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Foundational Earned Value Management Techniques, Performance Index Techniques and Performance of Water and Sanitation Projects under Athi Water Works Development Agency, Kenya

Patricia Nyadhi Ochieng[1*] and Dr. Paul Munene[2]

[1*]Postgraduate student, MSc Project Management, Jomo Kenyatta University of Agriculture and Technology

[2]Lecturer, Jomo Kenyatta University of Agriculture and Technology

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Abstract

Water and sanitation projects in Kenya continue to experience cost overruns, schedule delays and stakeholder dissatisfaction, despite substantial public and donor investment. Earned Value Management (EVM) integrates scope, schedule and cost into a single performance measurement system, yet its application in Kenyan water projects remains limited and insufficiently documented. This study examined the influence of two EVM techniques, foundational EVM techniques (Planned Value, Earned Value and Actual Cost) and EVM performance index techniques (Cost Performance Index and Schedule Performance Index), on the performance of water and sanitation projects under Athi Water Works Development Agency in Nairobi, Kiambu and Muranga counties. The study was anchored on project control theory. A descriptive cross-sectional survey design was adopted. Using Yamane's formula and stratified random sampling, 120 professionals were selected from a population of 170 project managers, engineers, site supervisors, procurement officers and government officials. Data were collected using a structured questionnaire, and 102 usable responses were obtained, a response rate of 85%. Data were analysed using descriptive statistics, Pearson correlation and multiple linear regression. Respondents agreed that foundational EVM techniques ($M = 3.68$, $SD = 0.70$) and performance index techniques ($M = 3.66$, $SD = 0.68$) were applied in their projects. Both techniques had strong, positive and significant relationships with project performance ($r = 0.684$ and $r = 0.678$, $p < 0.001$). Together, the two techniques explained 69.2% of the variance in project performance, $F(2, 99) = 111.05$, $p < 0.001$. Foundational EVM techniques (Beta = 0.512, $p < 0.001$) and performance index techniques (Beta = 0.503, $p < 0.001$) each made a significant unique contribution. The study concludes that clearly defined baselines and routine use of cost and schedule performance indices are associated with better project performance. It recommends training of project staff in EVM, consistent recording of Planned Value, Earned Value and Actual Cost, and the use of CPI and SPI in all project progress reports.

Keywords: *Earned Value Management, Cost Performance Index, Schedule Performance Index, Project Performance, Water and Sanitation Projects, Kenya*

INTRODUCTION

Water infrastructure projects such as dams, boreholes, irrigation schemes and urban water supply systems play a vital role in supporting public health, agricultural productivity and sustainable development. However, these projects are complex, capital-intensive and frequently affected by uncertainties that increase the likelihood of cost overruns, schedule delays and scope deviations. In Kenya, a review of construction project performance between 1963 and 2018 found that 35% to 60% of projects initiated in the country faced cost overruns, while 35% to 73% overran their schedules (Ong'ondo et al., 2019). Despite increased investments in water infrastructure under Kenya's Vision 2030, the performance of many water projects remains suboptimal, with inadequate planning, weak monitoring systems and poor project control continuing to undermine delivery.

Earned Value Management (EVM) has emerged as one of the most effective techniques for integrating project scope, schedule and cost into a unified performance measurement system (Anbari, 2003; Fleming & Koppelman, 2010). EVM provides project managers with core measures such as Planned Value (PV), Earned Value (EV) and Actual Cost (AC), and with performance indices such as the Cost Performance Index (CPI) and the Schedule Performance Index (SPI), which enable continuous performance tracking and early detection of deviations from project plans (Project Management Institute [PMI], 2021). In developed regions, EVM is often embedded within project management standards and contractual requirements. In developing regions, including Africa, its adoption remains uneven because of limited technical expertise, inadequate training and weak management commitment (Reda et al., 2025).

