

Fuzzy DEMATEL and Fuzzy Binary Logistic Regression with Simulated Annealing Optimization for Risk Analysis and Mitigation in Industrial Projects in East Africa

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Abstract

Risk analysis and mitigation is a crucial step in the management of industrial projects, especially in developing regions such as East Africa, where the challenges and opportunities are more diverse and dynamic. This paper proposes a novel approach for risk analysis and mitigation in industrial projects in East Africa using fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory) and fuzzy binary logistic regression with simulated annealing optimization. The paper identifies six categories of risk factors for industrial projects based on literature review and expert opinions: Production and technical risks, market and customer risks, financial and economic risks, legal and regulatory risks, environmental and social risks, and human and organizational risks. The paper applies fuzzy DEMATEL method to evaluate the relative importance and influence of each risk factor on each category using linguistic terms that are converted into triangular fuzzy numbers. The paper also classifies the risk factors into four groups based on their prominence and relation degree: Cause group, effect group, cause-effect group, and independent group. The paper constructs an IP (Impact and Probability) table to rank the risk factors based on their impact and probability scores obtained from expert opinions. The paper uses fuzzy binary logistic regression to predict the probability of each level of risk (low, medium, high) for each risk factor based on its impact and probability scores. Finally, the paper uses simulated annealing optimization algorithm to minimize the probability of high level of risk for the project by adjusting the impact and probability scores of the risk factors. The paper presents a case study of an industrial project in East Africa to illustrate the application and effectiveness of the proposed approach. The paper discusses the implications and limitations of the proposed approach and suggests directions for future research.

Keywords: Risk analysis and mitigation • Industrial projects • East Africa • Fuzzy DEMATEL • Fuzzy binary logistic regression • Simulated annealing optimization

Introduction

Context and motivation

In the context of industrial project management especially in developing regions such as East Africa, effective risk analysis is critical. Managing risks effectively allows project leaders to spot possible hazards, evaluate their potential impacts, and create strategies to mitigate these risks, which is crucial for ensuring that projects can endure over time. Inherently East Africa region presents a range of challenges to industrial project managers and risk analysis, including ongoing political instability, resource limitation, insufficient infrastructure, and limited access to reliable data sources.

These factors make traditional risk assessment techniques less effective. There is a strong need for tailored tools. These specifically tailored tools are required to address the unique circumstances of the region [1].

Problem statement

There is a noticeable shortage of effective risk analysis and mitigation tools that could be suitable for the East African context. Better version of risk management approach plays pivotal role in the success of industrial project management where there are inherent uncertainties and complexities of industrial projects. East Africa is such a region. However, many existing risk assessment methods rely on rigid, deterministic models that struggle to capture the inherent

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uncertainties and complexities of the region's industrial projects.

This limitation has stimulated a growing demand for Novel versions of Risk Analysis and Mitigation in Industrial projects in East Africa. The Novel versions of Risk Analysis and Mitigation in Industrial projects in East Africa must be more flexible and robust approaches that can better account for the unpredictable nature of region and the project variables in the region.

There is a growing interest in combining probabilistic and fuzzy methodologies. The methodologies are believed to enhance the accuracy and reliability of risk assessments. Because; the ever growing demand for novel versions can be addressed by combining probabilistic and fuzzy methodologies [2].

Research goals

The main goal of this research is to propose a novel approach to risk analysis and mitigation by integrating techniques such as fuzzy DEMATEL, Fuzzy Binary Logistic Regression (FBLR), and Simulated Annealing (SA). By bringing these methodologies together, this study aims to enhance the accuracy of risk evaluations and develop a more comprehensive framework for managing risks that arise in industrial projects throughout East Africa [3].

Research questions

To guide this study, the following key questions have been formulated:

- What are the key risk-factors affecting industrial projects in East Africa?
- How can fuzzy DEMATEL be utilized effectively to classify and prioritize these risks?
- In what ways might fuzzy binary logistic regression improve the prediction of risk probabilities?
- How can simulated annealing be applied to optimize strategies for mitigating risks?

