A Review on Key Contractor selection criteria for DB-EPC Projects

GAURAV SUHAS NALAMWAR[1], PROF. ASHISH PRUTHVIRAJ WAGHMARE[2]

[1] *PG Student, Department of Civil Engineering, AJEENKYA D Y Patil School of Engineering, Pune*

[2] *PG Coordinator/ Assistant Professor, Department of Civil Engineering, AJEENKYA D Y Patil School of Engineering, Pune*

Abstract- Choosing the right contractor is crucial for the success of Engineering, Procurement, and Construction (EPC) and Design-Build (DB) projects. Various factors should be considered to ensure that the best contractor is selected, such as the contractor's technical proficiency, expertise, financial stability, safety record, and overall reputation. The project's complexity and budgetary restrictions should also be taken into account. To achieve a fair and equitable selection process, the contractor's credentials should be reviewed against the project's specifications in a methodical and transparent manner. In this study, the factors influencing contractor selection in construction projects in India were analysed using interpretative structural modelling (ISM). Additionally, MICMAC analysis is utilized to distinguish between "driving factors" and "dependent factors." The ISM model indicated that financial stability, performance on works (quality), current projects in hand, and lowest bidder are the top criteria to consider while selecting contractors for DB/EPC projects. Joint venture/singlepoint of responsibility was identified as a factor that influences but is not influenced by other factors. The middle-level factors were transitional because they both influence and are affected by other factors. However, these results are based on expert judgments, which may introduce biases. Overall, this study provides valuable insights into the factors influencing contractor selection in construction projects in India, which can aid decision-makers in the selection process.

Indexed Terms- Contractor Selection; Engineering procurement & construction; Design-Build; Selection criteria;Prequalification Criteria.

I. INTRODUCTION

1.1 Need for Study

The contractor selection process is a critical aspect of Engineering, Procurement and Construction (EPC) and Design-Build (DB) projects. It is important to choose a competent and reliable contractor who can deliver the project within budget, time, and scope constraints, and with high quality standards. The contractor selection process affects the project outcomes and can have a significant impact on project success or failure.

The contractor selection criteria differ depending on the project size, kind, and complexity, as well asthe aims and expectations of the stakeholders. The criteria also change over time as the industry evolves and new technologies and practices are introduced. A comprehensive and systematic evaluation of the contractors' capabilities, experience, and performance is crucial to ensure the best value for the project.

A study on the contractor selection criteria for DB/EPC projects is necessary to understand the currentpractices and challenges in the industry, identify best practices, and provide recommendations for improvement. The study can also help project managers, owners, and stakeholders to make informed decisions and ensure that the contractors selected for the projects meet their expectations and requirements. Additionally, the study can provide insights into the factors that influence the contractorselection process, the trade-offs involved, and the risks associated with the process.

In conclusion, the need for a study on contractor selection criteria for DB/EPC projects is crucial for the industry to enhance the quality of the projects, reduce the risk of failure, and increase the value for the stakeholders.

According to Oxford Economics' Worldwide Infrastructure Outlook 2017, the global demand for infrastructure investment between calendar years 2016 and 2040 is estimated to reach $ 94 trillion. To accomplish the Sustainable Development Goals (SDG) for water and power, an additional $3.5 trillion is necessary. Asia accounts for half of the investment demands. The electricity and road sectors will account for more than two-thirds of this, followed by the telecom, rail, and water sectors.

The Engineering, Procurement, and Construction (EPC) market in India is expanding at a fast pace. Its exact size is challenging to estimate; however, studies and industry experts estimate that the construction industry in India was valued at INR 8,184 billion in FY13 and is predicted to be worth INR 9,013 billion in the upcoming years. Before the global economic crisis in 2008, the industry sawgrowth of more than 10% between 2005 and 2007. However, the growth slowed down to an average real growth rate of 4.8% from 2008 to 2014. But now, with a stable government in place that prioritizesinfrastructure development, the industry is expected to bounce back. The construction sector, after agriculture, is India's second largest contributor to the economy, employing over 40 million people in2012-13 and accounting for nearly 8.1% of the national GDP. It is expected to continue contributing 7.8% on an annual basis. Research suggests that the EPC market in India will grow at a Compound Annual Growth Rate (CAGR) of 20.26% between 2014 and 2019, driven by infrastructure investmentsfrom the government (GOI) of India. The GOI has targeted investment of US$1,020 billion in infrastructure development between 2012 and 2017, as per its 12th five-year plan, including investments from the central government, state governments, and private players.

