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Optimization of Cost and Quality in Oil and Gas Construction Site Using Modified Composite Multi-criteria Decision Analysis

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Abstract

The success of a project hinges on aligning the client's expectations – value for money and quality of project delivery. This is especially essential in the petroleum sector of the economy, because of the dire challenges such as the prevalent cost overruns and quality non-conformances in various countries, particularly in developing countries like Nigeria. Therefore, there is a need to intentionally undertake a study that seeks to optimize the cost and quality objectives of a project specifically. In this study, a modified composite Technique for Order of Preference by Similarity to Ideal Solution, (TOPSIS) with the Analytic Hierarchy Process, (AHP) algorithm approaches were engaged for optimal performance of the alternatives. Initially, the Relative Importance Index, (RII) validated the criteria ranking, such as corruption, late client payments, and contractor insolvencies, aligning closely with the literature, albeit with minor percentage deviations ranging from 2.6% to 10% lower. According to the TOPSIS/AHP analysis, the client/consultant alternative emerged as the top preference, closely approaching the model solution value of 0.673, followed by that of contractor at 0.618 and materials/equipment at 0.511. Additionally, labour with 0.411 ranked fourth, whereas risk/external factors and procedures/controls hierarchically came fifth and sixth with 0.296 and 0.230, respectively. Remarkably, these results affirm the client as focal point of in lead role of directing, supporting, and integrating construction site activities without usurping/assuming the exclusive responsibility of the contractor's contractual obligations, ultimately ensuring successful project performance, enhanced fulfilment of the expectations and needs of both clients and stakeholders.

Keywords: Optimization, cost, quality, composite, TOPSIS/AHP, decision, construction site

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1. Introduction

Arguably, the repeated failures of construction projects have raised significant concerns among researchers across various fields. Project completion within the set schedule, budget, and quality requirements have proven to be challenging (Shafei et al., 2020; Khadim et al., 2021). Regarding cost-related failures, Memon et al. (2010) identify several critical factors, to include poor site control management and supervision by contractors, financial difficulties, worker shortages, contractor inexperience and incompetence, and planning gaps and scheduling slips. Additionally, challenges in cost management are often linked to project size, complexity, uncertainty, uniqueness, and the effectiveness of material control (Kujala et al., 2014; Georgekutty and Mathew, 2012). Albtoush et al. (2021) note that inaccurate cost estimations are major causes of project cost escalations and must be addressed to prevent project failures. They categorize the influencing factors of construction cost estimation into four groups: project characteristics, estimation team, estimating procedures, and external factors.

On the quality front, various concerns plague construction projects, as both complex and labor-intensive ventures in quality management delivery (Khadim et al., 2023). Many issues arise when approved procedures and controls are overlooked during construction, resulting in visible problems only after projects transition to operation. In some instances, inadequate risk management leads to circumventing essential risks, constraints, and challenges, ultimately resulting in poor-quality delivery (Pialles, 2017).

Beyond the primary issues of cost overruns and quality non-conformance, such failures can lead to catastrophic consequences, including loss of life, damage to corporate reputation, and irreparable property loss. These outcomes are often difficult to quantify and must be actively prevented.

Nevertheless, according to Albtoush et al. (2022), success of any project hinges on achieving objectives related to time, quality, and cost while also fulfilling product goals such as customer satisfaction, technical specifications, and functionality. Execution of any project especially at the construction site remains a risk and which only a thorough understanding of the critical success factors inherent in a particular project, for proper organizational risk management options, can ensure its successful completion (Waleed, 2018). Moreover, the benefits of analyzing the costs associated with failure and repairs generally outweigh the costs of implementing improvements. Unfortunately, to control expenses, certain contractors have inadvertently increased quality costs by making compromises, as supported by literature and insights from industry experts who explained the negative repercussions of deviating from approved procedures.

Adedeji et al. (2015) indicate that client involvement during the construction phase averages 45%, though two-thirds of expenditures, quality non-conformances, and cost and time overruns largely arise from contractors' failure to adhere strictly to project management practices.

Lately, the sustained necessity to jointly optimize both cost and quality has led to increased considerations to the quality cost (Dimitrantzou et al., 2020). Quality management has increasingly focused on measuring the financial impact of quality delivery, enhancing productivity and profitability, and reducing unnecessary expenditures (Farooq et al., 2017; Yang, 2018).

While quality is key to ensuring product durability, the optimal balance of cost and quality is essential for achieving customer satisfaction. Consequently, there exists a specific value mix of cost associated with the expected minimum standard of quality, which can be addressed through multi-criteria decision-making (MCDM) optimization modelling for project integrity and deliverability.

In this study, the MCDM optimization challenge will begin with clearly defined objective constraints and the proper assignment of relevant factor criteria. These criteria must then be validated for their suitability based on the chosen optimization method (Patterson et al., 2021). For the sole purpose of analysis, this study will deploy a modified composite technique. The Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) together with the Analytic Hierarchy Process (AHP) algorithm are adopted. And this approach suffices to accommodate a broader all-inclusive weighting of the objective criteria (Ukoba et al., 2020).

1.1 The Modified Composite TOPSIS-AHP Approach

As a multi-criteria decision analysis method, TOPSIS is favoured over other techniques because it can be applied to a wide range of attributes and alternatives, requires fewer subjective inputs, exhibits logical and programmable behaviour, and produces alternative rankings that are relatively consistent.

AHP, generally, offers the benefit of evaluating a range of criteria with different units, much like any other MCDM technique. Moreover, it is capable of combining the analysis of quantitative and qualitative evaluation criteria (Bozbura et al., 2007). The AHP remains most complete program for MCDM, planning, allocating resources, and solving problems.

The hybrid of TOPSIS-AHP comes with enhanced and dependable method with the shortcomings of the separate approaches stripped off; and the model outcome is validated.

Even though it might be argued that the TOPSIS approach provides the best performance for evaluation, comparatively, hybridized TOPSIS-AHP composite procedure exemplified the accepted MCDM scheme with more realistic criteria weighting factors and complementary role (Kalbar et al. 2012; Ukoba et al. (2020).