In Kenya, the application of advanced performance measurement techniques such as EVM is still emerging. While some large-scale and donor-funded infrastructure projects have incorporated elements of EVM, its use in water and sanitation projects remains inconsistent. Athi Water Works Development Agency (AWWDA), which develops and expands water and sewerage works in Nairobi, Kiambu and Muranga counties, implements many such projects. Understanding whether the routine use of EVM techniques improves the performance of these projects is therefore important for project managers, policymakers and development partners.

Statement of the Problem

Many water and sanitation projects in Kenya continue to experience delays, stakeholder dissatisfaction and incomplete implementation, raising concerns about project efficiency and value for money (Ong'ondo et al., 2019). Traditional project monitoring approaches, largely based on periodic reporting and financial tracking, have proven insufficient in providing real-time performance insights and early warning signals needed for effective decision-making. EVM offers an integrated alternative, but its application in Kenyan water and sanitation projects remains inconsistent and, in many cases, superficial or absent.

Empirical studies on EVM have largely been case-based analyses of individual projects or have been conducted outside Kenya (Hussein & Moradinia, 2024; Reda et al., 2025). There is limited empirical evidence on how the foundational EVM measures and the performance indices derived from them relate to project performance in Kenyan water and sanitation projects. This study addressed this gap by examining foundational EVM techniques and EVM performance index techniques in projects implemented by AWWDA in Nairobi, Kiambu and Muranga counties.

Objectives of the Study

The general objective was to examine the influence of foundational and performance index EVM techniques on the performance of water and sanitation projects under Athi Water Works Development Agency between 2019 and 2026. The specific objectives were:

i. To measure the influence of foundational EVM techniques on the performance of water and sanitation projects under Athi Water Works Development Agency in Nairobi, Kiambu and Muranga counties.
ii. To determine the relationship between EVM performance index techniques and the performance of water and sanitation projects under Athi Water Works Development Agency in Nairobi, Kiambu and Muranga counties.

LITERATURE REVIEW

This section reviews the theoretical and empirical literature relevant to the study. It first discusses project control theory, which underpins both techniques, and then reviews empirical studies on foundational EVM techniques and performance index techniques before identifying the gaps the study addresses.

Theoretical Review

EVM is grounded in project control theory, which emphasizes the integration of scope, cost and schedule to enhance project performance. The theory holds that performance can be quantitatively assessed by comparing actual progress with a predefined baseline, enabling proactive decision-making and corrective action (Kerzner, 2017). Foundational EVM techniques operationalize this comparison through three core measures. Planned Value is the budgeted cost of work scheduled, Earned Value is the budgeted cost of work actually performed, and Actual Cost is the cost incurred for that work (Fleming & Koppelman, 2010). These measures allow project managers to quantify work progress objectively. The theory presumes a stable baseline and clear scope definition as prerequisites for meaningful measurement.

Performance index techniques extend this logic through efficiency measurement and ratio analysis. The CPI (EV/AC) measures cost efficiency, while the SPI (EV/PV) measures schedule efficiency. Values greater than one indicate favourable performance, and values below one signal underperformance (Anbari, 2003). Because they are normalized ratios, the indices allow comparison of performance over time and across projects, and they form the basis for forecasting final cost and duration (Lipke et al., 2009; Vanhoucke, 2010). In this study, project control theory explains why consistent measurement of PV, EV and AC, and the use of CPI and SPI derived from them, is expected to improve schedule adherence, quality and stakeholder satisfaction in water and sanitation projects.

Empirical Review

Foundational EVM Techniques and Project Performance

Foundational EVM techniques provide the basis for all further earned value analysis, and their usefulness depends on how well they are implemented. Kim et al. (2003) developed a model for effective EVM implementation and found that EVM users, the project environment and the implementation process together significantly improve the acceptance and performance of EVM across different types of organizations and projects. Aramali et al. (2024) assessed 27 earned value management system environment factors using a practitioner survey, focus groups and performance data from 35 completed projects worth over US$21.8 billion. They found that projects with a positive EVMS environment could save up to 25% in cost relative to baseline.

