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PROJECT MANAGEMENT PRACTICES AND SUSTAINABILITY OF SMALL DAMS AND WATER PAN PROJECTS IN MACHAKOS COUNTY, KENYA

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ABSTRACT

Arid and semi-arid lands (ASALs) experience persistent water scarcity due to low and erratic rainfall, making sustainable water infrastructure essential for socioeconomic development. Despite significant investments in small dams and water pans in Machakos County, Kenya, many of these projects experience declining functionality within a few years of completion. This study examined the influence of project management practices, specifically cost management and risk management, on the sustainability of small dams and water pan projects in Machakos County, Kenya. The study was anchored on the Theory of Strategic Cost Management and Risk Management Theory and adopted a descriptive research design. The target population comprised 324 respondents drawn from county officials, water company officials, project managers and engineers, and community beneficiaries. Using the Yamane sampling formula, a sample of 179 respondents was selected, of whom 162 returned completed questionnaires, representing a response rate of 90.5%. Primary data were collected using a structured questionnaire and analysed using descriptive statistics, Pearson correlation analysis, and multiple linear regression. The findings revealed that both cost management and risk management had positive and statistically significant effects on the sustainability of small dams and water pan projects. Cost management emerged as the strongest predictor of sustainability, indicating that effective budgeting, expenditure monitoring, procurement control, and maintenance financing are critical for ensuring long-term project functionality. Risk management also significantly enhanced sustainability through proactive risk identification, feasibility assessment, early warning systems, and preventive interventions. The study recommends adopting lifecycle-based cost management, establishing ring-fenced maintenance funds, strengthening routine risk monitoring and early warning systems, and developing a county-level sustainability framework to enhance the long-term performance of small dams and water pans in Machakos County.

Keywords: Cost management; Risk management; Project management practices; Sustainability; Small dams; Water pan projects; Machakos County; Kenya.

INTRODUCTION

Water scarcity remains one of the most pressing challenges of the 21st Century in many parts of the world. As of 2026, about 2.2 billion people worldwide still lack access to water sources, indicating a significant gap in global water security (UNESCO World Water Assessment Programme, 2026). Salehi (2022) notes that water insecurity is an ongoing world global problem that needs immediate intervention. According to Ling (2022), rapid population growth from 7.23 billion to 8.02 billion in the last century has intensified this challenge by mounting pressure on existing water resources. Estimations by Boretti and Rosa (2019) suggests that global demand for water, at 4,600 km^3 per year in 2019, is projected to grow to about 5,500 km^3 and 6,600 km^3 per year by 2050. The demand is driven by growing global population to about 9.4 billion and 10.2 billion people (O'Neill, 2024).

In Kenya, water scarcity is commonly reported in arid and semi-arid lands (ASALs), which constitute nearly 80% of the country's landmass (The State Department for the ASALs and Regional Development, 2025). These regions experience low, erratic rainfall and high evapotranspiration rates, making conventional water sources inefficient. To address this challenge, national and county governments have increasingly invested in the construction and management of various water projects including small dams and water pans as strategic interventions for harvesting and storing rainwater. Churu *et al*. (2023) observe that such water harvesting structures often help to enhance water availability for domestic use, livestock, irrigation, and aquaculture in ASAL communities.

Despite these efforts, the sustainability of many water projects including the small dams and water pans has become a growing concern. Numerous studies have linked the high failure rates of completed water projects in ASALs to inadequate project management practices. Particularly, Kamalan and Abedin-Maghanaki (2020) attribute the poor performance of many water projects to issues such as insufficient budget allocation, weak contractor oversight, inadequate technical expertise, and poor planning. These challenges often result in structural failures, rapid siltation, and reduced functionality shortly after project completion. Consequently, recurring water shortages often create anxiety, economic strain, and reduced resilience among affected communities.

Addressing water projects sustainability problem therefore requires effective project management practices to ensure that small dams and water pans give long-term benefits. Ronoh (2020) and Malusi (2023) pointed out that that properly-executed project management practices, with appropriate, cost control, and risk management can improve the sustainability of water projects. Such practices ensure that water harvesting structures are constructed within scope, delivered on time, remain financially viable, and are resilient to environmental and operational risks. Hence, justifying the need for a systematic evaluation of project management practices and their influence on the sustainability of small dams and water pans in ASALs in Kenya.

Statement of the Problem

Despite the ongoing efforts to improve water security, Machakos County, Kenya, still faces chronic water scarcity due to the inconsistent rainfall patterns and prolonged dry seasons throughout the year. Machakos County Annual Development Plan for the FY2025-2026 reports that the region's water level is below the average national natural endowment of 647m3 per capita per year (County Government of Machakos, 2025). The 2021's 'Environmental & Social Impact Assessment' Study for the proposed 'Mwania/Miwongoni Dam Water Supply Project for Machakos County' further noted that the annual average rainfall in Machakos County ranges between 500mm and 1000mm with short rains experienced in October to December and long rains only between March and May (AWWDA, 2021). These climatic conditions continue to mount pressure on existing water sources and heighten the need for sustainable water storage systems.