More supply-side changes are required to achieve the aim of a $5 trillion economy by 2025. Buildingnew infrastructure and modernizing current infrastructure will be critical to increasing India's competitiveness and meeting this aim. It will be especially important for the success of the Make in India initiative since manufacturing competitiveness is heavily reliant on infrastructure.

It is anticipated that India would need to invest $4.51 trillion on infrastructure by 2030 in order to achieve the objective of a $5 trillion GDP by 2025 and continue on an upward trend until 2030. The NIP's goal would be to make this happen as quickly as possible.

Infrastructure and construction sector receives the second-largest share of FDI inflows. As per KPMG Infrastructure Report, the contribution of Infrastructure and Construction activities in India was US$738.5 Billion in the FY2017 and is expected to become the third-largest market in the world by 2025. To meet the growing demands of the Indian economy, substantial investments in infrastructure will be required from both the public and private sectors. The public sector must play a pivotal role in ensuringthat infrastructure projects are completed efficiently, effectively, and within budget. Historically, the Central and State Governments have used item rate contracts for construction projects, where the government provides detailed design and quantity estimates and payments are made based on the amount of work done. However, these contracts have a track record of significant time and cost overruns, as well as ongoing disputes and large claims. This underperformance is due to poor project planning and estimating, as well as inadequate risk management by the government.

Multiple institutions, including NITI Aayog, MOSPI, EY, CIDC, and FIDIC, suggest using EPC/DB contracts for projects over 100 crores and replacing item rate contracts where feasible. The traditional procurement procedures currently used by the industry often result in budget and time overruns.

1.2 Research problems & questions

Over time, the nature of contracts in the construction industry has evolved from item rate packages tolump-sum, fixed-price, and time-bound agreements. As a result, the responsibility for project management has shifted from the owner/developer to the contractor.There is a clear movement from owner-managed projects to EPC Contracts, and the risk of schedule and expense overruns, as well as the obligation of designing and procuring materials and construction, has been handed to the contractor. Selecting a contractor becomes crucial in this situation. If a proper or appropriate proposalis chosen, the results may be improved. This challenge can be solved by using several factors to improve selection criteria.

1.3 Research Objectives

- To identify selection criteria for DB/EPC projects from literature review.
- To rank the critical selection criteria and find the interrelationships among them.

II. METHODOLOGY

Based on their research, the writers chose crucial parameters, which were then critically evaluated bya panel of specialists for the aim of selecting contractors. These criteria were whittled down to ten. Theapproach used is comparable to that of El-Razek et al (2008). A questionnaire was developed to take an opinion from expert. Total 20 experts in the panel were a mix of industry and academia.

Figure 1: Questionnaire format

Key Contractor Selection Criteria for DB-EPC projects											
SSIM Matrix											
Select the relationship between the criteria given in section i and section j.											
		i									
		Lowest Bidder	Single point responsibility/ Joint Venture	Safety compliance	Current projects in hand	Project team qualifications	Licences and professional registrations	Performance on works (Quality)	Financial stability of contractors	Technical capability of contractors	Previous work experience
j	Previous work experiences										x
	Technical capability of contractors									x	
	Financial stability of contractors								x		
	Performance on works (Quality)							x			
	Licences and professional registrations						x				
	Project team qualifications					x					
	Current projects in hand				x						
	Safety compliance			x							
	Single point responsibility/ Joint Venture		x								
	Lowest Bidder	x									
V is used for relation from factor i to factor j (i.e. if factor i will "help achieve" or "will help alternate" factor j)											
A is used for relation from factor j to factor i (i.e. if factor j will "help achieve" or "will help alternate" factor i)											
X is used for both direction relations (i.e. if factor i and j "help achieve each other											
O is used for no relations between two factors (i.e. if factor i and j are not related)											

(Source: Compiled by authors)

