Effect of project risk management strategies on environmental sustainability in Rwanda's mining sector: A case study of the Bashyamba mining and mineral processing project at GAMICO Ltd.

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ABSTRACT

This study examined the effect of project risk management strategies on environmental sustainability in Rwanda's mining sector, using the Bashyamba Mining and Mineral Processing Project at GAMICO Ltd as a case study. The study was motivated by persistent environmental challenges associated with mining, including land degradation, water pollution, waste generation, biodiversity loss, and the continuing need to translate environmental requirements into effective project-level practice. This study was primarily underpinned by Risk Management Theory, which provides the central theoretical explanation for how systematic identification, assessment, response, and monitoring of project risks can influence project outcomes. The study was further informed by Contingency Theory, Sustainable Development Theory, and Systems Theory, which provide complementary explanations of how project conditions, sustainability objectives, and interactions among organizational and environmental systems shape environmental performance.A quantitative approach was adopted using descriptive and explanatory research designs. The target population comprised 88 permanent staff directly involved in project planning, implementation, environmental management, compliance, engineering and maintenance, mining supervision, risk management, and mineral resources management. Because the population was small and manageable, a census sampling technique was used and all 88 eligible staff were included. Primary data were collected through a structured five-point Likert-scale questionnaire, supplemented by key informant interviews, while secondary information was obtained through environmental and compliance documentation. Data were analyzed using descriptive statistics, Pearson correlation, and multiple linear regression. All 88 questionnaires were returned, giving a 100% response rate. The results showed positive and statistically significant correlations between environmental sustainability and risk identification ($r = 0.502$, $p < 0.001$), risk assessment ($r = 0.599$, $p < 0.001$), risk response ($r = 0.542$, $p < 0.001$), and risk monitoring and control ($r = 0.748$, $p < 0.001$). The overall regression model was statistically significant, $F(4,83) = 29.957$, $p < 0.001$, and explained 59.1% of the observed variation in environmental sustainability ($R^2 = 0.591$; adjusted $R^2 = 0.571$). When the four predictors were considered simultaneously, only risk monitoring and control made a statistically significant unique contribution ($\beta = 0.572$, $p < 0.001$). The study concludes that project risk management is meaningfully associated with environmental sustainability, with continuous monitoring and control emerging as the strongest unique predictor in the study setting. It recommends that mining project managers strengthen continuous environmental monitoring, audits, compliance inspections, incident reporting, and timely corrective action, while linking risk registers and assessment outputs to ongoing project control systems.

Keywords: Environmental Sustainability; Mining; Project Risk Management; Risk Identification; Risk Assessment; Risk Response; Risk Monitoring and Control

I. INTRODUCTION

Mining is an important component of economic development because minerals support industrialization, infrastructure, energy systems, employment, and foreign-exchange generation. At the same time, mining activities interact directly with land, water, ecosystems, and surrounding communities and can generate substantial environmental risks. The literature reviewed in the study identifies land degradation, deforestation, soil erosion, water pollution, biodiversity loss, waste-related impacts, and greenhouse-gas emissions among the principal environmental concerns associated with mining (Azapagic, 2004; Hilson, 2012).

Environmental sustainability in mining therefore depends not only on the existence of regulations, but also on how environmental risks are anticipated, assessed, treated, monitored, and controlled throughout the project life cycle. Project risk management provides a systematic process for identifying, analyzing, responding to, and monitoring risks (Hillson, 2009; Project Management Institute [PMI], 2021). In mining, these processes can be applied to environmental risks through environmental impact assessments, baseline studies, risk registers, probability-impact analysis, mitigation measures, environmental monitoring systems, audits, inspections, and corrective actions.

