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(RESEARCH ARTICLE)

Research on Risk Management in International Engineering Project Contracting with Third World Countries in Africa

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Abstract

Risk management of international engineering project contracting with third world countries in Africa is a critical aspect that requires thorough investigation due to the unique challenges and complexities involved. The study delves into the various risk factors prevalent in international engineering projects with third world countries in Africa; different risk management strategy options and how they can be tailored to suit the specific context of international engineering projects with third world countries in Africa to enhance project success rates. The research will also investigate the application of the Analytic Hierarchy Process (AHP) method in prioritizing and selecting risk management strategies based on their importance and effectiveness in complex engineering projects.

Keywords: Risk Management; International Engineering Project Contracting; Third World Countries in Africa; Risk Factors; Analytic Hierarchy Process (AHP)

1. Introduction

The planning and scheduling of international engineering projects involves a varied array of analysis, research, designing and recommendations that to some degree are based on predictions of future situations (which may be political, economic, social, natural, etc.); availability of technology; skilled management and organization structure. Though as thorough as the initial phase may be, during the actual implementation and operation of the project, these factors may change, causing uncertainty and interference to original plans; ultimately causing the project to deviate from the scheduled goals. These interfering factors that cannot be determined in advance are what are termed as risks.

2. Characteristics of Risk

2.1. Objectivity

Risk objectivity refers to the impartial and unbiased assessment of risks associated with a particular project or activity. In the context of international engineering project contracting with third world countries in Africa, risk objectivity involves the systematic identification, analysis, and evaluation of potential risks without being influenced by personal biases or external factors. [1, 2, 3, 4]

2.1.1. Factors Influencing Risk Objectivity

- Political Stability: Objective assessment of the potential impact of political unrest, changes in government policies, and regulatory frameworks on project timelines and costs should be implemented. [1, 2, 3, 4]

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- Economic Conditions: Fluctuating economic conditions, currency exchange rates, inflation rates, and market volatility can introduce financial risks to international engineering projects. Objective analysis of these factors is essential for effective risk management. [1, 2, 3, 4]
- Social and Cultural Factors: Social dynamics, cultural differences, local community engagement, and labor practices can influence project risks with third world countries in Africa. Engineers need to objectively evaluate these aspects to anticipate potential challenges and mitigate associated risks. [1, 2, 3, 4]
- Environmental Considerations: Environmental risks such as natural disasters, climate change impacts, ecological sensitivities, and resource availability must be objectively assessed in international engineering projects. Failure to address these risks adequately can lead to project delays or failures. [1, 2, 3, 4]

2.2. Predictability

The notion that "risk has predictability" implies that risks can be anticipated, analyzed, and mitigated to a certain extent through systematic risk management processes. While it is true that some risks can be identified and quantified based on historical data, expert judgment, and probabilistic models, there are inherent limitations to predicting all possible risks accurately. Factors such as unforeseen events, human error, force majeure situations, and complex interdependencies within projects can introduce uncertainties that challenge the predictability of risks. [2, 3]

2.2.1. Factors Influencing

Factors such as corruption, lack of transparency, inadequate legal frameworks, social unrest, and environmental vulnerabilities add layers of complexity to risk assessment and management. The lack of reliable data sources and information asymmetry further hinder the accurate prediction of risks in such environments. [2, 3]

2.3. Benefits of Reward

While risk is often perceived as a negative factor that can lead to project failures or cost overruns, it is essential to recognize that risk also carries potential benefits of reward. [4, 5, 6, 7, 8]

2.3.1. Benefits of Reward Associated with Risk

- Opportunity for Higher Returns: Embracing certain risks can open up opportunities for higher returns on investment. For instance, venturing into emerging markets with growth potential may yield substantial profits despite the associated risks. [4, 5, 6, 7, 8]
- Competitive Advantage: Successfully navigating through risky situations can give a company a competitive edge by demonstrating resilience and adaptability. This can enhance the organization's reputation and position it favorably for future projects. [4, 5, 6, 7, 8]
- Learning and Innovation: Dealing with risks fosters a culture of learning and innovation within an organization. Overcoming challenges prompts teams to develop creative solutions and improve processes, leading to long-term benefits beyond the current project. [4, 5, 6, 7, 8]

2.4. Subject Relativity

One key aspect to consider is that risk perception is not universal and can differ among individuals, organizations, or even cultures. What one party may perceive as a significant risk, another may view as a minor concern. This subjectivity in risk perception can stem from various factors such as past experiences, expertise level, cultural background, and individual biases. These complexities further contribute to the subjective nature of risk assessment and management. Different stakeholders may prioritize risks differently based on their understanding and evaluation of these complex factors. [9, 10, 11, 12]

