Analytical Hierarchy Process Model for Selecting Road Contractors: A Case of Ethiopian Roads Administration

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ABSTRACT

*In the construction industry, the successful completion of a project mainly depends on the performance and capability of the contractor. It is therefore understood that the success of a project may be compromised without an appropriate and reliable process for identifying the most suitable contractor. Commonly, many organizations select contractors primarily on the lowest bid offer, as it is simple and emphasizes cost efficiency. However, this approach often undermines other important factors. Hence, incorporating a multi criteria decision making approach ensures a more balanced evaluation that considers both bid price and other key criteria. This study explores the application of the Analytical Hierarchy Process as a decision-making model for contractor's selection. A combination of descriptive and case study research design was employed to identify and prioritize the contractor selection criteria. An extensive literature review identified 23 contractor selection criteria, which were categorized into four main groups. A structured questionnaire was then used to collect primary data based on these criteria. Once the data is gathered, the criteria are ranked in order of significance and prioritized for use in the analytical hierarchy process model. The analysis revealed that past performance competency had the highest weight (38.56%) with a consistency ratio of 0.088***,** *followed by technical competency (24.16%) and financial competency (20.42%). Management competency ranked lowest at 16.84%, with a consistency ratio of 0.0529. In summary, the proposed model enhances the contractor selection process by integrating multiple key competencies to evaluate contractors across broader criteria.*

Keywords: Analytical Hierarchy Process, Bid Evaluation, Contractor selection, Multi criteria decision making.

1. INTODUCTION

The construction industry is a fundamental economic sector that influences the majority of other sectors. However, reports from 2021/2022 indicate that Ethiopia's construction industry has been experiencing fluctuations in growth due to economic and political changes [1]. From several subsectors, construction is one of the industries that contribute to the country's economy. Its major role in industrial production was indicated by its 72.2% share in the industrial sector and a 7.1% GDP growth rate in 2019/2020 G.C. [2]. Meanwhile, mining and quarrying, along with electricity and water, contributed 1.6% and 2.9% of the industrial sector, respectively. The share in industry of the construction sector and other industry sectors is typically shown in Figure 1 [3]. One of the most important public projects is construction of roads which act as a crucial infrastructure for the economic development of the country and helps to connect to other forms of transportation including railways, ships, and airplanes. For the fiscal year 2023-2024 the Ethiopian government has allocated 68.4 billion ETB to the Ethiopian Road Administration, comprising about 12 % of the country's total annual budget [4]. In a 2023 internal report by ERA, the administration noted that it oversees and funds numerous road construction projects, with 231 being handled by various contractors [5]. Despite the economic significance of the road construction industry, some projects continue to suffer from delays and budget overruns. Evaluations conducted by project management and review committees have shown that contractors perform below expectations, primarily due to challenges in meeting contractual obligations within the planned cost and schedule parameters.

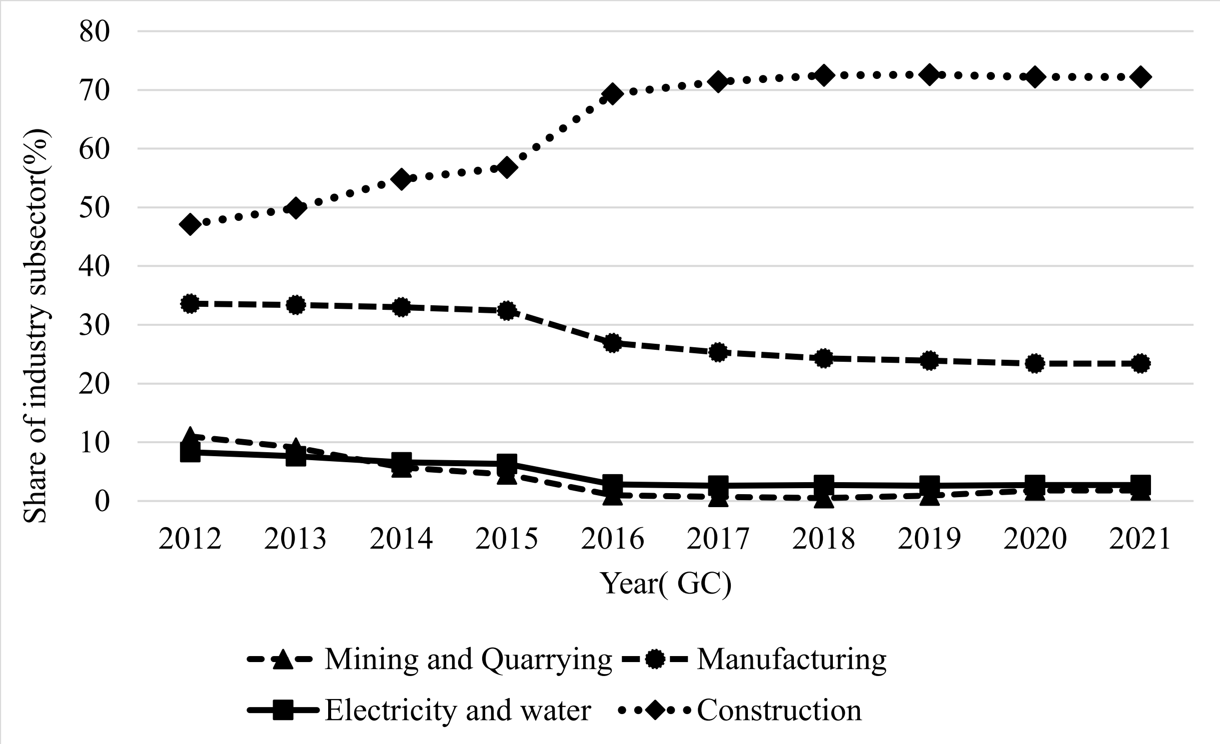

Figure 1: Construction sector's contribution to Ethiopia's domestic gross development [3]

It has been widely understood that, careful risk management is essential throughout all phases of a construction project from planning and design to execution and handover since each phase involves uncertainties related to cost, time, and quality. In this context, risk management refers to the systematic process of identifying, assessing, and mitigating potential risks that may influence project objectives. During the project delivery system, one of the most critical decisions during the procurement phase is contractor selection, which involves evaluating and awarding the contract to the most competitive and capable bidder. Given the complexity and inherent risks of construction activities, selecting the right contractor plays a decisive role in ensuring project success. Consequently, choosing the best contractor from the bids submitted to the client remains one of the most challenging tasks faced by clients in the construction industry [6]. The choice of contractor, among other factors, plays a significant role in determining the implementation and success of construction projects. This implies that low quality, schedule overruns, and low-cost performance will be experienced by the project if an unsuitable contractor is selected, [7], [8].