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Across Africa, environmental performance in mining has been affected by institutional, operational, and enforcement challenges. Evidence from Ghana, South Africa, and the Democratic Republic of Congo documents environmental consequences associated with inadequate management of water, waste, land, and mine closure (Banza et al., 2009; Hilson & Potter, 2005; Owusu-Nimo et al., 2018; Tutu et al., 2008). The literature also emphasizes that environmental impact assessment and regulatory compliance are more effective when integrated into continuing environmental management rather than treated as one-time compliance exercises (Glasson et al., 2013). Rwanda has established institutional and policy mechanisms for environmental protection and mining-sector regulation. The Rwanda Mines, Petroleum and Gas Board (RMB) and the Rwanda Environment Management Authority (REMA) are among the institutions responsible for the regulatory and environmental governance context in which mining projects operate. The thesis underpinning this article identified continuing concerns related to land degradation, water sedimentation, waste disposal, and rehabilitation, creating a need to understand how project-level risk management practices translate into environmental sustainability outcomes.

GAMICO Ltd operates within this regulatory environment, and the Bashyamba Mining and Mineral Processing Project provides a specific operational setting in which project risk management and environmental sustainability can be examined. The study focused on four project risk management dimensions: risk identification, risk assessment, risk response, and risk monitoring and control. Environmental sustainability was operationalized through water-quality protection, land rehabilitation, waste and tailings management, biodiversity conservation, and adherence to environmental laws and standards.

1.1 Statement of the Problem

Despite environmental regulations and formal environmental management requirements, environmental sustainability remains a continuing challenge in mining. Environmental risks may be recognized through environmental impact assessments and other technical studies, but the existence of an assessment does not by itself guarantee that identified risks will be prioritized, treated, monitored, and corrected throughout implementation. The underlying thesis identified persistent concerns relating to waste disposal, land rehabilitation, water quality, and ecosystem disruption and highlighted the possibility that environmental risk management may be applied reactively rather than as a continuous project-management process.

At the project level, an important unanswered question is whether the main components of project risk management are associated with measurable differences in environmental sustainability. In Rwanda, empirical evidence addressing this relationship within a specific mining project remains limited. This study therefore examined risk identification, risk assessment, risk response, and risk monitoring and control in relation to environmental sustainability at the Bashyamba Mining and Mineral Processing Project at GAMICO Ltd.

1.2 Research Objectives

i. determine the effect of risk identification strategies on environmental sustainability;
ii. establish the effect of risk assessment strategies on environmental sustainability
iii. determine the effect of risk response strategies on environmental sustainability;
iv. examine the effect of risk monitoring and control strategies on environmental sustainability.

II. LITERATURE REVIEW

2.1 Theoretical Review

This study was primarily underpinned by Risk Management Theory, which provides the central theoretical explanation for how systematic identification, assessment, response, and monitoring of project risks can influence project outcomes. The study was further informed by Contingency Theory, Sustainable Development Theory, and Systems Theory, which provide complementary explanations of how project conditions, sustainability objectives, and interactions among organizational and environmental systems shape environmental performance.

2.1.1 Contingency Theory

Contingency Theory holds that there is no single universally effective management approach; the effectiveness of management practices depends on the conditions in which they are applied (Donaldson, 2001). Mining projects operate under varying geological, technological, operational, environmental, and regulatory conditions. Consequently, risk identification, assessment, response, and control need to fit the specific characteristics of a project. The theory therefore supports the study's expectation that environmental risk management practices should be context-sensitive rather than applied mechanically.

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2.1.2 Risk Management Theory

Risk Management Theory provides the central theoretical basis for the study. It views uncertainty as an inherent feature of projects and emphasizes systematic identification, analysis, response, and monitoring of risks (Hillson, 2009; PMI, 2021). In the mining context, environmental risks such as water pollution, land degradation, waste impacts, and biodiversity loss require structured processes that continue throughout implementation. The theory directly underpins the four explanatory variables examined in this study and provides the clearest theoretical link between project risk management and environmental sustainability.

2.1.3 Sustainable Development Theory

Sustainable Development Theory provides the normative basis for the dependent variable. The Brundtland formulation defines sustainable development in terms of meeting present needs without compromising the ability of future generations to meet their needs (World Commission on Environment and Development [WCED], 1987). Applied to mining, the theory requires mineral development to be accompanied by protection of water, land, ecosystems, and other environmental resources. It therefore supports the use of water quality, land rehabilitation, waste and tailings management, biodiversity conservation, and regulatory compliance as indicators of environmental sustainability.

