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Effect of Risk Management Strategies on Performance of Geothermal Energy Projects in Kenya

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Abstract

Purpose: Geothermal energy plays a critical role in enhancing energy security and supporting sustainable economic development in Kenya. However, geothermal projects continue to experience cost overruns, implementation delays, operational inefficiencies and financial challenges arising from inadequate risk management. This study examined the effect of risk management strategies on the performance of geothermal energy projects implemented through Public–Private Partnerships (PPPs) in Kenya. Specifically, the study assessed the influence of risk identification, risk assessment, risk allocation and risk mitigation on project performance.

Methodology: The study adopted a positivist philosophy and a quantitative cross-sectional research design. The target population comprised 517 stakeholders drawn from geothermal PPP projects in Kenya, including project managers, technical staff, support staff and government officials. A sample of 222 respondents was selected using stratified and simple random sampling techniques. Primary data were collected using structured questionnaires. Instrument validity was established using the Content Validity Index (CVI = 0.89), while reliability was confirmed through Cronbach's alpha coefficients ranging from 0.83 to 0.89. Data were analyzed using descriptive statistics, Pearson correlation and linear regression.

Findings: The findings revealed that risk management strategies have a positive and statistically significant effect on the performance of geothermal energy projects ($\beta = 0.598$, $p < 0.05$). The regression model explained 35.5% of the variation in project performance ($R^2 = 0.355$), indicating that effective risk identification, risk assessment, risk allocation and risk mitigation improve operational efficiency, schedule performance, budget performance and infrastructure sustainability. The findings further demonstrate that structured risk management is particularly important in geothermal projects because of their high capital intensity, geological uncertainty and long implementation periods. The study also extends New Public Management, New Public Governance and Agency theories by demonstrating how managerial efficiency, collaborative governance and contractual accountability collectively enhance project performance.

Unique Contribution to Theory, Practice and Policy: The study recommends institutionalizing comprehensive risk management frameworks across all phases of geothermal project development. Strengthening risk identification, assessment, allocation and mitigation will improve project delivery, enhance investor confidence and support Kenya's renewable energy objectives under Vision 2030 and Sustainable Development Goal 7.

Keywords: *Risk Management Strategies, Geothermal Energy, Project Performance, Public–Private Partnerships, Kenya*

JEL Codes: *D81, H54, L32, Q42*

INTRODUCTION

The global transition towards low-carbon energy systems has accelerated investment in renewable energy technologies as countries seek to reduce greenhouse gas emissions while strengthening energy security. Among renewable energy sources, geothermal energy is uniquely positioned because it provides reliable baseload electricity independent of weather conditions, unlike solar and wind energy (International Energy Agency [IEA], 2024; Lund & Toth, 2021). Advances in geothermal exploration, drilling technologies and reservoir management have further enhanced its contribution to sustainable electricity generation and industrial heat supply, making it an important component of national energy transition strategies and the realization of Sustainable Development Goal 7 (Breede et al., 2024; IEA, 2024).

Kenya is Africa's leading producer of geothermal electricity and ranks among the world's major geothermal power producers (IEA, 2024; Ministry of Energy and Petroleum, 2025). The country has an estimated geothermal potential exceeding 10,000 MW within the Kenyan Rift Valley, although only a small proportion has been commercially exploited (Ministry of Energy and Petroleum, 2025; Rotich et al., 2024). Public investment through the Kenya Electricity Generating Company (KenGen) and the Geothermal Development Company (GDC), complemented by Public-Private Partnership (PPP) initiatives in fields such as Olkaria and Menengai, has significantly expanded geothermal generation capacity and reduced reliance on fossil fuels (IEA, 2024; Ministry of Energy and Petroleum, 2025). Nevertheless, geothermal projects continue to experience implementation challenges, including high exploration costs, financing constraints, geological uncertainty, contractual complexities, schedule delays and cost overruns, which adversely affect project performance and long-term investment sustainability (Rotich et al., 2024; Ministry of Energy and Petroleum, 2025).

Unlike conventional infrastructure projects, geothermal developments progress through distinct phases characterized by different risk profiles. The exploration and drilling phase is associated with geological uncertainty, reservoir characterization challenges, drilling failure and environmental risks because the commercial viability of geothermal resources cannot be confirmed until drilling is completed (Lukawski et al., 2016; Witter et al., 2019; Okwiri, 2023). Once viable resources have been established, projects move into the infrastructure development and power plant phase, where financial, contractual, procurement, construction and operational risks become more pronounced (Kępińska et al., 2024; Magicho & Kwasira, 2024). These distinct phases require different risk management approaches, highlighting the need for structured strategies that address both technical uncertainties during exploration and financial and operational risks during project development.

