Influence of Earned Value Management on the Performance of Construction Projects in Tanzania; Case of Construction Projects in Arusha City

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Abstract: ***Quality has remained the most important determining index for successful delivery of construction projects. It affects scope, schedule, and cost of a project which in turn influences customer satisfaction. These elements (time, scope, and cost) form the basis for existence and practical application of Earned Value Project Management. Earned Value Management (EVM) is a powerful project management quantitative technique applicable to any industry, for objectively monitoring physical progress of projects. It facilitates the integration of project scope, time and cost objectives and establishment of a baseline plan for performance measurement. However, Earned Value Management does not quantify quality performance progress of projects which is why projects can be delivered on time and cost but fail to achieve acceptable quality specification. Failure to attain technically acceptable levels of quality of construction projects has contributed immensely to project failures. This study assessed the influence of Earned Value Management on Quality performance measurement of Construction Projects. The study adopted a mixed method research design comprising experimental and survey designs. Experimental research design consists of 35 concrete samples randomly selected, tested and subjected to Chi-Squared and Correlation Analysis. The calculated p-value of Chi-Squared test at 34 degrees of freedom ($\chi^2_{(34,\ 0.05)}$) was 0.755, which is far lesser than the critical value of 48.602. The null hypothesis was accepted in that no significant difference was found between expected quality values and observed quality performance results. Analysis of objective two and three of the study found that the calculated p-value of 0.0402 is less than the critical level of 0.05, whereof the null hypotheses were rejected in that there is a strong and positive correlation between the model variables which indicates that Quality Performance Index (QPI) and Quality Variance (QV) are efficient monitoring and control tool for project quality performance. The survey research design was also adopted on a purposive sampling technique covering 38 respondents drawn from 44 construction industry practitioners. Structured questionnaires were used to collect qualitative data and achieved 86% of responses which were subjected to descriptive statistics. The study found that, 73% of respondents strongly agreed that lack of knowledge in relation to Earned Value Quality Project Management is the main cause of challenges experienced in integrating quality values into the traditional EVM for quality performance. This study recommended establishment of effective training programmes to the industry practitioners and also establishing sustainable policies to handle quality performance issues in the Tanzania construction sector.***

Keywords: Earned value management, Quality, Construction projects, Project performance

1. Introduction

In the present world, quality of construction projects has remained the most important parameter in the realization of typical construction projects, though cost and time parameters are the main preoccupying factors. According to Chan and Kumaraswamy [2], timely delivery of projects within budget and to the level of quality standard specified by the client is an index of successful project delivery. Olsen [13] suggests that, cost, time and quality are the success criteria bundled into the project description. Despite many decades of academic attention and practice on monitoring and controlling quality performance of construction projects, empirical evidences suggest that 61% of construction projects either failed or were challenged to meet quality success criteria and 74% faced schedule and cost overruns (Standish Group, [12]).

According to PMI [9]; [10], earned value management is a project control process based on a structured approach to planning, cost collection and performance measurement. It facilitates the integration of project scope, time and cost objectives and the establishment of a baseline plan for performance measurement. These elements (time, scope, and cost) form the basis for existence and practical application of Earned Value Management (EVM). On the contrary, the traditional Earned Value Project Management does not quantify quality performance progress of projects which is why projects are delivered on time and cost but fail to achieve acceptable quality specification. In 2011, the North American government requested the Department of Defence (DoD) to consider quality inclusion in the Earned Value Management System (EVMS) of Dod's acquisition program (Solomon, [11]). According to Yerabolu, [14] EVM is efficient to provide information on the project budget and costs status; however, it is still weak to inform whether the customers' quality requirements has been met.

Failure to attain technically acceptable levels of quality of construction projects has contributed immensely to project failures. This is probably one of the reasons the construction industry has been heavily criticized worldwide for its poor performance and productivity compared to other industries (Arditi & Gunaydin, [1]). In trying to apply EVM in agriculture project management, Marcelo et al., [8] evaluated the possibility of using the EVM to assess the operational performance of quality as the third element of earned value management. He found that EVM can be used to measure the performance hence proposed formulas to estimate the Quality Variance (QV) and Quality Performance Index (QPI) in managing agriculture projects.

Purpose

The purpose of the study was to assess the influence of earned value management on quality performance of construction projects. The study focused on five specific objectives namely to determine the difference between expected quality values defined as technical performance baseline and actual concrete quality performance results explained by compressive strength tests, to evaluate the correlation between expected quality values and actual concrete quality performance results whether it indicates efficiency of Quality Performance Index (QPI), to evaluate the correlation between expected quality values and actual concrete quality performance results whether indicates efficiency of Quality Variance (QV), to establish challenges encountered when trying to apply EVM in the construction industry, and to propose strategies for applying EVM for monitoring and controlling quality performance of construction projects.