In Nigeria, open tendering in which the lowest bidder is awarded the contract, has become the most widely used method of contractor selection [6]. However, this method has been criticized by many researchers because contractors often submit artificially low bids during periods of low activity, hoping to recover costs through subsequent claims [9]. To address such issues, computational models have been proposed to evaluate contractors based on project specifications and factual applicant data, thereby reducing the influence of opportunistic bidding. Consequently, contractor selection should consider multiple factors beyond cost alone. Most existing models, however, follow a relatively straightforward decision making procedure, without fully accounting for the chaotic and varied nature of contractor selection in a multi-criteria decision-making context [10].

Among the various Multi Criteria Decision Making methods available, the Analytic Hierarchy Process (AHP), developed by Saaty in the 1980s, is one of the most widely used techniques for contractor evaluation and selection [11]. It is a theory of measurement that is developed by pairwise comparison, and the priority scales are created using expert judgement. This study uses the Ethiopian Roads Administration (ERA) as a case study, an organization responsible for the construction of motorways, new link roads, rural and Woreda roads, rural and urban road rehabilitation and upgrading, and federal and regional road maintenance in conjunction with regional road authorities to meet the sector's goals. Further, the administration also goes through the process of selecting contractors in order to construct various road projects. In ERA, construction contracts are typically awarded based on the lowest bid offer, where the contract is granted to the firm that submits the lowest bid and meets the minimum qualification requirements. This approach is mandated under Ethiopia’s Public Procurement and Property Administration Proclamation No. 649/2009 and subsequent regulations, that emphasize transparency, fairness, and cost effectiveness in public procurements. Although cost focused selection ensures financial efficiency, it may not adequately reflect a contractor’s technical competence, experience, or ability to complete projects on time and within budget, potentially compromising project outcomes [12]. It has been argued that a common limitation of the low-bid approach is that contractors may submit unrealistically low bids, either intentionally or unintentionally, to secure the contract, which can lead to delays, quality issues, or disputes [12] . In contrast, several countries adopt multi-criteria evaluation methods, considering both cost and technical capabilities. For example, in the USA and many European countries, contractor selection often employes weighted scoring method, considering experience, financial stability, and past performance, aligning with best practice principles of project management [13], [14].

To address this limitation, this paper proposes an Analytical Hierarchy process based contractor selection model that incorporates both financial and technical criteria, offering a structured and objective alternative to the low bid approach. Accordingly, the study aims to identify major contractor selection criteria, determine the relative significance of each criterion using AHP, and develop a theoretical model for optimal contractor selection that aligns with international best practices.

1.1. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a mathematical technique that is well known for its effectiveness in solving complex decision-making problems. When decision makers have numerous criteria to consider, the AHP approach helps them select the optimal choice [15]. This method incorporates both quantitative and qualitative components and aids in organizing difficult decision-making issues into a step-by-step decision model. It is based on the notions that interconnections between clusters are unidirectional across the decision levels of the hierarchy and that there are no connections between clusters and elements. The AHP process works as follows: First, it identifies criteria and the appropriate sub-criteria, breaking down the decision into distinct aspects to be taken into account. It then performs pairwise comparisons of the components to provide a relative relevance scale. In order to compare the significance of each pair of items at each level of the hierarchy, experts in the relevant domains are asked to determine the relative value of each criterion with respect to those at the second level. At the second level and beyond, experts compare the significance of every pair of sub-criteria under the same criterion Figure 2 illustrates the hierarchical structure of Analytical Hierarchy Process [16].

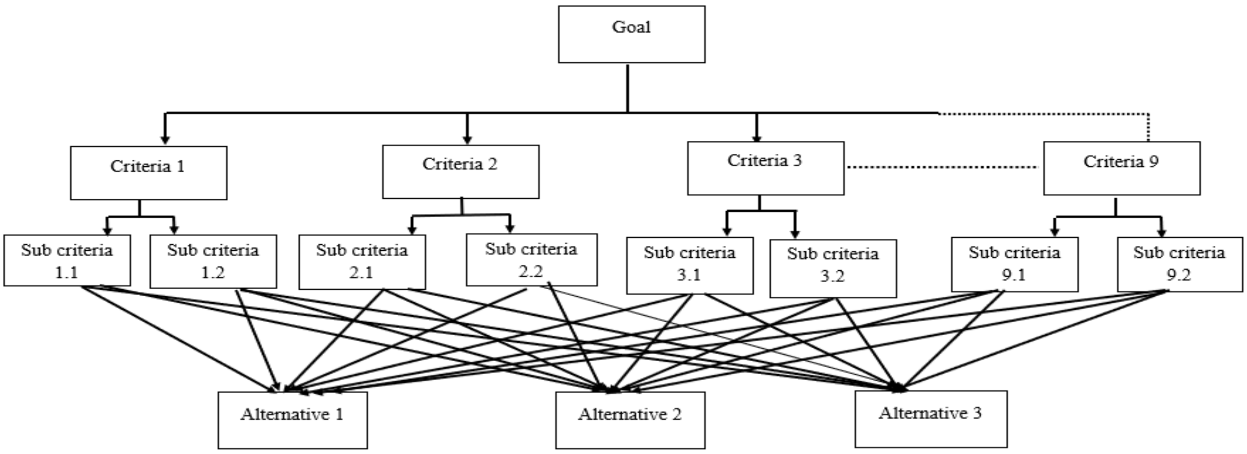

Figure 2: Typical hierarchical tree [16]

2. METHODS

Descriptive and case study research design is used for the study to obtain both a general understanding and an in-depth analysis of the contractor selection practices within the Ethiopian Roads Administration. The descriptive design helps to summarize and interpret the existing conditions, opinions, and practices related to contractor evaluation, while the case study approach enables a detailed examination of real-life projects to illustrate how the selection process is implemented in practice.