2.1.4 Systems Theory

Systems Theory views organizations and projects as interconnected systems in which changes in one component can affect other components (Meadows, 2008). Mining illustrates this interdependence because excavation, mineral processing, waste generation, water use, rehabilitation, community relations, and regulatory oversight can produce linked environmental effects. The theory therefore supports an integrated approach in which risk identification, assessment, response, and monitoring operate as connected processes rather than isolated activities.

Taken together, these theories provide a coherent foundation for the study. Contingency Theory explains the need for context-sensitive risk practices; Risk Management Theory explains the risk-management process; Sustainable Development Theory establishes the desired environmental outcome; and Systems Theory explains the interdependence among project activities and environmental effects.

2.2 Empirical Review

The empirical literature was organized around the four study objectives and the dependent variable. Previous evidence indicates that mining generates environmental risks involving land, water, waste, biodiversity, and rehabilitation. Studies of mining impacts have shown that ineffective management of waste and water can produce serious ecological and public-health consequences (Banza et al., 2009; Owusu-Nimo et al., 2018; Tutu et al., 2008), while research on rehabilitation and biodiversity indicates that environmental outcomes improve when these issues are incorporated into planning and management processes (Sonter et al., 2014, 2017). The evidence therefore supports environmental sustainability as a multidimensional outcome rather than a single compliance indicator.

2.2.1 Risk Identification and Environmental Sustainability

Risk identification is the starting point for anticipating environmental exposure. In mining, environmental impact assessments, baseline studies, inspections, stakeholder consultations, and risk registers help convert potential environmental threats into documented risks that can be prioritized. Glasson et al. (2013) emphasize that environmental impact assessment is most useful when its findings inform continuing management rather than functioning only as an approval requirement. The broader mining literature similarly documents environmental risks associated with land degradation, water pollution, biodiversity loss, and inadequate rehabilitation (Azapagic, 2004; Hilson, 2012).

The literature consequently supports the preventive value of risk identification, but it provides less direct evidence on whether identification practices independently predict environmental sustainability once assessment, response, and monitoring are considered simultaneously. This distinction is important because identification may generate the information needed for action without itself producing the environmental outcome. The present study addresses this issue by examining both the bivariate relationship and the unique regression contribution of risk identification.

2.2.2 Risk Assessment and Environmental Sustainability

Risk assessment extends identification by evaluating the likelihood and potential consequences of identified risks and prioritizing those requiring attention. Probability-impact matrices, risk ranking, and resource prioritization are particularly relevant in mining because environmental risks differ in severity, reversibility, and regulatory consequence (Aven, 2016; Hillson, 2009). Evidence from mining also shows that effective prioritization of environmental hazards can support better allocation of resources to water protection, waste control, rehabilitation, and biodiversity management.

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However, previous literature generally establishes the importance of risk assessment at a conceptual or sectoral level rather than testing its unique contribution alongside other project risk-management stages. The present study therefore tests whether risk assessment is associated with environmental sustainability and whether that association remains statistically distinguishable after controlling for risk identification, response, and monitoring and control.

2.2.3 Risk Response and Environmental Sustainability

Risk response concerns the actions taken after risks have been assessed. In project risk management, common responses include avoidance, mitigation, transfer, and acceptance (PMI, 2021). In mining, responses can involve redesigning activities, pollution prevention, water-treatment measures, rehabilitation of disturbed land, allocation of responsibilities, and management of residual risks. Research on mine rehabilitation and environmental management indicates that proactive responses can reduce long-term environmental impacts and improve post-mining outcomes (Hilson & Potter, 2005; Sonter et al., 2014). At the same time, response effectiveness depends on whether measures are implemented, resourced, monitored, and adjusted. This means that a formal mitigation plan may have limited environmental value if its implementation is not followed by continuing control. The present study therefore examines risk response both as an independent relationship with environmental sustainability and as a predictor within the full risk-management model.