Effective risk management is therefore fundamental to the successful implementation of geothermal projects, particularly under PPP arrangements where risks must be shared among multiple stakeholders. According to ISO 31000 (2018), risk management comprises systematic processes of risk identification, assessment, allocation and mitigation aimed at reducing uncertainty and improving project outcomes. Risk identification facilitates the early recognition of potential threats, risk assessment determines their likelihood and consequences, risk allocation assigns responsibility to the party best positioned to manage each risk, while risk mitigation focuses on minimizing the probability or impact of adverse events. Empirical evidence indicates that integrating these practices enhances project delivery through improved cost control, schedule adherence and operational performance in infrastructure and PPP projects (Rasheed et al., 2022; Nur et al., 2023; Magicho & Kwasira, 2024).

Project performance is increasingly viewed as a multidimensional construct that extends beyond the traditional measures of time, cost and quality, particularly for capital-intensive infrastructure projects (Toor & Ogunlana, 2010; Liu et al., 2016). Accordingly, this study measures geothermal project performance using four objective indicators: operational efficiency, schedule performance, budget performance and infrastructure sustainability. Operational efficiency reflects the extent to which geothermal facilities achieve planned operational targets with minimal disruptions; schedule performance measures completion of project activities within approved timelines; budget performance evaluates adherence to approved project costs; and infrastructure sustainability assesses the ability of project facilities to maintain reliable long-term operations (Liu et al., 2016; Du et al., 2023; Wang et al., 2022). These indicators provide measurable dimensions of project success and align with the study's methodological framework.

Although risk management has been widely studied in construction, infrastructure and PPP projects, evidence specific to geothermal energy projects remains limited. Existing studies in Kenya have largely examined isolated categories of risk, including market, political and operational risks, while broader geothermal research has focused predominantly on technical and geological uncertainties (Odhiambo et al., 2020; Rasheed et al., 2022; Kępińska et al., 2024). Consequently, limited empirical evidence exists on the integrated effect of risk identification, risk assessment, risk allocation and risk mitigation on the performance of geothermal energy projects, particularly within PPPs. Furthermore, few studies have explicitly considered the differing risk characteristics between the exploration/drilling and infrastructure development phases of geothermal projects. This study addresses these conceptual, contextual and methodological gaps by examining the effect of risk management strategies on the performance of geothermal energy projects implemented through Public-Private Partnerships in Kenya.

LITERATURE REVIEW

Theoretical Review

This study was anchored on New Public Management (NPM) Theory, New Public Governance (NPG) Theory, and Agency Theory, which collectively explain how risk management strategies influence the performance of geothermal energy projects implemented through Public-Private Partnerships (PPPs). New Public Management Theory advocates the application of private-sector management principles within public sector organizations to enhance efficiency, accountability and performance (Hood, 1991). In geothermal energy projects, the theory underscores the importance of prudent resource utilization, performance-oriented decision-making and systematic management practices that improve project delivery. From the perspective of this study, NPM provides the foundation for adopting structured risk management practices, including risk identification, assessment, allocation and mitigation, as mechanisms for minimizing project uncertainty, controlling costs and improving operational efficiency.

While NPM emphasizes efficiency, New Public Governance (NPG) Theory recognizes that complex infrastructure projects such as geothermal developments cannot be delivered effectively

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by a single organization but require collaboration among governments, private investors, contractors, regulators, financiers and local communities (Osborne, 2010). Since geothermal projects implemented through PPPs involve multiple actors with shared responsibilities and risks, collaborative governance becomes essential for coordinating risk identification, information sharing, joint decision-making and risk mitigation. Thus, NPG extends the efficiency perspective of NPM by demonstrating that effective risk management depends not only on sound managerial practices but also on institutional collaboration and stakeholder coordination.

However, collaboration alone does not eliminate conflicts of interest among project participants. Agency Theory explains how contractual relationships between principals and agents may create agency problems arising from divergent objectives and information asymmetry (Jensen & Meckling, 1976). In geothermal PPP projects, governments, private developers, contractors and financiers assume different responsibilities and risk exposures. Consequently, the collaborative governance advocated by NPG requires effective contractual arrangements to ensure that risks are allocated to the parties best able to manage them, thereby reducing opportunistic behaviour, strengthening accountability and improving project performance. Agency Theory therefore complements NPG by explaining why risk allocation and monitoring mechanisms are critical for successful collaborative governance.

