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Risk Management Strategies in Micro Hydropower Projects

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ABSTRACT

While Micro Hydropower Plants in Rwanda offer sustainable energy solutions, their success is often hindered by insufficient risk management strategies, leading to challenges such as delays, cost overruns, and operational inefficiencies. This study aimed to assess the influence of risk management strategies on performance of hydroelectric energy projects in Rwanda: A case of Micro Hydropower Plants. The study's specific objectives include: To determine the influence of risk identification, risk analysis, risk response and, risk review and control on performance of hydroelectric energy projects in Rwanda. The study is grounded on Theory of Constraints (TOC), Resource-Based View (RBV) and Goal-Setting Theory. Utilizing descriptive and correlational research designs, both quantitative and qualitative data were collected through questionnaires and semi-structured interviews; from a census of 105 participants, selected using a combination of stratified and purposing sampling. A pilot test was conducted with 11 respondents representing 10% of the sample size to determine the instrument's ability to produce consistent results over time. The validity was tested using Content Validity which resulted a content validity index of 0.8 by expert evaluation while the reliability of the research instrument (questionnaire) was also assessed using Cronbach's Alpha achieved 0.74. Data was analyzed using descriptive and inferential statistics, including correlation and regression analysis. The findings for four hypotheses were tested at α=.05 level of significance and the results were: Risk Identification; Risk Analysis; Risk Response and; Risk Review and Control had no significant influence on performance of hydroelectric energy projects were rejected since P=0.000<0.05, indicating that all the risk management strategies significantly contribute to enhancing project performance. The study concludes that while Rwanda's hydroelectric projects are generally successful, their sustainability can be improved through better risk management practices, including enhanced risk identification, response strategies, and ongoing monitoring. Further research should focus on evaluating the long-term effectiveness of risk mitigation strategies in hydroelectric projects, tracking outcomes across multiple projects to identify the most effective strategies for ensuring sustainability and maximizing return on investment.

Introduction

As the global demand for renewable energy sources rises, hydroelectric energy has acted as a pivotal contributor to sustainable energy production. According to the International Energy Agency (IEA) and the World Energy Outlook 2024 by the International Hydropower Association (IHA), hydroelectric energy accounts for a large share of renewable electricity with more electricity produced than all other renewable technologies combined (IEA, 2023; IHA, 2024). More than 90% of the world's stored energy comes from pumped storage hydropower (IHA, 2024). In North America, hydropower has been integral for over a century, with current efforts in the U.S. and Canada focused on upgrading infrastructure to improve efficiency and sustainability (Moran et al., 2018).

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Meanwhile, Asia—particularly India and China—has seen substantial investment in hydropower, positioning China as the world leader in installed capacity, where in 2022, China alone contributed 24 GW of new capacity, which is 75% of global expansion (IEA, 2024). However, China's capacity growth rates are expected to slow due to environmental and site constraints. Scholars highlight both the benefits and environmental risks of these hydropower projects, noting that while they provide significant power, they can also lead to substantial environmental disruptions (IEA, 2024; Sharma & Kar, 2018; Shaktawat, & Vadhera, 2020).

On the African continent, hydropower also remains an essential source of renewable energy, helping to alleviate power shortages and support economic growth in various regions (Shaktawat & Vadhera, 2020). However, African hydropower projects, like their global counterparts, face unique challenges such as insufficient infrastructure, funding constraints, and high exposure to climate-related risks, including droughts and fluctuating river flows (George, 2020). These constraints make risk management strategies crucial for project success, with scholars advocating for adaptive management approaches that can accommodate these regional uncertainties (Gurung, 2020; Kunya & Muchelule, 2023). Equally, Kenya presents a compelling case study for understanding risk management in hydropower projects. Amolo (2022) analysed financial risk management instruments used in Kenyan hydropower projects, emphasizing the role of insurance, hedging, and alternative risk transfer mechanisms in improving project performance. Kenya's renewable energy sector, while still growing, has demonstrated resilience in adopting innovative risk management strategies to address challenges related to funding, environmental impacts, and community engagement.

Hydroelectric energy projects are also vital for the development and sustainability of Rwanda, where energy demand is rising. Under urbanization and agglomeration pillar in Vision 2050, sustainable supply and demand for energy is one of the keys to be considered (Ministry of Finance and Economic planning, 2021). And, Currently, according to the Rwanda Energy Group (REG), Rwanda's generation capacity reached to 406.4 MW from 156.08 MW in 2014 (REG, 2024). And, hydropower remains the leading source of electricity in the country, contributing 37.94 % of the total energy generation with 109.66 MW Installed.