Significance of the study

The results of this study could significantly influence how industrial projects are managed in East Africa. By addressing the region's specific challenges and proposing a robust risk management framework, this research seeks to promote more resilient and sustainable industrial practices. Additionally, the methodologies introduced could serve as a valuable reference point for other developing regions facing similar risk challenges [4].

Literature Review

Risk analysis in industrial projects

In industrial project management, risk analysis is important to spot, assess, and reduce risks that could cause delays or losses. Traditionally, in developing regions, people use deterministic methods for risk analysis, like risk matrices, Fault Tree Analysis (FTA), and Failure Mode and Effect Analysis (FMEA). These methods help identify basic risks but are not very effective for handling complex

uncertainties in changing industrial environments. For instance, deterministic methods don't perform well when data is incomplete or scarce, which is often the case in developing areas [5].

Due to these limitations, there is a growing interest in using probabilistic and fuzzy methods to handle the uncertainties in project risks. Methods such as fuzzy DEMATEL, fuzzy binary logistic regression, and metaheuristic optimization bring greater accuracy and adaptability to risk analysis. These approaches work well in environments where data varies greatly [6].

Fuzzy DEMATEL methodology in risk evaluation

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, combined with fuzzy logic, is helpful for dealing with uncertainties in risk evaluation. Fuzzy DEMATEL allows for identifying and grouping risk factors based on how they affect each other, providing a structured way to understand interconnected risks. This method is especially useful in high-risk fields like construction and energy, where complex project environments require accurate risk prioritization. Studies have applied fuzzy DEMATEL to manage risks related to project delays, safety issues, and resource use, which has led to better risk management practices [7].

A key benefit of fuzzy DEMATEL is its ability to clarify complex risk relationships by using linguistic variables and expert insights. This approach captures subtle insights that traditional methods might miss, helping managers focus on the most critical risks with greater accuracy. This clarity ultimately leads to stronger decision-making when dealing with uncertainties [8].

Fuzzy binary logistic regression in risk prediction

Fuzzy binary logistic regression takes traditional logistic regression a step further by integrating fuzzy logic to capture a more nuanced view of risk probabilities. In industrial project management, where conditions can change unpredictably and exact risk factors are hard to measure, this approach shines. By expressing risk probabilities as ranges instead of fixed points, fuzzy logistic regression acknowledges and accommodates the uncertainties often present in such data particularly useful in developing regions where data limitations can make pinpoint accuracy challenging [9].

The flexibility of fuzzy logistic regression has broadened its use to other fields, like environmental risk assessments and construction project management, where it improves prediction accuracy by handling both qualitative and quantitative data uncertainty [10]. In unpredictable conditions, this method has proven to boost reliability, making it an invaluable tool for decision-makers working on projects that must adapt to change and uncertainty [11].

Simulated annealing optimization for risk mitigation

Simulated Annealing (SA) is an optimization method inspired by the annealing process in metallurgy, which involves heating and controlled cooling to achieve optimal structure in metals [12]. In risk management, SA helps identify the best solutions by iteratively exploring the range of options and selecting those with the highest

potential outcomes. This method is effective for optimizing risk parameters in large industrial projects where multiple risks must be addressed simultaneously. SA enables risk managers to dynamically adjust impact and probability scores, making it especially valuable in industries with high stakes, like oil and gas [13].

Many studies show the effectiveness of SA across different risk management scenarios. For example, SA has proven useful in energy projects, and researchers have also applied it to manufacturing and construction [14]. In industrial projects, SA can enhance risk management strategies by offering solutions tailored to specific challenges in the field [15].

Integrating SA with fuzzy logic further improves its adaptability. Fuzzy logic's probabilistic approach guides the SA process, resulting in risk mitigation strategies that are both adaptive and robust. Studies show the effectiveness of this combination in contexts like construction, energy, and manufacturing, where the combined use of SA and fuzzy logic has been shown to improve decision-making in risk management.