2.2.4 Risk Monitoring and Control and Environmental Sustainability

Risk monitoring and control provides the feedback mechanism through which project teams determine whether risk responses remain effective. It involves environmental monitoring, audits, inspections, reporting of incidents and deviations, review of controls, and corrective action. Evidence from mining and environmental management emphasizes the importance of continuous monitoring for water quality, waste and tailings, rehabilitation, biodiversity, and regulatory compliance (Lottermoser, 2010; ICMM, 2021). Monitoring and control may therefore have a more immediate connection with observable environmental outcomes than earlier stages of the risk cycle because it verifies implementation and triggers corrective action. Nevertheless, the empirical evidence available for Rwanda is limited at the project level. This study addresses that gap by testing both the bivariate association and the unique contribution of risk monitoring and control in a simultaneous regression model.

2.3 Research Gap and Contribution

Three related gaps emerge from the literature. First, much mining research emphasizes environmental impacts, regulatory compliance, or environmental impact assessment, while comparatively less attention is given to project risk management as an integrated process. Second, evidence from Rwanda has tended to emphasize regulatory and institutional dimensions, leaving limited project-level evidence on how risk identification, assessment, response, and monitoring operate together. Third, evidence from other mining jurisdictions cannot automatically be assumed to represent Rwanda's operational and regulatory context. The present study addresses these gaps through firm-level evidence from the Bashyamba Mining and Mineral Processing Project at GAMICO Ltd and by testing both bivariate associations and the unique contribution of the four risk-management dimensions.

III. METHODOLOGY

3.1 Research Design

The study adopted a quantitative research approach using descriptive and explanatory research designs. The descriptive component summarized respondents' perceptions of project risk management practices and environmental sustainability, while the explanatory component examined the statistical relationships and predictive contribution of the four risk-management dimensions. A cross-sectional design was used, with field data collected in 2026 concerning the project context and activities within the study scope of 2021–2025.

3.2 Study Area

The study was conducted at the Bashyamba Mining and Mineral Processing Project at GAMICO Ltd, located in Ruliba Cell, Kigali Sector, Nyarugenge District, City of Kigali, Rwanda. The site was selected because it provides an operational mining-project context in which environmental risk management practices and sustainability outcomes can be examined within Rwanda's regulatory environment.

3.3 Target Population, Sampling Technique and Sample Size

The target population comprised 88 permanent staff whose roles were directly connected to project planning, implementation, operational oversight, environmental management, compliance, risk management, engineering and maintenance, mining supervision, and mineral resources management. A census sampling technique was used. Because

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the eligible population was relatively small and manageable, the study sought participation from all 88 staff rather than selecting a subset. All 88 questionnaires were subsequently returned, producing a 100% response rate.

3.4 Data Collection Instruments and Procedures

Primary quantitative data were collected using a structured questionnaire measured on a five-point Likert scale, where 1 represented strongly disagree and 5 represented strongly agree. The instrument covered risk identification, risk assessment, risk response, risk monitoring and control, and environmental sustainability indicators. The measurement indicators were derived from the literature and established project-management and environmental-management guidance, including PMI (2021), Hillson (2009), Azapagic (2004), and ICMM (2021).

The questionnaire was pilot tested with approximately 10 respondents who were not part of the final study population and was refined before the main data collection. Semi-structured interviews were also conducted with selected key informants, including project managers, environmental officers, compliance officers, and senior management representatives. The interviews provided contextual information to support interpretation of the quantitative results but were not subjected to a separate inferential analysis. Secondary information was obtained through documentary review of Environmental Impact Assessment material, Environmental Management Plans, environmental audit and monitoring reports, water-related reports, and regulatory compliance records.

3.5 Validity and Reliability

Content and construct validity were strengthened through review of the instruments by academic supervisors and experts in project management and environmental sustainability, together with alignment of questionnaire items to established literature and the study constructs. The pilot exercise was used to identify ambiguity and improve item clarity before the main survey. Internal consistency was assessed using Cronbach's alpha. The coefficients were 0.785 for risk identification, 0.815 for risk assessment, 0.700 for risk response, 0.782 for risk monitoring and control, and 0.896 for environmental sustainability, indicating acceptable to strong internal consistency.