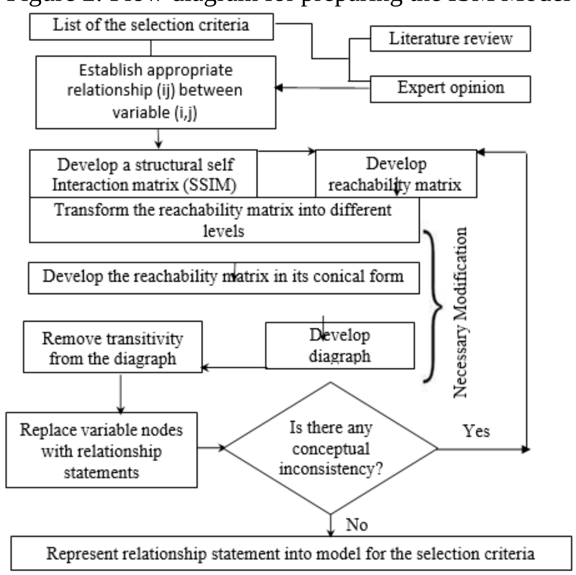
The final list of 10 factors for selection criteria of contractor is given below:

1. Previous work experiences
2. Technical capability of contractors
3. Financial stability of contractors
4. Performance on works (Quality)

5. Licenses and professional registrations
6. Project team qualifications
7. Current projects in hand
8. Safety compliance
9. Single point responsibility/ Joint Venture
10. Lowest Bidder

The authors utilized the ISM method to uncover the interaction between key elements in the study's second objective. ISM is a method based on expert opinions and the same experts who identified the final list of ten factors affecting contractor selection helped construct the ISM framework.

Figure 2: Flow diagram for preparing the ISM Model



(Source: Balon *et. al,* 2016)

Section three discusses why the ISM technique was chosen above others:

2.1 ISM AND MICMAC AnalysisISM
In this study, the ISM method was utilized to determine the interaction between crucial factors.ISM isbased on expert opinions, and the same experts who identified the final list of ten variables affecting contractor selection participated in constructing the ISM framework. The panel consisted oftwo academic specialists with over a decade of teaching and research experience in construction management. The SSIM was created using the ISM approach, which involved experts brainstorming,but there is no set standard for the number of experts required. Developing the SSIM involves challenges such as linking each variable, determining mutual influence, and establishing direction. Theexperts used four symbols to represent the relationship between factors: V for I influences j but is notimpacted by j, A for j influences I but I does not impact j, X for mutual influence, and O for independence with no impact. After careful consideration, the experts developed the SSIM matrix, theflowchart for which is presented in Figure 1.

MICMAC Analysis
The Method of Isolating Components in Mix and Matching, abbreviated as MICMAC, may also be utilized for classification analysis. The practice of classifying data into distinct classes or groups basedon specified features or characteristics is referred to as "classification analysis" in this context.

The purpose of MICMAC classification analysis is to find patterns or correlations in data that can be utilized to sort it into meaningful groupings. This can be accomplished through the use of statistical approaches, machine learning algorithms, or a mix of the two.

For example, in image processing, MICMAC classification analysis may be used to classify pictures into multiple classes based on their visual properties, such as people, buildings, trees, and automobiles.The algorithm in this application may use information like as colour, texture, shape, and size to categorize photographs.

MICMAC classification analysis may be used in a variety of disciplines, such as computer vision, natural language processing, contracts, and data mining. Organizations may obtain insights into their data and make educated decisions based on the patterns and correlations revealed in the research by adopting this technique.

Finally, MICMAC classification analysis may be a useful tool in the contractor selection process sinceit provides a systematic way to classifying contractors based on relevant data and a detailed study of their skills and performance. It reduces the likelihood of project failure and increases the likelihood ofsuccess.

III. DATA ANALYSIS AND FINDINGS

The experts reached agreement on the SSIM, which is shown in Table 1, based on theguidelinesoffered (described in the study methodology section).

Interpretations of the discovered correlations were utilized to create the first reachability matrix. According to the VAXO rule, 1 and 0 are used in place of V, A, X, and O to achieve this.

- When (i,j) is entered as 'V' in the SSIM, enter '1' for the element (i,j) and '0' for (j,i) in the initial reachability matrix.
- When (i,j) is entered as 'A' in the SSIM, enter '1' for the element (i,j) and '0' for (j,i) in the initial reachability matrix.
- When (i,j) is entered as 'X' in the SSIM, enter '1' for the element (i,j) and '1' for (j,i) in the initial reachability matrix.
- When (i,j) is entered as 'V' in the SSIM, enter '0' for the element (i,j) and '0' for (j,i) in the initial reachability matrix.