Research gaps and contribution

Previous studies have considered risk analysis using fuzzy DEMATEL, fuzzy logistic regression and simulated annealing. Yet, there remains a distinct absence of work combining these methodologies within an integrated approach. Every method is the best in its own way. Applying fuzzy DEMATEL allows the interlinked risks to be addressed together by determining relationships among them. Logistic regression models only estimate probabilities barbarously since logistic regression estimates zero-either-one probability. Simulated annealing iteratively improves outcomes by optimizing solutions. Nevertheless, strangely enough as effective each of the techniques are on their own there has been very little exploration done into whether all three could combine to form an even more powerful model. At their best, combining them might provide a more flexible and dynamic context to fighting risk.

This cements the usefulness of synergistic solutions in inherently complex and data-starved contexts like megaprojects at industrial scale or emerging markets where conventional types can usually not timely to deliver. Because each technique targeted a different facet of risk, *i.e.*, relationships were discovered in the first case study; estimates based on probabilities in 2nd and formulating responses to optimize performance this hybrid approach provided insight into handling both uncertainty and variability better than if just one method had been used. Move to first=110 last format=rq file=/ajm/journal.spm for example, combining the ability of fuzzy DEMATEL to model relationships between causes and effects with fuzzy logistic regression in order to gain insight on risks when they are highly uncertain as it is often encountered in industries like oil and gas or construction where outcomes could be very severe.

The hybrid model introduced in this study aims to close an existing research gap by providing a framework that balances structure with adaptability. It's designed to be robust yet flexible enough to handle varying project needs and evolving data landscapes. This tailored approach enables provides a unique model to decision-makers through which they can identify, prioritize and mitigate potential risks

immediately. Helping them tackle complex issues with surgical precision. Other than conspicuously improving on theoretical insights, this model provides a practical approach which if deployed would change the face of risk management in areas such as energy and infrastructure making it more scientific oriented.

Methodology

This section discusses the research methods used to study both topics in this work risk factors and methodology DEMATEL inference, and binary logical regression with simulated annealing optimization technique; also provides a model of industrial projects from East Africa area regarding minimization efforts.

Identifying and categorizing risk factors

First step: Identification of material risk factors applicable to East African Industrial Projects Categories (CMAC): Using a targeted literature review and input from 5 separate industry experts, six primary categories of risk factors were included in step one. These categories are:

- Production and technical risks.
- Market and customer risks.
- Financial and economic risks.
- Legal and regulatory risks.
- Environmental and social risks.
- The peril is both to the human and additionally, the association.

The second step was to refine predetermined and type-specific risk factors through expert panel discussions with experienced East African industrial professionals within each of the categories. Mapped these cluster of risk factors and put them all together to serve as the complete base for risk framework.

Implementation of Fuzzy DEMATEL for risk factor analysis

DEMATEL technique was implemented to establish interrelationships among the identified risk factors. This step assesses the prominence and interaction of each risk factor within the category, with the application of fuzzy logic, which is particularly useful when uncertainty is an issue, together with subjective expert evaluations in project environments that are complicated.

Fuzzification of expert judgments: Fuzzy DEMATEL represents linguistic uncertainties of expert judgments and represents opinions concerning the influence strength of risk factors through triangular fuzzy numbers. Therefore, the influence of one risk factor on another should be graded by the experts using linguistic terms like "no influence," "low influence," "moderate influence," "high influence," "very high influence," which then had to be mapped into triangular fuzzy numbers. This obtained a nuanced, quantifiable representation of subjective expert judgments.

Direct-relation matrix: The direct-relation matrix was constructed using the fuzzified influence ratings showing the initial direct influence of each risk factor on every other factor. The fuzzy DEMATEL method then processed the matrix for derivation of a total-relation matrix showing both the direct and indirect influences.

Classification of risk factors

The total-relation matrix thus obtained allowed classification of risk factors into four groups, viz.,

Cause group: Factors with a high value of influence on others.