2. Research Methodology

The study is articulated from a literature review to address the choice of MCDM optimization method of selection and validation. It is aimed at deriving the required computational values and model formulation. And because the success and failure of the construction project could be traceable right from the initiation stage through to the tendering to execution stages on the construction site, we considered an input value with a significant impact factor in the scientific formulation and development of the required procedure model. The need for a scientific model prompted the necessity to collate primary data for the formulation of the study questionnaire for participants, an instrument to convert qualitative to quantitative (numerically) and to validate data for effective preferential processing (Marshall and Rossman, 2014). The team of participants was professionals at the management (project, and quality managers) cadre, adjudged as major stakeholders with hands-on experience, competence and education, in the oil and gas industry using the Likert scale from 1 to 5.

The participants' responses are collated, filtered and analyzed for model validation. The proposed model data are subjected to Relative Important Index, (RII) (Jadhav et al. 2020), and the MDCM adopted modified composite TOPSIS /AHP scheme. A framework was developed to incorporate the various derived criteria lists according to Niazi and Painting (2017), and categorized into groups of alternatives.

Afterwards, the presented validation results are filtered and discussed regarding the criteria and alternatives: clients/consultants, contractor, risk/ external factors, materials and equipment, labour, procedures and controls. From the findings above, conclusions are made.

2.1 Research Design

Fundamentally, this study solution is approached from tendering stage through to site construction delivery. According to El-Reedy (2016), the most common types of contracts are as follows: measured contract, lump-sum, and cost-plus contract. In Nigeria, for example, the typical call to tender in a joint venture (JV) contract takes the potential contractor through the basic steps of the contract: identification, offer and acceptance, competency and capacity, and legal dimensions assessment processes of the contract, the client organization specifies the requisite requirements of the project and her detailed expectations from the interested contractor.

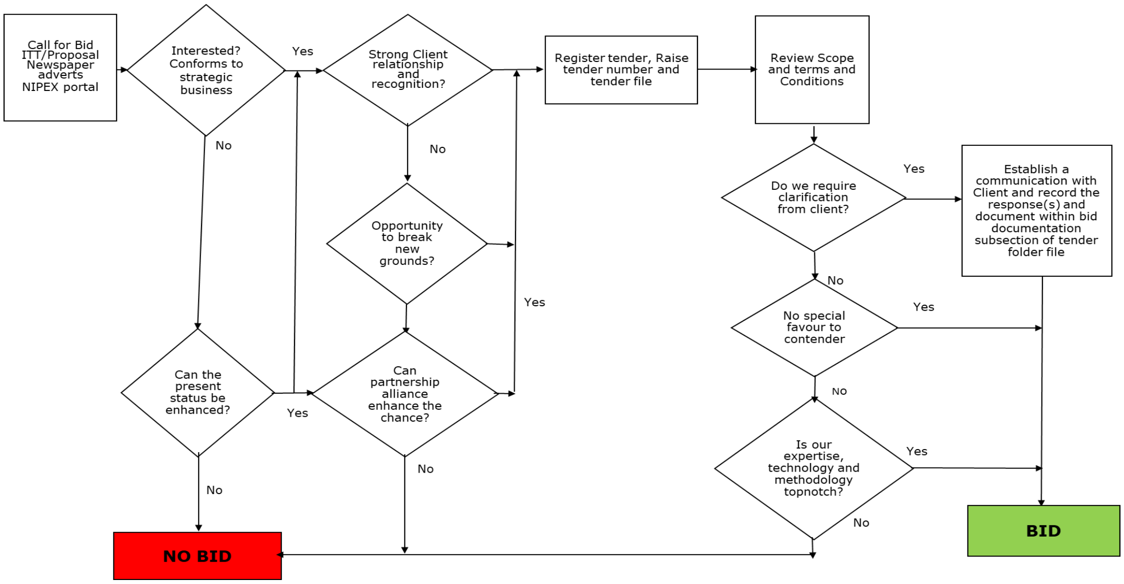

Figure 2.1: Current tender Process flowchart

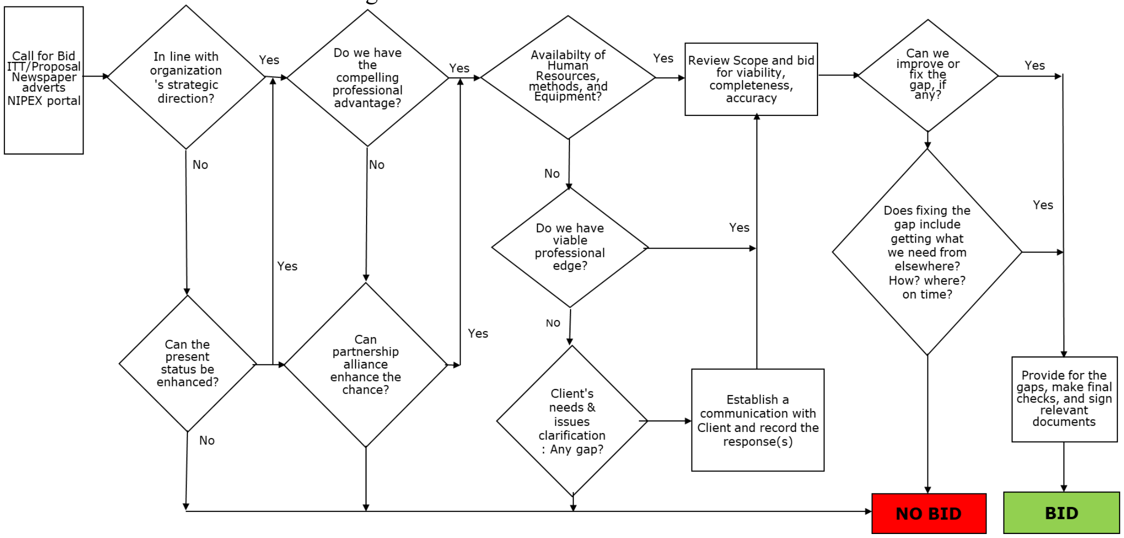

Figure 2.2 Proposed pre-tender process flowchart

In most major well-structured organizations, the current tender process flowchart represented in Figure 2.1 is typical for ease of operational approach to tendering. At every turn, there are questions for clarity that narrows down to establishing whether to bid or not. No excuses for unreasonable assumptions or claims are entertained from the contractor. Unfortunately, projects start failing from here when scope understanding gaps are left unattended.