Taken together, the three theories provide a coherent theoretical explanation for the study. New Public Management Theory explains why structured risk management enhances efficiency and project performance. New Public Governance Theory demonstrates that effective risk management in geothermal PPP projects depends on collaboration among multiple stakeholders. Agency Theory further explains how contractual accountability and equitable risk allocation strengthen collaborative governance by minimizing agency conflicts and ensuring that each project partner manages the risks within its area of responsibility. Collectively, these theories suggest that effective risk identification, risk assessment, risk allocation and risk mitigation improve geothermal project performance by integrating managerial efficiency, collaborative governance and contractual accountability.

Empirical Review

Risk Identification and Project Performance

Risk identification enables project stakeholders to recognize technical, financial, environmental and regulatory risks before they adversely affect project implementation. In geothermal energy projects, early risk identification is particularly important during the exploration and drilling phase, where geological uncertainty, reservoir quality and drilling success determine project viability (Lukawski et al., 2016; Jolie et al., 2021). Witter et al. (2019) observed that inadequate identification of subsurface risks often results in unsuccessful drilling, increased development costs and delayed project implementation. Similar findings have been reported in utility-scale renewable energy projects. For example, Zhang et al. (2022) found that systematic identification of technical, environmental and contractual risks significantly improved schedule adherence and cost control in large-scale hydropower projects, while Akinyele et al. (2023) reported that early identification of stakeholder and regulatory risks enhanced project delivery in utility-scale solar energy projects. These studies demonstrate that proactive risk identification reduces uncertainty and improves project performance. However, most existing studies focus on specific project phases or individual categories of risk, with limited evidence on the combined influence of risk identification within geothermal Public-Private Partnership (PPP) projects in Kenya.

Risk Assessment and Project Performance

Risk assessment enables project teams to evaluate the likelihood and consequences of identified risks and prioritize appropriate response strategies. In geothermal development, risk assessment is essential because uncertainties associated with resource exploration, drilling success, financing and environmental compliance vary considerably across project phases (Shortall et al., 2021; Kępińska et al., 2021). Empirical evidence from geothermal and other renewable energy projects indicates that systematic risk assessment improves investment decisions and enhances project resilience. For instance, Shortall et al. (2021) reported that probabilistic assessment of geological and financial risks improved investment confidence in geothermal developments. Similarly, Boateng et al. (2022) found that structured risk assessment contributed significantly to project success in hydropower projects by enabling timely resource allocation and contingency planning. Although these findings demonstrate the value of risk assessment, relatively few studies have examined its contribution alongside other risk management strategies within geothermal PPP projects in developing economies.

Risk Allocation and Project Performance

Risk allocation is a fundamental principle of PPP projects because it assigns responsibility for each identified risk to the party best able to manage it. Agency Theory suggests that appropriate contractual allocation reduces opportunistic behaviour, improves accountability and enhances project outcomes (Jensen & Meckling, 1976). In geothermal projects, exploration risks are often retained by governments because of the high uncertainty and investment costs, whereas construction and operational risks are transferred to private developers through contractual agreements (World Bank, 2020). Studies on renewable energy PPPs indicate that equitable risk-sharing arrangements improve investor confidence, reduce contractual disputes and enhance project delivery (Carbonara et al., 2015; Zhang et al., 2021). Likewise, research on large hydropower projects has shown that poorly allocated risks contribute to cost overruns, project delays and contractual conflicts (Osei-Kyei & Chan, 2018). Nevertheless, empirical evidence examining the influence of risk allocation on geothermal project performance in Kenya remains limited.

Risk Mitigation and Project Performance

Risk mitigation involves implementing strategies that reduce either the likelihood or impact of adverse events throughout the project lifecycle. In geothermal projects, mitigation measures include comprehensive drilling plans, reservoir monitoring, environmental management, contingency financing, insurance mechanisms and continuous stakeholder engagement (Jolie et al., 2021; Witter et al., 2019). Studies have consistently shown that proactive mitigation strategies improve operational reliability and reduce implementation risks. For example, Kępińska et al. (2021) demonstrated that financial risk mitigation instruments significantly enhanced investment security in European geothermal projects. Similarly, Akinyele et al. (2023) reported that continuous monitoring and adaptive management improved project performance in utility-scale solar projects, while Osei-Kyei and Chan (2018) found that proactive mitigation strategies

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enhanced schedule and cost performance in large infrastructure PPPs. Although previous studies support the positive influence of risk mitigation on project outcomes, they primarily examine individual mitigation practices rather than integrated risk management frameworks.