In addition, Hydropower projects like the Micro hydropower plants play a central role in meeting this demand, supporting Rwanda's Vision 2050 goal. Rwanda's micro-hydropower plants have grown considerably, supporting local and rural electrification., there are currently 11 operational micro-hydropower plants, primarily functioning as isolated networks managed through private sector partnerships (REG, 2024). However, like many infrastructure projects, Micro hydropower plants projects are exposed to a variety of risks, including financial, technical, environmental, and regulatory risks, which could affect its overall performance. The life cycle of hydroelectric project is linked to uncertainties and involve significant expenses. For instance, on construction stage of hydroelectric projects is usually more complex and riskier due to nature of different activities involved (Shaktawat & Vadhera, 2020). This situation imposes various uncertainty factors such as increase of costs. Therefore, managing these risks is critical to ensure the successful completion of such projects on time, within the budget and their long-term sustainability.

Rwanda is expanding its energy infrastructure to meet growing electricity demands and enhance energy security. However, many Micro Hydropower Plants face challenges due to inadequate risk management, resulting failure or underperformance of Hydroelectric power projects. According to Mukeshimana, Zhao, and Nshimiyimana (2021), the renewable energy sector in Rwanda, including hydropower, is challenged by technical, financial, and regulatory risks, which can lead to projects failure or underperformance if not properly addressed. As a result, the electricity sector is less able to build new large generating units and take advantage of economies of scale. Given the importance of hydropower to Rwanda's energy future, and the challenges faced by projects like Micro hydropower plants, this study will seek to address this gap by investigating how risk management strategies influence the performance of hydroelectric projects. By considering, risk identification, risk analysis, risk response and risk review and control; the research will focus on assessing the key risks involved in the Micro hydropower plants and evaluating the effectiveness of strategies employed to mitigate them, ultimately contributing to the improvement of project management practices in Rwanda's energy sector. The study was organized into introduction, literature review, findings and discussion, and conclusion.

Literature Review

Theoretical Review

The study is grounded on Theory of Constraints (TOC), Resource-Based View (RBV) and Goal-Setting Theory, to provide foundational insights that are relevant to understanding and improving hydroelectric project performance.

Theory of Constraints (TOC)

The Theory of Constraints (TOC), introduced by Goldratt (1984), was used to explain the risk management strategies. This theory emphasizes locating and resolving the most project bottlenecks in order to maximize overall efficiency and growth. Within the context of hydroelectric projects, common constraints include limited financial resources, skilled labour shortages, or regulatory challenges, which can impede progress. By using TOC, Rwanda's hydroelectric sector can prioritize and address these constraints to improve resource allocation and reduce delays. The TOC approach is essential to this study as it emphasizes the role of targeted risk mitigation, highlighting how overcoming specific limitations in resources and processes can lead to enhanced project performance.

Empirical review

Risk Identification and Performance of Hydroelectric Energy Projects

Different studies found risk identification, as the first and one of the most critical steps in the risk management process for any project, especially in large-scale and complex infrastructure projects such as hydroelectric energy developments. George (2020) emphasizes the importance of identifying risks in project risk management as a crucial step in ensuring the success of a project. The study discusses various methods for identifying risks, such as brainstorming sessions, checklists, and expert opinion. And, major risks identified in hydropower projects include technical breakdowns, environmental risks, regulatory non-compliance, and opposition from the community. The research findings by George suggest that effective risk identification not only clarifies potential threats but also supports in developing tailored risk response strategies.

Hakizimana et al. (2020) carried out an empirical evaluation of the environmental impact assessment (EIA) process for the Nyabarongo I hydropower plant in Rwanda, focusing specifically on identifying environmental risks. The researchers employed a mixed-methods approach that combined quantitative data collection through surveys with qualitative interviews. Nepal, Khanal, and Maelah (2021) explore the relative importance of various risks in hydropower projects, emphasizing financial risks like funding shortages and interest rate fluctuations. Utilizing a quantitative survey method, they find that financial uncertainties are perceived as the most critical by stakeholders. This study underscores the need for comprehensive risk identification strategies that address technical, environmental, and financial risks to enhance overall project performance and sustainability. In addition, Roy and Roy (2020) highlight the importance of identifying financial, technical, geological, and regulatory risks in small hydropower projects in Uttarakhand by analysing 36 Small Hydro Power Projects. Their use of the Delphi method, which involves expert consensus on significant risks, demonstrating that thorough risk identification is fundamental to implementing effective mitigation strategies and achieving project viability.