The basic understanding of the project scope framework would be established when expectations are subjected to exhaustive queries for unambiguous risk management interpretations, analysis and options, resources (methods, materials, machinery and manpower) availability and procedures, the thorough work breakdown and analysis through the prism of the organizational values and strategic interest, etc. The honest responses to the above questions ultimately narrow down the process to bid or not. Refer to the proposed pre-tender process flowchart of Figure 2.2.

2.1.1 Data Analysis

2.1.1.1 Relative Important Index (RII)

The choice of RII method was favoured to rank selected criteria due to its frequent use commonly in evaluating attitudes toward similar gathered factors in construction research of relativity importance (Shabniya, 2017; Ajit, 2017). The RII compares the consistency in data relativity. Below is the equation for the calculation of the RII value (Enshassi et al, 2009; Desai and Bhatt, 2013)

$$\mathrm{RII} = \frac{\sum_{i=1}^{5} W_i X_i}{A x N} \tag{1}$$

where: RII is the Relative Importance Index; W is Weight ascribed to each criterion by the respondents and varies from 1 to 5; Frequency of *i*-th response set for each cause, X; Highest weight, A (in this instance, 5); N, Aggregate number of respondents (Niazi and Painting, (2017).

2.1.1.2 Modified TOPSIS Method: Computations

The TOPSIS approach is distinguished from other optimization techniques because, fundamentally, the chosen alternative usually has the shortest distance to the ideal solution while the negative ideal solution portrays the farthest distance (Balioti,et al., (2018). The fundamental general actions must be performed after using a trade-off matrix tool to adopt modified TOPSIS/AHP composite method (Ukoba et al., 2020; Ince et al., 2017). The closer this positive distance is to ideal solution, the much more invaluable, and the desired optimal preferred solution.

Algorithm 1: The TOPSIS Algorithm

According to Ukoba et al., (2020) and Nascimento et al., (2023), the common approach to formulating the MDCN matrix is, first, establish the alternatives (*m*) and the criteria (*n*), respectively, given *m* and *j* = 1, 2, to *n*

$$C_{ij} = \begin{bmatrix} C_{11} & C_{12} & \cdots & \cdots & \cdots & C_{1n} \\ C_{21} & C_{22} & \cdots & \cdots & \cdots & C_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_{m1} & C_{m2} & \cdots & \cdots & \cdots & C_{mn} \end{bmatrix} \tag{2}$$

Then follows the 6 steps usually involved in the TOPSIS method calculations as fundamentally expressed in (Roszkowska, E. 2011; Ukoba et al., 2020; Nascimento et al., 2023; Abdulgader et al., 2018; Triantaphyllou et al. 1998):

i. Construct the decision matrix, C, and weight of criteria, D (usually calculated from Algorithm 2 below, the AHP method) where C = C_{ij} ; and is the element of the matrix in i-th column and j-th row. While D = $\lfloor d_i \rfloor$ = (d1, d2 …., dn), a weight (priority) vector, where $\sum_{i=1}^{m} di = 1$

ii. Obtain normalized matrix R;

$$\mathrm{R} = \{(r_{ij})\} \equiv \frac{c_{ij}}{\left(\sum_{i=1}^{m} c_{ij}^2\right)^{1/2}} = r_{ij} = \frac{c_{ij}}{\sqrt{\left(\sum_{i=1}^{m} c_{ij}^2\right)}} \tag{3}$$

where: r_{ij} are elements of normalized matrix

iii. Compute weighted normalized matrix, V; and V = $\{V_{ij}\}$= $r_{ij}\ x\ d_i$ = R x D (4)

where V_{ij} are elements of weighted normalized matrix

iv. Define A+ and A-, the ideal and non-ideal solutions respectively;

$$A^{+} = (v_1^{+}, \dots, v_i^{+}, \dots, v_m^{+}) = \{(\max_j v_{ij} \mid i \in P), (\min_j v_{ij} \mid i \in N)\} \quad (5)$$

$$A^{-} = (v_1^{-}, \dots, v_i^{-}, \dots, v_m^{-}) = \{(\min_j v_{ij} \mid i \in P), (\min_j v_{ij} \mid i \in N)\} \quad (6)$$

N symbolizes negative criteria and P the positive criteria; where i ranges from 1 to m and j, from 1 to n

v. Calculate relative distance by applying ‘Euclidean metric’ from the + and - ideal solutions Relative distance from positive (‘+’) and negative (‘-’) ideal solution:

$$S_i^{+} = \sqrt{\sum_{i=1}^{m} (v_i^{+} - v_{ij})^2}; \text{ i = 1, 2 ... n} \quad (7)$$

$$S_i^{-} = \sqrt{\sum_{i=1}^{n} (v_i^{-} - v_{ij})^2}; \text{ i = 1, 2 ... m} \quad (8)$$

where i is 1 to m and j is 1 to n

Now, calculate each of the alternative relative proximity to the ideal solution, L_f:

$$L_f = \frac{S_i}{S_i^{+} + S_i^{-}}; \quad 0 \le L_f \le 1, \qquad \text{where i is 1 to m} \quad (9)$$

vi. Obtain optimum solution.

Algorithm 2: Evaluation of the Weight Factors using AHP

Also, (Ukoba et al., 2020; Yadav and Sharma, 2015) highlighted the 9-steps below for determination of the weight factors s state:

- Step 1: . Specify the criteria ‘*m*’ and form a matrix (*m x m*); *i* = 1, 2, …, *m*
  i. Assign the number; *j* = 1, 2 …, *m* in the order of importance of criteria (*m*) to the project, where the elements in the matrix are characterized in *i*-th column and *j*-th row.
  ii. Produce the corresponding transpose *j* = 1, 2 …., *m* and insert in *i* = 1, 2 ..., *m:* where *m* is criteria count. $C_{ji} = 1/C_{ij}$, *i* and *j is 1 to m.*
  iii. Generate the rest data in the matrix C; C = C_{ij} (10)

Where C = Cij a derived from the i-th column and j-th row of the decision matrix element

- Step 2: Obtain the normalized matrix R, with pairwise comparisons of criteria and sub-criteria comparison scale value of the degree of importance from 1 to 9 (Saaty, 1990 & Saaty 1980). The top level of the hierarchy represents the primary goal, while the bottom level encompasses a range of viable options. Intentionally, the AHP method to the challenge is organized hierarchically at levels, each at a finite level: the top level representing the overall goal and the lower the possible alternatives (Yadav and Sharma, 2015).