Although previous studies consistently report positive relationships between risk management and project performance, most have focused on construction, transport infrastructure, hydropower or utility-scale solar projects, with relatively limited attention to geothermal energy developments. Existing geothermal studies have largely concentrated on geological uncertainty, drilling risks or investment barriers, while studies on PPPs have often examined risk allocation or contractual governance independently (Lukawski et al., 2016; Shortall et al., 2021; Jolie et al., 2021). Consequently, limited empirical evidence exists on the integrated influence of risk identification, risk assessment, risk allocation and risk mitigation on the performance of geothermal energy projects implemented through PPPs, particularly in Kenya. This conceptual, contextual and methodological gap provided the basis for the present study.

Conceptual Framework

The study conceptualizes risk management strategies as the independent variable comprising four dimensions: risk identification, risk assessment, risk allocation, and risk mitigation. Project performance is the dependent variable and is measured through operational efficiency, project completion, sustainability, stakeholder satisfaction, and achievement of project objectives. The study proposes that effective implementation of risk management strategies positively influences the performance of geothermal energy projects in Kenya.

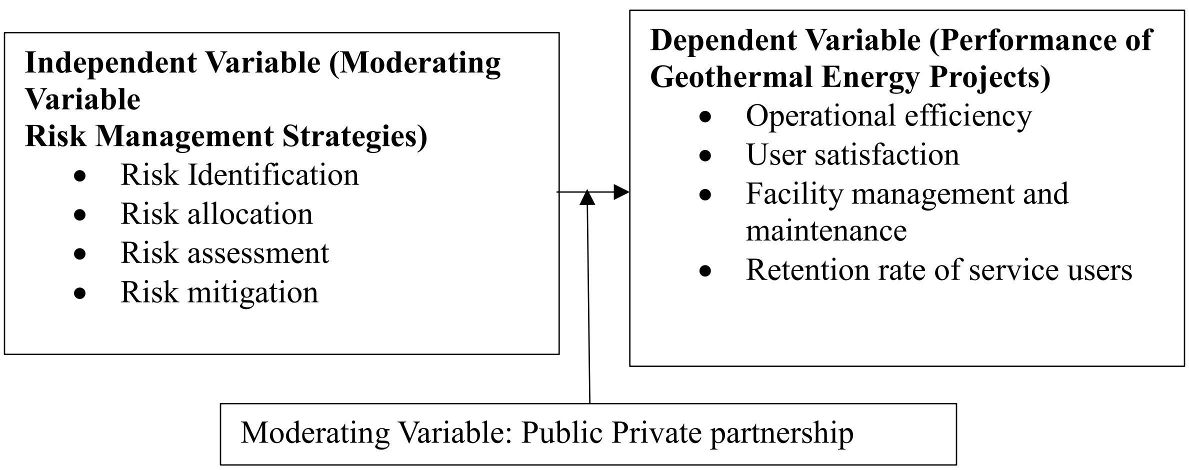

Figure 1: Conceptual Framework

Hypothesis

H_0: Risk management strategies have no statistically significant effect on the performance of geothermal energy projects in Kenya.

H_1: Risk management strategies have a statistically significant positive effect on the performance of geothermal energy projects in Kenya.

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METHODOLOGY

This study adopted the positivist research philosophy, which assumes that reality is objective and can be measured using empirical methods. The philosophy was considered appropriate because the study sought to establish the effect of risk management strategies on the performance of geothermal energy projects through objective measurement and statistical analysis.

A quantitative research approach employing a cross-sectional survey design was adopted. The cross-sectional design enabled the collection of data from respondents at a single point in time, allowing the study to examine the relationship between risk management strategies and project performance without manipulating the study variables.

The study was conducted among geothermal energy projects implemented through Public-Private Partnerships (PPPs) in Kenya. The target population comprised 517 respondents, including senior management, middle-level management, technical staff, support staff, and officials from institutions involved in geothermal energy project implementation. A sample of 222 respondents was determined using Yamane's (1967) sampling formula. Stratified sampling was first employed to ensure proportional representation of various stakeholder categories, after which simple random sampling was used to select individual respondents.

Primary data were collected using a structured questionnaire consisting of closed-ended items measured on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The questionnaire captured information on four dimensions of risk management strategies, namely risk identification, risk assessment, risk allocation, and risk mitigation, together with measures of project performance.

The research instrument was subjected to validity and reliability testing before the main survey. Content validity was established through expert evaluation, yielding a Content Validity Index (CVI) of 0.89, indicating that the instrument adequately measured the intended constructs. Reliability was assessed using Cronbach's alpha coefficient, with values ranging between 0.83 and 0.89, exceeding the recommended threshold of 0.70 and demonstrating satisfactory internal consistency.