Risk Analysis and Performance of Hydroelectric Energy Projects

Qazi et al. (2021) employed a risk matrix-based Monte Carlo simulation method to prioritize risks in sustainable construction projects, enabling them to simulate the likelihood and impact of each risk on project outcomes. In the context of hydropower projects, such tools help in planning and allocating resources more effectively. Similarly, Roy and Roy (2020) took a case-study approach to evaluate risk management in small hydropower projects in Uttarakhand, finding that innovative approaches to managing financial and operational risks significantly improved project sustainability. These methodologies—surveys, simulations, and case studies—are effective for analyzing how risk management strategies influence hydropower project performance, offering insights applicable to the Rwandan context.

Similarly, Mukeshimana et al. (2021) emphasize the importance of strategic risk assessment in the context of Rwanda's renewable energy development, including hydroelectric projects. Using an integrated SWOT-ISM (Strengths, Weaknesses, Opportunities, Threats - Interpretive Structural Modeling) approach, they evaluated both internal and external risks impacting project sustainability in Rwanda. This approach helped to prioritize risks systematically, thereby enhancing decision-making processes for better project outcomes. Their findings indicate that a comprehensive risk analysis allows hydroelectric projects to adapt to local socio-economic conditions, which is critical in improving performance, especially in a context with unique regulatory and environmental constraints. Yüksel et al. (2024) presented a comprehensive risk analysis and decision-making model specifically for hydroelectric energy investments. Utilizing a combination of fuzzy logic and multi-criteria decision-making methods, this study assessed various risks associated with hydropower projects and proposed a structured approach for decision-making. The findings emphasized the importance of integrating advanced analytical methods where priority analysis was into risk management strategies to enhance investment decisions and project performance.

Risk Response and Performance of Hydroelectric Energy Projects

Roy and Roy (2020) investigated small hydropower projects in India and recommended a customized approach to risk response that accounts for each project's unique conditions. Using case study analysis as their primary method, they identified technical, geological, and regulatory factors as high-priority risks requiring immediate response. They advised risk transfer by encouraging investor collaboration with insurance companies. Additionally, they recommended risk mitigation through private investment, hence long-term strategies, including technology adoption and compliance with environmental standards.

Nepal, Khanal, and Maelah (2021) conducted a survey-based study using a Likert scale to gauge the relative importance of various risks in Nepal's hydropower projects, focusing on how financial, environmental, and political risks are managed through structured responses. Their findings indicate that timely and proactive risk responses, such as adjusting project financing strategies, can significantly enhance project performance by preventing delays and financial losses. Similarly, Sharma and Kar (2018) and Tang, *et al.* (2018) showed that regular risk assessments and immediate response mechanisms improved both project timelines and cost efficiency. Also, they highlighted how dynamic risk response systems ensure long-term project sustainability by addressing environmental and operational risks.

Amolo (2022) explored financial risk management instruments and their influence on the performance of hydropower projects in Kenya. Using a mixed-methods approach, which combined quantitative surveys and case study analyses, the study assessed the application of financial instruments like alternative risk transfer, insurance and hedging in managing risks associated with hydropower projects. The study revealed that projects implementing comprehensive financial risk management strategies demonstrated improved financial performance, reduced cost overruns, and minimized project delays, thereby enhancing overall project success.

Risk Review and Control and Performance of Hydroelectric Energy Projects

A hybrid uncertainty model was used by Tang, Li, and Tu (2018) to assess sustainability risk evaluation in large-scale hydropower projects. Their study evaluated the connection between risk management strategies and project performance using simulation techniques and quantitative data analysis. They found that project resilience is increased when risk responses are integrated with sustainability assessments.

Mohammadi, Tavakolan, and Khosravi (2018) conducted a comprehensive review focusing on factors that influence safety performance in construction projects, noting that safety is intrinsically tied to risk management practices. The study highlighted that regular safety assessments, which form part of risk review and control processes, directly improve project performance by reducing incidents and delays. Their findings suggest that incorporating continuous safety evaluations and adapting control measures based on emerging risk indicators can lead to a safer and more efficient project environment. This approach is relevant for hydroelectric projects, where construction safety risks must be proactively managed to ensure consistent project progress.