2.5. Variability

"Risk has variability" in the context of this study means that risks associated with projects are neither static nor uniform; but rather exhibit variability in terms of their nature, impact, and likelihood of occurrence. This cannot be understated due the natural complexity of international engineering projects which have tagged along with them a high degree of variability in risks as they progress through different phases. The variability in risks in most cases has a direct correlation with factors such stakeholder dynamics, technological advancements, or market conditions. [2, 13, 14, 15]

Traditional risk management approaches that rely on fixed assumptions and standardized procedures may not be suitable for addressing the dynamic and diverse risks encountered with third world countries in Africa. Instead, project managers and stakeholders need to adopt flexible and adaptive risk management strategies that can accommodate the changing nature of risks throughout the project lifecycle. [2, 13, 14, 15]

3. Overview of Risk Management In Relation to International Engineering Project Contracting With Third World Countries in Africa

Risk Management can be divided into five aspects, namely;

- Risk identification: Risk identification is the first step in risk management, which is the process of analyzing, judging, and categorizing the potential risks faced by engineering projects before they occur, and having a certain intuitive understanding of the possible consequences, making a qualitative analysis of the risks.
- Risk estimation: Risk estimation is based on the outcome of risk identification. It involves analyzing a large amount of collected data to estimate the nature of the risk, the probability of the risk occurring, and the magnitude of the risk's consequences, in order to reduce the measurement uncertainty of the project. Risk estimation is a quantitative analysis of risk
- Risk evaluation: Risk Evaluation refers to using scientific methods to rank the identified and estimated risks according to their weight, comprehensively considering the probability of risk events occurring and the consequences of losses, and evaluating the overall risk of engineering projects.
- Risk response: Risk response refers to the actions taken to address identified risks and their Potential impact on the project. It aims to minimize the negative effects of risks on project objectives by either eliminating the risk altogether, reducing its likelihood or impact, transferring the risk to another party through insurance or contracts, or accepting the consequences if the risk materializes.
- Risk monitoring and control: Risk monitoring involves continuously tracking identified risks throughout the project lifecycle to ensure that any changes in risk exposure are promptly identified and addressed. This process often involves regular risk assessments, progress tracking against predefined risk mitigation plans, and the implementation of corrective actions when necessary. Risk control focuses on implementing strategies to minimize the probability and impact of identified risks. This may include risk transfer through insurance, contractual agreements with suppliers or partners, diversification of resources or markets, contingency planning, or other proactive measures aimed at reducing the overall project risk profile.

4. Risk Identification in International Engineering Project Contracting With Third World Countries in Africa

4.1. The Main Methods for Identifying Project Risks

- Check listing: This method involves creating a comprehensive checklist of potential risks that may arise during the course of a project. The implementation of the check listing method begins with identifying all possible risks that could impact the project. This step requires input from various stakeholders including engineers, project managers, contractors, and local authorities. Once the risks are identified, they are categorized based on their potential impact and likelihood of occurrence. After compiling the list of risks, each risk is assessed based on its severity and probability. This assessment helps in prioritizing risks based on their potential impact on the project objectives. Risks that are deemed high in severity and likelihood are given more attention and resources for mitigation.
- Flow Chart: The flow chart method of risk management is a visual representation of the various steps involved in managing risks throughout the project lifecycle. It provides a structured approach to identifying, analyzing, and responding to risks in a systematic manner. The first step in the flow chart method is to identify all potential risks that could affect the project. This involves brainstorming with project stakeholders, reviewing historical data from similar projects, and conducting risk assessments to determine possible threats. Once risks have been identified, they need to be analyzed to understand their potential impact on the project objectives. This step involves assessing the likelihood of each risk occurring and evaluating the severity of its consequences. After analyzing the risks, they are evaluated based on their significance and prioritized according to their potential impact on the project. Risks that pose a high threat to project success are given more attention during this stage.
- SWOT Analysis: SWOT analysis is a strategic planning tool used to identify and understand the Strengths, Weaknesses, Opportunities, and Threats related to a project or business venture with:-
  - Strength being factors such as technical expertise, experience in similar projects, access to resources, established partnerships with local entities, and a strong project management team.
  - Weaknesses being factors such as limited financial resources, lack of local knowledge or cultural understanding, inadequate infrastructure, political instability, or insufficient stakeholder engagement.