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 29. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondents' characteristics and study variables. Inferential statistics comprising Pearson correlation analysis and simple linear regression were employed to determine the relationship between risk management strategies and the performance of geothermal energy projects. Statistical significance was evaluated at the 5% significance level ($p < 0.05$).

The regression model estimated in the study was specified as follows:

$$Y = \beta_0 + \beta_0 X_1 + \varepsilon$$

Where:

- Y = Performance of geothermal energy projects
- β_0 = Constant (intercept)
- β_1 = Regression coefficient

- X = Risk management strategies
- ε = Error term

Ethical considerations were observed throughout the study. Permission to conduct the research was obtained from the relevant authorities, participation was voluntary, informed consent was sought from all respondents, and confidentiality and anonymity of the information provided were maintained. The collected data were used solely for academic purposes.

RESULTS AND DISCUSSION

Response Rate

A total of 222 questionnaires were administered to respondents drawn from geothermal energy projects implemented through Public-Private Partnerships in Kenya. Out of these, 214 questionnaires were successfully completed and returned, representing a response rate of 96.4%, while 8 questionnaires were either incomplete or not returned, representing 3.6%. The achieved response rate exceeded the minimum threshold of 70% recommended for survey research, indicating that the collected data were adequate for statistical analysis.

Table 1: Response Rate

Response	Frequency	Percentage (%)
Returned	214	96.4
Unreturned	8	3.6
Total	**222**	**100.0**

The high response rate enhanced the credibility and representativeness of the findings by minimizing non-response bias. It also reflected the willingness of stakeholders involved in geothermal energy projects to participate in the study.

Descriptive Statistics

Risk Management Strategies

Respondents were requested to indicate their level of agreement with statements measuring the implementation of risk management strategies within geothermal energy projects. The construct comprised four dimensions: risk identification, risk assessment, risk allocation, and risk mitigation. Mean scores and standard deviations were computed to determine respondents' perceptions.

Table 2: Risk Management Strategies

Construct	Mean	Std. Deviation
Risk Identification	4.18	0.63
Risk Assessment	4.09	0.67
Risk Allocation	4.14	0.61
Risk Mitigation	4.27	0.59
Composite Mean	4.17	0.63

The findings indicate that respondents generally agreed that risk management strategies were implemented in geothermal energy projects, as reflected by a composite mean score of 4.17. Risk mitigation recorded the highest mean score (Mean = 4.27), suggesting that project managers placed considerable emphasis on reducing the likelihood and impact of project risks. Risk assessment recorded the lowest mean score (Mean = 4.09), although it still reflected a high level of implementation. The relatively low standard deviations indicate consistency in respondents' opinions regarding the implementation of risk management practices.

Correlation Analysis

Pearson's Product Moment Correlation analysis was conducted to determine the relationship between risk management strategies and the performance of geothermal energy projects in Kenya.

Table 3: Correlation between Risk Management Strategies and Project Performance

Variable	Project Performance
Risk Management Strategies	0.596**
Sig. (2-tailed)	0.000
N	214

** Correlation is significant at the 0.01 level (2-tailed).

The results indicate a moderate positive and statistically significant relationship between risk management strategies and the performance of geothermal energy projects ($r = 0.596$, $p < 0.001$). This implies that improvements in risk identification, risk assessment, risk allocation, and risk mitigation are associated with improved project performance. Consequently, geothermal energy projects that adopt comprehensive risk management practices are more likely to achieve operational efficiency, sustainability, stakeholder satisfaction, and successful project completion.

Effect of Risk Management Strategies on Performance of Geothermal Energy Projects

To determine the effect of risk management strategies on the performance of geothermal energy projects, a simple linear regression analysis was performed.

Table 4: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of Estimate
1	0.596	0.355	0.352	0.469

The regression results indicate that risk management strategies explain 35.5% of the variation in the performance of geothermal energy projects ($R^2 = 0.355$). This suggests that although other factors also influence project performance, risk management strategies constitute an important predictor of successful geothermal project implementation.

Table 5: ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	25.971	1	25.971	116.643	0.000
Residual	47.219	212	0.223		
Total	**73.190**	**213**			

The ANOVA results indicate that the regression model is statistically significant ($F = 116.643$, $p < 0.001$). This demonstrates that risk management strategies significantly predict the performance of geothermal energy projects.