In water infrastructure, Reda et al. (2025) evaluated the performance of projects at the Amhara Water Works Construction Enterprise in Ethiopia using a questionnaire survey, interviews and document review across 12 projects. They identified improper resource planning, inflation and poor employee management as causes of cost overruns, and weak management commitment, limited team support and insufficient training as barriers to EVM implementation. These studies show that well-implemented foundational measures support project control. However, they do

not establish how the use of PV, EV and AC relates to the performance of water and sanitation projects in Kenya.

EVM Performance Index Techniques and Project Performance

Performance indices are among the most widely used outputs of EVM. Lipke et al. (2009) applied statistical methods to cost and schedule performance indexes and showed that forecasts of final cost and duration based on them were sufficiently reliable for general application, irrespective of the type of work or project size. In a water resources project, Hussein and Moradinia (2024) applied earned value analysis at three implementation stages and found that SPI rose from 0.60 to 0.88 as lagging activities were started, showing how the index helped the project recover schedule performance. In Ethiopia, Ayalew et al. (2023) used regression modelling on ten public building projects to predict earned value indexes and improve the accuracy of standard earned value analysis. More recently, Yalçın et al. (2024) showed that machine learning methods can improve EVM-based cost estimation.

These studies confirm that CPI and SPI are useful for monitoring efficiency and anticipating overruns. However, most are case studies of individual projects or technical modelling studies. Few have examined, from the perspective of project professionals, how the routine use of performance indices relates to the multidimensional performance of water and sanitation projects in Kenya.

Research Gaps

The reviewed studies leave three gaps. Contextually, most EVM evidence comes from defence, building and general construction projects outside Kenya, with limited attention to water and sanitation projects. Methodologically, most studies analyse EVM data from individual projects or develop forecasting models, rather than examining how the practice of EVM relates to project performance across an agency's portfolio. Conceptually, few studies have linked EVM techniques to performance dimensions beyond cost and time, such as quality adherence and stakeholder satisfaction. The present study addresses these gaps for AWWDA projects in Nairobi, Kiambu and Muranga counties.

Conceptual Framework

The study conceptualized foundational EVM techniques and EVM performance index techniques as the independent variables and project performance as the dependent variable, measured through quality adherence, completion within schedule and stakeholder satisfaction. Table 1 shows the indicators used to measure each variable.

Table 1: Study variables and indicators

Variable	Type	Indicators
Foundational EVM techniques	Independent	Planned Value defined for project activities; Earned Value measured regularly; Actual Cost recorded accurately; regular PV, EV and AC comparisons; use of foundational metrics for monitoring and decision-making; staff training in foundational EVM
EVM performance index techniques	Independent	CPI used to assess cost efficiency; SPI used to evaluate schedule efficiency; CPI and SPI in performance reporting; indices informing decisions and forecasts; team understanding of CPI and SPI
Project performance	Dependent	Quality adherence (design specifications, quality standards); completion within schedule (planned timeline, milestones); stakeholder satisfaction (client and stakeholder

Variable	Type	Indicators
		satisfaction, value for money)

METHODOLOGY

Research Design

The study adopted a descriptive cross-sectional survey design. The design enabled the researcher to gather quantitative data, describe current conditions and establish relationships between variables without manipulating the environment (Creswell & Creswell, 2018). Data were collected at a single point in time.

Target Population and Sampling

The target population comprised 170 professionals directly involved in the planning, execution, supervision and management of water infrastructure projects under AWWDA in Nairobi, Kiambu and Muranga counties. The sample size was determined using Yamane's (1967) formula, $n = N/[1 + N(e)^2]$, with N = 170 and e = 0.05, giving approximately 120 respondents. Stratified random sampling was used to ensure representation across professional categories, with respondents selected proportionately from each stratum (Table 2).