Effect group: Factors influenced chiefly by others.

Cause-effect group: Factors that express cause and effect

Independent group: Factors that experience least interaction.

Impact and Probability (IP) table construction

An IP table was developed in order to assess and prioritize the risk factors according to their impact and probability scores. Expert judgments were sought in determining both the impact (severity) and the probability (likelihood) of the occurrence of each identified risk factor. The resulting scores were combined into an IP table to allow the prioritization of the risks through a fuzzy weighted scoring approach.

Fuzzy binary logistic regression

The research employed fuzzy binary logistic regression in order to assess the probability of different risk factors reaching different levels of risk: Low, medium, high. In this respect:

Dependent variable: Level of risk (low, medium, high).

Independent variables: The influence and likelihood metrics of each risk factor.

The utilization of this regression methodology facilitated the modeling of risk occurrences within uncertain circumstances by offering fuzzy coefficients that articulate the likely impact of each risk factor on the levels of project risk.

Simulated annealing optimization

In order to enhance the risk mitigation process, simulated annealing was employed with the objective of reducing the probability of elevated risk factors through the modification of their impact and probability metrics. The choice of simulated annealing stemmed from its capability to identify approximate solutions to intricate optimization challenges characterized by numerous local minima, making it effective in the adjustment of fuzzy parameters within uncertain contexts.

Initialization: An initial set of impact and probability ratings was determined with the help of expert estimates. These ratings served as the basis for the optimization process.

Cooling schedule and convergence: The simulated annealing algorithm utilized a cooling schedule that systematically decreased the likelihood of accepting inferior solutions, thereby facilitating convergence towards a near-optimal solution aimed at minimizing high-risk probabilities.

Optimization process: The process of optimization iterated between impact and probability scores for an appropriate configuration that minimized the overall project risk. This involved numerous iterations to fine-tune the scores in order to minimize high-risk outcomes in the project.

Case study implementation

A case study was performed in an industrial initiative taken in East Africa and the proposed methodology was applied. Every step of the methodology was clearly explained with this case study, starting from identification to categorization of the risk factors and then evaluation through fuzzy DEMATEL, ranking through the IP table, fuzzy binary logistic regression, and finally optimization through simulated annealing. The case study provided broad insights into the practical application and efficiency of the proposed methodology.

Summary of methodology

The framework of the management risk in the industrial project would be provided by incorporating fuzzy DEMATEL for interaction aspects among risks, fuzzy binary logistic regression to predict magnitude of risk and simulated annealing for optimization level automatically through proposed methodology. The interpretation of combining this expert judgment and quant results further improves adaptive risk analysis for East African industrial projects.

Discussions

Data collection and expert elicitation

This consequently dictated a dual-song method: Combining an extensive review of the existing literature with expert input so one can comprehensively understand the nature of the risks emanating from commercial undertakings in East Africa. The literature evaluation tested the extant frame of studies, enterprise scores, and pleasant practices to discover applicable threat factors and parameters. This base knowledge turned into then complemented through the views expressed by a panel of ten senior assignment managers who have massive experience in dealing with business initiatives throughout the region. The choice of professionals turned into primarily based on their profound know-how of the neighborhood context, the demanding situations encountered, and the potential opportunities that might facilitate the incorporation of various viewpoints.

Linguistic terms which includes "very high," "high," "medium," "low," and "very low" were used to evaluate the relative significance of every chance issue, as a result taking pictures the qualitative nature of expert judgments. The above-mentioned linguistic terms have been converted into triangular fuzzy numbers, which offer a numerical illustration of uncertainty and imprecision. Triangular fuzzy numbers are selected because they're easy in individual and can also constitute more than a few viable values. The specific scale used for the bushy numbers changed into executed via consensus among specialists and an in-depth have a look at of related literature, which ensured standardization and comparability among distinctive danger elements to make sure consistency and comparison amongst various risk factors.