Chebotareva, Strielkowski, and Streimikiene (2020) focused on renewable energy projects in Russia, using a probabilistic risk analysis and risk matrix to monitor and control risks. The study found that systematic risk assessments and regular updates to risk control strategies allow for better management of financial, operational, and safety risks. Projects with effective control mechanisms had improved resilience, reduced delays, and better financial outcomes, underscoring the critical role of risk control in achieving sustainable performance.

Yüksel et al. (2024) developed a model for risk review and decision-making in hydroelectric investments using fuzzy logic and multi-criteria decision-making techniques. This model facilitated continuous assessment, allowing projects to adapt to risks more flexibly. Their findings showed that comprehensive risk review frameworks lead to proactive risk management, supporting both short-term project efficiency and long-term performance.

Methodology

The study adopted a descriptive and correlational research designs with questionnaire and interview guide for data collection from a census of 105 respondents. A pilot study involved 11 respondents for a reliability test that yielded a Cronbach's Alpha of 0.74 while the validity was tested through expert opinion that yielded a coefficient of 0.8. The data analysis techniques employed in this study included descriptive and inferential statistics of correlation and regression. The simple regression model was used for testing hypotheses H_01, H_02, H03, and H_04; for example, to test hypothesis one, the simple regression model took the form.

$$Y = \beta_0 + \beta_1 X_{1+} + \varepsilon$$

Then a multiple regression analysis:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Findings and Discussion

Out of the targeted 105 participants, 84 returned duly filled and complete questionnaires, resulting in 80% return rate.

Risk Identification and Performance of Hydroelectric Energy Projects

The study was to determine the influence of risk identification on the performance of hydroelectric energy projects in Rwanda through correlation and regression.

Relationship between Risk Identification and performance of hydroelectric Energy Projects

A correlation analysis sought to establish the existence of a relationship between Risk Identification and Performance of Hydroelectric Energy Projects.

Table 1: Risk Identification and Performance of Hydroelectric Energy Projects

		Risk Identification	**Performance of Hydroelectric Energy Projects**
Risk Identification	Pearson Correlation	1	.889**
	Sig. (2-tailed)		.000
	N	84	84
Performance of Hydroelectric Energy Projects	Pearson Correlation	.889**	1
	Sig. (2-tailed)	.000	
	N	84	84

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

The correlation results show that there is a strong positive correlation (R = 0.889) between Risk Identification and the Performance of Hydroelectric Energy Projects, which is statistically significant ($p = 0.000 < 0.05$. This indicates that Risk Identification and the Performance of Hydroelectric Energy Projects are strongly and positively correlated. Specifically, as the thoroughness and effectiveness of risk identification increase, the performance of hydroelectric energy projects also improves significantly. This result aligns with previous findings by Hakizimana et al. (2020) who observed a statistically significant relationship between effective risk management and the successful performance of projects. This suggests that improving risk identification in hydroelectric energy projects can lead to better overall project outcomes.

Effect of Risk Identification on Performance of Hydroelectric Energy Projects

A regression analysis sought to determine the linear effect of Risk Identification on the Performance of Hydroelectric Energy Projects.

Table 2: Effect of Risk Identification on Performance of Hydroelectric Energy Projects

Model	**R**	**R Square**		**Adjusted R Square**	**Std. Error of the Estimate**	
Summary	.889[a]	.789		.787	.44834	
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
ANOVA	Regression	61.803	1	61.803	307.458	.000[b]
	Residual	16.483	82	.201		
	Total	78.286	83			
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Coefficients	(Constant)	.451	.200		2.253	.027
	Risk Identification	.872	.050	.889	17.534	.000

a. Dependent Variable: Performance of Hydroelectric Energy Projects
b. Predictors: (Constant), Risk Identification

An R^2 value of 0.789 with a p-value of 0.000 ($p < 0.05$); indicates that Risk Identification explains 78.9% of the variation in the Performance of Hydroelectric Energy Projects, showing a very strong relationship between the two variables. Additionally, the model was a good fit for the data, with an $F(1,82) = 307.458$ ($p = 0.000 < 0.05$), which is statistically significant, indicating that Risk Identification significantly influences the performance of hydroelectric energy projects. Both the intercept ($\beta = 0.451$, $p = 0.027 < 0.05$) and for Risk Identification ($\beta = 0.872$, $p = 0.000 < 0.05$) are statistically significant. This means that for every unit change in Risk Identification, the Performance of Hydroelectric Energy Projects improves by 0.872 units.