The final reachability matrix is produced by applying the transitivity principle and the initial reachability matrix. The connection between element a and element b and the relationship between element b and element c indicates that element a is linked to element c. The reachability and antecedentset of each enabler, comprising the factor and other factors it can assist in accomplishing, is determined using the final reachability matrix. The intersection of the reachability set and the antecedent set is referred to as the intersection set, and if the intersection and reachability match, the factors are considered to be at the top level. The aforementioned process is reiterated until all levels are recognized and the factors at the highest level are eliminated from the element set to enable further computation. The ISM model is formed by four layers as shown in tables 2-7 after four research iterations. The ISMmodel is created using the levels determined by the computation process.

Table 1: SSIM Matrix (Select the relationship between the factors given in Section I and Section J)

j \ i	Lowest Bidder	Single point responsibility/ Joint Venture	Safety compliance	Current projects in hand	Project team qualifications	Licences and professional registrations	Performance on works (Quality)	Financial stability of contractors	Technical capability of contractors	Previous work experience
Previous work experiences	V	A	V	V	V	A	V	V	A	X
Technical capability of contractors	V	O	V	V	A	A	V	X	X	
Financial stability of contractors	V	O	V	X	X	V	X	X		
Performance on works (Quality)	O	O	X	X	A	A	X			
Licences and professional registrations	V	O	V	V	X	X				
Project team qualifications	V	O	V	V	X					
Current projects in hand	A	O	A	X						
Safety compliance	V	O	X							
Single point responsibility/ Joint Venture	O	X								
Lowest Bidder	X									

(Source: Compiled by authors)

Table 2: Initial Reachability Matrix

J \ i		1 Previous work experiences	2 Technical capability of contractors	3 Financial stability of contractors	4 Performance on works (Quality)	5 Licences and professional registrations	6 Project team qualifications	7 Current projects in hand	8 Safety compliance	9 Single point responsibility/ Joint Venture	10 Lowest Bidder
1	Previous work experiences	1	0	1	1	0	1	1	1	0	1
2	Technical capability of contractors	1	1	1	1	0	0	1	1	0	1
3	Financial stability of contractors	0	1	1	1	1	1	1	1	0	1
4	Performance on works (Quality)	0	0	1	1	0	0	1	1	0	0
5	Licences and professional registrations	1	1	0	1	1	1	1	1	0	1
6	Project team qualifications	0	1	1	1	1	1	1	1	0	1
7	Current projects in hand	0	0	1	1	0	0	1	0	0	0
8	Safety compliance	0	0	0	1	0	0	1	1	0	1
9	Single point responsibility/ Joint Venture	1	0	0	0	0	0	0	0	1	0
10	Lowest Bidder	0	0	0	0	0	0	1	0	0	1

(Source: Compiled by authors)

Table 3: Final Reachability matrix

j \ i		Previous work experiences	Technical capability of contractors	Financial stability of contractors	Performance on works (Quality)	Licences and professional registrations	Project team qualifications	Current projects in hand	Safety compliance	Single point responsibility/ Joint Venture	Lowest Bidder	**Driving Variables**
1	Previous work experiences	1	1	1	1	1	1	1	1	0	1	9
2	Technical capability of contractors	1	1	1	1	1	1	1	1	0	1	9
3	Financial stability of contractors	1	1	1	1	1	1	1	1	0	1	9
4	Performance on works (Quality)	0	1	1	1	1	1	1	1	0	1	8
5	Licences and professional registrations	1	1	1	1	1	1	1	1	0	1	9
6	Project team qualifications	1	1	1	1	1	1	1	1	0	1	9
7	Current projects in hand	0	1	1	1	1	1	1	1	0	1	8
8	Safety compliance	0	0	1	1	0	0	1	1	0	1	5
9	Single point responsibility/ Joint Venture	1	0	1	1	0	1	1	1	1	1	8
10	Lowest Bidder	0	0	1	1	0	0	1	0	0	1	4
	Dependent Variables	6	7	10	10	7	8	10	9	1	10	

(Source: Compiled by authors)