Table 6: Regression Coefficients

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	1.617	0.241	—	6.708	0.000
Risk Management Strategies	0.598	0.055	0.596	10.800	0.000

The estimated regression model was:

Substituting the estimated coefficients gives:

$Y=1.617+0.598X$

The regression coefficient for risk management strategies was positive and statistically significant ($\beta = 0.598$, $t = 10.800$, $p < 0.001$). This implies that a one-unit improvement in risk management strategies results in an estimated 0.598-unit increase in the performance of geothermal energy projects, holding other factors constant. Therefore, the null hypothesis stating that risk management strategies have no significant effect on the performance of geothermal energy projects in Kenya was rejected.

Discussion

The findings indicate that risk management strategies have a positive and statistically significant effect on the performance of geothermal energy projects in Kenya ($\beta = 0.598$, $p < 0.001$). The regression model further shows that risk management strategies explain 35.5% of the variation in project performance, confirming that they are an important determinant of successful geothermal project implementation. Although other organizational, technical and external factors also influence project performance, the findings demonstrate that strengthening risk management substantially improves operational outcomes.

The significance of risk management is particularly evident in geothermal energy projects because of the sector's unique characteristics. Unlike many conventional infrastructure projects, geothermal developments require substantial upfront investment during exploration and drilling before the commercial viability of geothermal reservoirs is confirmed. This exposes project developers to considerable geological uncertainty and financial risk. Once commercially viable resources are identified, projects enter a capital-intensive infrastructure development phase characterized by complex procurement processes, contractual obligations, regulatory compliance requirements and long implementation periods. Consequently, weaknesses in identifying, assessing, allocating or mitigating risks at any stage may lead to cost overruns, implementation delays and reduced operational performance. The positive relationship observed in this study therefore suggests that comprehensive risk management enables project stakeholders to manage these uncertainties more effectively throughout the project lifecycle.

The findings also support the theoretical framework underpinning this study. New Public Management Theory argues that structured management practices improve efficiency and organizational performance through effective planning and resource utilization (Hood, 1991). The positive effect of risk management strategies observed in this study indicates that systematic management of project risks contributes to improved project implementation and operational efficiency. New Public Governance Theory further suggests that infrastructure projects implemented through Public–Private Partnerships require collaboration among governments, private investors, financiers, contractors and regulators to manage shared risks effectively (Osborne, 2010). In geothermal projects, where multiple stakeholders participate across exploration, construction and operation, collaborative risk management strengthens coordination and improves project delivery. Agency Theory complements these perspectives by emphasizing that clearly defined contractual responsibilities and equitable risk allocation reduce information asymmetry, limit opportunistic behaviour and improve accountability among project partners (Jensen & Meckling, 1976). Collectively, these theories explain why structured risk management enhances the performance of geothermal PPP projects.

The findings are consistent with previous empirical studies reporting that effective risk management improves infrastructure project performance. Lukawski et al. (2016) observed that systematic management of exploration uncertainty supports informed investment decisions in geothermal developments, while Witter et al. (2019) reported that early management of geological and drilling risks reduces project uncertainty and enhances project viability. Similarly, Kępińska et al. (2021) found that financial risk management mechanisms increase investor confidence and improve the sustainability of geothermal projects. Comparable evidence from utility-scale renewable energy and Public–Private Partnership projects indicates that integrated risk management contributes to improved cost performance, schedule adherence and operational efficiency by reducing technical, financial and contractual uncertainties (Carbonara et al., 2015; Rasheed et al., 2022). These findings suggest that although geothermal projects possess distinctive geological risks, the principles of structured risk management remain fundamental to successful infrastructure delivery.

The present study extends the existing literature by providing empirical evidence from Kenya's geothermal sector, where relatively few studies have examined the combined effect of risk management strategies on project performance. Previous research has often focused on individual categories of risk, such as geological, financial or contractual risks, whereas this study demonstrates that risk management should be viewed as an integrated management system encompassing risk identification, assessment, allocation and mitigation. The findings therefore reinforce the importance of institutionalizing comprehensive risk management frameworks across all phases of geothermal project development, from exploration and drilling through infrastructure construction and long-term operation.

A noteworthy observation is that the regression model treated risk management strategies as a composite construct. Consequently, while the results confirm the overall importance of risk management, they do not indicate whether individual dimensions such as risk identification, risk assessment, risk allocation or risk mitigation contribute differently to project performance. Future studies should estimate these dimensions separately using multiple regression or structural equation modelling to determine their relative influence and identify the most critical risk management practices for geothermal energy projects.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study examined the effect of risk management strategies on the performance of geothermal energy projects implemented through Public–Private Partnerships in Kenya. The study concludes that effective risk management is a critical success factor in geothermal project delivery because it enables project stakeholders to anticipate, manage and respond to the technical, financial, contractual and operational uncertainties that characterize geothermal development. Given the sector's high upfront capital requirements, subsurface geological uncertainty and long project implementation periods, structured risk management provides an essential foundation for improving project performance throughout the project lifecycle.