- Step 3: Generate a normalized pair-wise matrix K, resolving each element in the matrix by dividing with the corresponding column n total value.

$$\text{K} = \{(K_{ij})\} \equiv \frac{C_{ij}}{\sum_{i=1}^{m} C_{ij}} \quad (11)$$

where r_{ij} are elements of normalized matrix R where *i* and *j* is 1 to *m*.

$$K = K_{ij} \quad (12)$$

Using the K matrix above, calculate the priority vector weights matrix, d: for each criterion in j-th row;

$$d_j = \frac{\sum_{i=1}^{m} r_{ij}}{m} \quad (13)$$

where i and j is 1 to m. The calculated weighting factors ascertain the accuracy.

- Step 4: Each pairwise comparison matrix column is multiplied by the matching weight.

$$\text{D} = \text{C x d} \quad (14)$$

where i and j is 1 to m

- Step 5: Divide sum of row entries by the corresponding weight. Compute the average value as β

$$E_j = \frac{D_j}{d_j} \quad (15)$$

where i and j is 1 to m

$$\text{Average value, } \beta - \frac{\sum_{i=1}^{m} E_i}{m} \tag{16}$$

where i and j is 1 to m

- Step 6: the calculation of the Consistency Index (CI) comes next as

$$\text{CI} = (\beta - m)/(m - 1) \tag{17}$$

- Step 7: The Consistency Ratio (CR) or Permissive Error (E) is calculated as = CI / RI ≤ 0.1; where Random Index, RI value is calculated from a table data derived from m value (Yu, C. S., 2002)
- Step 8: Consistency Ratio (CR): Once this ratio is reached and hence, consistent criteria result within CR ≤ 0.1 is established, then the weights are now reverted to the TOPSIS (Algorithm 1) method calculations, as in the equation (18) below.

$$A_{ij} = \begin{bmatrix} A_{11} & A_{12} & \cdots & \cdots & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & \cdots & \cdots & A_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ A_{m1} & A_{m2} & \cdots & \cdots & \cdots & A_{mn} \end{bmatrix} \tag{18}$$

where i is 1 to *m* and j is 1 to *n*.

- Step 9: Normalize the matrix Aij to get Rij matrix by the formula given as

$$R_{ij} = \frac{A_{ij}}{\sum_{i=1}^{m} A_{ij}} \tag{19}$$

Reverting to the Algorithm 1 calculations, continue till the optimum model solutions are established.

2.2 Methods of Data Analysis

The TOPSIS/AHP composite method was adopted in this study. Specifically, the TOPSIS method, as Hwang and Yoon (1981) put it, is made easy and effective with a powerful decision-making approach with numerous advantages of optimization: simplicity, rationality, comprehensibility, excellent computational efficiency and effectively quantifies the relative performance of each alternative using a straightforward mathematical framework (Parida, 2019).

2.2.1 Model Formulation

2.2.1.1 Formulation of the scientific model

When the decision to bid or not to bid is over, it is expected that a model shall particularly evolve and aimed at, among others, the ranking of criteria /alternatives and resources to establish the objective costs and quality optimization of the project. The proposed process model will be based on the TOPSIS/AHP hybrid method of optimization.

Figure 2.3 represents the development and construction process flowchart. This proposed process, as an expansion of what was outlined in the proposed pre-tender process in Figure 2.2, evolves from the necessary developmental requirements of the tender. Emphatically, the difference is that during this same tender stage, a crucial focal point for efficient results would be the involvement of the primary stakeholders, who understand their roles matched up with competence and objectivity in meeting the set objective function of optimal cost and quality delivery. Primarily, the contractor organization, on this proposed process model, through her team, determines the set criteria and the alternatives/ criteria weights, synthesizes the derivable requisite project information to formulate the decision matrix construct.

Upon completing the decision matrix, the normalization of the weights and computation of the optimal solution will be carried out using the AHP and TOPSIS optimization methods, respectively. The identified alternatives and criteria will then be ranked, and the system will be examined for the necessary availability of resources—encompassing methods, machinery, manpower, and materials. A positive outcome from this investigation will support the decision to proceed with project development and construction, which is critical at this stage.

Since this proposed model simulates a real-life project, these steps are performed iteratively during each project cycle activity. If the assessment of resource availability yields a negative response, further analysis will be needed to determine whether the gaps can be addressed within the required timeframe. If the response remains negative, a “no bid” or termination of the process will be indicated. Conversely, if the response is positive, the process will continue as described.

The team must possess hands-on expertise and be able to dynamically navigate all foreseeable risk options, implementing measures to mitigate or minimize these risks. Effective risk management involves continuously identifying, analyzing, and generating dynamic responses all the way through the project lifespan. In fact, some potential risks, when comprehensively analyzed and managed, are transformed to opportunities. This where experience and competences are brought to bear. Remarkably, as any potential errors could lead to significant failures at any stage of the project. Following this, the commercial stage of the project bid will be evaluated.