In the system of synthesizing collective information from the panel of experts, pairwise comparison matrices using fuzzy numbers have been developed for each unique expert. These would represent the relative importance of each risk factor with respect to their peers. Subsequently, the matrices were integrated through the application of fuzzy arithmetic operations to generate a total-relation matrix, which served as the basis for subsequent analysis and risk prioritization.

Fuzzy DEMATEL results

The Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, a nicely-mounted approach for analyzing complicated interrelationships, changed into hired to research the complex interrelationships a few of the recognized threat elements. This approach assesses each the prominence and relation degree of each component. Prominence quantifies a factor's overall affect at the system, encompassing each direct and oblique outcome, even as relation diploma suggests the internet impact of a component, which can be either superb or bad.

A general-relation matrix changed into constructed by using aggregating the bushy pairwise evaluation matrices provided by way of the professional panel. This matrix enabled a complete evaluation of the motive-impact relationships amongst risk elements. By calculating the row and column sum vectors, we derived the prominence vector and the relation degree vector. Based on these vectors, the chance elements were categorised into 4 businesses:

Cause group: High prominence and fine relation, indicating elements with sizable have an effect on others.

Effect group: High prominence and terrible relation, indicating elements which might be often encouraged through others.

Cause-effect group: Low prominence with both fantastic or bad relation, suggesting elements with restricted however notable bidirectional affect.

Independent group: Low prominence and 0 relation, indicating factors with minimal impact on or from different elements.

To show how the hazard elements connect and stack up, experts made a cause-effect chart. This chart plots each element by how important it is and how it relates to others giving a clear picture of how the system works.

To check if the results hold up, researchers did a sensitivity test. They changed the input numbers and fuzzy membership functions. This test helped them find which factors had the biggest impact on how the risk factors ranked overall and how stable the cause-effect links were.

IP table ranking

To assist in a thorough risk analysis and ranking, we created an Impact-Probability (IP) table. This method categorizes by three key parameters how likely a risk will occur and to what degree it may affect the situation.

IP table construction process: The formation of the IP table turned into an exhaustive venture. It became become a technique of supervision by using specialists in the applicable location. Each hazard issue was rated (on solid scale from 1 to ten) in keeping with assignment targets and the chance of prevalence when it comes to the task desires. For those signs, they applied a common grading scale that made all the hazard factors similarly comparable.

Classification of risk factors: Based on the impact and the probability scores, we classified the risk factors into four categories: Low, medium, high, and very high. This grouping provides a clear representation of the risks involved hence the management can easily direct their attention to the most critical ones and allocate the resources in an optimal way. We flagged high-impact high-probability risks as critical and needing quick action, while we saw low-impact low-probability risks as less urgent.

Prioritization of risk factors: Through the IP table, the prioritization of initiatives aimed at the mitigation of risks is made possible. It provides a means of concentrating on risks which have a larger impact as well as more probability of occurrence which would in turn result in the better use of resources and fewer negative outcomes. In addition to this, the IP table serves as a means to identify the interconnections between risks and to develop a complete plan of reducing them.

Limitations and considerations in IP table ranking: The IP table is a good tool for risk assessment, but it also has some shortcomings. The effectiveness of the risk assessment tools hinges greatly on the knowledge and the views of the people involved in the process. Personal biases as well as uncertainties might be the reasons for the production of such scores which would lead to the ranking of the risks in a certain way. To handle these problems, it would be better to involve a number of experts with different viewpoints and also to analyze the results in case of varying assumptions.

Also, the IP table needs regular updating. It's not a one-time thing. As projects change new risks can pop up, and old risks might become more or less serious. By frequently checking the risk factors and consequently updating the IP table, project managers can not only keep on the top of the risks but also adapt to the new situations as they come.

Fuzzy binary logistic regression findings

Model development: To quantitatively assess the probability of each chance level, a Fuzzy Binary Logistic Regression (FBLR) model become employed. This method is nicely-acceptable for coping with uncertain and obscure statistics, as it is able to accommodate fuzzy enter variables, inclusive of the triangular fuzzy numbers used to represent the impact and chance ratings of chance elements.