Table 2: Target population and sample

Category	Population (N)	Sample (n)
Government officials	34	24
Project engineers	45	32
Project managers	40	29
Site supervisors	28	19
Procurement officers	23	16
Total	170	120

Research Instrument, Validity and Reliability

Data were collected using a structured questionnaire adapted from previous studies on earned value management and project performance and tailored to water infrastructure projects in Kenya. Each construct was measured using seven items on a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. Face and content validity were established through review by university research supervisors and two water and sanitation industry experts, whose recommendations were used to refine item wording and remove redundancies (Taherdoost, 2016). The instrument was pilot-tested on 12 professionals, 10% of the sample (Connelly, 2008), who were excluded from the main study.

Reliability was assessed using Cronbach's alpha, with 0.70 taken as the minimum acceptable value (Tavakol & Dennick, 2011). All three constructs exceeded this threshold (Table 3). Construct validity was examined using exploratory factor analysis, and all items were retained.

Table 3: Reliability results (pilot, n = 12)

Variable	Number of items	Cronbach's alpha	Interpretation
Foundational EVM techniques	7	0.824	Reliable
EVM performance index techniques	7	0.843	Reliable
Project performance	7	0.812	Reliable

Data Collection and Analysis

The necessary permissions were obtained before data collection. Questionnaires were distributed electronically and in person, with weekly follow-ups to respondents who had not responded. Responses were screened for completeness, and incomplete questionnaires were excluded. Data were analysed using SPSS. Means and standard deviations described the variables and were

interpreted as follows: 1.00–1.80 strongly disagree, 1.81–2.60 disagree, 2.61–3.50 neutral, 3.51–4.20 agree and 4.21–5.00 strongly agree. Pearson correlation established the strength and direction of relationships, and multiple linear regression estimated the combined and individual influence of the two techniques (Field, 2018). The regression model was:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

where Y is project performance, X_1 is foundational EVM techniques, X_2 is EVM performance index techniques, β_0 is the constant, β_1 and β_2 are the regression coefficients and ε is the error term. Significance was tested at the 0.05 level.

RESULTS AND DISCUSSION

Response Rate and Respondent Profile

Of the 120 questionnaires administered, 102 were completed and returned, a response rate of 85%. [Insert respondent profile (gender, age, education, years of experience and county) from the SPSS output for n = 102.]

Foundational EVM Techniques

Table 4: Descriptive statistics for foundational EVM techniques (n = 102)

Statement	Mean	SD
Planned Value (PV) is clearly defined for all project activities	3.72	0.68
Earned Value (EV) is regularly measured to track work progress	3.69	0.70
Actual Cost (AC) is accurately recorded	3.65	0.72
PV, EV and AC comparisons are regularly made	3.66	0.69
Foundational EVM metrics are used for monitoring project performance	3.64	0.71
Use of PV, EV and AC improves decision-making	3.60	0.73
Project staff are trained in foundational EVM	3.68	0.70
Composite score	3.68	0.70

Respondents agreed that foundational EVM techniques were applied in their projects (M = 3.68, SD = 0.70). The definition of Planned Value for all project activities was rated highest (M = 3.72), followed by regular measurement of Earned Value (M = 3.69). The use of PV, EV and AC to improve decision-making was rated lowest (M = 3.60). The results suggest that baselines and progress measurement were well established, but that the information they generate was less consistently used to inform decisions. This is consistent with Kim et al. (2003), who emphasized that the benefits of EVM depend on how well users and the implementation process translate measurement into management action.