The study's target group are road contractors who were supervised by the Ethiopian Road Administration, professional engineers, project managers, road project consultants, tender assessment committees, and procurement specialists. Further, the study employs a sort of non-probability sampling method called purposive sampling to select contractors and consultants, and a probability sampling technique to select the employer. A purposive sampling method is used to select contractors and consultants because they possess relevant experience and specialized knowledge about the selection and evaluation process. On the other hand, a probability sampling technique is applied to select employers to ensure fair representation and reduce selection bias. Primary and secondary data sources were used for the analysis including; questionnaires, bid documents, financial data reports and published articles. Data presentation, frequency determination, and coding are done using SPSS Version 21.0.1.0. The Analytical Hierarchy Process (AHP) analysis in this study was conducted using Super Decisions software 3.2.0. Figure 3 provides a summary of the total study methodology that is used in the current study.

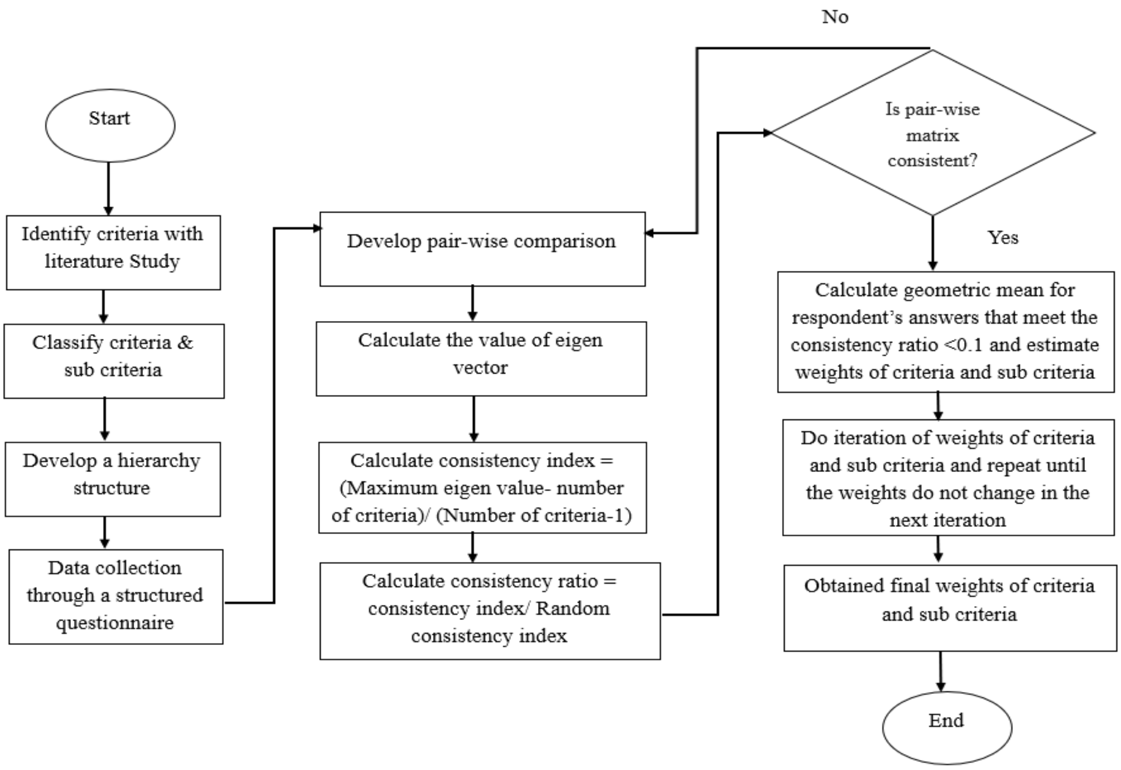

Figure 3: Research methodology

3. RESULTS AND DISCUSSIONS

3.1. Identification of Major Contractor Selection Criteria

The first objective of the study is to identify major contractor selection criteria. The study uses a mean score and ranking approach, using Equation 1. Table 1 shows that tender evaluation criteria answered by 87 respondents.

$$RII = \frac{5_{n_5} + 4_{n_4} + 3_{n_3} + 2_{n_2} + 1_{n_1}}{A * N} \quad (1)$$

Where:

RII= Relative Important Index

n_5= Number of respondents for strongly agree

n_4= Number of respondents for agree

$n_{3=}$ Number of respondents for neutral

$n_{2=}$ Number of respondents for disagree

$n_{1=}$ Number of respondents for strongly disagree

A= Highest weight

N= Total number of respondents

3.2. AHP Model Development

To implement the proposed AHP model effectively, a series of systematic steps must be followed. These procedures are essential for ensuring the accurate application of AHP in determining the contractor evaluation criteria. Below are the key steps that are applied:

Step 1: Determine the main criteria and sub-criteria that will be applied to the model (see Table 1).

Step 2: Take into consideration the most basic AHP scale for determining relative weights.

Step 3: The weights assigned to each criterion have been determined, and the matrix is created by averaging the responses from the three groups of participants who filled out the questionnaire. Here below is a pairwise comparison matrix that is used to assess a set of n criteria based on their respective weights. Equation 2 shows that a real matrix of size $m * m$ where m is the number of evaluation criteria taken in to account. The significance of each a_{ij} in matrix A represents, the j^{th} criterion relative importance to the i^{th} criterion.

$$A = a_{ij} = \begin{bmatrix} a_{1,1} & \cdots & a_{1,n} \\ \cdots & \cdots & \cdots \\ a_{n,1} & \cdots & a_{n,n} \end{bmatrix} \quad (2)$$

Here, the criteria in this case are $a_{1,} \, a_2 \cdots a_n$.Where"n" is the total number of criteria. A scale from 1 to 9 was used to establish the relative importance of the two criteria.