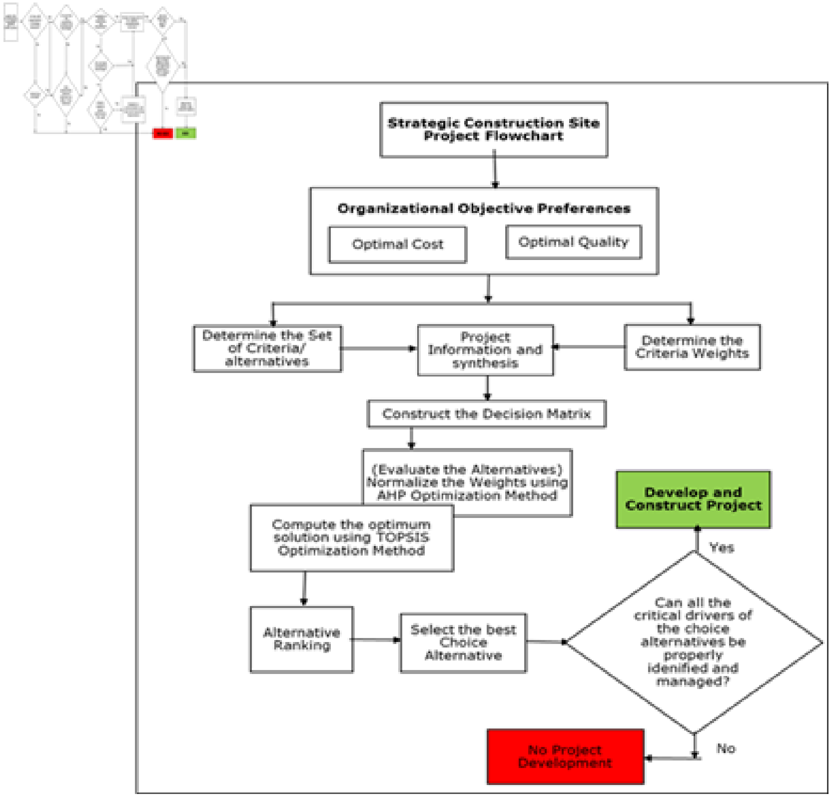

Figure 2.3 Proposed Developments and Construction Process Flowchart

2.2.1.2 Development of a computational procedure Model

The proposed analytical processes outline a multi-criteria approach for the project life cycle. The new decision model effectively addresses various components of the problem and resolves the shortcomings of the current approach, which lacks the flexibility to handle sudden emergencies and team dynamics. The improved Multi-Criteria Decision-Making (MCDM) model is presented in a structured manner.

Table 2.1 Impact Assessment

Impact	Description of criteria attributes	Scale
Very Significant	Very Significant core criteria mix control of cost and quality or due diligence are greatly observed, continually	5
Significant	High significant core criteria mix control of cost and quality or due diligence are observed, continually	4
Average	Continual activities without defects, moderate criteria mix control of cost and quality, and effects on the activities' performance indicators	3
Below Average	Intermittent activities with the least core criteria mix control, without defects but slight effects on the activities' performance indicators	2
Negligible	Intermittent activities with the least core criteria mix control, a number of defects and minimal effects on the activities' performance indicators	1

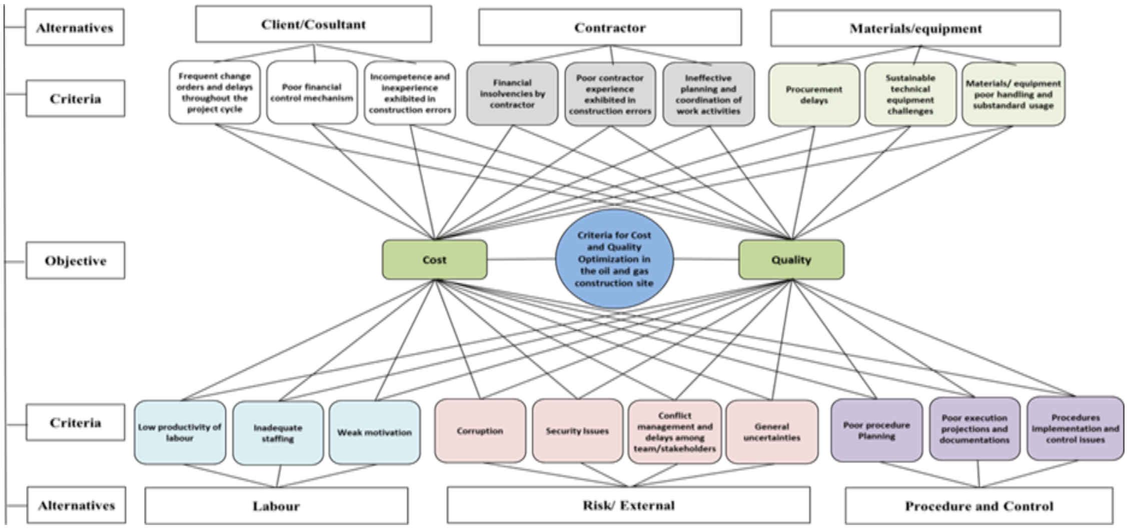

Figure 2.4: Alternative model for cost and quality sustainable MCDM Optimization

Figure 2.2 illustrates a tendering flowchart that helps the contractor organization determine whether to bid on an advertised tender. Following this, Figure 2.3 (Proposed Developments and Construction Process Flowchart) guides the project analysis based on the criteria and alternatives listed in Figure 2.4. This qualitative assessment will undergo AHP/TOPSIS evaluation analysis for optimal sequencing.

Table 2.2 The Alternative's performance assessment

Impact	Alternative Performance description	Scale
Very Significant	All stakeholders including construction field team hardly could observe the slight gap due to the very high performance standard on requirements	5
Significant	All stakeholders including construction field team observed with slight dissatisfaction the high performance standard on requirements	4
Average	All stakeholders including construction field team observed with moderate dissatisfaction the high performance standard on requirements	3
Below Average	Construction team reneged on its performance standard on requirements, hence, the low effectiveness, efficiency and productivity ensured	2
Negligible	Construction team reneged on its performance standard on requirements, hence, the minimal effectiveness, efficiency and productivity ensured	1

Table 2.1 evaluates the impact of various criteria based on perceptions using the Likert 5-point scaling approach (Sullivan & Artino, 2013). Table 2.2 shows performance evaluations of alternatives on the same scale, refined by Subject Matter Experts (SMEs). Higher scores indicate greater effectiveness, efficiency, and productivity, defining ideal solutions, while lower scores highlight less favourable options among the six alternatives: clients/consultants, contractors, materials/equipment, labour, risks/external factors, and procedures and controls.

Uncontrolled costs and quality issues can lead to significant project impacts. Criteria are defined through the project's objectives and its contributions to the oil and gas sector. Ultimately, optimizing cost and quality benefits all stakeholders and standardizes the resulting procedures for successful project delivery. The ideal solution aims to maximize scores for each alternative, as shown in Table 2.2, contrasted with ineffective projects' potential failure.