3.6 Data Analysis Procedures

Quantitative data were analyzed using descriptive statistics, Pearson correlation, and multiple linear regression. Frequencies and percentages were used to summarize respondent characteristics; means and standard deviations summarized perceptions of the study variables. Pearson correlation was used to determine the direction and strength of bivariate associations between each risk-management dimension and environmental sustainability. Multiple linear regression was then used to estimate the simultaneous contribution of the four explanatory variables and to distinguish their unique contributions after accounting for overlap among predictors.

The regression model was specified as $ES = \beta 0 + \beta 1RI + \beta 2RA + \beta 3RR + \beta 4RMC + \varepsilon$, where ES denotes environmental sustainability, RI risk identification, RA risk assessment, RR risk response, RMC risk monitoring and control, and ε the error term. Diagnostic checks included normality assessment and review of regression assumptions. The final regression output reported $R = 0.769$, $R^2 = 0.591$, adjusted $R^2 = 0.571$, and Durbin-Watson = 1.274. Because the analysis is based on the final thesis output, these reported values were retained rather than replaced with values from earlier drafts.

3.7 Ethical Considerations

Participation was voluntary and based on informed consent. Respondents were informed of the academic purpose of the study and their right to participate without coercion. Confidentiality and anonymity were maintained, and information collected from participants and project documents was handled for academic purposes. The final thesis material did not report a specific ethics committee approval number.

IV. FINDINGS & DISCUSSION

4.1 Response Rate and Respondent Profile

All 88 questionnaires were returned, giving a 100% response rate. The respondents included 40 participants with bachelor's degrees (45.5%), 36 with diplomas (40.9%), and 12 with master's degrees (13.6%). The respondents were therefore drawn from a range of formal educational backgrounds relevant to technical, managerial, environmental, compliance, and operational functions in the project.

4.2 Reliability of the Study Constructs

All five constructs met the study's acceptable internal-consistency threshold, supporting the use of the questionnaire scales in subsequent analysis.

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Table 1

Internal consistency of study constructs

Construct	Cronbach's alpha	Interpretation
Risk identification	0.785	Acceptable internal consistency
Risk assessment	0.815	Strong internal consistency
Risk response	0.700	Acceptable internal consistency
Risk monitoring and control	0.782	Acceptable internal consistency
Environmental sustainability	0.896	Strong internal consistency

4.3 Descriptive Evidence on Environmental Sustainability

Respondents generally reported positive environmental sustainability outcomes. Regulatory compliance recorded the highest mean (M = 4.66, SD = 0.565), followed by water-quality protection (M = 4.56, SD = 0.756), biodiversity protection (M = 4.49, SD = 0.830), waste and hazardous-material management (M = 4.41, SD = 0.839), and land rehabilitation (M = 4.37, SD = 0.792). These descriptive results indicate generally favorable perceptions of environmental performance at the project, while the inferential results below provide a more rigorous test of the relationship between project risk management and environmental sustainability.

Table 2

Descriptive indicators of environmental sustainability

Environmental sustainability indicator	Mean	SD
Compliance with REMA and RMB environmental regulations	4.66	0.565
Water quality is effectively protected	4.56	0.756
Land rehabilitation and restoration are effectively implemented	4.37	0.792
Waste, tailings and hazardous materials are managed responsibly	4.41	0.839
Negative impacts on biodiversity and ecosystems are minimized	4.49	0.830

4.3.1 Risk Identification and Environmental Sustainability

Risk identification had a positive and statistically significant bivariate relationship with environmental sustainability ($r = 0.502$, $p < 0.001$). Respondents reported strong implementation of environmental impact assessments, baseline studies, inspections, stakeholder consultation, and risk registers; the highest risk-identification item in the thesis was the conduct of EIAs before project commencement (M = 4.56, SD = 0.741). However, risk identification did not make a statistically significant unique contribution in the multiple regression model ($\beta = 0.019$, $p = 0.851$). This means that the bivariate association should not be interpreted as evidence that identification alone predicts environmental sustainability after the other risk-management dimensions are controlled. The finding is consistent with the literature suggesting that identification creates the information needed for preventive management, but its environmental value depends on subsequent assessment, response, monitoring, and corrective action (Glasson et al., 2013; Azapagic, 2004). The result therefore answers Objective One by showing a positive association but no statistically distinguishable unique predictive contribution in the full model.