Although small dams and water pans have been constructed in Machakos County, Kenya, to mitigate water shortages; their long-term sustainability remains questionable (County Government of Machakos, 2025). Lilian and Mutiso (2019) established that about 67% of water projects in ASAL counties fail within the first five years of operation. In Machakos County, recurring issues such as siltation, structural degradation, spillway failures, and reduced storage capacity have been widely reported (Ronoh, 2020; Kosgei, 2021). The County Government of Machakos (2025) noted that 37 small dams and water pans required desilting and rehabilitation in the 2023/2024 financial year alone, indicating significant sustainability challenges.

Several studies have attributed these systemic failures to weaknesses in project management practices. Senaratne et al. (2024) argued that scope creep, inadequate stakeholder engagement, cost overruns, and unmanaged risks significantly undermine project performance. In Machakos County, Kosgei (2021) reported that approximately 82% of water projects fail largely because of inadequate stakeholder consultations and limited community engagement during planning and implementation. Ahmed *et al.* (2023) also observed that poor cost control mechanisms often result in cost overruns exceeding 50% of the initial budget, making long-term maintenance financially unattainable.

Additional studies further demonstrate that many projects are unsustainable due to poor project management practices that undermine their long-term functionality and resilience. According to Munyugi and Nteere (2024), about 40% of completed water projects in ASALs fail to sustain operations beyond the initial implementation phase due to poor risk management practices. In 2024, Jama observed that 59% of the water projects completed in 2021 remained non-operational, with 25% experiencing on-off operations due to machine and resource management ineffectiveness (Jama, 2024). Obialor *et al.* (2019) further observed that less than half of desilted water projects remain functional for more than 40 years due to rapid sedimentation and insufficient maintenance. Narayan *et al*. (2021) also reported that over 82% of rehabilitated small dams are vulnerable to flood damage when hydraulic safety measures are inadequate.

Despite these documented challenges, limited empirical research has examined how project management practices - specifically cost management, and risk management - influence the sustainability of small dams and water pans in Machakos County, Kenya. This study therefore sought to fill this gap by assessing the extent to which these practices influence sustainability of water projects in the Machakos County, Kenya. The findings give insights into how each of these project management practices contribute to the long-term functionality and resilience of small dams and water pans in the region.

Objectives of the Study

The main objective of this study was to assess the influence of project management practices on the sustainability of small dams and water pan projects in Machakos County, Kenya.

Specific Objectives

i. To assess the influence of cost management on the sustainability of small dams and water pan projects in Machakos County, Kenya.
ii. To evaluate the influence of risk management on sustainability of small dams and water pan projects in Machakos County, Kenya.

LITERATURE REVIEW

Theoretical Review

Theory of Strategic Cost Management (TSCM)

The Theory of Strategic Cost Management (TSCM) emphasizes the need to integrate cost planning, cost control, and value optimization in a project lifecycle to enhance its performance (Abdelraheem, 2023). Theorists Shank and Govindarajan came up with this theory in 1990s to

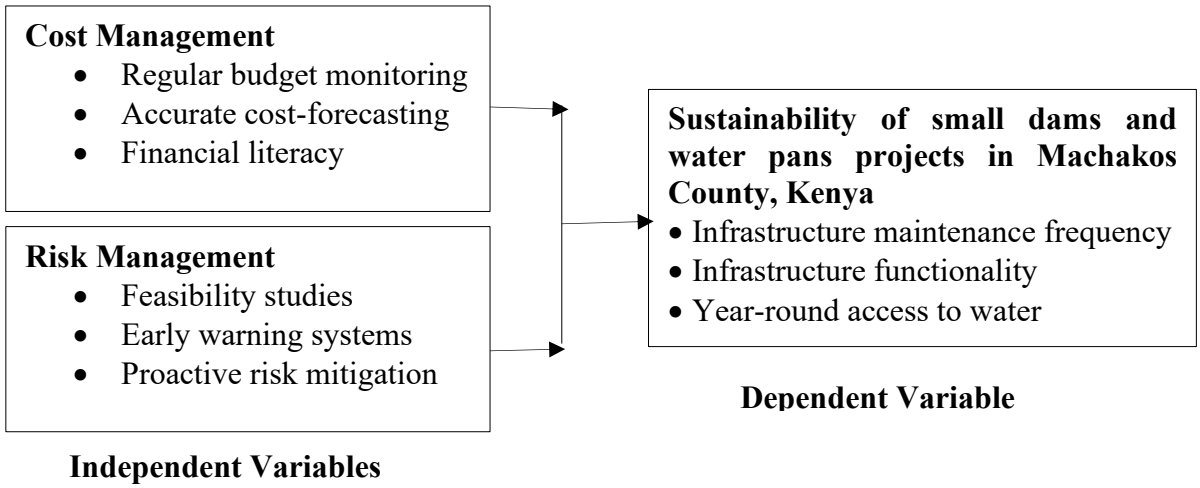
demonstrate the importance of integrating cost of a project with strategic decision-making (Duçi, 2021). They argued that cost management in a project should focus on both minimizing expenses and maximizing value throughout the project's lifecycle. In particular, it should include aligning financial decisions with long term project goals. Venkataraman and Pinto (2023) established that effective cost management reduces the likelihood of cost overruns, enhance resource allocation, and improve project sustainability. Conversely, poor cost management can lead to stalled projects, compromised quality, and high maintenance charges. For small dams and water pans, effective cost management can ensure optimal resource allocation with good financial efficiency. The TSCM approach has been applied to this study to explore how cost management practices can influence sustainability by ensuring infrastructure remains functional and economically viable over a longer period.