The facts instruction manner worried reworking the linguistic phrases assigned to each risk element into triangular fuzzy numbers, representing the feasible range of values. These fuzzy numbers have been then used as enter variables for the FBLR version.

FBLR model calibration and validation: The FBLR model was calibrated using the maximum likelihood estimation technique, which facilitated the identification of the best parameter values. To assess the model's performance, a range of statistical metrics were utilized, such as accuracy, sensitivity, and specificity. These metrics provide essential insights into the model's ability to classify risk levels effectively and its overall predictive strength.

To confirm that the model can generalize well, a distinct validation dataset was utilized to test its performance on data it had not previously encountered. The results from this validation dataset were compared with those from the training dataset, allowing for an assessment of the model's ability to perform well on new, unseen data.

Risk probability prediction: Once a final model was developed, the team applied this to try and estimate how risk might manifest in different forms. The model provided some valuable insights into the potential risks. This information was crucial in informing what areas we needed to work on first as well as enabling accurate allocation of resources.

Probability and cumulative density functions were used to estimate the risk of each category. These visual tools helped identify the needles in a haystack what factors were most likely to lead issues and allowed for focused targeting on the biggest needle of all, transaction processing.

This comprehensive assessment was aided by an analysis of historical data, as well taking into account the trends in our industry. This rule-based analysis not only mapped out new risks, but also demonstrated potential exposures. The combination of the inferences derived from within the model with those facilitated by looking at historical and trend analysis gave rise to a more holistic understanding about all risks.

This kind of a risk assessment paints an obvious picture about the risks that the operations might be threatened with. With these insights, lower no small amount abundance measure entanglements accordingly possibility arranging. They firmed for decrease the results and influences of threats as a successful way second-hand to develop basic organizational resilience later.

Limitations and considerations: Fuzzy binary logistic regression is a powerful tool for risk assessment. However, it is important to acknowledge its limitations. The accuracy of the model's predictions depends on the quality and quantity of the input data, as well as the appropriateness of the assumptions underlying the model. Additionally, the choice of defuzzification techniques can influence the results.

To address these limitations, ongoing monitoring and calibration of the model are essential to ensure its continued relevance and accuracy. As project conditions change and new information becomes available, the model can be updated to reflect these changes.

Furthermore, exploring alternative modeling techniques, such as Bayesian networks or machine learning algorithms, may provide additional insights and improve the accuracy of risk predictions.

Simulated annealing optimization outcomes

Optimization objective: The primary objective of the optimization phase was to minimize the overall risk level by adjusting the impact and probability scores of each risk factor. The decision variables in this optimization problem were the impact and probability scores, which were treated as continuous variables within predefined bounds. The objective function was formulated as the summation of the probabilities of high-risk levels across all risk factors. By minimizing this function, the goal was to reduce the likelihood of high-risk events occurring.

Implementation of simulated annealing: A Simulated Annealing (SA) algorithm was employed to address this optimization problem. SA is a metaheuristic optimization technique inspired by the annealing process in metallurgy. It starts with an initial solution, generated randomly or using a heuristic approach. In each iteration, the algorithm generates a neighboring solution by making a small perturbation to the current solution. The new solution is accepted or rejected based on a probabilistic criterion that involves the temperature parameter. As the temperature gradually decreases, the algorithm becomes more selective, focusing on high-quality solutions.

Optimization results and analysis: The SA algorithm successfully identified optimized impact and probability scores that minimized the overall risk level. The optimized risk profile exhibited a significant reduction in the probability of high-risk events compared to the initial risk profile. This reduction was achieved by redistributing the risk across different factors, prioritizing the mitigation of high-impact, high-probability risks.