4.3.2 Risk Assessment and Environmental Sustainability

Risk assessment showed a positive and statistically significant correlation with environmental sustainability ($r = 0.599$, $p < 0.001$). The thesis findings indicate strong perceptions of practices such as prioritizing high-risk environmental issues and using assessment results to influence resource allocation. These findings are consistent with risk-management literature emphasizing probability-impact evaluation and prioritization as mechanisms for directing management attention toward significant risks (Aven, 2016; Hillson, 2009). In the simultaneous regression model, however, risk assessment had a positive but statistically insignificant coefficient ($\beta = 0.125$, $p = 0.257$). This suggests that part of the bivariate relationship overlaps with the other risk-management processes. In practical terms, assessment may support environmental sustainability by determining which risks require attention, while measurable outcomes depend on whether those priorities are converted into responses and then continuously monitored. Objective Two is therefore answered by a positive bivariate relationship but no statistically significant unique contribution in the full model.

4.3.3 Risk Response and Environmental Sustainability

Risk response had a positive and statistically significant bivariate relationship with environmental sustainability ($r = 0.542$, $p < 0.001$). The study considered avoidance, mitigation, transfer, and acceptance, including environmental

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measures such as pollution prevention, land rehabilitation, and management of residual risks. This finding is broadly consistent with evidence that proactive rehabilitation and risk-response measures can reduce long-term environmental impacts (Hilson & Potter, 2005; Sonter et al., 2014). Risk response was nevertheless not statistically significant in the simultaneous regression model ($\beta = 0.145$, $p = 0.113$). This result suggests that the positive association observed at the bivariate level is not sufficiently distinct from the effects of identification, assessment, and monitoring and control when all four dimensions are considered together. Objective Three is therefore answered by evidence of a positive association but not a statistically significant unique predictive contribution.

4.3.4 Risk Monitoring and Control and Environmental Sustainability

Risk monitoring and control had the strongest bivariate relationship with environmental sustainability ($r = 0.748$, $p < 0.001$) and was the only statistically significant unique predictor in the regression model ($\beta = 0.572$, $p < 0.001$). The study assessed monitoring systems, periodic environmental audits and compliance inspections, incident reporting, corrective action, and regular review of environmental controls. The result indicates that the continuing verification and correction of environmental performance was more strongly associated with sustainability outcomes than any other single risk-management dimension in the simultaneous model. This finding is consistent with the empirical and practice-oriented literature emphasizing continuous environmental monitoring, waste and tailings control, rehabilitation, biodiversity management, and regulatory compliance (Lottermoser, 2010; ICMM, 2021). It also supports the systems perspective because monitoring provides feedback that connects identification, assessment, response, and corrective action. Objective Four is therefore answered clearly: risk monitoring and control showed both a strong bivariate relationship and a statistically significant unique contribution to environmental sustainability.

4.4 Overall Regression Model

Table 3

Pearson correlations with environmental sustainability

Risk-management dimension	Pearson r	p-value	N
Risk identification	0.502	<0.001	88
Risk assessment	0.599	<0.001	88
Risk response	0.542	<0.001	88
Risk monitoring and control	0.748	<0.001	88

All four dimensions were positively and significantly associated with environmental sustainability at the bivariate level. Risk monitoring and control had the strongest association, followed by risk assessment, risk response, and risk identification.