Risk Management Theory (RMT)

Risk Management Theory (RMT) emphasizes the systematic identification, assessment, and mitigation of risks that may otherwise affect project progress (Ullah *et al*., 2021). Theorist Daniel Bernoulli promulgated the Risk Management Theory (RMT) in 1738 to show how projects can create value under uncertainties (Komu & Mungai, 2024). Nearly all project faces some sort of risk, which affect them positively or negatively. Such risks arise from environmental conditions, technical failures, financial uncertainties, or stakeholder dynamics. In the context of small dams and water pans, risks included siltation, flooding, structural failures, equipment breakdowns, and climate variability (Kosgei, 2021). Ajayi *et al*. (2020) observed that it is difficult to avoid risks completely but it is possible to take precautionary measures to control the impact. In some cases, however, after having assessed the frequency and severity of risks identified, project managers may advisably retain the risk or a portion of it especially when it is cost effective to do so. Wijaya (2021) also advised that where risk cannot be avoided or retained, they can be spread through duplication of documents or records to minimize potential losses in terms of frequency and magnitude. The RTM has been applied to this study to examine whether proactive risk management can influence project sustainability and consequently reduce the likelihood of project collapse or non-functionality.

Conceptual Framework

A conceptual framework is an analytical tool showing the relationship between independent variables and dependent variable of a study (Borkowski, 2024). The structure serves as a roadmap outlining how different concepts of study variables are expected to influence each other within the study, hence helping the study to link theoretical knowledge to practical applications (Castiblanco Jimenez *et al*., 2023). Figure 2.1 is a conceptual framework graphically illustrating how project management practices (cost management, and risk management) as independent variables of the study, influence the dependent variable, which is the sustainability of small dams and water pans projects in Machakos County, Kenya.



Cost Management

Cost-management practices contribute to a bigger part of success of any project. According to Dabirian *et al*. (2023), cost management entails identifying, acquiring, allocating and utilizing resources needed to complete a given project within the cost estimates of the entire project. For many projects, cost management may include activities like regular budget monitoring, cost-effective purchasing, and use of historical cost data to ensure projects are completed within the defined budget (Venkataraman & Pinto, 2023).

To be cost-effective entails minimizing expenses while maximizing profitability. Effective cost management practices are good for a project's sustainability, especially when working with limited budgets. Pojar (2023)'s study in assessment of how cost-effective practice as regular budget monitoring enhances organizational sustainability established that it improves budget oversight, ensuring that the project operates within the initially set budget. Paul *et al.* (2024) also established that cost-effective management practices such as buying materials in bulk can save a lot of money, enhancing project sustainability. Cost-effectiveness therefore allows project managers to minimize unnecessary expenses and simultaneously maximize value for money.

Another important area of effective cost management is accurate cost forecasting. It involves using previous and current data to estimate future patterns and trends in a project's expenditure (Duçi, 2021). In a study by Holm and Schaufelberger (2021) about the use of historical cost data on cost estimation, it was established that the past and present financial information set the baseline for estimating future costs. For project managers, they can analyze the financial data relating to expenditures to determine trends and patterns in expenses, which helps them to avoid under- or over-estimation for upcoming activities. Managers can also identify factors driving costs upwards, thus make informed decisions about how best to keep the costs low without affecting operations.

Ngiri and Njagi (2022) support this claim, arguing that in this modern business era, companies are increasingly looking for project managers with the necessary skills to challenge the dynamic global market. Among other things, organizations want financial managers who can make wise financial decisions and still remain competitive amidst shifting consumer preferences, and rising cost of materials. Through a descriptive and cross-sectional research approaches, with 96 CEOs sampled from different registered construction companies in Nairobi, it was established that financial literacy can enhance strategic resource mobilization in a project, which is increasingly important to service provisions to clients and supporting organizational sustainability (Ngiri and Njagi, 2022). Cost management practices for this study included regular budget monitoring, accurate cost-forecasting, and financial literacy, with the focus being on how each influenced sustainability of small dams and water pans projects in Machakos County, Kenya.

Risk Management

Risk management in a project aims to prevent uncertainties that may otherwise make a project unsustainable if not properly managed. Ahmad *et al.* (2022) describes risk in a project to be any occurrence or situation that may affect objectives of that project positively or negatively. In project management, managers use project risk management (PRM) framework to identity, analyze and respond to different risks.