Table 1 Major contractors' selection criteria

Item	Criteria	RII	Mean	Rank
1	Annual turnover	0.9684	4.8419	1
2	Contractors working capital	0.9485	4.7425	2
3	Financial stability	0.9099	4.5493	3
4	Bid price	0.8897	4.4484	4
5	Cash flow projection	0.8617	4.3085	5
6	Expertise in the field	0.8171	4.0853	6
7	Not able to finish a contract	0.7926	3.9628	7
8	Past record conflict and dispute	0.7851	3.9253	8
9	The quantity of comparable work completed by the contractor	0.7776	3.8878	9
10	Performance of contractor on previously completed project	0.7662	3.8311	10
11	The quality of the project delivered through the allocated time and budget	0.7545	3.7725	11
12	Sufficient equipment/plant	0.7355	3.6774	12
13	Technical competency of staff members	0.7268	3.634	13
14	Contractors' knowledge regarding work methodology	0.7205	3.6024	14
15	Health and safety principles implementation	0.711	3.5549	15
16	The extent of QA/QC programs that have been used in previous projects	0.7045	3.5224	16
17	The comprehensiveness of the work technique description	0.6464	3.2321	17
18	Responding to tender specific requirements	0.6248	3.124	18
19	Project management skill	0.6026	3.013	19
20	Risk management	0.5951	2.9756	20
21	Number of personnel for the key position	0.5876	2.9381	21
22	Managerial capability	0.5242	2.6208	22
23	Subcontractors' management	0.4764	2.3819	23

3.3. AHP Process

As previously stated, there are four primary steps to implement AHP: i) structure the hierarchy model; ii) computing pairwise comparisons; iii) synthesizing and computing decisions for weight prioritization; and iv) assessing the consistency of the outcomes.

3.3.1. Structure of the hierarchy

By using a pairwise comparison between each data set's criteria, the AHP divides the contractor selection process into a hierarchy consisting of the Goal, Criteria, and Alternatives. Financial, past performance, technical, and management competency are the factors that AHP uses to conduct the pairwise comparison. The alternatives are the number of contractors bidding for the contract. Table 2 represents Saaty rating scale which is used to determine the relative weights for the selection criteria.

Table 2 The Saaty rating scale [17].

Intensity of importance	Definition	Explanation
1	Equal importance	i and j are equivalent
3	Somewhat more important	i is slightly preferred to j
5	Much more important	i is strongly preferred to j
7	Very much important	i is very strongly preferred to j.
9	Absolutely more important	i is absolutely preferred to j
2,4,6,8	Intermediate values	When compromised is needed

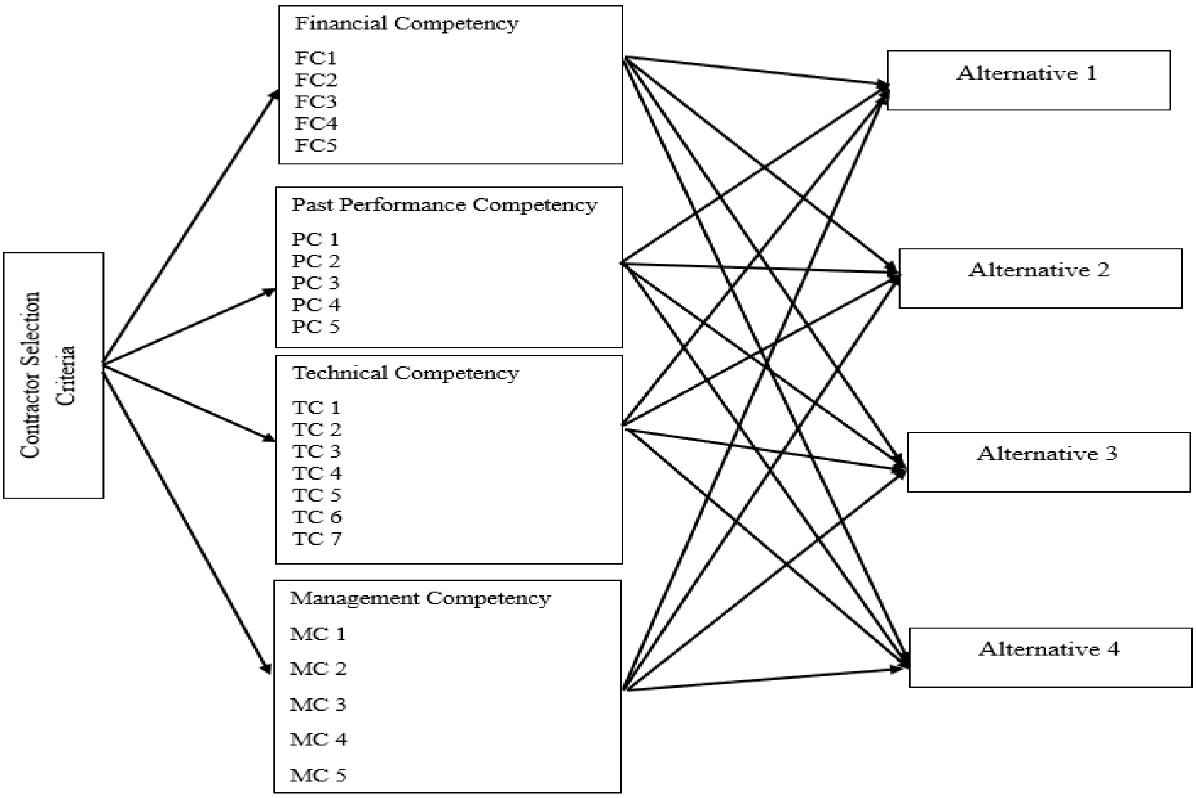

Figure 4 A hierarchical representation of the AHP model.

3.3.2. Performing Pair Wise Comparisons

After developing the hierarchy, pairwise comparison was methodically carried out across the structure. Table 3 presents the summary of results of the pairwise comparison of the criteria for each of the four primary criteria: Financial competency (FC), Past performance competency (PC), Technical Competency (TC), and Management competency (MC).