  - Opportunities being factors such as favorable government policies, economic growth trends, emerging technologies, potential for market expansion, or partnerships with local communities.
  - Threats may include factors such as political unrest, regulatory changes, currency fluctuations, environmental issues, supply chain disruptions, or security concerns. By conducting a comprehensive SWOT analysis at various stages of the project lifecycle, stakeholders can gain valuable insights into potential risks and opportunities, enabling them to make informed decisions and implement effective risk management strategies.
- Work Breakdown Structure (WBS): WBS method is a systematic approach that involves breaking down the project scope into smaller, more manageable components, which helps in organizing and understanding the various elements of the project. When applied to risk management, the WBS method allows project managers to identify potential risks at a granular level, assess their impact on different project components, and develop strategies to address and mitigate these risks effectively.

4.2. Classification of Risk Factors Associated with International Engineering Projects

From Table.1 below, it can be seen that after the risks associated with International Engineering Projects were both identified and classified, their individual characteristics differed from that of ordinary local engineering projects. In a general sense, they take into consideration more external risks at various levels, that is, considering the politics of the country where the project is located, changes in economic and social factors, fluctuations in the construction market, changes in construction regulations, consistency of contract systems; and not forgetting the internal risks brought on by the project itself.

Table 1 Classification of Risk Factors associated with International Engineering Projects

Classification of Risk	Factors
Environmental Risk	• Flood, earthquake, fire, typhoon, lightning and other uncontrollable natural forces • Unknown hydrological and meteorological conditions • Complex engineering geological conditions • Adverse weather conditions • The impact of construction on the surrounding environment
Political Risk	• Political instability • Tense international relations • Frequent altering of government policies • Corruption • Lack of sound legal system • Refusal to pay debts • Poor international reputation
Economic Risk	• Inflation • Foreign exchange risk • Fluctuations in labor and material supply • Interest rate fluctuations • Delayed Payment
Internal Project Risk	• Duration risk • Financial risk • Quality risk • Personal injury, safety and health accidents, and damage to engineering equipment. • Environmental and pollution issues • Issues related to communication and coordination with all participating parties

5. Risk Estimation and Evaluation in International Engineering Project Contracting With Third World Countries in Africa

In this context, risk estimation and evaluation uses a combination of quantitative and qualitative methods to estimate the weight of the risk; its degree of impact; possibility/frequency of occurrence; identification of the source of the risk; as well as to output results necessary for the stage of risk response.

In present times, there are quite a number of methods that can be used to estimate and evaluate risks in international engineering project contracting. Some of the commonly used methods include Check listing, Analytic Hierarchy Process (AHP), Statistics and probability, Fuzzy Mathematics, Sensitivity Analysis, Monte Carlo simulation, CIM model, and Influence diagrams to mention the least. From the list above, the first five methods are qualitative in nature whilst the remaining three that follow are quantitative in nature.

This study will only focus on The Analytic Hierarchy Process (AHP) and its application on an engineering case analysis.

5.1. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a flexible and easily understandable method for engineering risk assessment. Analytic Hierarchy Process (AHP) is generally used during the bidding stage of engineering projects to evaluate engineering risks, enabling project managers to have a comprehensive understanding of the risk situation of the proposed project before bidding, and to determine the degree of risk of the engineering project, providing a basis for deciding whether to bid or not.

5.1.1. Analytic Hierarchy Process (AHP) Step Break Down (Bid Acceptance Risk Estimation And Evaluation):

- Establishing the Hierarchy: The first step in using AHP for contract/bidding risk assessment is to establish a hierarchy of the decision-making criteria. This hierarchy typically consists of three levels: the goal, criteria, and alternatives. In the context of international engineering projects, the goal may be to select the most suitable contractor or bid proposal while considering various risk factors.
- Defining Criteria and Sub-Criteria: Once the hierarchy is established, the next step is to define the criteria and sub-criteria that will be used to evaluate the risks associated with each contract or bid. These criteria can include financial stability, technical expertise, past performance, compliance with regulations, political stability of the country, cultural differences, etc.
- Pairwise Comparisons: A key aspect of AHP is the pairwise comparison process, where decision-makers compare each criterion and sub-criterion against one another in terms of their relative importance. This process helps assign numerical weights to each criterion based on their significance in relation to the overall goal.
- Consistency Check: After completing pairwise comparisons, a consistency check should be performed to ensure that decision-makers have provided reliable judgments. Inconsistencies may indicate a need for revisiting comparisons or clarifying decision-making criteria.
- Aggregating Judgments: Once all pairwise comparisons are made and consistency is verified, the next step involves aggregating these judgments to calculate overall priorities for each criterion and sub-criterion. This aggregation process typically utilizes mathematical calculations to derive final weights.
- Risk Assessment and Evaluation: With weighted criteria in place, decision-makers can now assess and evaluate contract/bidding risks by applying these weights to different alternatives (contractors or bids). By multiplying the weights with performance scores or risk levels associated with each alternative, an overall risk assessment can be obtained.