3.0 Results and analysis

The results of the MCDM models have been articulated and presented below, and followed by the discussions. The modified TOPSIS and AHP composite algorithms with the aid of the Microsoft Excel spreadsheet application is offered in post-processing of data for optimization. The AHP/TOPSIS composite optimization model analysis is as in section 3.2 (Stages 1 to 6).

3.1 Model validation by RII and Average Scores Scheme

Table 3.1 presents the model validation against the literature; and from another mode, also presented in Figure 3.1. General average participants' scores are represented per criterion A11 to A613 in Figures 3.2. The detailed result is discussed in section 3.3 below.

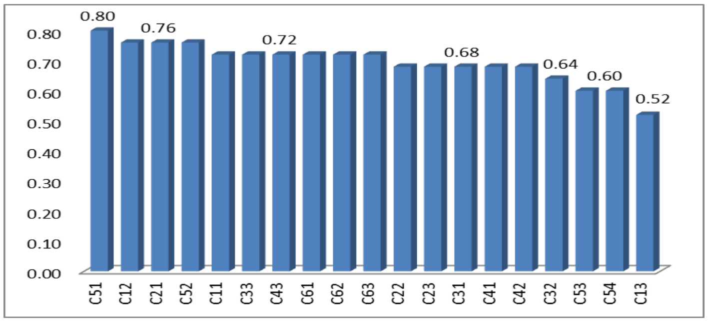

Figure 3.1 RII General Ranking of Criteria weighting

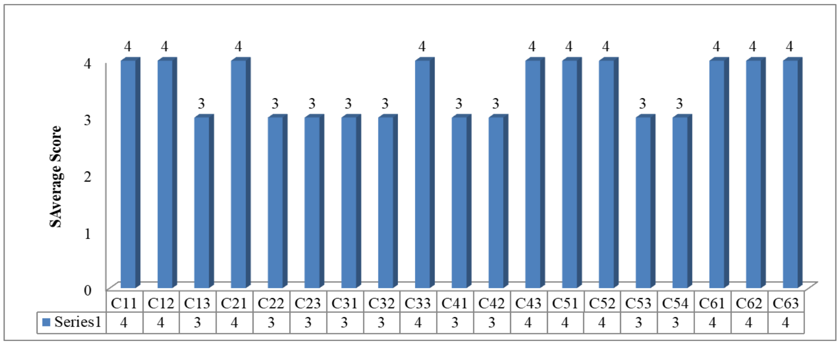

Figure 3.2 Respondent's individual criterion perception initial scores

3.2 Model validation by TOPSIS/ AHP Analysis Optimization Scheme

Stage 1: Create the choice matrix with the criteria weight value defined

Criteria	Type	Alternatives						Weight	Ranking
		V1	V2	V3	V4	V5	V6		
C11	-	4	0.6	1.2	1.8	2.1	2.4	0.052632	1
C12	-	4	0.8	1.6	2.4	2.8	3.2	0.052632	1
C13	-	3	0.6	1.2	1.8	2.1	2.4	0.052632	1
C21	-	0.8	4	1.6	2.4	2.8	3.2	0.052632	1
C22	-	0.6	3	1.2	1.8	2.1	2.4	0.052632	1
C23	-	0.6	3	1.2	1.8	2.1	2.4	0.052632	1
C31	-	0.8	1.6	3	2.4	2.8	3.2	0.052632	1
C32	-	0.6	1.2	3	1.8	2.1	2.4	0.052632	1
C33	-	0.8	1.6	4	2.4	2.8	3.2	0.052632	1
C41	-	0.8	1.6	2.4	3	2.8	3.2	0.052632	1
C42	-	0.8	1.6	2.4	3	2.8	3.2	0.052632	1
C43	-	0.8	1.6	2.4	4	2.8	3.2	0.052632	1
C51	-	0.8	1.6	2.4	2.8	4	3.2	0.052632	1
C52	-	0.8	1.6	2.4	2.8	4	3.2	0.052632	1
C53	-	0.6	1.2	1.8	2.1	3	2.4	0.052632	1
C54	-	0.6	1.2	1.8	2.1	3	2.4	0.052632	1
C61	-	0.8	1.6	2.4	2.8	3.2	4	0.052632	1
C62	-	0.8	1.6	2.4	2.8	3.2	4	0.052632	1
C63	-	0.8	1.6	2.4	2.8	3.2	4	0.052632	1
								1	19

Stage 2: The normalization value of the choice matrix is determined

Criteria	Type	Alternatives					
		V1	V2	V3	V4	V5	V6
C11	-	0.716	0.1074	0.2148	0.3222	0.3759	0.4296
C12	-	0.609711	0.121942	0.243884	0.365826	0.426798	0.487769
C13	-	0.609711	0.121942	0.243884	0.365826	0.426798	0.467769
C21	-	0.121942	0.609711	0.243884	0.365826	0.426798	0.487769
C22	-	0.121942	0.609711	0.243884	0.365826	0.426798	0.487769
C23	-	0.121942	0.609711	0.243884	0.365826	0.426798	0.487769
C31	-	0.133259	0.266519	0.499722	0.399778	0.466408	0.533037
C32	-	0.121942	0.243884	0.609711	0.365826	0.426798	0.487769
C33	-	0.121942	0.243884	0.609711	0.365826	0.426798	0.487769
C41	-	0.133259	0.266519	0.399778	0.499722	0.466408	0.533037
C42	-	0.133259	0.266519	0.399778	0.499722	0.466408	0.533037
C43	-	0.121942	0.243884	0.365826	0.609711	0.426798	0.487769
C51	-	0.121942	0.243884	0.365826	0.426798	0.609711	0.487769
C52	-	0.121942	0.243884	0.365826	0.426798	0.609711	0.487769
C53	-	0.121942	0.243884	0.365826	0.426798	0.609711	0.487769
C54	-	0.121942	0.243884	0.365826	0.426798	0.609711	0.487769
C61	-	0.121942	0.243884	0.365826	0.426798	0.487769	0.609711
C62	-	0.121942	0.243884	0.365826	0.426798	0.487769	0.609711
C63	-	0.121942	0.243884	0.365826	0.426798	0.487769	0.609711