Table 4: Level identification (Iteration I)

ij	Reachability set	Antecedent set	RS ∩AS	Level
1	1,2,3,4,5,6, 7,8,10	1,2,3,5,6,9	1,2,3,5,6	
2	1,2,3,4,5,6, 7,8,10	1,2,3,4,5,6,7	1,2,3,4,5,6, 7	
3	1,2,3,4,5,6, 7,8,10	1,2,3,4,5,6,7 ,8,9,10	1,2,3,4,5,6, 7,8,10	1
4	2,3,4,5,6,7, 8,10	1,2,3,4,5,6,7 ,8,9,10	2,3,4,5,6,7, 8,10	1
5	1,2,3,4,5,6, 7,8,10	1,2,3,4,5,6,7	1,2,3,4,5,6, 7	
6	1,2,3,4,5,6, 7,8,10	1,2,3,4,5,6,7 ,9	1,2,3,4,5,6, 7	
7	2,3,4,5,6,7, 8,10	1,2,3,4,5,6,7 ,8,9,10	2,3,4,5,6,7, 8,10	1
8	3,4,7,8,10	1,2,3,4,5,6,7 ,8,9	3,4,7,8	
9	1,3,4,6,7,8, 9,10	9	9	
10	3,4,7,10	1,2,3,4,5,6,7 ,8,9,10	3,4,7,10	1

(Source: Compiled by authors)

Table 5: Level identification (Iteration II)

ij	Reachability set	Antecedent set	RS ∩AS	Level
1	1,2,5,6,8	1,2,5,6,9	1,2,5,6	
2	1,2,5,6,8	1,2,5,6	1,2,5,6	
5	1,2,5,6,8	1,2,5,6	1,2,5,6	
6	1,2,5,6,8	1,2,5,6,9	1,2,5,6,	
8	8	1,2,5,6,8,9	8	2
9	1,6,8,9	9	9	

(Source: Compiled by authors)

Table 6: Level identification (Iteration III)

ij	Reachability set	Antecedent set	RS ∩AS	Level
1	1,2,5,6	1,2,5,6,9	1,2,5,6	3
2	1,2,5,6	1,2,5,6	1,2,5,6	3
5	1,2,5,6	1,2,5,6	1,2,5,6	3
6	1,2,5,6	1,2,5,6,9	1,2,5,6,	3
9	1,6,9	9	9	

(Source: Compiled by authors)

Table 7: Level identification (Iteration IV)

ij	Reachability set	Antecedent set	RS ∩AS	Level
9	9	9	9	4

(Source: Compiled by authors)

From the above Tables 2-7, we can observe that the financial stability of contractors (3), Performanceon works (Quality) (4), Current projects in hand (7) and Lowest Bidder (10) are top-level factors, andso appear at the top of the digraph. At the second level, there is only one factor which is Safety compliance (8). At level three there are four factors i.e. Previous work experience (1), Technical capability of contractors (2), Licenses and professional registrations (5), and Project team qualifications (6) are placed. At level four there is only one factor i.e., Single point responsibility/ JointVenture (9) are placed. The level denotes how significant a factor is. The primary and underlying causes of the actual issue are the factors at the lowest level.

Table 8: Final conical matrix

		i: 3 Financial stability of contractors	4 Performance on works (Quality)	7 Current projects in hand	10 Lowest Bidder	8 Safety compliance	1 Previous work experiences	2 Technical capability of contractors	5 Licences and professional registrations	6 Project team qualifications	9 Single point responsibility/ Joint Venture
j	3 Financial stability of contractors	1	1	1	1	1	1	1	1	1	0
	4 Performance on works (Quality)	1	1	1	1	1	0	1	1	1	0
	7 Current projects in hand	1	1	1	1	1	0	1	1	1	0
	10 Lowest Bidder	1	1	1	1	0	0	0	0	0	0
	8 Safety compliance	1	1	1	1	1	0	0	0	0	0
	1 Previous work experiences	1	1	1	1	1	1	1	1	1	0
	2 Technical capability of contractors	1	1	1	1	1	1	1	1	1	0
	5 Licences and professional registrations	1	1	1	1	1	1	1	1	1	0
	6 Project team qualification	1	1	1	1	1	1	1	1	1	0
	9 Single point responsibility/Joint Venture	1	1	1	1	1	1	0	0	1	1

(Source: Compiled by authors)

Using the information about level placement and the final reachability matrix, a conical matrix (alsoknown as a lower triangular matrix) is generated (Table 8). A conical matrix is essentially asequential organization of the components of the final reachability matrix according to the defined levels. It is used to establish the interrelationships between the variables.