One of the risk management practices for a project is conducting feasibility studies. A feasibility study is an in-depth analysis of a project's viability based on its financial, social, technical and environmental dimensions just before the study begins (Sankar et al., 2021). According to Mohammed *et al*. (2019), a feasibility study establishes whether a project is practical and with good chance of success. A successful feasibility study can help identify

potential issues and challenges likely to impact the technical, legal, social, markets or financial aspects of that project. Such information can further help make informed decisions.

Project team can also use early warning systems (EWS) to detect potential risks before they become disasters. According to Qian and Lin (2016), EWS are critical in project management and sustainability because they enable project team to take corrective action before a disaster occurs. For example, in the construction of small dams and water pans projects, EWS would detect a small crack on the walls, and signal project team to correct it before it turns into a catastrophic disaster like infrastructure collapse.

In addition, proactive risk mitigations can be used to reduce or eliminate risks before they occur. It involves fixing potential security issues before they happen. The strategy ensures that potential threats are addressed so they do not escalate into disasters. A study by Bongei (2024) established that project managers of small dams and water pans projects can identify potential risks likely to occur at any phase of the project lifecycle. Then they make informed decisions to prevent such risks from occurring, or even reduce their negative impact if they will occur. Risk management practices for this study included feasibility studies, early warning systems, and proactive risk mitigation, with the focus being on how each influenced sustainability of small dams and water pans projects in Machakos County, Kenya.

Sustainability of Small Dams and Water Pan Projects in Machakos County

Sustainability of small dams and water pans projects in Machakos County has been studied in the past. For example, Nzomo (2020) explored how project planning affects sustainability of water projects in Mavoko-Machakos County, Kenya. The study focused on stakeholder's participation, technology choice, project funding and management skills as independent variables and sustainability of water projects as the dependent variable of the study. The sustainability of water projects indicators for the study included functionality of water projects, year-round access to water, continual water flow, and continued water improvement (Nzomo, 2020). The study used a descriptive research design with a sample size of 137 respondents obtained through stratification and random sampling methods (Nzomo, 2020). The findings revealed that project planning and its elements significantly influenced sustainability of water projects in Mavoko-Machakos County, Kenya. The study recommended that project managers prioritize project planning and its elements in water projects in order to make them sustainable in the long-term.

Malii *et al*. (2025) also assessed how stakeholder management influences sustainability of solid waste management projects in Machakos, Kenya. The study focused on stakeholder management practices including stakeholder identification, analysis and engagement as independent variables while sustainability of solid waste management projects including economic, social and environmental viability as dependent variable. The study used a correlational cross-sectional survey design to establish a sample size of a sample size of 23 county chief officers, 23 directors, 23 deputy directors and 139 sub-county officers. The results revealed that stakeholder management as independent variable and project leadership as moderate variable has a positive and significant effect on solid waste project sustainability.

In this study, the sustainability of small dams and water pan projects in Machakos County was conceptualized as the dependable variable, influenced by these project management practices: scope, stakeholder, cost and risk management practices. The interaction of these factors was believed to influence specific projects sustainability, which was then assessed through measurable indicators like infrastructure maintenance frequency, infrastructure functionality, and year-round access to water.

Empirical Review

Cost Management and Sustainability of Small Dams and Water Pan Projects

Additionally, past studies have looked at the impact of cost management on the sustainability of small dams and water pan projects. Bichang'a and Kimutai (2024) assessed the influence of cost management practices on the sustainability of water projects in Kericho County. The study employed a descriptive research design, targeting 16 completed water projects as unit of analysis. The quantitative questionnaire was analyzed using descriptive, multiple regression and Pearson correlation methods whereas qualitative data through content analysis. The findings revealed that cost management practices like using financial models, price variations and forecasts improved sustainability of water projects. Also, proper project budgeting enhanced transparency and accountable use of funds (Bichang'a and Kimutai, 2024).

Similarly, Jiang (2023) examined how water investment financing influences sustainable development of water projects under the United Nations and World Bank. The study highlighted specific challenges and actionable solutions for water finance and challenges, including economics and practice of financing water investment needs. Findings revealed some promising practices to help address challenges within financing water investments. The study recommended development practices that could help stimulate communication while advocating for a better water financing and investment approach. Moreover, the study advised that filling the funding gap for water financing and investment by multi-sectorial approach to capital funding. Water construction projects have historically obtained their support mainly from public sources like government budgetary allocations, grants, and concessionary loans. In a concluding remark, Jiang (2023) emphasized the need for financing water investment projects to enhance security and sustainability of water as required locally, regionally and globally.

Additionally, Kinyua *et al.* (2015) assessed financial management aspects on sustainability of community water projects in Kieni West District in Nyeri County. The study primarily aimed at establishing financial management factors that influence sustainability of community water projects. Research employed a descriptive research design, with a target population of 150 water community officials and a sample size of 109 respondents selected through a stratified sampling method. Findings showed that adequate financial management practices, including sufficient understanding, identification and estimation of the operation and maintenance cost is very important in ensuring sustainable delivery of water supplies. Kinyua *et al.* (2015) further suggested that project managers embrace participatory budgeting as it enhances transparency, increasing project sustainability in the long-term.