The linear equation: $Y=0.451+0.872X_1$.

This shows that increasing Risk Identification is expected to result in a significant improvement in the performance of hydroelectric energy projects.

Test for Hypothesis One

H_{01}: There is no significant relationship between Risk Identification and Performance of Hydroelectric Energy Projects in Rwanda; was rejected ($p = 0.000 < 0.05$). This indicates that there is a significant relationship between Risk Identification and the Performance of Hydroelectric Energy Projects in Rwanda.

Risk Analysis and Performance of Hydroelectric Energy Projects

The study was to establish the influence of risk analysis on performance of hydroelectric energy projects in Rwanda through correlation and regression.

Relationship between Risk Analysis and Performance of Hydroelectric Energy Projects

The table below presents the Pearson correlation results between Risk Analysis and the Performance of Hydroelectric Energy Projects for selected micro hydropower plants in Rwanda.

Table 3: Relationship between Risk Analysis and performance of hydroelectric Energy Projects

		Risk Analysis	**Performance of Hydroelectric Energy Projects**
Risk Analysis	Pearson Correlation	1	.891**
	Sig. (2-tailed)		.000
	N	84	84
Performance of Hydroelectric Energy Projects	Pearson Correlation	.891**	1
	Sig. (2-tailed)	.000	
	N	84	84

Source: Author, 2025

The correlation results show that there is a strong positive correlation ($R = 0.891$) between Risk Analysis and the Performance of Hydroelectric Energy Projects, which is statistically significant ($p = 0.000 < 0.05$). This indicates that Risk Analysis and Performance of Hydroelectric Energy Projects are strongly positively correlated, meaning that as the quality and extent of Risk Analysis improve, the performance of the projects also improves significantly.

This finding is consistent with the view George (2020) that thorough Risk Analysis plays a crucial role in enhancing project outcomes. It supports the argument that effective risk management, such as through detailed analysis of potential risks, contributes significantly to the success and performance of hydroelectric energy projects.

Effect of Risk Analysis on Performance of Hydroelectric Energy Projects
The table below presents the Model Summary for the effect of Risk Analysis on the Performance of Hydroelectric Energy Projects in Rwanda.

Table 4: Effect of Risk Analysis on Performance of Hydroelectric Energy Projects

Model	**R**	**R Square**	**Adjusted R Square**		**Std. Error of the Estimate**	
Summary	.891[a]	.794	.791		.44397	
ANOVA		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
	Regression	62.123	1	62.123	315.1	.000[b]
	Residual	16.163	82	.197		
	Total	78.286	83			
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Coefficients	(Constant)	.409	.200		2.046	.044
	Risk Analysis	.902	.051	.891	17.75	.000

a. Dependent Variable: Performance of Hydroelectric Energy Projects
b. Predictors: (Constant), Risk Analysis

An R^2 value of 0.794 with $p = 0.000 < 0.05$, suggesting that Risk Analysis accounts for 79.4% of the variation in the performance of hydroelectric energy projects. This indicates a strong explanatory power of the independent variable in predicting the dependent variable. The model is found to be a good fit for the data, as indicated by the $F (1, 82) = 315.1$ ($p = 0.000 < 0.05$). The coefficients analysis reveals that the constant term has a coefficient of $\beta = 0.409$ ($p = 0.044 < 0.05$), which is statistically significant, representing the expected level of hydroelectric project performance when Risk Analysis is excluded. Risk Analysis has a coefficient of $\beta = 0.902$ ($p = 0.000 < 0.05$), indicating that for each unit increase in Risk Analysis, the performance of the hydroelectric energy project improves by 0.902 units.

Thus, the regression model: $Y = 0.409 + 0.902X_2$

This analysis demonstrates that Risk Analysis significantly and positively affects the performance of hydroelectric energy projects.

Test for Hypothesis Two
H_{02}: There is no significant relationship between Risk Analysis and Performance of Hydroelectric Energy Projects in Rwanda; was rejected ($p = 0.000 < 0.05$). Thus, the test confirms that Risk Analysis has a significant influence on performance of hydroelectric energy projects in Rwanda.

Risk Response and Performance of Hydroelectric Energy Projects
The study sought to establish the influence of Risk Response on the Performance of Hydroelectric Energy Projects.

Relationship between Risk Response and Performance of Hydroelectric Energy Projects
The table below presents the Pearson correlation results between Risk Response and the Performance of Hydroelectric Energy Projects for selected micro hydropower plants in Rwanda.