The findings demonstrate that integrating risk identification, risk assessment, risk allocation and risk mitigation into project planning and implementation contributes to improved operational efficiency, better schedule and budget performance, and enhanced infrastructure sustainability. Beyond improving individual project outcomes, the study highlights the strategic importance of institutionalizing comprehensive risk management frameworks within geothermal Public–Private Partnership projects to strengthen investor confidence, support informed decision-making and promote sustainable development of Kenya's geothermal energy sector. The study therefore contributes empirical evidence that can inform policy, project governance and risk management practices in large-scale renewable energy infrastructure projects.

Recommendations

Based on the findings, the study makes the following recommendations:

First, geothermal energy project developers should institutionalize comprehensive risk management frameworks that integrate risk identification, assessment, allocation, and mitigation throughout the entire project life cycle.

Second, government agencies responsible for geothermal energy development should strengthen policy and regulatory frameworks that support proactive risk management practices within Public-Private Partnership projects. This will enhance investor confidence, improve accountability, and facilitate timely project implementation.

Third, project managers should undertake continuous risk monitoring and periodic risk reviews to identify emerging risks and implement appropriate mitigation measures before they adversely affect project performance.

Fourth, capacity-building initiatives should be implemented to strengthen the competencies of project teams in modern risk management techniques, thereby improving decision-making and project resilience.

Contribution to Theory, Practice and Policy

This study examined the effect of risk management strategies on the performance of geothermal energy projects implemented through Public–Private Partnerships in Kenya. The findings demonstrate that effective risk management is a critical success factor in geothermal project delivery because it enables stakeholders to anticipate, manage and respond to the technical, financial, contractual and operational uncertainties that characterize geothermal development. Given the sector's high upfront capital requirements, subsurface geological uncertainty and long project implementation periods, institutionalizing structured risk management throughout the project lifecycle is essential for improving operational efficiency, schedule performance, budget performance and infrastructure sustainability.

Beyond individual project outcomes, the findings have important policy implications for Kenya's energy sector. Improving risk management practices can enhance investor confidence, reduce project delays and cost overruns, and strengthen the delivery of geothermal projects implemented through Public–Private Partnerships. These outcomes are critical to achieving the country's long-term energy objectives under Kenya Vision 2030, which identifies reliable and affordable energy infrastructure as a foundation for industrialization, economic growth and improved quality of life (Government of Kenya, 2007). Strengthening risk management also supports the Bottom-Up Economic Transformation Agenda (BETA) by promoting sustainable investment in renewable energy infrastructure, enhancing energy security and creating an enabling environment for private sector participation. Furthermore, the findings contribute to Kenya's commitment to Sustainable Development Goal 7, which seeks to ensure access to affordable, reliable, sustainable and modern energy for all (United Nations, 2015). The study therefore provides evidence to policymakers, project developers and investors that strengthening institutional risk management frameworks is not only essential for improving geothermal project performance but also for advancing Kenya's broader economic transformation and sustainable development agenda.

REFERENCES

African Development Bank. (2023). African economic outlook 2023: Mobilizing private sector financing for climate and green growth in Africa. African Development Bank.

Breede, K., Dzebisashvili, K., Liu, X., & Falcone, G. (2013). A systematic review of enhanced (or engineered) geothermal systems: Past, present and future. Geothermal Energy, 1(4). https://doi.org/10.1186/2195-9706-1-4

Carbonara, N., Costantino, N., Gunnigan, L., & Pellegrino, R. (2015). Risk management in motorway Public–Private Partnership projects. International Journal of Project Management, 33(6), 1210–1223. https://doi.org/10.1016/j.ijproman.2015.02.003

Du, J., Wang, S., Zhang, Y., & Li, Y. (2023). Performance evaluation of Public–Private Partnership infrastructure projects: A sustainability perspective. Sustainability, 15(10), 7951. https://doi.org/10.3390/su15107951

Energy and Petroleum Regulatory Authority. (2023). Energy sector statistics report 2023. Government Printer.

Government of Kenya. (2025). Draft national geothermal strategy. Ministry of Energy and Petroleum.

Hayes, A. F. (2018). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach (2nd ed.). Guilford Press.