5.1.2. Analytic Hierarchy Process (AHP) Step Break Down (Bid Proposal Risk Estimation And Evaluation)

- The first step would be to utilize the work breakdown structure (WBS) method to segment the entire project into manageable segmented work packages according to similarity in the nature of work or consecutive execution of works. This allows risk analysis to be performed on each individual segmented work package.
- The second step would be to identify and classify risks for each specific work package, and then construct a risk framework diagram composed of risk factors and sub-factors for that particular work package.
- The third step would be to construct a judgment matrix comprising of the factors and sub-factors from the second step and ask experts of the field to judge the importance of each element in the factor layer and sub-factor layer according to certain rules before proceeding to calculate the weight value of each element.
- The fourth step would then be to construct a judgment matrix that reflects the hazard degree of each risk factor. The hazard degree is usually represented by the three concepts of high risk, medium risk and low risk. It is here that experts of the field will be involved once again in order for the relative hazard degree value of each sub-risk factor to be calculated.
- The fifth step would be to utilize computer software to test the consistency of the expert's judgments. Since expert evaluation experience and conscious subjective judgment vary, the results of steps three and four will need to be checked for the consistency. If the inspection fails, the experts will need to go through the evaluation process again until the consistency check is favorable.

- Step six would involve unifying the calculated relative hazard values of each sub-factor according to the probability value of the risk of the work package being high risk, medium risk or low risk.
- Step seven would involve making sure all the work packages have been analyzed and evaluated in accordance with step six before arranging them together again in order to obtain the overall risk level of the project.
- Step eight would involve Decision-making and management in correspondence with the outcome of step seven.

6. Risk Response in International Engineering Project Contracting

International engineering projects are multinational economic activities with multiple influencing factors and complex project environments. Risk events may occur in various stages of international engineering projects, and if they occur, they will have an impact on the project. Therefore, reasonable risk response measures and methods should be taken to eliminate or reduce the various possibilities of risk events and minimize risk losses as much as possible. The formulation and implementation of risk response measures are the focus of risk management and a key factor in the success of international engineering projects.

Based on the degree of risk impact, probability and time of risk occurrence, various risk response measures can be taken. Below are some of them:

6.1. Risk Avoidance

Risk avoidance countermeasures aim to avoid potential losses or uncertainties that may arise by avoiding project risk factors. Risk avoidance is the simplest method amongst the various risk response measures out there as one has the option of not taking up an offer/ bid.

For instance, if it is predicted that the political situation of a certain country is unstable and the situation cannot be rectified in the near future, the said country will definitely default on the bid, making the international engineering project contract void. Adopting risk avoidance here will make it possible to cut on losses that will be caused by this political event risk. From an economic perspective this method is viable as the costs and losses associated with hoping that the contract will become valid again will exceed the economic benefits of the project if it were to be completed.

6.2. Loss Control Measures

Loss control measures are the means and measures that project managers adopt to reduce the chance of losses, or to deal with project risks by reducing the severity of losses that occur. As opposed to risk avoidance, loss control measures are a proactive risk response measure.

Loss control includes two aspects: loss prevention and loss suppression. Loss prevention is to take preventive measures to reduce the chance of loss, such as preparing and implementing various safety plans; loss suppression on the other hand attempts to reduce the severity of the risk of loss through the formulation of contingency plans.

6.3. Risk Retention

Risk retention refers to the deliberate decision by a party involved in the project to accept and bear the financial consequences of certain risks that may arise during the project execution. This means that instead of transferring the risk to another party through insurance or contractual agreements, the entity retains the risk within its own organization.

Before deciding on risk retention, it is crucial to identify and assess all potential risks associated with the project. Once risks are identified, it is essential to evaluate the potential impact and likelihood of occurrence for each risk. This assessment helps in determining which risks are suitable for retention based on their severity and frequency. A cost-benefit analysis then needs to be conducted in order to weigh the advantages and disadvantages of retaining specific risks. Factors such as the availability and cost of insurance, risk tolerance levels, financial capacity, and overall project objectives play a significant role in this evaluation.

It should be borne in mind that when choosing risk retention, it is important to implement effective risk mitigation strategies to minimize the impact of the retained risks. This may involve developing contingency plans, enhancing project monitoring mechanisms, or diversifying operations to reduce vulnerability. Furthermore the decision to retain risks should also be supported by clear legal provisions within project contracts. These contracts should outline each party’s responsibilities regarding risk management and establish mechanisms for resolving disputes that may arise due to retained risks.

6.4. Risk Transfer

Risk transfer involves shifting the financial burden and responsibility for potential risks from one party to another through contractual agreements. This mechanism allows for the allocation of risks to the party best equipped to manage or mitigate them, thereby enhancing the overall project's chances of success. Benefits of a successful risk transfer are improved cost certainty, enhanced project resilience and optimized resource allocation.