Risk Management and Sustainability of Small Dams and Water Pans Projects

Past studies have also examined the role of risk management on sustainability of water projects. Stoyanova *et al.* (2018) assessed how various risk management strategies influence successful completion of a project, which further enhances the sustainability of that project. The study aimed at exploring project risks in the water sector in Bulgaria, then use the insights to recommend strategies for risk management. Information about project risk was retrieved from the survey conducted between July and September, 2016. The study administered structured interviews to experts in environmental protections department in the administration of 16 municipalities (Stoyanova *et al.*, 2018). The findings gave insight into several cost issues likely to affect a project's sustainability. The results showed that 50% of the respondents agreed at least one of these factors signified a potential risk in a project: Not executing part of the contract by the beneficiary, incorrect budgeting, resignation of the staff in the project team, incorrect selection of project team, ineffective, communication, environmental and climate risk (Stoyanova *et al.*, 2018). The study recommended the use of a risk management framework, which shows when to mitigate, avoid, accept or transfer. According to the matrix, project

managers should mitigate risks when they are unexpected, avoid when critical, accept when irrelevant, and transfer when systematic (Stoyanova *et al.*, 2018).

Mogha *et al*. (2024) also explored the influence of risk management strategy on the sustainability of a project: Case of Afya Pure Drinking Water Project in Kigoma Region, Tanzania. The study employed a descriptive research design (qualitative and quantitative). The study sample were determined by random sampling. The sampled population included all water stakeholders at the Afya Pure Drinking water in Kigoma Municipality, Tanzania. The study used oral interviews and questionnaires for primary data collection. It also included observations and documentations, for primary and secondary data sources respectively. Observations by authors revealed that Kigoma Municipality was largely hit by water scarcity. A descriptive analysis of the responses from interviewees revealed that water projects need effective risk management practices to achieve sustainability (Mogha *et al*., 2024). Additional analysis of documentation and questionnaire responses revealed poor community participation in water projects as one of the key hindrances to project sustainability (Mogha *et al*., 2024). Based on these findings, study recommended effective community involvement in project management and regular project assessment for the purpose of enhancing sustainability of water projects in the long-term (Mogha *et al*., 2024).

Munyugi and Nteere (2024) also assessed risk management strategies in the performance of NGO-led water projects: Case of Isiolo County, Kenya. The primary aim of the study was to determine the influence of risk reduction on the performance of such water projects. The study employed a descriptive research design targeting 36 NGO-led water projects in the County. The study used simple random sampling technique to constitute a sample size of 216 respondents, comprising management employees working with these NGOs. Primary data were collected using a structured questionnaire, and analyzed using both the descriptive statistics (frequency, percentage, mean) and inferential statistics (Pearson correlation and regression). The findings revealed risk management practices had significant positive relationships with water projects performance, with risk transfer leading with the highest coefficient (0.387, $p = 0.000$), then followed by risk reduction (0.345, $p = 0.000$) (Munyugi and Nteere, 2024). Based on the study findings, the authors further recommended that NGOs prioritize risk transfer in the management of water projects through contracts and reinforced preventive measures in order to enhance performance.

RESEARCH METHODOLOGY

The study adopted a descriptive research design to examine the relationship between project management practices and the sustainability of small dams and water pans in Machakos County, Kenya. A descriptive design was considered appropriate because it enables researchers to describe existing phenomena and examine relationships among variables in their natural setting without manipulating them (Ansari et al., 2022; Haldin et al., 2021; Rezigalla, 2020).

The target population comprised 324 respondents drawn from 37 completed and functional small dams and water pan projects rehabilitated during the 2023/2024 financial year. The respondents included county water officials, water company management officials, project managers and engineers, and community beneficiaries. Using the Yamane (1967) formula with a 5% margin of error, a sample size of 179 respondents was determined. Stratified sampling was used to categorize respondents into homogeneous groups, while purposive sampling was employed to select participants with relevant knowledge and experience in the planning, implementation, management, and utilization of the projects (Bongei, 2024; Magano, 2021).

Primary data were collected using a structured questionnaire consisting of 42 items organized into six sections covering demographic information, cost management, risk management, and project sustainability. Responses were measured using a five-point Likert scale ranging from strongly disagree to strongly agree, which is widely recognized for measuring respondents'

perceptions and attitudes (Pescaroli et al., 2020; Dhir & Gupta, 2021). Prior to the main survey, a pilot study involving 18 respondents was conducted in Kajiado County to assess the clarity, validity, and reliability of the research instrument (Tate et al., 2023).

The validity of the questionnaire was established through expert review to assess face and content validity, while construct validity was evaluated using exploratory factor analysis, with factor loadings of at least 0.50 considered acceptable (Aslam et al., 2020; Luthfiyah et al., 2023). Reliability was assessed using Cronbach's alpha coefficient, with a threshold of 0.70 indicating satisfactory internal consistency of the measurement scales (Rustam & Tentama, 2020; Sürücü & Maslakci, 2020).

Data were coded and analyzed using Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the data, while Pearson correlation analysis examined relationships among the study variables. Multiple linear regression analysis was subsequently employed to determine the influence of cost management, and risk management on the sustainability of small dams and water pan projects.