Stage 3: The normalized weighted value of the decision matrix is calculated

Criteria	**Type**	Alternatives					
		V1	V2	V3	V4	V5	V6
C11	-	0.037684	0.005653	0.011305	0.016958	0.019784	0.022611
C12	-	0.03209	0.006418	0.012836	0.019254	0.022463	0.025672
C13	-	0.03209	0.006418	0.012836	0.019254	0.022463	0.025672
C21	-	0.006418	0.03209	0.012836	0.019254	0.022463	0.025672
C22	-	0.006418	0.03209	0.012836	0.019254	0.022463	0.025672
C23	-	0.006418	0.03209	0.012836	0.019254	0.022463	0.025672
C31	-	0.007014	0.014027	0.026301	0.021041	0.024548	0.028055
C32	-	0.006418	0.012836	0.03209	0.019254	0.022463	0.025672
C33	-	0.006418	0.012836	0.03209	0.019254	0.022463	0.025672
C41	-	0.007014	0.014027	0.021041	0.026301	0.024548	0.028055
C42	-	0.007014	0.014027	0.021041	0.026301	0.024548	0.028055
C43	-	0.006418	0.012836	0.019254	0.03209	0.022463	0.025672
C51	-	0.006418	0.012836	0.019254	0.022463	0.03209	0.025672
C52	-	0.006418	0.012836	0.019254	0.022463	0.03209	0.025672
C53	-	0.006418	0.012836	0.019254	0.022463	0.03209	0.025672
C54	-	0.006418	0.012836	0.019254	0.022463	0.03209	0.025672
C61	-	0.006418	0.012836	0.019254	0.022463	0.025672	0.03209
C62	-	0.006418	0.012836	0.019254	0.022463	0.025672	0.03209
C63	-	0.006418	0.012836	0.019254	0.022463	0.025672	0.03209

Stage 4: The Proximity Model Ssolutions are determined

Criteria Code	Type	A+	A-
C11	-	0.00565	0.03768
C12	-	0.00642	0.03209
C13	-	0.00642	0.03209
C21	-	0.00642	0.03209
C22	-	0.00642	0.03209
C23	-	0.00642	0.03209
C31	-	0.00701	0.02805
C32	-	0.00642	0.03209
C33	-	0.00642	0.03209
C41	-	0.00701	0.02805
C42	-	0.00701	0.02805
C43	-	0.00642	0.03209
C51	-	0.00642	0.03209
C52	-	0.00642	0.03209
C53	-	0.00642	0.03209
C54	-	0.00642	0.03209
C61	-	0.00642	0.03209
C62	-	0.00642	0.03209
C63	-	0.00642	0.03209

Stage 5: The separation extent from Proximity Model Solutions are calculated

Separation measures	Alternatives					
	V1	V2	V3	V4	V5	V6
d+	0.048416	0.050365	0.06033	0.068433	0.083246	0.089674
d-	0.099478	0.081496	0.063	0.047823	0.034962	0.026861

Stage 6: The relative proximity to the proposed model solutions (positive) is computed

	Alternatives					
	V1	V2	V3	V4	V5	V6
Relative Proximity	0.672629	0.618044	0.510826	0.411358	0.295763	0.230496
Ranking	1	2	3	4	5	6

Table 3.2 with corresponding Figures 3.3 present the summary of the proposed model solutions (positive).

3.3 Discussion of Findings

The respondents in this study show noteworthy characteristics: 60% are project managers and 40% are quality managers. Both groups include individuals from both clients and contractors. All respondents have had both relevant training and work experience in the petroleum industry (construction) for a substantial duration, spanning between 6 to over 15 years. Specifically, 20% of the population has got between 6 and 8 years of experience, another 20% have between 8 and 15 years, while 60% has close to 16 years and more of the work they do. Therefore, it is reasonable to conclude that the participants are well-qualified for this study.

Additionally, it is important to note that individual criterion weighting scores, when aggregated according to various alternative factors for optimization, can either enhance or diminish the overall value related to a specific alternative. This indicates that several criteria should not be combined into a single alternative factor. Consequently, individual criteria are not utilized in the optimization scheme for the alternative factors. While this analysis can uncover unique individual characteristics related to the criteria, it does not equate to the alternative parameters. Therefore, the parameters for the alternatives are exclusively calculated within the framework of the optimization scheme. For further details, please refer to Section 3.2, which discusses the TOPSIS/AHP Optimization Scheme analysis.

3.3.1 Model Validation

Model validation, is an important component of research that authenticates the proposed modelling scheme. First of all, model validation as a process of proof of credibility in Patterson et al., (2021) subjects the proposed model to conditions and results akin to those derived from the existing literature. The close relativity of the data from existing literature and the proposed establishes the validity of the proposed model.

3.3.1.1 Model Validation by RII and Average Ranking of criteria

The first five ranked criteria in this study align with findings from existing literature, as confirmed in Table 3.1. The parameters validated in this model include corruption, poor financial control by clients or consultants, contractor financial insolvencies, and security-related issues, consistent with the work of Niazi and Paintings (2017).

Table 3.1 Model Validation: RII comparative ranking of Literature and Present study

Cause of Cost Overrun	RII		Rank
	Literature	Present	
Corruption, C51	0.89 [a]	0.80 [b]	1
Delay in progress payments by Client, C12	0.82 [a]	0.76 [b]	2
Financial difficulties by Contractor, C21	0.80 [a]	0.76 [b]	3
Security Issues, C52	0.78 [a]	0.76 [b]	4
Frequent change orders and delays, C11	0.77 [a]	0.72 [b]	5

[a]Niazi and Paintings, 2017; [b]Authors

From Table 3.1, corruption remains the most significant factor, deviating by only 10% less than Niazi and Paintings (2017). Delays in client progress payments scored 0.76, compared to 0.82 in the literature, reflecting a 7.3% deviation and ranking second. Financial difficulties faced by contractors and security issues both scored 0.76, while frequent change orders and delays ranked fifth with a score of 0.72. The rankings are consistent, though deviations vary. These differences may be attributed to the multi-objective focus on both cost and quality in this study, as well as the varying levels of corruption impact across regions.