Commonly used Risk Transfer Mechanisms include:

- **Insurance Policies**: One common method of risk transfer is through insurance policies. Project owners can purchase various types of insurance coverage to protect against specific risks such as construction delays, natural disasters, political instability, or financial losses.
- **Contractual Agreements**: Risk transfer can also be achieved through contractual agreements between project stakeholders. For example, a construction contract may include clauses that specify which party is responsible for certain risks, such as cost overruns or design errors.
- **Indemnification Clauses**: Indemnification clauses are another form of risk transfer where one party agrees to compensate the other for any losses or damages arising from specified risks.

6.5. Risk Monitoring In International Engineering Project Contracting

The last process of risk management is risk monitoring. Risk monitoring is used to track identified risks, monitor residual risks, identify emerging risks, modify risk management plans, ensure the implementation of risk plans, and evaluate the effectiveness of risk mitigation.

The purpose of risk monitoring is to determine:

- Whether the risk response measures have been implemented as planned
- Whether the risk treatment has achieved the expected results
- Whether new response measures will have to be adopted
- Whether the project assumptions are still valid
- Whether the risk status has changed
- Whether factors that could be leading to new risks have emerged
- Whether appropriate emergency plans have been formulated
- Whether risks that have not yet been realized have emerged

7. General Engineering Case Analysis of Risk Management in International Engineering Project Contracting With Third World Countries in Africa

7.1. Project Risk Identification

Unlike typical local engineering contract projects, international engineering projects with third world countries in Africa have their own unique characteristics. The risks faced by these engineering projects have been identified below based on the definition and identification methodology of risk management described in previous chapters. The risks faced by these kind of projects can be classified into environmental risks, political risks, economic risks, and internal project risks.

Table 2 Classification of Risk Factors associated with International Engineering Projects in Africa

Classification of Risk	Factors
Environmental Risk	• Impact of rainy season on construction • Remote geographical location • Poor quality of material • Poor local medical service conditions
Political Risk	• War and Turmoil • Frequent altering of government policies • Lack of sound legal system • Corruption • Economic backwardness and poor security conditions • Language barriers and cultural difference
Economic Risk	• Fluctuation of Exchange rates • Inflation • Various taxes and fees • Difficulty purchasing engineering materials • Project payment risk
Internal Project Risk	• Contractors on a tight schedule • Non familiarity with FIDIC contracts, local codes and standards • Access to engineering equipment from abroad and their maintenance during use is difficult • Poor subcontractor ability