Table 3 Pair wise comparison matrix

Criteria	FC 1	...	FC 5	Eigenvector	Criteria vector (w)
FC 1	1	...	FC_{15}	$\left(v_{ij}=\prod_{k=1}^{k} a_{ij}\right)^{\frac{1}{k}}$	Wi= ${}^{vi}/_{\sum vi}$
⋮	⋮	1	⋮		Wi= ${}^{vi}/_{\sum vi}$
FC 5	${}^{1}/_{FC_{15}}$	...	1		Wi= ${}^{vi}/_{\sum vi}$
Eigenvalue λmax	$\sum c_{ji*}w_i$				$\sum w_{i=1}$
Consistency Ratio	$\frac{\frac{\lambda max-n}{n-1}}{RI}$				

Criteria	PC 1	...	PC 6	Eigenvector	Criteria vector (w)
PC 1	1	...	PC_{16}	$\left(v_{ij}=\prod_{k=1}^{k} a_{ij}\right)^{\frac{1}{k}}$	Wi= ${}^{vi}/_{\sum vi}$
⋮	⋮	1	⋮		Wi= ${}^{vi}/_{\sum vi}$
PC 6	${}^{1}/_{PC_{16}}$	...	1		Wi= ${}^{vi}/_{\sum vi}$
Eigenvalue λmax	$\sum c_{ji*}w_i$				$\sum w_{i=1}$
Consistency Ratio	$\frac{\frac{\lambda max-n}{n-1}}{RI}$				

Criteria	TC 1	...	TC 6	Eigenvector	Criteria vector (w)
TC 1	1	...	TC_{16}	$\left(v_{ij}=\prod_{k=1}^{k} a_{ij}\right)^{\frac{1}{k}}$	Wi= ${}^{vi}/_{\sum vi}$
⋮	⋮	1	⋮		Wi= ${}^{vi}/_{\sum vi}$
TC 6	${}^{1}/_{TC_{16}}$	...	1		Wi= ${}^{vi}/_{\sum vi}$
Eigenvalue λmax	$\sum c_{ji*}w_i$				$\sum w_{i=1}$
Consistency Ratio	$\frac{\frac{\lambda max-n}{n-1}}{RI}$				

Criteria	MC 1	...	MC 5	Eigenvector	Criteria vector (w)
MC 1	1	...	MC_{15}	$\left(v_{ij}=\prod_{k=1}^{k} a_{ij}\right)^{\frac{1}{k}}$	Wi= ${}^{vi}/_{\sum vi}$
⋮	⋮	1	⋮		Wi= ${}^{vi}/_{\sum vi}$
MC 5	${}^{1}/_{MC_{15}}$	...	1		Wi= ${}^{vi}/_{\sum vi}$
Eigenvalue λmax	$\sum c_{ji*}w_i$				$\sum w_{i=1}$
Consistency Ratio	$\frac{\frac{\lambda max-n}{n-1}}{RI}$				

Where: FC= Financial competency, PC= Past perormance competency, MC= Management competency, TC= Technical competency, λmax= Maximun eigen value, n = Number of criteria w = Criteria vector, RI = Random consistency index, $a_{ij=}$ pairwise compasrsion values.

3.3.3 Weight prioritization and consistency assessment in decision making

After structuring the hierarchy and forming the pairwise comparisons, the next step is calculation of weights and consistency checking (Table 4).

3.4. Discussion of AHP Results

The current study and ERA's approach consider similar evaluation elements, such as financial competency, technical competency, past performance, available resource (equipment, personnel), and legal compliance. For example, ERA includes requirements like financial performance history, experience, and key personnel availability, which aligns with the sub criteria that is proposed in the current research. Further, the current study highlighted past performance competency as the most important major category, particularly noting factors like project quality and past conflict history. ERA also evaluates contractors' non- performance history and pending litigation, as a part of its post qualification examination ensuring that contractors with the history of non-performance are filtered out.

Table 4 Summary of AHP results for main and sub criteria for selection of contractor

Criteria	Aggregated pairwise matrix $\left(v_{ij} = \prod_{k=1}^{k} a_{ij}\right)^{\frac{1}{k}}$	Sub criteria	Criteria weight $\left(Wi = vi/_{\sum vi}\right)$	Criteria (%)	Rank	Consistency
Main criteria (FC, PC, TC & MC)	$\begin{bmatrix} 1 & 1/2 & 1/2 & 2 \\ 2 & 1 & 2 & 2 \\ 2 & 1/2 & 1 & 1 \\ \frac{1}{2} & 1/2 & 1 & 1 \end{bmatrix}$	FC	0.2042	20.66%	3	$\lambda max = 4.19$
		PC	0.3856	38.54%	1	$CI = 0.06$
		TC	0.2416	23.81%	2	$CR = 0.0694$
		MC	0.1684	16.99%	4	
FC (Financial competency)	$\begin{bmatrix} 1 & 1/3 & 1 & 1/2 & 1/2 \\ 3 & 1 & 1 & 1/2 & 2 \\ 1 & 1 & 1 & 1 & 3 \\ 2 & 2 & 1 & 1 & 2 \\ 2 & 1/2 & 1/3 & 1/2 & 1 \end{bmatrix}$	FC 1	0.1201	12.25%	5	$\lambda max = 5.333$
		FC 2	0.2314	22.98%	3	$CI = 0.083$
		FC 3	0.2373	23.75%	2	$CR = 0.07368$
		FC 4	0.2784	27.76%	1	
		FC 5	0.1326	13.26%	4	
PC (Past performance competency)	$\begin{bmatrix} 1 & 1/3 & 1/4 & 4 & 1/2 & 1/2 \\ 3 & 1 & 1/2 & 3 & 1 & 1/3 \\ 4 & 2 & 1 & 4 & 1 & 1/3 \\ 1/4 & 1/3 & 1/4 & 1 & 1/3 & 1/3 \\ 2 & 1 & 1 & 3 & 1 & 1/3 \\ 2 & 3 & 3 & 3 & 3 & 1 \end{bmatrix}$	PC 1	0.1000	10.64%	5	$\lambda max = 6.566$
		PC 2	0.1485	14.82%	4	$CI = 0.113$
		PC 3	0.2105	20.67%	3	$CR = 0.0880$
		PC 4	0.0522	5.46%	6	
		PC 5	0.1493	14.85%	2	
		PC 6	0.3391	33.55%	1	
Criteria	Aggregated pairwise matrix $\left(v_{ij} = \prod_{k=1}^{k} a_{ij}\right)^{\frac{1}{k}}$	Sub criteria	Criteria weight $\left(Wi = vi/_{\sum vi}\right)$	Criteria (%)	Rank	Consistency
TC (Technical competency)	$\begin{bmatrix} 1 & 1/5 & 1/4 & 1/3 & 1/2 & 1/3 \\ 5 & 1 & 1 & 1/3 & 3 & 3 \\ 4 & 1 & 1 & 1/3 & 1 & 1/2 \\ 3 & 3 & 3 & 1 & 4 & 4 \\ 2 & 1/3 & 1 & 1/4 & 1 & 1/3 \\ 3 & 1/3 & 2 & 1/4 & 3 & 1 \\ 4 & 3 & 3 & 2 & 3 & 2 \end{bmatrix}$	TC 1	0.0419	4.33%	7	$\lambda max = 7.647$
		TC 2	0.1526	15.25%	3	$CI = 0.107$
		TC 3	0.0932	9.56%	5	$CR = 0.0794$
		TC 4	0.2577	24.77%	2	
		TC 5	0.0636	6.71%	6	
		TC 6	0.1139	12.06%	4	
		TC 7	0.2769	27.31%	1	
MC (Management competency)	$\begin{bmatrix} 1 & 1 & 2 & 1 & 2 \\ 1 & 1 & 2 & 1 & 3 \\ 1/2 & 1/2 & 1 & 1/3 & 1/2 \\ 1 & 1 & 3 & 1 & 3 \\ 1/2 & 1/3 & 2 & 1/3 & 1 \end{bmatrix}$	MC 1	0.2382	23.88%	1	$\lambda max = 5.23$
		MC 2	0.2618	25.99%	3	$CI = 0.058$
		MC 3	0.0981	9.98%	5	$CR = 0.0529$
		MC 4	0.2810	27.99%	2	
		MC 5	0.1206	12.16%	4	