Table 5: Relationship between Risk Response and Performance of Hydroelectric Energy Projects

		Risk Response	**Performance of Hydroelectric Energy Projects**
Risk Response	Pearson Correlation	1	.853**
	Sig. (2-tailed)		.000
	N	84	84
Performance of Hydroelectric Energy Projects	Pearson Correlation	.853**	1
	Sig. (2-tailed)	.000	
	N	84	84

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

The correlation results show that there is a strong positive correlation ($R = 0.853$) between Risk Response and Performance of Hydroelectric Energy Projects, which is statistically significant ($p = 0.000 < 0.05$). This indicates that Risk Response and Performance of Hydroelectric Energy Projects are strongly positively correlated, meaning that as the effectiveness of Risk Response improves, the performance of hydroelectric energy projects also improves significantly. This finding aligns with the argument of Nepal (2021) who stipulated that effective Risk Response strategies are crucial for improving the performance of hydroelectric energy projects. Proper risk management ensures that potential issues are addressed proactively, leading to better project outcomes and overall performance.

Effect of Risk Response on Performance of Hydroelectric Energy Projects
A regression analysis sought to determine the linear effect of Risk Response on the Performance of Hydroelectric Energy Projects.

Table 6: Effect of Risk Response on Performance of Hydroelectric Energy Projects

Model	**R**	**R Square**	**Adjusted R Square**		**Std. Error of the Estimate**	
Summary	.853[a]	.727	.724		.51039	
ANOVA		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Model	Regression	56.925	1	56.925	218.524	.000[b]
	Residual	21.361	82	.260		
	Total	78.286	83			

Coefficients		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Model	(Constant)	.575	.229		2.514	.014
	Risk Response	.835	.057	.853	14.783	.000

a. Dependent Variable: Performance of Hydroelectric Energy Projects
b. Predictors: (Constant), Risk Response

An R^2 value of 0.727 ($p = 0.000<0.05$); indicates that Risk Response accounts for 72.7% of the variation in the Performance of Hydroelectric Energy Projects. The model was a good fit for the data, with an $F(1, 82) = 218.524$ ($p = 0.000 < 0.05$), indicating a statistically significant relationship between the variables. The coefficients of the intercept ($\beta = 0.575$, $p = 0.014<0.05$) and Risk Response ($\beta = 0.835$, $p = 0.000<0.05$) were both statistically significant. This suggests that for every unit increase in Risk Response, the Performance of Hydroelectric Energy Projects improves by 0.835 units.

The linear equation can be represented as: $Y = 0.575 + 0.835X_3$.

This demonstrates the positive and significant impact of Risk Response on the Performance of Hydroelectric Energy Projects.

Test for Hypothesis Three

H_{03}: There is no significant relationship between Risk Response and the Performance of Hydroelectric Energy Projects in Rwanda; was rejected ($p = 0.000<0.05$). Thus, the test confirms that Risk Response has a significant influence on the performance of hydroelectric energy projects in Rwanda.

Risk review and control and Performance of Hydroelectric Energy Projects

The study was to assess the influence of risk review and control on performance of hydroelectric energy projects in Rwanda through correlation and regression.

Relationship between Risk review and control and performance of hydroelectric Energy Projects

The table below presents the Pearson correlation results between Risk Review and Control and the Performance of Hydroelectric Energy Projects for selected micro hydropower plants in Rwanda.

Table 7: Relationship between Risk Review and Control and Performance of Hydroelectric Energy Projects

		Risk Review and Control	**Performance of Hydroelectric Energy Projects**
Risk Review and Control	Pearson Correlation	1	.892**
	Sig. (2-tailed)		.000
	N	84	84
Performance of Hydroelectric Energy Projects	Pearson Correlation	.892**	1
	Sig. (2-tailed)	.000	
	N	84	84

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

The correlation results show a very strong positive correlation ($R = 0.892$) between Risk Review and Control and the Performance of Hydroelectric Energy Projects, which is statistically significant ($p = 0.000 < 0.05$). This indicates that there is a strong and positive relationship between effectively reviewing and controlling risks and the overall performance of hydroelectric energy projects. As Risk Review and Control activities increase, the performance of these energy projects improves to a significant extent.

This result is consistent with the findings from previous studies, such as those by Chebotareva (2020) which noted the significant relationship between risk management practices and project performance. Effective risk review and control measures are critical in ensuring the successful performance and sustainability of complex energy projects, including hydroelectric initiatives.