Research Methods

Kothari, [7] defines experimental research design as the framework or structure of an experiment where the researcher tests the hypotheses of causal relationships between variables by performing procedures that reduce bias and increase reliability, while permit drawing inferences about causality. The study adopted a mixed method research design comprising experimental and survey designs. The study collected data using questionnaire from a sample of 44 respondents randomly selected. The target population involved 5 Quantity Surveyors, 10 Engineers, 20 Contractors and 15 Architects, all totaling to 50. The collected data was tested and subjected to Chi-Squared and correlation analysis. Concrete compressive strength for general construction varies from 15N/mm2 to 15N/mm2 and higher in commercial and industrial structures. The study tested the hypothesis on the significant difference between expected quality values and observed quality results of concrete used in construction projects. The study also used survey research design to establish causes of challenges experienced in integrating quality values into the traditional EVM and also suggest strategies for integrating quality performance metrics in the traditional EVM so as to quantify quality progress of construction projects. This design was appropriate for this study since Kothari, [7] notes that descriptive survey research is intended to produce information about the aspects of the research.

The study used Chi-Square test statistic as follows.

$$\chi 2 = \frac{(O-E)^2}{E} \quad \text{-----------------------(i)}$$

Where:

$\chi 2$ = The Chi-Square

O= observed quality results

E = expected quality values

$$r = \frac{\sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\overline{x})^2\sum_{i=1}^{n}(y_i-\overline{y})^2}} \quad \text{-------(ii)}$$

2. Results and Analysis

Demographic Response Analysis

The study covered a sample of 44 respondents out of which 38 filled and returned the questionnaires giving 86% of respondents. Out of 38 respondents, 77% of respondents are male and 23% are females. Regarding the number years of experience of respondents out of 38 respondents, 50% of them ranged between 10-19 years, 24% was between 0-9 years and 16% was between 20-29 years.

Analysis of Quantitative Data

The difference between expected quality values and observed quality results

The study sought to establish whether there is a significant difference between expected quality values defined as technical performance baseline and observed quality results explained by concrete compressive strength tests. The calculated P-value of Chi-Squared test at 34 degrees of freedom ($\chi^2_{(34,\ 0.05)}$ = 0.755) and it is far lesser than the critical value of 48.6.

From statistical analysis, it was found that earned value project management is a quantitative project management tool that influences quality performance results of a construction project. That is to say, if technical performance is properly planned, and strictly adhered to, the desired results are always achieved. These findings are in line with De Marco & Narbaev [5] whose study suggests that successful delivery of construction projects is influenced by Earned value-based performance monitoring and control.

Efficiency of Quality Performance Index (QPI)

The study sought to determine whether the correlation between expected quality values defined as technical performance baseline and observed quality performance results explained by compressive strength tests indicates efficiency of Quality Performance Index (QPI) in monitoring quality performance of projects. The findings in Table 1 show the computation of Quality Performance Index (QPI) basing on conventional method of Project Management. The acronym **fv-** stands for favorable, while unfv-stands for unfavorable.

Table 1: Conventional Analysis of QPI Data

Expected	*Observed*	*QPI*	*QPI <1*	*QPI >1*	*Expected*	*Observed*	*QPI*	*QPI <1*	*QPI >1*
15.00	11.56	0.77	unfv		25.00	25.56	1.02		fv
20.00	17.11	0.86	unfv		25.00	25.56	1.02		fv

20.00	11.70	0.59	unfv		25.00	26.81	1.07		fv
20.00	17.26	0.86	unfv		25.00	21.04	0.84	unfv	
20.00	19.19	0.96	unfv		25.00	18.89	0.76	unfv	
25.00	25.41	1.02		fv	25.00	26.67	1.07		fv
25.00	26.59	1.06		fv	25.00	39.70	1.59		fv
25.00	27.78	1.11		fv	25.00	26.59	1.06		fv
25.00	32.15	1.29		fv	25.00	25.70	1.03		fv
25.00	23.56	0.94	unfv		30.00	28.00	0.93	unfv	
25.00	30.67	1.23		fv	30.00	34.89	1.16		fv
25.00	22.81	0.91	unfv		30.00	33.11	1.10		fv
25.00	19.33	0.77	unfv		30.00	31.11	1.04		fv
25.00	26.59	1.06	unfv		30.00	32.38	1.08		fv
25.00	19.41	0.78	unfv		30.00	32.67	1.09		fv
25.00	25.48	1.02		fv	30.00	31.93	1.06		fv
25.00	17.41	0.70	unfv		30.00	29.32	0.98	unfv	

Table 2 presents the regression analysis of QPI. The findings of the analysis suggest that; first, the calculated P-value of 0.0402 is less than the alpha level of 0.05. Basing on the analysis, the calculated P-value being less in itself is enough to reject the null hypothesis. Second, the finding of the analysis suggests that the Pearson Product Moment Correlation Coefficient marked as Multiple R was calculated to be 0.8. This suggests that, that there is and strong positive correlation between the variables of the model variables. These findings support the theoretical fact that Quality Performance Index (QPI) is an efficiency quality performance monitoring tool. These findings are also supported by Marcelo et al., [8] who concluded that Quality Performance Index (QPI) indicates how efficient the project is conducted to meet objectives.