RESEARCH FINDINGS AND DISCUSSION

A total of 179 questionnaires were administered to respondents drawn from Machakos County officials, water company officials, project managers and engineers, and community beneficiaries. Out of these, 162 questionnaires were completed and returned, representing a response rate of 90.5%. According to Babbie (2020), a response rate above 70% is considered adequate for social science research, indicating that the achieved response rate was excellent with a broader representation of stakeholders involved in the planning, implementation, and use of small dams and water pans in Machakos County, Kenya.

Descriptive Analysis

Cost Management

Cost management had a mean of 4.048 and a standard deviation of 0.526. Table 1 demonstrates that the highest-rated item was regular sharing of budget expenditure information (CM2, M = 4.099), followed by the use of official contracts to manage purchase agreements (CM7, M = 4.086), financial decisions based on reliable data and expert opinion (CM6, M = 4.080), and the existence of a clear budget from the start (CM1, M = 4.074). Cost estimates helping to avoid unexpected expenses also scored highly (CM5, M = 4.056), followed by purchase decisions comparing costs and benefits (CM8, M = 4.025), and materials being bought on a large scale to lower cost (CM4, M = 3.988). The lowest-rated item was quick adjustment of necessary budget changes when problems were noticed (CM3, M = 3.975).

Table 1: Descriptive Statistics for Cost Management

Statement summary	Mean	Std. deviation	Agree/Strongly agree (%)
Project had a clear budget from the start	4.074	0.769	77.8
Budget expenditure information was regularly shared	4.099	0.724	80.9
Necessary budget changes were made quickly	3.975	0.780	72.8
Materials were bought in large scale to lower cost	3.988	0.841	72.2
Cost estimates helped avoid unexpected expenses	4.056	0.766	75.9
Financial decisions were based on reliable data and expert opinion	4.080	0.713	79.6
Official contracts were used to manage purchase agreements	4.086	0.717	82.1
Purchase decisions compared costs and benefits	4.025	0.819	75.3

The cost management results are important because small dam and water pan sustainability is strongly affected by whether funds are sufficient, properly allocated and used for the right technical works. The findings imply that, although formal cost management mechanisms existed, responsiveness to emerging budget issues still need to be improved. Effective cost management can help to allocate funds to all critical project activities, hence ensuring the projects completes in time and within set time and budget. Poor cost management may, however, result in funding shortages, budget overruns, use of substandard materials, incomplete spillway works or delayed maintenance (Nabil, 2024). The findings therefore support the Theory of Strategic Cost Management, which emphasizes cost planning and cost control as tools for achieving long-term value rather than simply minimizing expenditure (Holm & Schaufelberger, 2021).

Risk Management

Risk management had an overall mean of 3.992 and a standard deviation of 0.478. Although this was the lowest mean among the independent variables, table 2 shows that the highest-rated item was the project team being good at managing risks (RM1, M = 4.043), followed by regular checking for signs of risks throughout the project and prioritization of risk prevention (RM5 and RM8, M = 4.031). Potential risks being identified early also scored highly (RM4, M = 4.019), followed by consideration of different project options during feasibility study (RM3, M = 4.006). Early warning systems signaling collapse or siltation risk recorded a mean of 3.981, while risk prevention methods being reviewed and updated recorded scoring (RM7, M = 3.975), feasibility study identifying possible risks before the project began (RM2, M = 3.944), and lastly risk prevention enabled response before problems occurred (RM9, M = 3.901).

Table 2: Descriptive Statistics for Risk Management

Statement summary	Mean	Std. deviation	Agree/Strongly agree (%)
Project team was good at managing risks	4.043	0.742	74.7
Feasibility study identified possible risks before the project began	3.944	0.758	73.5
Different project options were considered during feasibility study	4.006	0.776	75.3
Potential risks were identified early	4.019	0.735	77.8
Risk signs were checked regularly throughout the project	4.031	0.691	81.5
Early warning systems signalled collapse or siltation risk	3.981	0.718	75.9
Risk prevention methods were reviewed and updated	3.975	0.722	72.8
Risk prevention was prioritized	4.031	0.726	76.5
Risk prevention enabled response before problems occurred	3.901	0.749	69.1

Risk management is crucial to ensuring sustainability of small dams and water pans in ASALs. The findings suggest that risk monitoring existed among the sampled projects even though the anticipatory responses still needed to be improved. The ASALs face recurring water project issues like siltation, embankment erosion, seepage, cracking, drought pressure, livestock damage, and heavy runoff events (Buganova *et al.*, 2021). In response, the project teams must have an effective plan for identifying and preventing occurrences of risks. The results indicate that respondents perceived the project teams to have some risk control capacity, but the relatively lower score for proactive response implies that some risks may still be identified late or acted upon slowly. This argument is consistent with risk management theory, which suggests that projects perform better when risks are identified, assessed, monitored and controlled before they materialize into losses (Ajayi *et al*., 2020). For water infrastructure such as dams and water

pans, risk management should continue throughout the construction, operation and maintenance stages.