Effect of Risk review and control on Performance of Hydroelectric Energy Projects

The table below presents the Model Summary for the effect of Risk Analysis on the Performance of Hydroelectric Energy Projects in Rwanda.

Table 8: Effect of Risk review and control on Performance of Hydroelectric Energy Projects

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**		
Summary	.892[a]	.796	.793	.44164		
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
ANOVA	Regression	62.292	1	62.292	319.379	.000[b]
	Residual	15.993	82	.195		
	Total	78.286	83			
Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
Coefficients	(Constant)	.501	.194		2.582	.012
	Risk Review and Control	.847	.047	.892	17.871	.000

a. Dependent Variable: Performance of Hydroelectric Energy Projects
b. Predictors: (Constant), Risk Review and Control

An R^2 value of 0.796 with $p = 0.000<0.05$, indicating that Risk Review and Control explains 79.6% of the variation in the Performance of Hydroelectric Energy Projects. The model was a good fit for the data, as the F-statistic is highly significant, $F(1, 82) = 319.379$, $p = 0.000 < 0.05$). Both the intercept ($\beta = 0.501$, $p = 0.012 < 0.05$) and the Risk Review and Control ($\beta = 0.847$, $p = 0.000 < 0.05$) coefficients are statistically significant, suggesting that the effectiveness of risk review and control has a strong and positive effect on the performance of hydroelectric energy projects. Specifically, for every unit increase in Risk Review and Control, the performance of hydroelectric energy projects increases by 0.847 units.

The relationship can be modelled using the equation: $Y=0.501+0.847X_4$.

This indicates that Risk Review and Control plays a major role in improving the performance of hydroelectric energy projects, with a strong positive effect.

Test for Hypothesis Four

H_{04}: There is no significant relationship between risk review and control and the performance of hydroelectric energy projects in Rwanda; was rejected ($p = 0.000 < 0.05$). Thus, risk review and control significantly contribute to the performance of hydroelectric energy projects. The effectiveness of risk management strategies, particularly the review and control process, enhances project performance and outcomes. The findings of the study are supported by Shaktawat (2020), which argues that effective risk review and control measures help identify potential issues early, mitigate risks, and improve project performance. This approach leads to better decision-making and more successful project implementation. Failure to implement thorough risk management processes often results in inefficiencies and poor project outcomes.

The Combined Effect of Risk Management Strategies on Performance of Hydroelectric Energy Projects

A multiple linear regression analysis was done to examine the combined effect independent variables on Performance of Hydroelectric Energy Projects.

Table 9: The Combined Effect of Risk Management Strategies on Performance of Hydroelectric Energy Projects

Model	**R**	**R Square**	**Adjusted R Square**		**Std. Error of the Estimate**	
Summary	.950[a]	.903	.898		.30983	
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
ANOVA	Regression	70.702	4	17.676	184.132	.000[b]
	Residual	7.584	79	.096		
	Total	78.286	83			
Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	T	Sig.
Coefficients	(Constant)	-.044	.148		-.296	.768
	Risk Identification	.199	.084	.202	2.370	.020
	Risk Analysis	.397	.065	.392	6.132	.000
	Risk Response	.117	.072	.120	1.638	.105
	Risk review and Control	.289	.075	.305	3.862	.000

a. Performance of Hydroelectric Energy Projects
b. Predictors: (Constant), Risk, Identification, Risk Analysis, Risk Response, Risk review and Control

An R^2 value of 0.903 with $p = 0.000 < 0.05$, suggesting that the combined risk management strategies (Risk Identification, Risk Analysis, Risk Response, and Risk Review and Control) explain 90.3% of the variation in the performance of hydroelectric energy projects. This indicates a very strong explanatory power of the independent variables in predicting the dependent variable. The model is found to be a good fit for the data and variables, as indicated by the $F(4, 79) = 184.132$ ($p = 0.000 < 0.05$).

The coefficients analysis reveals that the constant term has a coefficient of $\beta = -0.044$ ($p = 0.768 > 0.05$), which is not statistically significant at the 0.05 level, suggesting that the baseline level of hydroelectric project performance (when all risk management strategies are excluded) is not statistically different from zero.