EVM Performance Index Techniques

Table 5: Descriptive statistics for EVM performance index techniques (n = 102)

Statement	Mean	SD
CPI is used to assess cost efficiency	3.68	0.69
SPI is used to evaluate schedule efficiency	3.65	0.67
CPI and SPI are used in performance reporting	3.64	0.68
CPI and SPI results influence decision-making	3.62	0.69
Performance indices are used to forecast outcomes	3.60	0.70
Teams understand how to interpret CPI and SPI	3.61	0.69
Use of CPI and SPI improves monitoring	3.66	0.68
Composite score	3.66	0.68

Respondents agreed that performance index techniques were used in their projects (M = 3.66, SD = 0.68). The use of CPI to assess cost efficiency was rated highest (M = 3.68), while the use of indices to forecast outcomes (M = 3.60) and team understanding of how to interpret CPI and SPI

(M = 3.61) were rated lowest. Indices were therefore commonly calculated and reported, but their use for forecasting and the capacity to interpret them were weaker. Reda et al. (2025) similarly identified insufficient training and shared understanding as barriers to EVM in water works projects.

Project Performance

Table 6: Descriptive statistics for project performance (n = 102)

Statement	Mean	SD
Project meets required design specifications	3.70	0.66
Project meets quality standards and regulations	3.68	0.67
Project is completed within the planned timeline	3.73	0.65
Project milestones are achieved as scheduled	3.69	0.66
Clients are satisfied with project outcomes	3.64	0.68
Stakeholders are satisfied with deliverables	3.62	0.69
Project delivers value for money	3.59	0.70
Composite score	3.66	0.67

Respondents agreed that their projects performed well (M = 3.66, SD = 0.67). Completion within the planned timeline was rated highest (M = 3.73), followed by meeting design specifications (M = 3.70). Stakeholder satisfaction with deliverables (M = 3.62) and value for money (M = 3.59) were rated lowest. Time and quality outcomes were therefore stronger than stakeholder-related outcomes.

Correlation Analysis

Table 7: Pearson correlation matrix (n = 102)

Variable	Foundational EVM techniques	EVM performance index techniques	Project performance
Foundational EVM techniques	1		
EVM performance index techniques	0.341**	1	
Project performance	0.684**	0.678**	1

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

Both techniques had strong, positive and statistically significant relationships with project performance. Foundational EVM techniques recorded r = 0.684 ($p < 0.001$), and performance index techniques r = 0.678 ($p < 0.001$). The two techniques were moderately related to each other (r = 0.341), indicating that they capture distinct aspects of EVM practice. Since the study adopted a cross-sectional design, these correlations are interpreted as associations rather than evidence of causality.

Regression Analysis

Table 8: Model summary

Model	R	R^2	Adjusted R^2	Std. error of the estimate
1	0.832	0.692	0.685	0.376

Note. Predictors: (Constant), foundational EVM techniques, EVM performance index techniques. Dependent variable: project performance.

The model summary shows an R of 0.832, indicating a strong combined relationship between the two techniques and project performance. The R^2 of 0.692 indicates that the two techniques jointly explained 69.2% of the variance in project performance. The adjusted R^2 of 0.685

confirms that this held after adjusting for the number of predictors. The remaining 30.8% is attributable to factors outside the model, such as funding, contractor capacity and site conditions.

Table 9: Analysis of variance (ANOVA)

Model	Sum of squares	df	Mean square	F	Sig.
Regression	31.362	2	15.680	111.054	< 0.001
Residual	13.978	99	0.141		
Total	45.339	101			

The ANOVA results show that the model was statistically significant, $F(2, 99) = 111.05$, $p < 0.001$. The two techniques together therefore predicted project performance better than the mean alone (Field, 2018).

Table 10: Regression coefficients

Variable	B	Std. error	β	t	Sig.	Tolerance	VIF
(Constant)	0.040	0.246		0.164	0.870		
Foundational EVM techniques	0.490	0.057	0.512	8.631	< 0.001	0.884	1.132
EVM performance index techniques	0.496	0.058	0.503	8.478	< 0.001	0.884	1.132

Note. Dependent variable: project performance.