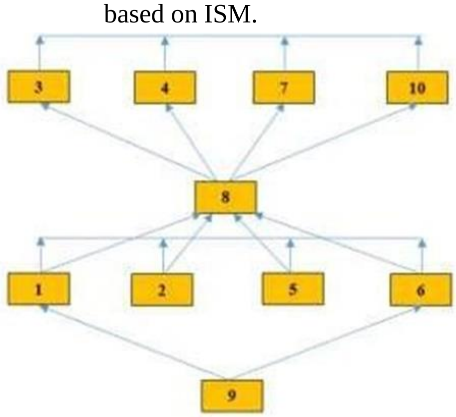
Table 9: Driving & Dependent variables for MICMAC analysis.

Factors	Dependent Variables	Driving Variables
Previous work experiences	6	9
Technical capability of contractors	7	9
Financial stability of contractors	10	9
Performance on works (Quality)	10	8
Licences and professional registrations	7	9
Project team qualifications	8	9
Current projects in hand	10	8
Safety compliance	9	5
Single point responsibility/ Joint Venture	1	8
Lowest Bidder	10	4

(Source: Compiled by authors)

The final graphical model is built on the levels specified in Tables 2-7, and the link between components is defined using the conical matrix (Talib et al. 2011), as seen in Table 8.

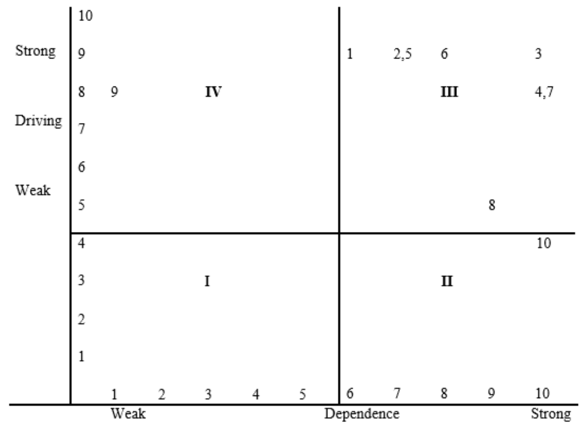
Figure 2: Model depicting relation among variables based on ISM.



(Source: Compiled by authors)

Four levels have been discovered, and Figure 4 depicts all four levels, with Single point responsibility/Joint Venture (9) at the bottom and having an impact on Previous work experiences (1), and Project team qualifications (6). In the third level, four factors, Previous work experiences (1), Technical capability of contractors (2), Licenses and professional registrations (5) and Project team qualificationsare set. The middle-level factors are transitional because they both influence and are affected by other factors. Safety compliance (8) is classified as level 2, meaning it has an impact on factors at levels 1 and 2 and is impacted by factors at levels 3 and 4. Financial stability of contractors (3), Performance on works (Quality) (4), Current projects in hand (7) and Lowest Bidder (10) are the factors listed firstbecause they have an impact on others but have no influence on others.

Figure 4: Graph of MICMAC Analysis



(Source: Compiled by authors)

Fuzziness in the ISM MICMAC research confirms the results of the proposed ISM model. Cross-Impact Matrix Multiplication Applied to Classification is an acronym for the MICMAC study. The MICMAC analysis is based on matrix multiplication properties (Kannan et al. 2009). The MICMAC study's purpose is to assess inhibitor reliance and driving power (Mandal and Deshmukh 1994; Wakchaure and Jha 2011). It is primarily employed to find inhibitors that oversee driving the complete system. It is an approach for visually categorizing inhibitors into four clusters, namely autonomous, dependent, connecting, and driving clusters (Jena et al. 2017). Table-9 displays the driving and dependent power of each variable.

Table 9 is used to generate a MICMAC matrix. The matrix is categorized into four groups. Thecomponents in Cluster 1 are referred to as autonomous variables, indicating that they possess no driving strength and exhibit no interdependence. These variables are irrelevant to the system, having no connection with other factors and being unaffected by the system (Jena et al., 2017). This cluster lacks all of the components. Cluster two has components that are highly dependent on one another. Others influence these aspects, while they have no influence on others (Jena et al. 2017). The variablesin this cluster include safety compliance (8) and lowest bidder (10) and have a strong dependent power.The factors in Cluster three are identified as having substantial driving and dependent power. Since these variables are dynamic, any action taken on them will affect other variables and also result in a feedback effect on themselves. These factors serve as a connector between the components (Jena et al., 2017). This cluster comprises features such as past work experience (1), contractor technical capability (2), contractor financial stability (3), job performance (quality) (4), licenses and professional registrations (5), project team qualifications (6), and current projects in hand (7). Finally, variables with strong driving forces are assigned to the fourth quadrant. They have an impact but are not altered by other factors. The only element in this quadrant is single point responsibility/joint venture (9).