A primary difference lies in AHP's weighted scoring VS ERA's pass/fail approach. While the AHP analysis assigns weights to prioritize criteria, ERA does not apply weightage or scoring; contractors only need to meet the minimum requirements. In ERA system, all criteria are essential but do not contribute differently to an overall score, where as in the current study criteria are weighted. In addition, ERA's financial evaluation phase solely determines the contract award by selecting the lowest bid, assuming all technical requirements are met. In contrast, AHP approach ranks criteria, which support a best-value selection method rather than strictly selecting the lowest bid.

To ensure the reliability and validity of the results, the research instruments underwent both reliability testing and content validity assessment. The reliability analysis, performed using Cronbach's Alpha (α), showed acceptable to excellent internal consistency across all major variables: financial competency (α = 0.777), management competency (α = 0.748), technical competency (α = 0.935), and past performance competency (α = 0.912). A reliability value that gives the value of α > 0.9 (Excellent); α > 0.8 (Good); α > 0.7(Acceptable); α > 0.6 (Questionable); α > 0.5 (Poor) and α< 0.5 (Unacceptable) [18]. The study therefore used the Cronbach's value that ranged between 0.7 and above to determine reliability of instruments. In addition, content validity was ensured through a pilot study involving construction industry professionals, followed by a review by colleagues with experience in the road construction sector. Feedbacks from the pilot test helped refine the questionnaire and confirm that each item adequately represented the intended construct.

Therefore, the findings presented in this study are based on validated and reliable data, ensuring that the comparison between the current study and ERA's approach is both credible and methodologically sound. If ERA aims to advance its contractor selection approach beyond minimum standards, adopting a weighted criteria method such as AHP could help prioritize contractors who not only offer cost effectiveness but also demonstrate higher competency essential for project success.

3.5. Case Study

A case study was conducted on a tender that was announced in the *Ethiopian Herald* newspaper and on the Ethiopian Roads Administration's website on September 29 and 30, 2020, for the road construction project. This particular tender was selected because it represents a typical ERA procurement process, with clearly defined prequalification and bid evaluation stages that align with the objectives of this research. In addition, the Ethiopian Road Administration provide complete and accessible documentation, including bid evaluation reports, financial and technical data, which made it suitable for applying both the existing ERA selection procedure and the proposed AHP based model.

The employer sought to assess potential bidders capable of successfully completing the project. Out of nine bidders, four contractors passed the prequalification round and were included in the analysis. These four contractors were first evaluated using the ERA's existing selection approach, and then re-assessed using the proposed AHP-based model to compare outcomes. Hence, the scenario described in the case study represents a shortlist of four contractors considered for contract award.

3.5.1. Contractor's profile

The contractor's profile is studied thoroughly, and the vast details about their turnover, projects completed by them, equipment, machines, and tools owned or required by them, and the technical personnel available with them are consolidated to create a short profile that gives an idea of their strengths and weaknesses in the respective criteria under consideration. The contractor's profile is shown in Table 5 in tabular form.

Two processes were used in the evaluation of bids: post-qualification and financial evaluation. After assessing the post-qualification applications in accordance with the requirements specified in the bidding document, the Tender Assessment Committee advised all bidders who had submitted both their financial bids and qualification documents to proceed with the opening of their financial bids. Based on the outcome of the evaluation, the Tender Assessment Committee recommended that Contractor 2 be invited for pre-contract discussions and the eventual award of the construction works.

Table 5: Contractor's profile

Item no.	Applicants	Grade	Country of Registration
1	Bidder 1	GC-1	China
2	Bidder 2	GC-1	
3	Bidder 3	GC-1	Ethiopia
4	Bidder 4	GC-1	

3.5.2. Contractor selection based on AHP model

Following a prequalification process that involved reviewing the contractors' files and performance records, only four contractors were found to be eligible for the project. This project, together with these four contractors, serves as a prototype for validating the proposed AHP based model. The decision makers evaluated each contractor's performance in relation to the twenty-three sub criteria outlined in the previous section, which represent the main criteria's that are used in contractor selection process.

The evaluation criteria were grouped under four major categories; past performance competency, technical competency, financial competency and management competency. The alternative options under consideration were designated as Bidder 1, Bidder 2, Bidder 3, and Bidder 4.

The first phase in the Analytical Hierarchy Process (AHP) involves clearly formulating the problem and establishing the decision hierarchy, which defines the goal, criteria, and sub-criteria before moving to the pairwise comparison stage. Figure 4 shows the hierarchical structure and the flow of decision making applied in this study. After defining the criteria, Saaty's fundamental scale of pairwise comparisons was used to assess the relative importance of one element over another. This scale allows decision makers to express judgments consistently and to quantify qualitative assessments, which is particularly useful in multi criteria decision making contexts such as contractor selection. Subsequently, for Bidder '1', '2', '3', and '4', their respective weights, pairwise comparison matrices, consistency index, and consistency ratio were computed to ensure logical consistency of the judgements. The results of these comparisons are presented in Table 6.