Table 2: Regression Statistics for QPI

Multiple R	0.8					
R Square	0.6					
Adjusted R Square	0.6					
Standard Error	4.2					
Observations	34					
ANOVA						
	df	SS	MS	F	Sign. F	
Regression	1.0	851.9	851.9	47.7	0.000	
Residual	32.0	571.3	17.9			
Total	33.0	1423.2				
	Coeff.	Std Error	t-Stat	P-Value	< 0.95	>0.95
Intercept	-11.6	5.4	-2.1	0.0402	-22.6	-0.5
Expected Q-Values	1.5	0.2	6.9	0.0	1.0	1.9

Efficiency of Quality Variance (QV)

The study sought to how the correlation between expected quality values defined as technical performance baseline and observed quality performance results explained by compressive strength tests indicates efficiency of Quality Variance (QV). Table 3 presents the computation of Quality Variance (QV) basing on conventional method of Project Management. The acronym **fv**-stands for favorable, while unfv stands for unfavorable.

Table 3: Conventional Analysis of QV Data

Expected	Observed	QV	QV < 0	QV > 0	Expected	Observed	QV	QV < 0	QV > 0
15	11.56	(3.44)	unfv		25	25.56	0.56		fv
20	17.11	(2.89)	unfv		25	25.56	0.56		fv
20	11.7	(8.30)	unfv		25	26.81	1.81		fv
20	17.26	(2.74)	unfv		25	21.04	(3.96)	unfv	
20	19.19	(0.81)	unfv		25	18.89	(6.11)	unfv	
25	25.41	0.41		fv	25	26.67	1.67		fv
25	26.59	1.59		fv	25	39.7	14.70		fv
25	27.78	2.78		fv	25	26.59	1.59		fv
25	32.15	7.15		fv	25	25.7	0.70		fv
25	23.56	(1.44)		unfv	30	28	(2.00)	unfv	
25	30.67	5.67		fv	30	34.89	4.89		fv
25	22.81	(2.19)	unfv		30	33.11	3.11		fv
25	19.33	(5.67)	unfv		30	31.11	1.11		fv
25	26.59	1.59		fv	30	32.38	2.38		fv
25	19.41	(5.59)	unfv		30	32.67	2.67		fv
25	25.48	0.48		fv	30	31.93	1.93		fv
25	17.41	(7.59)	unfv		30	29.32	(0.68)	unfv	

Table 4 presents the regression analysis of QV. The findings of the analysis suggest that; first, the calculated P-value of 0.0402 is less than the alpha level of 0.05. Basing on the forgone analysis, the null hypothesis is rejected. This suggests that, that there is and strong positive correlation between the variables of the model thus proves that Quality Variance (QV) is an efficiency quality performance monitoring tool. These findings are also in line with those of Marcelo et al., [8] who concluded that Quality Variance (QV) indicates how efficient the project is conducted to meet objectives.

Table 4: Summary of Regression Statistics for QV

Multiple R	0.8					
R Square	0.6					
Adjusted R Square	0.6					
Standard Error	4.2					
Observations	34					
ANOVA						
	df	SS	MS	F	Sign. F	
Regression	1.0	851.9	851.9	47.7	0.000	
Residual	32.0	571.3	17.9			
Total	33.0	1423.2				
	Coeff.	Std Error	t-Stat	P-Value	< 0.95	>0.95
Intercept	-11.6	5.4	-2.1	0.0402	-22.6	-0.5
Expected Q-Values	1.5	0.2	6.9	0.0	1.0	1.9

Analysis of Qualitative Data

Challenges encountered when applying EVM

The third objective of the study was to establish challenges encountered by construction industry practitioners when applying EVM in monitoring and controlling quality performance of projects. The study focussed on three factors namely, level of knowledge and application of EVM due to lack of commercial books and articles on the subject. High costs of collecting data for EVM analysis and estimation of per cent completion of projects. Difficulty of EVM reporting causes resistance of employees and contractors when trying to put EV into practice. The study employed a 5-.point Likert Scale response where: Strongly Disagree =1, Disagree =2, Neutral=3, Agree = 4, Strongly Agree =5.