IV. CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

4.1 Conclusion

Based on a literature analysis and expert opinion, the study first identified the ten mostessential parameters utilized for contractor selection for DB/EPC projects throughout the world. Following that,an ISM model, together with the MICMAC matrix, is built based on expert opinion. The authors discovered mixed findings when they examined the MICMAC matrix and ISM model together (Figures 4 and 5). The ISM model places Single point responsibility/ Joint Venture (9) at the lowest level, implying that this factor has an influence on others but is not influenced by them. The MICMACanalysis supports this assertion, as this component is placed in Cluster four, which further confirms thesame. Many problems may be traced back to these criteria, and any modification in themcan have a domino effect. As demonstrated in Figure 10, Single point responsibility/ Joint Venture (9) affects Previous work experiences (1) and Project team qualifications (6) but has no effect on the technical capabilities of contractors (2) and Licenses and professional registrations (5). Figure 10 depicts the interrelationships between the level three elements. Previous work experience (1), Technical capacity of contractors (2), Licenses and professional registrations (5), and Project team qualifications (6) are all grouped in cluster three, showing that they are linking factors. There is no autonomous factor in theentire system. Safety compliance (8) is classified as level 2, meaning it has an impact on factors at levels 1 and is impacted by factors at levels 3 and 4. Financial stability of contractors (3), Performanceon works (Quality) (4), Current projects in hand (7), and Lowest Bidder is positioned at the top of the ISM model, indicating that they influence level 2, level 3, and level 4 elements but not others. These results appear to conflict with the results from the MICMAC analysis, which suggests that onlythe Lowest Bidder (10) and Safety compliance (8) are dependent variables, while the financial stability of contractors (3), Performance on works (Quality) (4), and Current projects in hand (7) are linking variables.

4.2 Limitations

The study identified the key criteria for choosing contractors in Design Build projects, however,it has some limitations. The biggest issue is that the relationships between the selection criteria are solely dependent on the expertise and practical experience of the evaluators. This means that the evaluator's personal bias could influence the results.

The study makes a substantial contribution to the corpus of knowledge despite the inherent limitationsof ISM by proposing a model that emphasizes the interaction among those factors that are more crucial for contractor selection. Future research can evaluate and refine the suggested model.

4.3 Recommendations

This thesis enlightens academics and professionals about how the important factors in contractor selection for DB projects relate to one another. A conceptual framework is created to help people comprehend how the important selection factors for contractors working on DB projects interact with one another. The project managers working on DB projects can use this thesis as a starting point to better grasp the connections and interdependencies between the important factors in contractor selection. Understanding the important criteria as well as the push-pull relationship between the criteria may be done with the help of the proposed ISM. Researchers might use this thesis as a starting point for additional fieldwork to empirically test the suggested model.

REFERENCES

[1] Al-Reshaid, K., & Kartam, N. (2005). Design–build pre-qualification and tendering approach for public projects. International Journal of Project Management, 23(4), 309-320.

[2] Bonyani, A., & Alimohammadlou, M. (2020). A new approach for evaluating international EPC contractors in Iran's energy sector. International journal of construction management, 20(7), 775-782.

[3] Balon, V., Sharma, A. K., & Barua, M. K. (2016). Assessment of barriers in green supply chain management using ISM: A case study of the automobile industry in India. Global Business Review, 17(1), 116-135.

[4] Calahorra-Jimenez, M., Molenaar, K., Torres-Machi, C., Chamorro, A., & Alarcón, L. F. (2020). Structured approach for best-value evaluation criteria: US design–build highway procurement. Journal of Management in Engineering, 36(6), 04020086.

[5] Calahorra-Jimenez, M., Torres-Machi, C., Chamorro, A., Alarcón, L. F., & Molenaar, K. (2021).Importance of Noncost criteria weighing in best-value design–build US highway projects. Journal of Management in Engineering, 37(4), 04021027.

[6] El Asmar, M., Lotfallah, W., Whited, G., & Hanna, A. S. (2010). Quantitative methods for design- build team selection. Journal of Construction Engineering and Management, 136(8), 904-912.

[7] Ernzen, J., & Vogelsang, K. (2001). Evaluating design-build procurement documents for highway projects: How good are they? Transportation research record, 1761(1), 148-158.