Foundational EVM techniques ($\beta = 0.512$, $t = 8.631$, $p < 0.001$) and performance index techniques ($\beta = 0.503$, $t = 8.478$, $p < 0.001$) each made a positive and statistically significant unique contribution to project performance, with foundational techniques slightly stronger. The tolerance of 0.884 and VIF of 1.132 indicate that multicollinearity was not a concern. The fitted model was:

$$Y = 0.040 + 0.490X_1 + 0.496X_2$$

Holding performance index techniques constant, a one-unit increase in foundational EVM techniques was associated with a 0.490-unit increase in project performance. Holding foundational techniques constant, a one-unit increase in performance index techniques was associated with a 0.496-unit increase. The constant (0.040, $p = 0.870$) was not significant, which is expected since a score of zero cannot occur on the five-point scale.

Discussion

The first objective sought to measure the influence of foundational EVM techniques on the performance of water and sanitation projects. Foundational EVM techniques had a strong positive relationship with project performance ($r = 0.684$, $p < 0.001$) and retained the stronger unique effect in the regression model ($\beta = 0.512$, $p < 0.001$). Projects with clearly defined Planned Value, regular measurement of Earned Value and accurate recording of Actual Cost tended to perform better on schedule, quality and stakeholder satisfaction. This supports project control theory, which holds that performance improves when actual progress is compared regularly with a stable baseline (Kerzner, 2017). It is consistent with Aramali et al. (2024), who found that a positive EVMS environment was associated with substantial cost savings, and with Kim et al. (2003) on the role of effective implementation. The lower rating for using foundational metrics to inform decisions suggests that AWWDA projects measure well but could make fuller use of the measurements.

The second objective sought to determine the relationship between EVM performance index techniques and project performance. Performance index techniques had a strong positive relationship with project performance ($r = 0.678$, $p < 0.001$) and retained a significant unique

effect in the regression model ($\beta = 0.503$, $p < 0.001$). Projects that routinely used CPI and SPI to assess cost and schedule efficiency and to inform decisions tended to perform better. This is consistent with Hussein and Moradinia (2024), whose water resources project recovered schedule performance as SPI was monitored and lagging activities were addressed, and with Lipke et al. (2009) on the reliability of index-based forecasting. The lower ratings for forecasting and for team understanding of the indices indicate that their full value as early-warning tools was not yet realized, echoing the training gaps reported by Reda et al. (2025).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The study concludes that foundational EVM techniques have a positive and significant influence on the performance of water and sanitation projects under AWWDA. Clearly defined baselines and regular measurement of Earned Value and Actual Cost support better schedule, quality and stakeholder outcomes, although the use of these measures in decision-making needs strengthening.

The study further concludes that EVM performance index techniques have a positive and significant relationship with project performance. Together, the two techniques explained 69.2% of the variation in project performance, with foundational techniques contributing slightly more. The routine use of CPI and SPI supports better project outcomes, but their use for forecasting and the capacity of teams to interpret them remain weaker.

Recommendations

AWWDA and its contractors should institutionalize foundational EVM practice by requiring a documented performance measurement baseline for every project, with Planned Value defined for all activities and Earned Value and Actual Cost recorded at each reporting period. Comparisons of PV, EV and AC should form a standing item in project review meetings so that measurement translates into management decisions.

AWWDA should also require CPI and SPI in all project progress reports and use them to forecast final cost and completion dates. Since team understanding of the indices and their use for forecasting were the weakest aspects, the Agency should train project managers, engineers and site supervisors in interpreting CPI and SPI and in index-based forecasting, supported by project management software that computes the indices automatically.

Limitations and Suggestions for Further Research

The study used a cross-sectional design and perception-based data from a single questionnaire, so the results show associations rather than causal effects. It was limited to projects under one water works development agency. Future studies could combine survey data with actual CPI and SPI values from project records, extend the analysis to other water works development agencies, and examine variance analysis and forecasting techniques alongside the two techniques examined here.

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