7.2. Project Risk Estimation and Evaluation

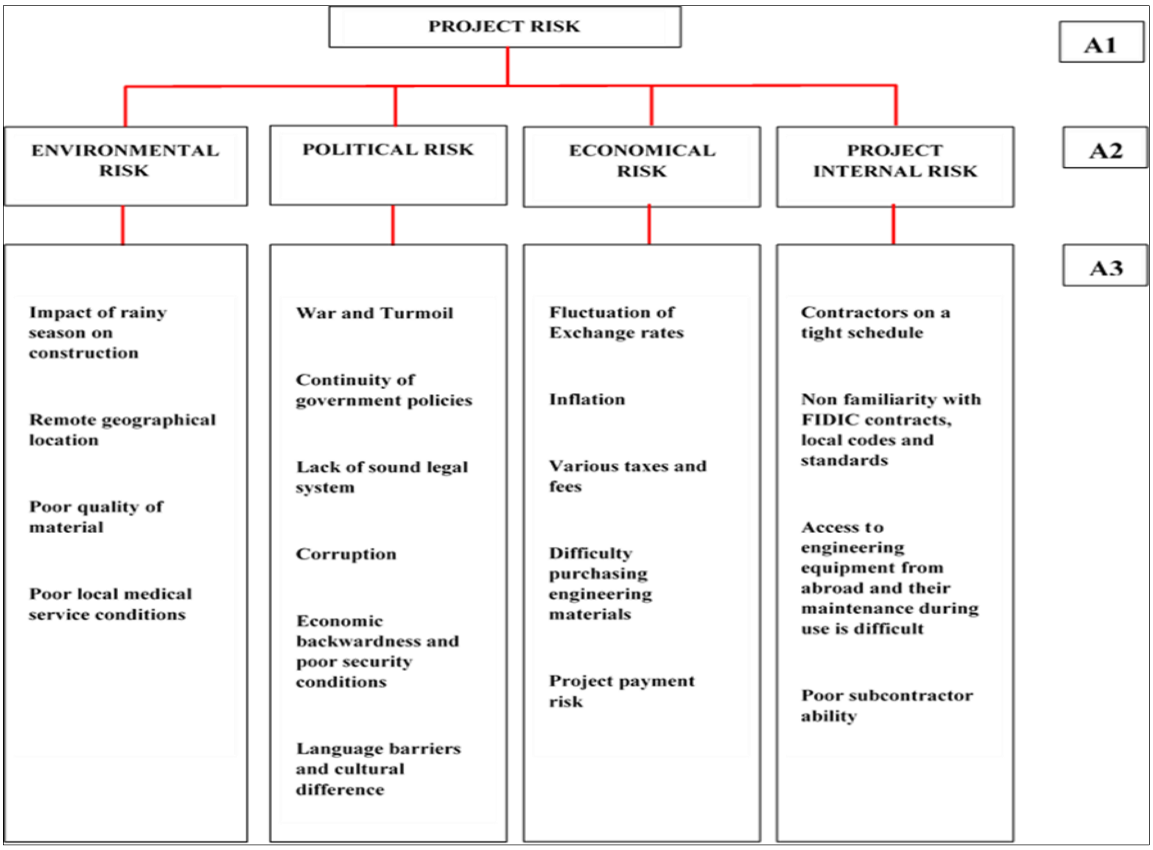

Figure 1 Project risk framework diagram

With reference to the above frame work diagram, the expert survey method can used to give a weight value to the degree of risk for each risk factor of the level A2; forming a judgment matrix as shown in the diagram and table below:

$$R = \begin{pmatrix} 1 & 3 & 1/2 & 5 \\ 1/3 & 1 & 1/4 & 2 \\ 2 & 4 & 1 & 3 \\ 1/5 & 1/2 & 1/3 & 1 \end{pmatrix}$$

Table 3 Judgment Matrix of Project Risk Factors

	Environmental Risk	**Political Risk**	**Economic Risk**	**Internal Project Risk**
Environmental Risk (C1)	1	3	1/2	5
Political Risk (C2)	1/3	1	1/4	2
Economic Risk (C3)	2	4	1	3
Internal Project Risk (C4)	1/5	1/2	1/3	1

Then we can now proceed on to calculate the weight coefficient value of each indicator.

$$M_i = \prod_{j=1}^{n} b_{ij}$$

Where $i = 1,2 \ldots \ldots n$

$$M_1 = 1 \times 3 \times 1/2 \times 5 = 7.5 \; M_2 = 1/3 \times 1 \times 1/4 \times 2 = 0.1667$$

$$M_3 = 2 \times 4 \times 1 \times 3 = 24 \; M_4 = 1/5 \times 1/2 \times 1/3 \times 1 = 0.0333$$

Then, we calculate the root value of M_i for each row, where $\overline{w}_i$ represents the root value of M_i for each row.

$$\overline{w}_i = \sqrt[n]{M_i} \text{ where } i = 1,2 \ldots . n \; \overline{w}_1 = \sqrt[4]{7.5} = 1.6549 \; \overline{w}_2 = \sqrt[4]{0.1667} = 1.6549$$

$$\overline{w}_3 = \sqrt[4]{24} = 2.2134 \; \overline{w}_4 = \sqrt[4]{0.0333} = 0.4272$$

Then we shall perform $(\overline{w}_1 \overline{w}_3 \overline{w}_3 \overline{w}_4)^T$ normalization to obtain each feature vector

$\boldsymbol{w_i} = \frac{\overline{w}_i}{\sum_{j=1}^{n} \overline{w}_j}$ So we get

$$\boldsymbol{w_1} = 1.6549/4.9345 = 0.3353 \; \boldsymbol{w_2} = 0.6390/4.9345 = 0.1295$$

$$\boldsymbol{w_3} = 2.2134/4.9345 = 0.4486 \; \boldsymbol{w_4} = 0.4272/4.9345 = 0.0866$$

Since $\boldsymbol{w_1} + \boldsymbol{w_2} + \boldsymbol{w_3} + \boldsymbol{w_4} = 1$, the weight of each indicator on the same layer complies with the requirement that each indicator on the same layer is assigned a value of one.