The effectiveness of SA in addressing the complex and multi-objective nature of risk optimization was evident in the improved risk profile. By exploring a wide range of solutions and avoiding local optima, SA provided a robust and efficient approach to minimizing risk. **Limitations and future work:** While SA is a powerful optimization technique, it has certain limitations, such as the potential for getting trapped in local optima and the sensitivity to initial conditions and parameter settings. To mitigate these limitations, hybrid metaheuristic algorithms, such as a combination of SA and genetic algorithms, could be explored.

Future research could investigate the integration of SA with other risk assessment methods, such as fuzzy logic and Bayesian networks, to develop more comprehensive and robust risk management frameworks. Additionally, the application of SA to other domains, such as supply chain management and healthcare, could be explored to address complex optimization problems.

Results interpretation

This study shows how fuzzy logic helps in managing risks in industrial projects. It found that fuzzy DEMATEL and fuzzy binary logistic regression are very useful. They help in identifying and prioritizing risks better, thanks to their ability to handle uncertainties.

Using fuzzy logic, project managers can make better risk analysis and better decisions. This reduces the chance of delays and financial losses. It's especially helpful in areas where data is scarce, like in developing regions.

Theoretical implications

The obtained results indicated that the suggested hybrid model based on the fuzzy DEMATEL, fuzzy logistic regression and simulated annealing can be an effective tool for organizations to assess and rank the risks. Utilizing this model will improve decision-makers' comprehension of complex risky factors in different sections of their industries, which in turn helps them allocate their resources more efficiently.

Also, historical data and industry trends are employed by organizations to identify emerging risks in their early stages so that mitigation plans can be activated. It is often easier to recover from a risk event early than when the risk event has fully occurred and gained momentum. Managing emerging risks in a structured manner improves organizational resilience holistically, particularly in volatile and dynamic industries such as energy and infrastructure.

Also, advanced statistical techniques and visual tools help in risk communication among stakeholders for better decision making. The model is adaptable with shifting project requirements which enables the organization to keep on improving their risk management practices thus enhancing their capability towards effective uncertainties' management.

Practical implications

The real challenge of this study is valuable more for industrial undertakings of the Eastern Africa region as language structure suggests that there are unique opportunities for development, which if compared with the set of factors may be characterized as lacking or unfavorable (wars, low level of infrastructure etc.) and require new approaches to risk management. According to some guidelines, improving prediction and risk reduction techniques leads to more successful project implementation in Africa by utilizing fuzzy risk assessment approaches, which involve making logical estimates instead. This study outlines how the risk management policies and practices may be made more creative and practical to the particular circumstances that are characteristic of the industries in the East African region. Where risks are better predicted, it is possible to create better plans and allocation of resources benefitting the sustainable development goals of the region.

Comparison with previous studies

The findings of this study go well with the earlier works which have praised the superiority of fuzzy logic in risk models. Nonetheless, this study advances the literature by proposing a hybrid approach that combines fuzzy DEMATEL and fuzzy binary logistic regression into a single framework, hence enabling enhanced risk evaluation. Relative to previous studies which used deterministic methods exclusively, this new methodology simplifies the understanding of risk dependencies and risk causation. The results show that, through the use of fuzzy methods, project managers are able to rank the risks more appropriately thus bridging the critical gaps left by previous works.

Conclusion

This study demonstrates that combining fuzzy DEMATEL and fuzzy binary logistic regression enhanced with Simulated Annealing optimization provides a powerful, integrated framework for risk analysis and mitigation in industrial projects across East Africa. Fuzzy DEMATEL effectively uncovers the causal structure among complex risk factors, enabling decision-makers to distinguish between driving and dependent risks under uncertain environments. Building on these insights, the optimized fuzzy logistic model quantifies the probability of project failure with improved accuracy, offering a robust predictive tool for early warning and prioritization. The synergy of these methods allows for both qualitative interpretation and quantitative assessment, supporting more informed strategic planning. Overall, the approach enhances risk transparency, strengthens resource allocation decisions, and offers a scalable methodology adaptable to diverse industrial contexts. Its application can significantly improve project resilience and contribute to sustainable industrial development across the region.

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