a) Level of Knowledge and Application of EVM

With regard to the level of knowledge and application of EVM in the construction industry, 9% of the respondents were neutral, 18% agreed and 73% strongly agreed. The findings of this objective are supported by Brandon (1998) who suggests that, low level of knowledge and application of EVM in the construction industry is the main reasons as to why EVM is not applied in the construction industry for application of EVM in monitoring and controlling quality performance of projects. This is because, awareness EVM is minimal in the construction corporate world and there are relatively little commercial books and articles on the subject (Brandon, [4]).

b) High costs of EVM data collection

From the analysis of data with regards to high cost EVM of data collection 3% of the respondents strongly disagreed, 9% disagreed, 5% were neutral, 28% agreed and only 55% strongly agreed. This analysis leads to the conclusion that the highest (55%) percentage of respondents' claims that high cost of EVM data gathering is the main challenge for not applying EVM in monitoring and controlling quality performance of projects.

c) Difficulty of EVM reporting

The study objective intends to find out if difficulty of reporting quality basing on EVM causes resistance of employees and contractors when trying to put QEVM into practice. From the table below, 2% of the respondents strongly disagree, 11% disagree, 25% agree and 61% strongly agree.

Strategies for applying EVM in the construction industry

This study sought to suggest mitigation strategies for applying EVM in the construction industry in Tanzania. The study findings focused on introduction of continuous training to the industry practitioners on construction project management principles, sustainable and effective policy to address issues affecting quality of construction projects. The findings are as follows:

1) Introduction of and continuous training on application EVPM

The study found that, introduction of and training on application of EVMP can be one of the mitigation strategies for applying EVM in the construction industry for monitoring and controlling quality performance of projects. From the table 4.11 below 35% of respondents agreed and 65% strongly agreed.

2) Establishment of sustainable and effective policy for addressing issues affecting quality of construction projects

On establishment of sustainable and effective policy for addressing issues affecting quality of construction projects 7% agree of respondents and 93% strongly agreed. The findings of the study are supported by the study by Brandon, [3] and Marcelo et al., [6] which suggest that, Project management knowledge is very beneficial, particularly in large and complicated project like construction, since experts in various specialties can provide valuable services.

3. Conclusions

The results gotten from this research work is of great importance to the Tanzania construction industry as Earned Value Quality Management is a very essential tool in monitoring quality progress of work. The study also confirms that expected quality values defined by the project technical specifications influence observed quality performance results. To achieve expected quality performance results the project quality variables are controlled by carrying our concrete compressive strength tests to ensure conformity to the expected project plans. Therefore quality performance earned value management plays a crucial role in answering project quality management questions that are critical to the success of every project.

There is a strong and positive correlation between expected quality values defined by EVM performance baseline and observed quality results as defined by concrete compressive strength test. This this indicates that Quality Performance Index (QPI) is an efficiency tool for monitoring progress of project quality. The quantitative calculation of the project quality progress is in line with earned value performance index that a performance measure with a quality performance index greater than one (>1) indicates a favourable condition of the project, while a performance measure with a quality performance index less than one (<1) indicates an unfavourable condition PMI, [9,10].

There is also a strong and positive correlation between expected quality values defined by EVM performance baseline and observed quality results as defined by concrete compressive strength test. This this indicates that Quality Variance (QV) is also an efficiency tool for monitoring progress of project quality. Performance variance is the difference between planned performance and the actual performance. Variance when calculated can be zero, plus or minus. Plus or zero variance are considered favourable and minus value values are termed unfavourable PMI, [9, 10].

From the study findings, lack of knowledge in relation to Quality Earned Value Project Management is the main cause of challenges experienced in integrating quality values into the traditional EVM for quality performance measurement of construction projects. Continuous training to the industry practitioners on construction project management principles is one of the strategies proposed as the measure of improving the traditional EVM so as to integrate quality in the EVM for quality performance of construction projects.

4. Recommendations

The project management process is complex, usually requiring extensive and collective attention to elements forming the project triangle. If these elements are not taken seriously, they might lead to failure in the implementation of projects. Based on the findings, the study recommends that; Project Management awareness must be created and adequate training programs and seminars should be set on some close defined intervals and it must be a compulsory skill within the industry. This will equip the specialists with latest tools of project management and its application. Also, there should be frequent progress meetings with stakeholders where issues affecting quality delivery of projects can be addressed. The study also recommends that well-developed mitigation strategies should be adopted and practiced in the construction industry while given close monitoring in the course of projects execution. Quality integrated Earned Value Management is a good mitigation strategy which should be adopted by the Construction Industries to aid minimise project quality failures. Lastly, the government policies must be flexible enough to tackle crippling issues in the industry.

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