The next step is to conduct a consistency test on the judgment matrix. For this, we will need to calculate the maximum eigenvalue, and then use the maximum eigenvalue λ_{max} to find the judgment matrix deviation consistency index CI.

$$A_{w_1} = 1 \times 0.3353 + 3 \times 0.1295 + \frac{1}{2} \times 0.4486 + 5 \times 0.866 = 1.3811$$

$$A_{w_2} = \frac{1}{3} \times 0.3353 + 1 \times 0.1295 + \frac{1}{4} \times 0.4486 + 2 \times 0.866 = 0.5266$$

$$A_{w_3} = 2 \times 0.3353 + 4 \times 0.1295 + 1 \times 0.4486 + 3 \times 0.866 = 1.8970$$

$$A_{w_4} = \frac{1}{5} \times 0.3353 + \frac{1}{2} \times 0.1295 + \frac{1}{3} \times 0.4486 + 1 \times 0.866 = 0.3679$$

$$\lambda_{max} = \sum_{i=1}^{4} \frac{A_{w_i}}{4 \times w_i} = 1.029 + 1.0166 + 1.0572 + 1.0621 = 4.1656$$

$$CI = \frac{\lambda_{max} - 4}{4 - 1} = 0.1656/3 = 0{,}0552$$

After calculating the CI, we will need to find the respective average random-consistency index and use it to perform the consistency check.

Table 4 Average random-consistency index table

Matrix Order	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

RI value is 0.9 since matrix order is 4. $\frac{CI}{RI} = \frac{0.0552}{0.9} = 0.061 < 0.1$ The consistency of the judgment matrix is acceptable.

From the calculations, it can be seen that the weight of environmental risks is 33.53%, political risks are 12.95%, economic risks are 44.86 %, and internal project risks are 8.66%.

In the same manner, judgment matrix tables of level A3 of project risk factors can be constructed. Each of the judgment matrix table and calculation results are as follows:

7.3. Determination Of The Weights Of Various Risk Factors

Table 5 Judgment Matrix of Environmental Risk Factors

	Impact of rainy season on construction	**Remote geographical location**	**Poor quality of material**	**Poor local medical service conditions**
Impact of rainy season on construction (C1)	1	3	1/3	4
Remote geographical location (C2)	1/3	1	1/5	2
Poor quality of material (C3)	3	5	1	7
Poor local medical service conditions (C4)	1/4	1/2	1/7	1

$$w = (0.2532, 0.1082, 0.5731, 0.0655)\ , \lambda_{max} = 4.0583\ , CI = 0.0194\ , RI = 0.9$$

$\frac{CI}{RI} = 0.0216 < 0.1$ ((The consistency of the judgment matrix is acceptable.))

Table 6 Judgment Matrix of Political Risk Factors

	War and Turmoil	Government policies	Lack of sound legal system	Corruption	Economic backwardness and poor security conditions	Language barriers and cultural difference
War and Turmoil (C1)	1	2	3	1/2	1/3	4
Government policies (C2)	1/2	1	2	1/3	1/4	3
Lack of sound legal system (C3)	1/3	1/2	1	1/5	1/4	2
Corruption (C4)	2	3	5	1	2	8
Economic backwardness and poor security conditions (C5)	3	4	4	1/2	1	5
Language barriers and cultural difference (C6)	1/4	1/3	1/2	1/8	1/5	1

$$w = (0.1596, 0.1005, 0.0640, 0.3544, 0.2813, 0.0401),\ \lambda_{max} = 6.1747\ ,\ CI = 0.0349$$

$RI = 1.24$, $\frac{CI}{RI} = 0.0282 < 0.1$ ((The consistency of the judgment matrix is acceptable.))

Table 7 Judgment Matrix of Economic Project Risk Factors

	Fluctuation of Exchange rates	Inflation	Various taxes and fees	Difficulty purchasing engineering materials	Project payment risk
Fluctuation of Exchange rates (C1)	1	2	4	1/3	1/2
Inflation (C2)	1/2	1	2	1/7	1/5
Various taxes and fees (C3)	1/4	1/2	1	1/8	1/6
Difficulty purchasing engineering materials (C4)	3	7	8	1	2
Project payment risk (C5)	2	5	6	1/2	1

$$w = (0.1507, 0.0699, 0.0433, 0.4553, 0.2809),\ \lambda_{max} = 5.0510\ ,\ CI = 0.0127$$

$RI = 1.24$, $\frac{CI}{RI} = 0.0114 < 0.1$ ((The consistency of the judgment matrix is acceptable.))

Table 8 Judgment Matrix of Internal Project Risk Factors

	Contractors on a tight schedule	**Non familiarity with FIDIC contracts, local codes and standards,**	**Access to engineering equipment from abroad and their maintenance during use is difficult**	**Poor subcontractor ability**
Contractors on a tight schedule (C1)	1	2	1/4	3
Non familiarity with FIDIC contracts, local codes and standards (C2)	1/2	1	1/5	1/2
Access to engineering equipment from abroad and their maintenance during use is difficult (C3)	4	5	1	7
Poor subcontractor ability (C4)	1/3	2	1/7	1

$$w = (0.1985, 0.0848, 0.6170, 0.0996),\ \lambda_{max} = 4.174,\ CI = 0.0588$$

$RI = 1.24$, $\frac{CI}{RI} = 0.0654 < 0.1$ ((The consistency of the judgment matrix is acceptable.))

