efficient contractor selection in this function. Managers put a great emphasis on contractor behavioral capability including: financial capability, managerial skills, contractor's resources and innovations. Managers also value the value added of outsourcing in making their decisions. It can be predicted that outsourcing effectiveness will be effective in their future decisions. In the end, the commitment and experience of the contractor, although less than other factors, has played a role in the decisions of MAPNA managers.

References

[1] Chen, M Bubshalt. A. A. & Al-Gobali, K. H. (2013). Contractor prequalification in Saudi Arabia. Journal of Management in Engineering, 12, 50–54.

[2] Chan, R., Kumar, M. (2007) Lean management model for construction of high-rise apartment buildings. Journal of construction engineering and management American Society of Civil Engineers, Reston, 2007, vol.133, no 5, pp. 374-384.

[3] Monfared, Masoud, Salari, Masoud (2016)" Investigating Selection of Top Contractors by Considering the Role of Internal Resources of the Organization. Project Management Quarterly, Volume 3 (1), pp. 18-27.

[4] Herroelen, W.S. Leus, R. Demeulemeester, E.L., 2014. Critical chain project scheduling-do not oversimplify. Project Management Journal 33(4): 46–60.

[5] Taghvaei, C.Hadyeh. & Esmaeilian, Majid.(2017). Supplier Evaluation and Ranking Using a Combined Approach of Kano and TOPSIS Methods in the Fuzzy Environment. Second International Conference on Industrial Management. Babolsar, University of Mazandaran.

[6] Sarayloo, Zahra.& Farhadi, Ali. (2017). Supplier Selection and Ranking Using Delphi Techniques, Hierarchical Analysis and Taguchi Loss Function. Second International Conference on Management and Accounting Techniques, Tehran.

[7] Hosseinpour, Afsaneh. & Mahmoud Alborzi. (2017). Combining Data Envelopment Analysis and Hierarchical Analysis Process in Selection of Contractors Tendered. Second International Conference on Management and Accounting. Tehran.

[8] Hasani Derakhshandeh, Sholeh. (2017) Multi-criteria Decision Making Technique for Selecting the Best Oil and Gas Equipment Supplier. Fifth International Conference on Economics. Management, Accounting with Value Creation Approach. Shiraz.

[9] Jain, Vipul. & Kumar, Arun. (2018). Supplier selection using fuzzy AHP and TOPSIS. Neural Computing and Applications. Volume 29, Issue 7, pp 555–564.

[10] Fikri, Dweiri. Kumar, Sameer. (2016). Designing an integrated AHP based decision support system for supplier selection in automotive industry. Expert Systems with Applications, Volume 72, 15 April 2017, Pages 467-468.

[11] El Mokadem, M. (2017). The classification of supplier selection criteria with respect to lean or agile manufacturing strategies. Journal of Manufacturing Technology Management, Vol. 28 No. 2, pp. 232-249.

[12] Olson, N, Soetanto, AR J Dainty, J Glass, A D F Price. (2006)Towards an explicit design decision process: the case of the structural frame/ Construction Management and Economics. London: Jun 2006. Vol/ 24, Iss. 6; pg. 603.

[13] Banaitienė, Nerija. Neringa GudienėAudrius Banaitis, Jorge Lopes.(2013)"Development of a Conceptual Critical Success Factors Model for ConstructionmProjects: a Case of Lithuania" 11th International Conference on Modern Building Materials, Structures and Techniques, MBMST.

[14] Samiaah M. Hassen M. Al-Tmeemya, Hamzah Abdul-Rahmanb, Zakaria Haruna , 2011, Future criteria for success of building projects in Malaysia, International Journal of Project Management

[15] KARBAKHSH RAVARI, H., salajegheh, S., Sheikhi, A. (2020). Providing an practical model of contractor selection and prioritization in project - based companies (Case Study: MAPNACompany), 14(49), 133-146.
[16] Chen, Chen- Tung, Sue- Fen Hung. 2007. Applying fuzzy method for measuring criticality in project network.International Journal of Information Sciences177:2448- 58.