Sustainability of Small Dams and Water Pan Projects

The dependent variable, sustainability of small dams and water pan projects in Machakos County, Kenya, recorded an overall mean of 4.245 and a standard deviation of 0.401. This was the highest mean among all the study constructs. Table 3 demonstrates that the highest-rated sustainability item was the ability of the dam or water pan to retain a good amount of water during dry seasons (SUS7, M = 4.340), followed by the infrastructure remaining physically intact (SUS4, M = 4.290), maintenance reducing cracks, siltation and leakage (SUS2, M = 4.278), and communities using water year-round for household needs (SUS8, M = 4.259). The project continuing to serve local communities as intended also scored highly (SUS5, M = 4.228), followed by maintenance activities reducing over time (SUS1, M = 4.222), and the project appearing physically strong (SUS6, M = 4.204), and lastly maintenance intervals increasing project functionality and the project significantly reducing water problems in the region (SUS3 and SUS9, M = 4.191).

Table 3: Descriptive Statistics for Sustainability of Small Dams and Water Pan Projects

Statement summary	Mean	Std. deviation	Agree/Strongly agree (%)
Maintenance activities have reduced over time	4.222	0.621	89.5
Maintenance has reduced cracks, siltation and leakage	4.278	0.652	90.1
Maintenance intervals have increased project functionality	4.191	0.664	87.0
Infrastructure has remained physically intact	4.290	0.684	88.3
Project continues to serve local communities as intended	4.228	0.653	87.7
Project appears physically strong	4.204	0.697	85.2
Dam or water pan retains good water during dry seasons	4.340	0.632	91.4
Communities use water year-round for household needs	4.259	0.701	87.7
Project significantly reduced water problems in the region	4.191	0.701	84.6

The sustainability findings suggest that the rehabilitated, repaired or desilted projects continued to perform the purpose for which they were established. These findings suggest that respondents generally perceived the projects as functional, physically stable and beneficial to the local communities. Sustainability in this study was not limited to physical existence of infrastructure. Instead, it also covered infrastructure maintenance frequency, functionality and year-round access to water. This interpretation is consistent with the study definition of project sustainability as long-term positive impact on the environment, economy and society after it is handed over to the intended beneficiaries without compromising future generations (Jama, 2024; George-Williams *et al.*, 2024). Nevertheless, sustainability must be continuously examined and improved because water infrastructure in ASAL areas can deteriorate quickly if maintenance, community ownership, cost controls and risk monitoring weaken after project completion.

Correlation Analysis

Pearson correlation analysis was computed to determine the strength and direction of association between project management practices and sustainability of small dams and water pan projects in Machakos County, Kenya. Correlation coefficients range from -1 to +1. A

positive coefficient indicates that an increase in one variable is associated with an increase in the other variable, while a negative coefficient suggests an inverse relationship (Aslam, 2021). Table 4 presents the Pearson correlation matrix. The significance value was used to determine whether the observed relationship was statistically significant at the 0.05 level of significance.

Table 4: Pearson Correlation Matrix

Variable	Cost management	Risk management	Sustainability
Cost management	1.000		
Risk management	-0.167	1.000	
Sustainability	0.353	0.194	1.000

Cost management also had a positive correlation with sustainability ($r = 0.353$, $p < 0.001$), indicating a moderate positive and statistically significant relationship. Moreover, risk management had a weak positive but statistically significant relationship with sustainability ($r = 0.194$, $p = 0.013$).

Regression Analysis

Multiple regression analysis was computed to assess the combined influence of cost management and risk management constructs on the sustainability of small dams and water pan projects in Machakos County, Kenya. Regression analysis was suitable because the study sought to establish how much variation in sustainability could be explained by the four project management practices and which practice had the strongest predictive effect when the other variables were held constant. Table 5 presents the multiple regression model summary.

Table 5: Regression Model Summary

R	R Square	Adjusted R Square	Std. error of estimate
0.490	0.240	0.221	0.354

The model summary shows that the combined correlation between the four project management practices and the sustainability of small dams and water pans in Machakos County, Kenya, was R = 0.490. The coefficient of determination was R square = 0.240, while the adjusted R square was 0.221. This means that the independent variables (cost management and risk management) jointly influenced 24% of the variation in sustainability of small dams and water pan projects in Machakos County, Kenya. The remaining 76% may be explained by other factors not included in the model, such as rainfall variability, hydrological conditions, land tenure issues, post-completion maintenance financing, community governance structures, political support, quality of engineering designs, and environmental conditions (Jama, 2024; Kariuki, 2024; Lillian & Mutiso, 2019).

Additionally, the adjusted R square of 0.221 suggests that after adjusting the number of predictors in the model, the four project management practices combined still explained only 22.1% of the variation in the sustainability of water projects in Machakos County, Kenya. In other words, sustainability of small dams and water pan projects may be influenced by many technical, environmental, social and institutional factors that go beyond the direct control of the four project management practices. Overly, the model suggests that project management practices moderately influence sustainability of water projects in Machakos County, Kenya, even though they do not account for all the sustainability outcomes.