Risk Identification has a coefficient of $\beta = 0.199$ ($p = 0.020 < 0.05$), indicating that for each unit increase in Risk Identification, the performance of the hydroelectric energy project improves by 0.199 units. Risk Analysis has a coefficient of $\beta = 0.397$ ($p = 0.000 < 0.05$), suggesting that a unit increase in Risk Analysis leads to a 0.397-unit improvement in project performance. Risk Response has a coefficient of $\beta = 0.117$ ($p = 0.105 > 0.05$), which is not statistically significant at the 0.05 level, suggesting that this strategy has a weaker impact on project performance compared to the other risk management strategies. Risk Review and Control shows a coefficient of $\beta = 0.289$ ($p = 0.000 < 0.05$), meaning that an increase in risk review and control efforts leads to a 0.289-unit improvement in project performance.

Thus, the regression model: $Y = -0.044 + 0.199X_1 + 0.397X_2 + 0.117X_3 + 0.289X_4$

This analysis demonstrates that Risk Identification, Risk Analysis, and Risk Review and Control significantly and positively affect the performance of hydroelectric energy projects. Risk Response, while showing a positive relationship, has a marginal effect on performance.

Conclusions

The study concludes that Rwanda's hydroelectric energy projects are largely successful in achieving their objectives in terms of timely completion, adherence to budget, operational performance, electricity quality, and environmental sustainability. However, the sustainability of these projects can be further enhanced through continuous monitoring and refining of the risk management strategies in place. Prioritization of risks based on impact and likelihood plays a key role in mitigating potential issues. Proactive risk response strategies, particularly risk mitigation, are crucial for the successful completion of hydroelectric projects. Respondents strongly favoured risk mitigation strategies, followed by risk retention for manageable risks. Although risk transfer mechanisms such as insurance were acknowledged, they were not as widely implemented. Continuous risk monitoring, regular feedback mechanisms, and the maintenance of detailed risk-related documentation significantly contribute to the success and sustainability of hydroelectric projects. These proactive practices ensure that emerging risks are quickly addressed, lessons are learned, and future projects benefit from improved risk management strategies.

It is recommended that Rwanda focus on continuous risk monitoring throughout the project lifecycle, with regular reviews and adjustments to existing risk management strategies to adapt to evolving project conditions. Further research should explore the long-term effectiveness of risk mitigation strategies in hydroelectric projects. This could involve tracking the outcomes of risk management approaches over the course of several projects to evaluate which strategies provide the best return on investment and contribute most to project sustainability.

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References

Amolo, A. E. (2022). Financial risk management instruments and performance of hydro-power projects in Kenya. University of Nairobi. https://doi.org/10.51244/ijrsi.2024.1108048http://erepository.uonbi.ac.ke/handle/11295/161427

Chebotareva, G., Strielkowski, W., & Streimikiene, D. (2020). Risk assessment in renewable energy projects: A case of Russia. Journal of Cleaner Production, 269, 122110. https://doi.org/10.1016/j.jclepro.2020.122110

George, C. (2020). The Essence of Risk Identification in Project Risk Management: An Overview. International Journal of Science and Research (IJSR), 9(2), 973-978. https://doi.org/10.21275/sr20215023033

Gurung, S. (2020). Risk analysis for the sustainable hydropower development in Nepal. International Journal of Advanced Engineering, Sciences and Applications, 1(2), 1-5. https://doi.org/10.47346/ijaesa.v1i2.39

Hakizimana, E., Wali, U. G., Sandoval, D., & Venant, K. (2020). Environmental impact assessment of hydropower plants in Rwanda: Nyabarongo I hydropower plant (NHPP I). Energy and Environmental Engineering, 7(2), 27-37. https://doi.org/10.13189/eee.2020.070202

Hopkin, P. (2018). Fundamentals of risk management: Understanding, evaluating and implementing effective risk management. Kogan Page Publishers.

Kunya, I. O., & Muchelule, Y. (2023). Risk Management Practices and Performance of Renewable Energy Projects in Nairobi County. World Journal of Innovative Research (WJIR, 14(4)

Qazi, A., Shamayleh, A., El-Sayegh, S., & Formaneck, S. (2021). Prioritizing risks in sustainable construction projects using a risk matrix-based Monte Carlo simulation approach. Sustainable Cities and Society, 65, 102576. https://doi.org/10.1016/j.scs.2020.102576

REG. (2023). Updated Rwanda LCPDP Plan 2023-2050. Home. https://www.reg.rw/fileadmin/user_upload/Updated_Rwanda_LCPDP_Plan_2023-2050_-_June_2023.pdf.