Table 3.2: TOPSIS/AHP method: Relative Proximity Ranking of Alternatives

Alternative	Relative Proximity Model Solutions	Ranking
Client/ Consultant, V1	0.673	1
Contractor, V2	0.618	2
Materials/ Equipment, V3	0.511	3
Labour, V4	0.411	4
Risk / External factor,V5	0.296	5
Procedure and Control, V6	0.230	6

Other criteria, such as incompetence and inexperience errors ranked lowest at an RII of 0.52. A proficient construction team should minimize such errors. Further discussions on the RII values of 0.80 and 0.76 are summarized below:

Corruption (RII 0.80): This is ranked as the most significant criterion. This issue is global and remains endemic, posing a major threat to project success. Typically and always, corruption transforms to increase in construction costs and varied quality nonconformities (Xie et al., 2022; Wang and Yuan, 2011; Shehu et al., 2014).

Poor Financial Control (RII 0.76): This factor comes next to corruption. It often results in escalated construction costs, particularly in developing countries grappling with inflation and fluctuating foreign exchange rates, as seen in Nigeria and Ghana (Omoregie and Radford, 2006; Frimpongs et al., 2003). This ranking aligns with literature findings.

Financial Insolvencies by Contractor (RII 0.76): Also in the second group, this factor has an RII value of 0.76, agreed upon by all respondents. It can hinder project completion in terms of schedule, cost, and quality, reflecting findings from previous research in Ghana's construction industry (Frimpongs et al., 2003) and Vietnam's construction industry (Le-Hoai et al., 2008)

Security Issues (RII 0.76): A significant concern, ranked fourth, remains a critical concern. In Nigeria, construction projects often require the provision of security personnel and equipment to protect on-site teams from threats, and there have been recorded fatalities in the past.

To address these factors, a suitable Multi-Criteria Decision-Making (MCDM) approach combining quantitative and qualitative assessments according to Sitorus et al., (2019) will be employed. Consequently, the TOPSIS/AHP optimization ranking method of alternatives will be utilized. the TOPSIS/AHP optimization ranking method.

3.3.1.1 Model Validation: TOPSIS/AHP Optimization Ranking of Alternatives

The optimal analysis of the alternatives with the TOPSIS/AHP method approach presents the results of the proposed model as shown in Table 3.2. Also, Figure 3.3 illustrates the relative results of the model ideal solution. The client/consultant ranks first with a score of 0.673, followed by the contractor at 0.618. The procedure and controls rank sixth with a score of 0.230, indicating the least closeness to the ideal solution. The other rankings include Materials/Equipment in third place (0.511), Labour in fourth (0.411), and Risks/External Forces in fifth (0.296). For detailed steps of the modified TOPSIS/AHP analysis, refer to Section 3.2. These ranking values give credence to the validity of the proposed alternatives model as a fitting function of the listed criteria in Table 3.1 above.

The ranking of the client/consultant is critical, as it represents the initiator and financier of construction projects, which aligns with existing literature. The contractor is key in executing the project and managing resources to achieve efficient completion (Adedeji et al., 2015).

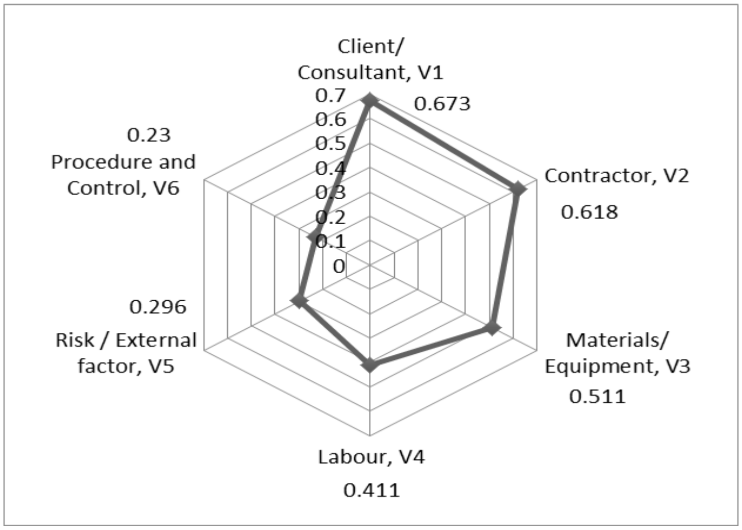

Figure 3.3 Optimization Approach: Alternative Relative Closeness

Project costs correlate directly with the quality of materials; higher costs typically lead to better quality, while delays and defective equipment can increase expenses (Wang and Hubbard, 2017). Completing and achieving the dual objectives of construction projects regarding time and budget are challenging because of the unique nature of the industry (Shafiei et al., 2020; Andrić et al., 2019).

Risks can become profit opportunities when clients and contractors analyze them based on their expertise. Effective quality assurance relies on thorough procedures, training, and planning. Although the Procedure and Controls ranked lowest, they are essential for setting quality standards on-site and ensuring project success (Xie et al., 2022). Overall, the results align with the existing literature, validating the proposed model and the flowchart in Figure 2.2.

4.0 Conclusions

This study encompassingly highlights respondents' perceptions on optimizing both cost and quality in oil and gas construction sites. Among the 19 criteria identified in the questionnaire, four emerged as critical: a) corruption; b) delays in client progress payments; c) financial struggles faced by contractors; and d) security concerns. Notably, the ranking of these factors displayed slight deviations (2.6% to 10%) from existing literature; however, this is not surprising. Previous studies focused solely on cost, while this research encompasses a comprehensive approach that integrates cost and quality in multi-objective optimization.

The intertwined responsibilities of the client and contractor are vital for effective project direction and execution, placing them at the forefront as the most prominent among the other six ranking alternatives regarding proximity model solutions. The contractor is primarily responsible for resource deployment—manpower, materials, methods, and machinery—with the client or consultant providing essential oversight to ensure that each activity adds value. The client plays a crucial role in witnessing, reviewing, scrutinizing, supporting, and approving the contractor’s plans, even amidst risks and external challenges under their control.

In conclusion, the greatest potential for optimizing cost and quality in oil and gas construction lies in the enhanced commitment and collaboration between the client/consultant and contractor. This proactive approach fosters close supervision, integration, and coordination of various work activities, leading to substantial project performance improvements. Moreover, project managers and their teams must remain focused and resolve any personal conflicts of interest that could jeopardize organizational goals. By rejecting integrity crises and unethical practices, they establish clear expectations for all stakeholders, reinforcing a culture of excellence and accountability throughout the team.

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