Analysis of Variance

Analysis of Variance, also known as ANOVA, was computed to determine whether there are significant differences among the means of the independent variables. Table 4.18 presents the ANOVA results.

Table 6: ANOVA Results

Model	Sum of squares	Df	Mean square	F	Sig.
Regression	6.219	2	1.555	12.399	<.001
Residual	19.686	159	0.125		
Total	25.905	161			

The ANOVA results show that the regression model was statistically significant, F (4, 157) = 12.399, p < 0.001. Figure 1 presents the standardized regression coefficients for the study variables. The statistics imply that the four project management practices, when considered together, significantly predicted sustainability of small dams and water pan projects in Machakos County, Kenya. The significant F-statistic confirms that the multiple regression model provided a better prediction of sustainability than a model without the independent variables would. Therefore, the study proceeded to interpret the individual regression coefficients to determine the contribution of each practice.

Figure 1: Standardized Regression Coefficients for Project Management Practices

Regression Coefficients

Regression coefficients were also computed to show how much each independent variable contributes to or predicts the dependent variable in a regression model. Table 5 presents the regression coefficients results.

Table 5: Regression Coefficients

Predictor	Unstandardized B	Std. error	Standardized beta	t	Sig.
Constant	1.227	0.486		2.526	0.013
Cost management	0.273	0.055	0.358	4.954	<.001
Risk management	0.239	0.060	0.284	3.994	<.001

The regression coefficients results show that cost management also had a positive and statistically significant influence on sustainability (B = 0.273, beta = 0.358, t = 4.954, p < 0.001). Lastly, risk management had a positive and statistically significant influence on sustainability (B = 0.239, beta = 0.284, t = 3.994, p < 0.001).

The standardized beta values show that cost management was the strongest predictor of sustainability, followed by risk management,

The regression results therefore suggest that improvements in cost management and risk management are likely to have the most practical effect on the sustainability of small dams and water pans in Machakos County, Kenya. Water infrastructure sustainability requires adequate budgeting, procurement decisions, maintenance financing, timely correction of defects, risk prevention, and early response to emerging threats such as siltation, cracks, leakage, and embankment failure (Lillian & Mutiso, 2019; World Bank, 2021; Roque, 2022).

Based on the unstandardized coefficients, the regression equation for predicting sustainability of small dams and water pan projects was expressed as follows:

$$\mathbf{Y = 1.227 + 0.273(X_1) + 0.239(X_2)}$$

A one-unit increase in cost management construct would increase sustainability by 0.273 units, while a one-unit increase in risk management construct would increase sustainability by 0.239 units. Therefore, the empirical model indicates that Cost management construct and risk management construct significantly influence the sustainability of small dams and water pans in Machakos County, Kenya.

Conclusion

cost management practices were present among the sampled projects. Cost management as a construct appeared to be the most important predictor of sustainability among the four project management practices studied. It means the sustainability of water projects depends heavily on whether budgets are clear, funds are properly allocated, expenditure is monitored, procurement is controlled, and cost decisions are based on reliable information. Without robust cost management, projects may physically exist but fail to remain functional due to lack of maintenance funding, poor material quality or delayed corrective works.

Fourth, risk management practices were visible among the sampled projects, and they significantly contributed to sustainability outcomes. Small dams and water pans in ASALs operate in environments where siltation, runoff damage, drought, leakage, embankment erosion and community use pressures can undermine long-term performance. Risk management practices such as feasibility studies, risk identification, early warning systems, monitoring and preventive actions can help to protect the infrastructure and its benefits. Risk management should therefore continue beyond project completion into the operation and maintenance phase.

Recommendations of the Study

For cost management, the study recommends adopting lifecycle costing as a mandatory budgeting approach. Budgets should not only cover construction, desilting, or rehabilitation, but also routine inspections, embankment repairs, spillway protection, fencing, community training, emergency maintenance, and periodic desilting. Since cost management was identified as the strongest predictor of sustainability, the study recommends high level of budget transparency, expenditure reporting, procurement monitoring, and value-for-money decision-making. Procurement should not be based only on the lowest price. Budgets should take into account the technical suitability and long-term durability of water infrastructure. In addition, Machakos County should establish a ring-fenced maintenance fund supported by county allocations, water-user contributions, development partners, community arrangements, and climate resilience funds to prevent potential fund shortfalls.

Finally, for risk management and overall sustainability, the study recommends making risk assessment compulsory at all stages of small dam and water pan projects. Feasibility studies should identify technical, environmental, social, and financial risks before and after implementation. Project teams should maintain risk registers that show risk probability, impact, mitigation measures, responsible persons, and review dates at all stages of project. Early warning systems should also be introduced through routine inspections, community reporting channels, rainfall monitoring, siltation tracking, leakage reports, and embankment assessments

covering all stages of a project. More broadly, Machakos County should develop a sustainability framework covering scope, stakeholders, costs, risks, monitoring, environmental protection, and community ownership at all levels of a project. Each completed project should also have a sustainability handover report and periodic evaluation showing indicators such as water retention, maintenance frequency, embankment condition, user satisfaction, and reduction of water access problems.

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