[8] El Wardani, M. A., Messner, J. I., & Horman, M. J. (2006). Comparing procurement methods for design-build projects. Journal of construction engineering and management, 132(3), 230-238.

[9] Goel, A. (2016). Understanding pre-qualification preferences of public clients in traditional and design-build procurement systems. International Journal of Procurement Management, 9(6), 684-700.

[10] Gransberg, D. D., & Senadheera, S. P. (1999). Design-build contract award methods for transportation projects. Journal of Transportation Engineering, 125(6), 565-567.

[11] Gransberg, D. D., & Gad, G. M. (2014). Geotechnical Requirements in the Design–Build Selection Process. Transportation Research Record, 2408(1), 26-33.

[12] Leśniak, A., Plebankiewicz, E., & Zima, K. (2012). Design and build procurement system–contractor selection. Archives of Civil Engineering, 58(4), 463-476.

[13] Migliaccio, G. C., Gibson, G. E., & O'connor, J. T. (2009). Procurement of design-build services: Two-phase selection for highway projects. Journal of management in engineering, 25(1), 29-39.

[14] Molenaar, K. R., & Gransberg, D. D. (2001). Design-builder selection for small highway projects. Journal of Management in Engineering, 17(4), 214-223.

[15] Martin, H., & Ramjarrie, K. (2021). Cloud contractor selection model for design-build open tender. Journal of Construction Engineering and Management, 147(4), 04021020.

[16] Moran, R. M., Odeh, I., & Ashuri, B. (2022). Key Challenges in Megabridge Design–Build Project Procurement. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 14(1), 04521039.

[17] Noorzai, E. (2020). Performance analysis of alternative contracting methods for highway construction projects: Case study for Iran. Journal of Infrastructure Systems, 26(2), 04020003.

[18] Phipps, A. R. (2000). Maine builds longest-span precast segmental bridge with unique design-build selection process. Transportation research record, 1696(1), 71-75.

[19] Palaneeswaran, E., & Kumaraswamy, M. M. (2005). Web-based client advisory decision

support system for design–builder prequalification. Journal of Computing in Civil Engineering, 19(1), 69-82.

[20] Palaneeswaran, E., & Kumaraswamy, M. M. (2001). Reinforcing design-build contractor selection: A Hong Kong Perspective. HKIE Transactions, 8(1), 7-12.

[21] Palaneeswaran, E., & Kumaraswamy, M. M. (2000). Contractor selection for design/build projects. Journal of construction engineering and management, 126(5), 331-339.

[22] Paek, J. H., Lee, Y. W., & Napier, T. R. (1992). Selection of design/build proposal using fuzzy-logic system. Journal of Construction Engineering and Management, 118(2), 303-317.

[23] Park, M. J., Lee, E. B., Lee, S. Y., & Kim, J. H. (2021). A digitalized design risk analysis tool with machine-learning algorithm for EPC contractor's technical specifications assessment on bidding. Energies, 14(18), 5901.

[24] Potter, K. J., & Sanvido, V. (1994). Design/build prequalification system. Journal of Management in Engineering, 10(2), 48-56.

[25] Potter, K. J., & Sanvido, V. (1994). Design/build prequalification system. Journal of Management in Engineering, 10(2), 48-56.

[26] Sagvekar, S., & Wayal, A. S. (2019). Early contractor involvement (ECI): Indian scenario of construction project delivery. Int. J. Sci. Technol. Res, 8, 807-811.

[27] Shalwani, A., Lines, B. C., & Smithwick, J. B. (2019). Differentiation of evaluation criteria in design-build and construction manager at risk procurements. Journal of Management in Engineering, 35(5), 04019017.

[28] Xia, B., Chan, A., Zuo, J., & Molenaar, K. (2013). Analysis of selection criteria for design-builders through the analysis of requests for proposal. Journal of Management in Engineering, 29(1), 19- 24.

[29] Xia, B., & Chan, A. P. (2012). Identification of selection criteria for operational variations of the design-build system: A Delphi study in China. Journal of civil engineering and management, 18(2), 173-183.

[30] Xia, B., Chen, Q., Xu, Y., Li, M., & Jin, X. (2015). Design-build contractor selection for public sustainable buildings. Journal of management in engineering, 31(5), 04014070.

[31] Xia, B., Skitmore, M., & Zuo, J. (2012). Evaluation of design-builder qualifications through the analysis of requests for qualifications. Journal of Management in Engineering, 28(3), 348-351.