Table 4

Regression model summary

Statistic	Value
R	0.769
R^2	0.591
Adjusted R^2	0.571
Std. Error of Estimate	0.37101
Durbin-Watson	1.274

The four risk-management dimensions jointly explained 59.1% of the observed variation in the environmental sustainability measure ($R^2 = 0.591$), with an adjusted R^2 of 0.571. The overall regression model was statistically significant, $F(4,83) = 29.957$, $p < 0.001$. The Durbin-Watson statistic was 1.274. Values around 2 are commonly associated with independent residuals, whereas values below 2 can indicate positive residual autocorrelation when observations have a meaningful sequential or temporal order. However, this study used cross-sectional survey data collected from 88 respondents rather than time-series or panel observations, and the respondents were not ordered chronologically. Accordingly, the Durbin-Watson statistic has limited substantive interpretive value in this study and should not be treated, on its own, as evidence of time-dependent autocorrelation or as a reason to invalidate the regression model. The statistic is reported transparently as part of the regression diagnostics, while the study design provides the principal basis for considering independence of observations.

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Table 5

Multiple regression coefficients

Predictor	B	Standardized β	t	p
Constant	0.715	—	1.766	0.081
Risk identification	0.018	0.019	0.188	0.851
Risk assessment	0.121	0.125	1.142	0.257
Risk response	0.170	0.145	1.601	0.113
Risk monitoring and control	0.562	0.572	5.347	<0.001

The coefficients confirm the distinction between correlation and regression. Each dimension had a significant positive bivariate association with environmental sustainability, but only risk monitoring and control retained a statistically significant unique contribution when the four dimensions were entered simultaneously. The overall model was significant, so the four dimensions collectively provide meaningful explanatory information even though three individual coefficients were not statistically significant after overlap among predictors was controlled.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The study concludes that project risk management strategies are positively associated with environmental sustainability at the Bashyamba Mining and Mineral Processing Project at GAMICO Ltd. Risk identification, risk assessment, risk response, and risk monitoring and control each showed statistically significant bivariate relationships with environmental sustainability. The overall regression model was also statistically significant and explained 59.1% of the observed variation in the environmental sustainability measure. At the individual level, however, only risk monitoring and control made a statistically significant unique contribution to environmental sustainability. This result does not imply that risk identification, risk assessment, or risk response are unimportant. Rather, their contributions were not statistically distinguishable from the other dimensions in the simultaneous model. The evidence therefore supports an integrated risk-management system in which early identification and assessment create the basis for action, response measures address identified risks, and continuous monitoring and control provides the feedback and corrective mechanism through which environmental performance is maintained.

5.2 Recommendations

First, mining project managers should strengthen continuous environmental monitoring and control because this was the strongest unique predictor of environmental sustainability in the study. Monitoring systems should cover key environmental indicators and should be linked to routine inspections, audits, incident reporting, performance targets, and documented corrective actions. Second, environmental audits and compliance inspections should be conducted systematically, with findings assigned to responsible officers, deadlines established, and closure of corrective actions verified. This recommendation follows directly from the strong contribution of monitoring and control and the importance of compliance and feedback in maintaining environmental performance.

Third, mining projects should maintain active links between risk registers, risk assessments, and monitoring systems. Identified environmental risks should remain visible throughout implementation, while assessment results should inform project planning, resource allocation, and the selection of controls. This will help ensure that risk identification and assessment are translated into operational action rather than remaining primarily documentation exercises. Fourth, environmental response measures should be documented with measurable outcomes. Where avoidance, mitigation, rehabilitation, transfer, or acceptance of residual risk is selected, project managers should define the expected environmental result, responsible person, implementation timeframe, and monitoring indicator. This would strengthen the connection between response planning and environmental performance.

Fifth, regulators and mining-sector stakeholders, including RMB and REMA, should continue strengthening project-level monitoring, compliance inspections, and evidence-based enforcement. Regulatory oversight can be made more effective when it is informed by documented project monitoring results, corrective-action records, and trends in environmental performance. Finally, mining companies should provide regular training for project managers, environmental officers, contractors, and operational staff on integrated environmental risk management, monitoring, reporting, and corrective action. Capacity building should be linked to the specific environmental risks and controls relevant to each project rather than treated as a generic compliance activity.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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