Hood, C. (1991). A public management for all seasons? Public Administration, 69(1), 3–19. https://doi.org/10.1111/j.1467-9299.1991.tb00779.x

International Energy Agency. (2024a). The future of geothermal energy. https://www.iea.org/reports/the-future-of-geothermal-energy

International Energy Agency. (2024b). World energy outlook 2024. https://www.iea.org/

International Organization for Standardization. (2018). ISO 31000:2018 Risk management—Guidelines. ISO.

International Renewable Energy Agency. (2022). Renewable energy finance and investment report. IRENA.

International Renewable Energy Agency. (2024). Renewable capacity statistics 2024. IRENA.

Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. Journal of Financial Economics, 3(4), 305–360. https://doi.org/10.1016/0304-405X(76)90026-X

Jolie, E., Scott, S., Faulds, J. E., Chambefort, I., Axelsson, G., Gutiérrez-Negrín, L. C., Regenspurg, S., Ziegler, M., Ayling, B., Richter, A., & Zemedkun, M. T. (2021). Geological controls on geothermal resources for power generation. Nature Reviews Earth & Environment, 2(5), 324–339. https://doi.org/10.1038/s43017-021-00154-y

KenGen. (2024). Annual report and financial statements 2023/2024. Kenya Electricity Generating Company PLC.

Kenya Ministry of Energy. (2023). Energy sector strategic plan 2023–2027. Government Printer.

Kenya Ministry of Energy. (2024). Kenya national energy statistics report. Government Printer.

Kępińska, B., Kujbus, A., Karytsas, S., Boissavy, C., Mendrinos, D., Karytsas, C., & Kasztelewicz, A. (2021). Risk insurance fund for geothermal energy projects in selected European countries: Operational and financial simulation. Gospodarka Surowcami Mineralnymi – Mineral Resources Management, 37(3), 139–158.

Liu, J., Love, P. E. D., Smith, J., Matthews, J., & Sing, C. P. (2016). Praxis of performance measurement in Public–Private Partnership projects. Journal of Management in Engineering, 32(6), 04016016.

Lukawski, M. Z., Anderson, B. J., Augustine, C., Capuano, L. E., Beckers, K. F., Livesay, B., & Tester, J. W. (2016). Uncertainty and risk evaluation during the exploration stage of geothermal development. Geothermics, 64, 382–391. https://doi.org/10.1016/j.geothermics.2016.06.018

Lund, J. W., & Toth, A. N. (2021). Direct utilization of geothermal energy 2020 worldwide review. Geothermics, 90, 101915.

OECD. (2020). Getting infrastructure right: A framework for better governance. OECD Publishing.

Odhiambo, K. O. (2021). Risk factors, contract management and performance of Public–Private Partnership renewable energy projects: The case of geothermal renewable energy projects in Kenya (Master's thesis, University of Nairobi).

Osborne, S. P. (2010). The new public governance? Emerging perspectives on the theory and practice of public governance. Routledge.

Osei-Kyei, R., & Chan, A. P. C. (2018). Review of studies on the critical success factors for Public–Private Partnership projects. International Journal of Project Management, 33(6), 1335–1346. https://doi.org/10.1016/j.ijproman.2015.02.008

Public–Private Partnership Directorate. (2024). Annual Public–Private Partnership status report. National Treasury.

Rotich, I. K., Chepkirui, H., Musyimi, P. K., & Kipruto, G. (2024). Geothermal energy in Kenya: Evaluating health impacts and environmental challenges. Energy for Sustainable Development, 82, 101522. https://doi.org/10.1016/j.esd.2024.101522

Shortall, R., Davidsdottir, B., & Axelsson, G. (2021). Geothermal energy for sustainable development: A review of sustainability impacts and assessment frameworks. Renewable and Sustainable Energy Reviews, 149, 111363.

Toor, S. U. R., & Ogunlana, S. O. (2010). Beyond the iron triangle: Stakeholder perception of key performance indicators for large-scale public sector development projects. International Journal of Project Management, 28(3), 228–236.

Witter, J. B., Trainor-Guitton, W., Siler, D. L., & Faulds, J. E. (2019). Risk and uncertainty in geothermal exploration: Lessons for project development. Geothermics, 78, 233–242.

World Bank. (2017). Public–Private Partnerships reference guide (Version 3).

World Bank. (2020). Mobilizing private finance for geothermal development.

World Bank. (2023). Kenya economic update: Energy for sustainable development.

World Bank. (2024). Private participation in infrastructure (PPI) database: Annual report.

Yescombe, E. R. (2017). Public–Private Partnerships for infrastructure: Principles of policy and finance (2nd ed.). Butterworth-Heinemann.