Table 6 Pairwise comparison and normalization matrices for each criterion

Pairwise Comparison Matrix for Financial Competency					**Normalization Matrix**					
FC	Bidder1	Bidder2	Bidder 3	Bidder 4	FC	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Criteria weight
Bidder 1	1	$1/4$	$1/3$	$1/8$	Bidder 1	0.0625	0.0285	0.0357	0.0871	0.0534
Bidder 2	4	1	2	$1/7$	Bidder 2	0.2500	0.1142	0.2142	0.0995	0.1695
Bidder 3	3	1/2	1	$1/6$	Bidder 3	0.1875	0.0571	0.1071	0.1161	0.1169
Bidder 4	8	7	6	1	Bidder 4	0.500	0.800	0.6428	0.6970	0.6599
Sum	16	8.75	9.33	1.434	$\boldsymbol{\lambda max = 4.202, CI = 0.067\ RI = 09\ , CR = 0.074}$ < 0.1 Ok!					

Pairwise Comparison Matrix for Past Performance Competency

PC	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Bidder 1	1	1/4	1/3	1/7
Bidder 2	4	1	3	1/5
Bidder 3	3	1/3	1	1/6
Bidder 4	7	5	6	1
Sum	15	6.583	10.33	1.509

Normalization Matrix

PC	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Criteria weight
Bidder 1	0.0667	0.0379	0.0322	0.0946	0.0578
Bidder 2	0.2667	0.1518	0.2903	0.1324	0.2103
Bidder 3	0.200	0.0506	0.0967	0.1104	0.1144
Bidder 4	0.4667	0.7594	0.5806	0.6624	0.6173

$\boldsymbol{\lambda max = 4.228, CI = 0.076\ RI = 0.9\ , CR = 0.0844}$ < 0.1 Ok!

Pairwise Comparison Matrix for Technical Competency

TC	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Bidder 1	1	1/5	1/2	1/7
Bidder 2	5	1	2	1/6
Bidder 3	2	1/2	1	1/5
Bidder 4	7	6	5	1
Sum	15	7.7	8.5	1.509

Normalization Matrix

TC	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Criteria weight
Bidder 1	0.0667	0.0259	0.0588	0.0946	0.0615
Bidder 2	0.3333	0.1297	0.2352	0.1104	0.2022
Bidder 3	0.1333	0.0649	0.1176	0.1324	0.1121
Bidder 4	0.4666	0.7792	0.58823	0.6624	0.6241

$\boldsymbol{\lambda max = 4.202, CI = 0.067\ RI = 0.9\ , CR = 0.0750}$ < 0.1 Ok!

Pairwise Comparison Matrix for Management Competency

MC	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Bidder 1	1	1/4	1/3	1/6
Bidder 2	4	1	2	1/5
Bidder 3	3	1/2	1	1/5
Bidder 4	6	5	5	1
Sum	14	6.75	8.33	1.566

Normalization Matrix

MC	Bidder 1	Bidder 2	Bidder 3	Bidder 4	Criteria weight
Bidder 1	0.0714	0.0370	0.040	0.1063	0.0637
Bidder 2	0.2857	0.1481	0.240	0.1276	0.2003
Bidder 3	0.2142	0.0740	0.120	0.1276	0.1340
Bidder 4	0.4285	0.7407	0.600	0.6382	0.6019

$\boldsymbol{\lambda max = 4.189, CI = 0.0630\ RI = 0.9\ , CR = 0.0701}$ < 0.1 Ok!

3.6. Summary of the Results on Case Study

As it can be observed from Table 6, Bidder 4 was determined to have the highest index based on the case study's findings. The comparison of bidders' ranks based on established models and current practice is shown in Table 7.

Table 7 Rank of bidders based on the two methods

Bidders	Rank based on current practice	Rank based on developed model
1	3	4
2	1	2
3	2	3
4	4	1

The differing results between the Ethiopian Road Administration method and the Analytical Hierarchy Process (AHP) can be justified by recognizing the broader scope and comprehensive evaluation offered by the AHP method. While the administration prioritizes cost efficiency, often resulting in selecting the lowest bidder, the AHP approach considers multiple criteria, such as technical expertise, financial stability, past performance, and project management capabilities. This broader evaluation ensures that the selected contractor is qualified to deliver high quality outcomes and minimize project risks. Hence, adopting the AHP technique introduces a structured and transparent decision-making framework that balances cost considerations with quality and performance factors. It enhances consistency in evaluation, reduces subjectivity, and supports better-informed contractor selection decisions, which ultimately contribute to improved project outcomes.

3.7. Sensitivity Analysis

Super decision software version 3.2 was used to do the sensitivity analysis, which tested the adaptability and accuracy of multi criteria judgements through criteria change. To see how the weights of the main criteria; financial competency, past performance competency, technical competency and managerial competency affected the bidders' overall rating, sensitivity analysis was carried out, $\pm 10\%$ adjustment was made to each criterion. The sensitivity analysis conducted using super decision software demonstrates that despite varying the percentage of weight assigned to different criteria, there is no change in the contractor selection ranking. The analysis confirms that the contractor rankings remain consistent, and no rank reversal point is observed.