By calculating the project risk levels A2 and A3, we can obtain the weight coefficient of each of the risk factors of the entire project. Below is table summarizing the weight coefficient index.

Table 9 Weight coefficient Index of Risk in Project

Risk Factors		**LEVEL A2**	**LEVEL A3**	**OVERALL**
Environmental Risk	C1	0.3353	0.2532	0.0849
	C2	0.3353	0.1082	0.0363
	C3	0.3353	0.5731	0.1922
	C4	0.3353	0.0655	0.0220
Political Risk	C1	0.1295	0.1596	0.0207
	C2	0.1295	0.1005	0.0130
	C3	0.1295	0.0640	0.0083
	C4	0.1295	0.3544	0.0459
	C5	0.1295	0.2813	0.0364
	C6	0.1295	0.0401	0.0052
Economic Risk	C1	0.4486	0.1507	0.0676
	C2	0.4486	0.0699	0.0313
	C3	0.4486	0.0433	0.0194
	C4	0.4486	0.4553	0.2043
	C5	0.4486	0.2809	0.1260
Internal Project Risk	C1	0.0866	0.1985	0.0172
	C2	0.0866	0.0848	0.0073
	C3	0.0866	0.6170	0.0534
	C4	0.0866	0.0996	0.0086

From the values of weight coefficients, we can now proceed to classify the risks in classes of high to low.

- RISK CLASS 1 (X > 0.1) - Poor quality of material, Difficulty purchasing engineering materials, Project payment risk.
- RISK CLASS 2 (0.005<0.1) - Impact of rainy season on construction, Fluctuation of Exchange rates, Access to engineering equipment from abroad and their maintenance during use is difficult.
- RISK CLASS 3 (0.03<0.05) - Remote geographical location, Poor local medical service conditions, War and Turmoil, Corruption, Economic backwardness and poor security conditions, Inflation.
- RISK CLASS 4 (0.00<0.03) - Continuity of government policies, Lack of sound legal system, Language barriers and cultural difference, Various taxes and fees, Contractors on a tight schedule, Non familiarity with FIDIC contracts, local codes and standards, Poor subcontractor ability

7.4. Project Risk Response

7.4.1. Response to RISK CLASS 1

- Poor quality material:
  - Contact local geological department for geological data.
  - Hire experienced domestic engineering and technical personnel for material search.
- Difficulty purchasing engineering materials
  - Allocate funds to procure and have them delivered to site regardless of distance.
  - Find suitable alternative materials.
- Project Payment Risk
  - Make sure in advance that the contract has a provision for tackling this matter.

7.4.2. Response to RISK CLASS 2

- Impact of rainy season on construction:
  - Fully utilize rainwater statistics to understand precipitation patterns.
  - Have Construction start during the dry season with work and rest schedules being adjusted during the rainy season.
  - During rainy season focus should be on less rain-impacted projects like earthworks and sub-base construction.
- Fluctuation of Exchange rates
  - Make sure to utilize The United States Dollar instead of local unstable currency.
- Access to engineering equipment from abroad and their maintenance during use is difficult
  - Have equipment procured and delivered to site of works well in advance.
  - Have access to local mechanics of expert skillset capable of maintaining machinery.

7.4.3. Response to RISK CLASS 3

- Remote geographical location:
  - Nothing can be done.
- Poor local medical service conditions
  - Have in house trained health personnel and health related equipment ready on site.
- War and Turmoil
  - Intensify security
  - Set precautionary and safety guidelines for workers. No late night movement as well.
- Corruption
  - Seek assistance from relevant authorities if difficulties are faced.
- Economic backwardness and poor security conditions
  - Intensify security.
  - Set precautionary and safety guidelines for workers. No late night movement as well.
- Inflation
  - Make sure in advance that the contract has a provision for tackling this matter.

7.4.4. Response to RISK CLASS 4

  - Provide cultural and language training to engineering and technical personnel.
  - Hire local managers to handle external events and conflicts with local employees or natives.
  - Hire technical personnel with experience in work internationally.

  - Hire foreign project management consulting companies for project management

8. Conclusion

The study focused on developing a risk factor analysis system for international engineering projects, analyzing risk factors based on project characteristics, development trends, and risk sources. Stemming from that analysis, a risk management method system was also introduced, covering risk identification, estimation, evaluation, response, and monitoring. Furthermore, practical use of AHP method was used to conduct an empirical analysis of the risk management method system in international engineering project contracting with third world countries in Africa; demonstrating its effectiveness.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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