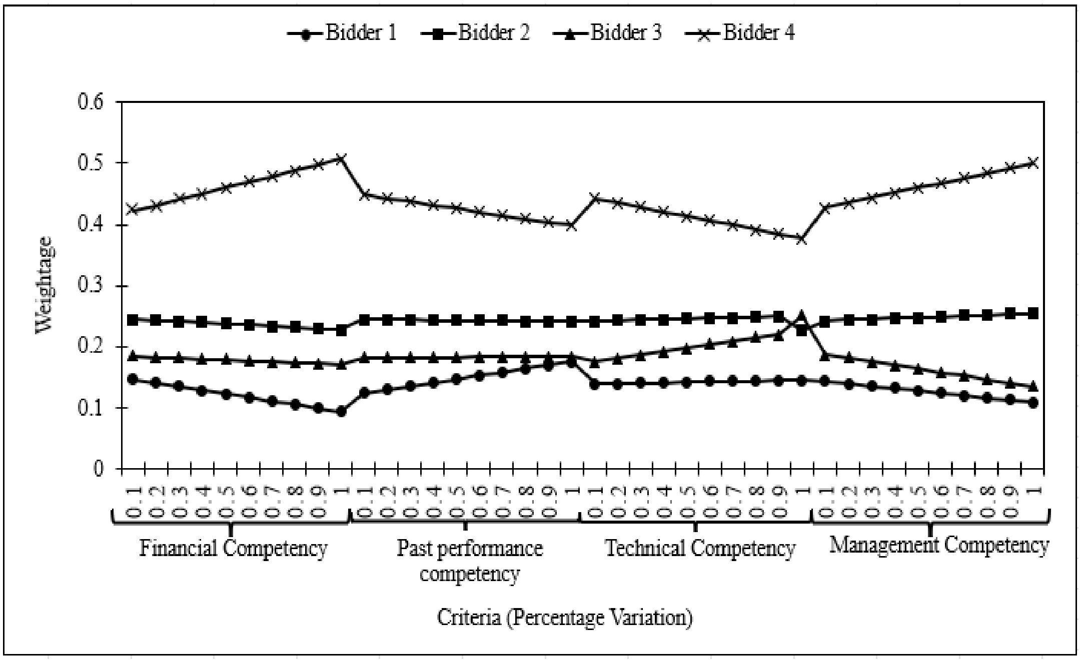

Figure 5 Sensitivity analysis for various percentage

4. CONCLUSIONS

A total of 23 contractor selection criteria were identified through an extensive literature review. These criteria were categorized into four main groups: financial, technical, past performance, and management competency. The Analytic Hierarchy Process (AHP) model assigned weights to these four main criteria to reflect their relative importance in the contractor selection process. The results from the AHP analysis showed that past performance competency was the most critical factor, carrying the largest weight of 38.56%. Following past performance, technical competency was the second most important criterion, with a weight of 24.16%. Technical competency includes factors like the availability of specialized equipment, the expertise of technical staff, and the contractor's ability to implement health, safety, and quality control measures.

Financial competency was ranked third, with a weight of 20.42%, this criterion evaluates a contractor's financial health, including their cash flow projections, bid price, and financial stability, annual turnover and working capital. Lastly, management competency ranked fourth, with a weight of 16.84%. Although it is the least weighted of the four main criteria, it still plays an essential role in determining a contractor's ability to manage resources, personnel, and subcontractors effectively.

A case study was conducted to the proposed AHP model. The model was tested with four contractors engaged in an ERA road construction project. Based on the AHP assessment, Contractor 4 was selected as the most suitable choice. To ensure the scientific validity of the model, consistency tests were carried out. The AHP consistency ratio (CR) for all pairwise comparison matrices were found to be below the acceptable threshold of 0.10, confirming logical consistency in the judgments provided by respondents. However, since the validation was based on a single case study, future research is recommended to apply the model to multiple projects across different contexts and include additional selection criteria to enhance the model's generalizability and robustness.

The proposed AHP-based decision-making model enhances the contractor selection process by integrating multiple key competencies including; past performance, technical ability, financial stability, and management skills. This multi-criteria approach ensures that contractors are evaluated on a broader set of factors, which not only improves project outcomes but also encourages higher standards in the industry.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

[1] H. Suliman, "Causes and Effects of Cost Overrun on Construction Project in Bahrain: Part I (Ranking of cost overrun factors and risk mapping)," *Modern Applied Science,* vol. 11, no. 7, 2017.

[2] Plan and Development Commision, "Annual Report, Ethiopia," 2019-2020.

[3] National Bank of Ethiopia, " Annual Report," 2021/2022.

[4] Ministry of Finance, "2016 FY GoE Budget summary," Addis Ababa, 2016.

[5] Ethiopia Roads Administration, "Construction Projects 2015 Implementation & 2016 E.C Plan," 2016.

[6] O. Olatunji, "Bid or no-bid decision factors of indigenous contractors in Nigeria," *Engineering, Construction and Architectural Management, 24(3),,* pp. 378-392, 2017.

[7] D. Ayettey, "Contractor selection Criteria in Ghanaian Construction Industry: Benefits and Challenges.," *Journal of Building Construction and Planning Research,6,* pp. 278-297, 2018.

[8] A. Khoso, "Embedded Remote Group Environment Through Modification In Macbeth- An Application of contractor's Selection In Construction.," *Journal of Civil Engineering and Management,27(8),* pp. 595-616, 2021.

[9] A. Birjandi, "Evaluation and selecting the contractor in bidding with incomplete information using MCGDM method," *Soft computing,* vol. 23, no. 20, pp. 10569-10585, 2019.

[10] S. Bishaw, "Development of Fuzzy Decision Model for Ethiopian Construction contractors selection," *PHD diss., Addis Ababa Science and Technology University,* 2019.

[11] M. Rahimdel, "Application of analytical hierarchy process to selection of primary crusher," *International Journal of Mining Science and Technology, 24(4),,* pp. 519-523, 2014.

[12] M. Demesew, "Assessment of Tender Evaluation System for Public Building Project Works in Ethiopia," *Thesis, Jimma University,* 2019.

[13] M. Hasnain, "Best Value Contractor Selection in Road Construction Projects: ANP- Based Decision Support System," *International Journal of Civil Engineering,* vol. 16, pp. 695-714, 2017.

[14] Y. Khoso, "'Extended review on contractor selection in construction projects'," *Canadian Journal of Civil Engineering, Vol. 47, No. 7,* pp. 771-789, 2020.

[15] C. Benfares, "Multi-Criteria Decision Making Semantic for Mental Healthcare. In Research Anthology on Mental Health Stigma, Education, and Treatment," *IGI Global: Hershey, PA, USA,* pp. 178-192, 2021.

[16] S. Anna, "Analytic Hierarchy Process in Multiple–Criteria Decision–Making: A Model Example," *SHS Web of Conference 90,0109,* pp. 1-10, 2021.

[17] R.W. Saaty, "The analystic Hierarchy Process_What it is and How it is used," *Pergamon Journals Ltd,* vol. 9, pp. 161-176, 1987.

[18] C. Sylvester, "Cronbach's Alpha: A Cornerstone in Ensuring Reliability and Validity in Environental Health Assessment," *ES Energy & Environment,* pp. 1-14, 2023.