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Examination of the Impact of Value Engineering Implementation on the Overall Maintenance Performance of Gravel Roads Maintenance Projects in Tanzania

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ABSTRACT: Despite significant advancements in road infrastructure, the Tanzania gravel roads (GR) network continues to face challenges, with a staggering 65 percent of the network still remaining in poor condition. Hence, this paper examines the impact of value engineering (VE) implementation on the overall maintenance performance of gravel road maintenance projects in Tanzania using a partial least squares (PLS) structural equation modeling approach. The results revealed a strong positive relationship between VE principles implementation and the overall performance, accounting for 83.3% of the variance. In advancing the current state-of-the-practice in GR projects maintenance management, this study enhances understanding of VE phases, maintenance-related methods, and activities. These findings serve as a benchmark for decision-makers seeking to enhance projects performance in Tanzania, with potential applicability to regions facing similar climate and weather conditions worldwide.

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In many countries, particularly in developing nations, gravel roads serve as vital arteries linking rural communities to essential social and economic services such as education, markets, and healthcare. In this study, gravel roads (GR) are defined as roads catering to low-volume traffic, typically less than 300 Average Annual Daily Traffic (AADT), designed to fulfill the social and economic needs of the population. Despite significant investment in maintenance plans for gravel roads in Tanzania, maintenance efforts are consistently plagued by challenges related to cost, time, and quality, resulting in only moderately satisfactory maintenance performance (NAO, 2023). This moderate level of satisfaction stems from the lack of consistent, objective approaches to addressing the challenges faced in maintenance performance. Research indicates that up to 60% of total maintenance costs are attributed to the depletion of gravel road maintenance resources (Verhaeghe *et al.*, 2010). Consequently, this study explores the potential of value engineering (VE) as an approach to addressing these challenges and improving maintenance performance. Value engineering (VE) emerges as a promising tool to mitigate the challenge. VE is associated with several benefits to construction projects, such as improvements in performance, efficiency, competitiveness, transparency, and reputation, in addition to the creation of a common value culture (Dahiru, 2019). VE further entails an organized, systematic process of technical appraisal of a project, product or process aimed at eliminating

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unnecessary costs while enhancing quality, scope and performance (Ramus *et al.,* 2006). Value engineering, as defined by (Miles, 1947), is a systematic method aimed at providing essential functions of a system or project at the lowest overall cost possible, often involving the substitution of materials or methods with less expensive alternatives without compromising functionality. In developed countries, VE has been recognized as a valuable tool for addressing construction project challenges related to quality, cost, and time (Lin *et al.*, 2011). Similarly, in developing nations, the adoption of value engineering is on the rise, as it aims to enhance cost-effectiveness and efficiency (Kissi *et al*., 2015). In developing countries, the level of implementation of VE is very modest (Creswell, 2017). Despite limited awareness of VE principles, previous studies have demonstrated its potential as a pre-designed model for overcoming construction project challenges (Abidin *et al*., 2007). VE has been shown to reduce costs, manage time effectively (Robichaud *et al*., 2011), and enhance overall project quality, resulting in significant monetary benefits. The formal approach to VE, often referred to as the 40-hour job plan, typically encompasses five phases: information, function, creativity, evaluation, and development and presentation (Miles, 1947). Throughout these phases, mistakes and challenges provide opportunities for learning and continuous improvement. However, research in this area is lacking, particularly concerning gravel roads, as most studies have focused on modeling paved road performance (Pinard *et al.,* 2006). To address these gaps, this paper examines the impact of value engineering (VE) implementation on the overall maintenance performance of gravel road maintenance projects in Tanzania.

MATERIALS AND METHODS

Value engineering principles and activities: According to SAVE (2007), value engineering principles are organized into distinct phases: information, function, creativity, evaluation, and development and presentation. The information phase involves selecting areas of study by establishing an information base, while the function phase focuses on exploring project details to identify opportunities for change and generate alternative solutions. During the creativity phase, various alternatives to meet project needs are brainstormed, the evaluation and development and presentation phase is dedicated to identifying the benefits of ideas and determining the best options for improvement. Value engineering, as noted by Male *et al.*, (1998), is an approach aimed at enhancing the efficiency of a project or system. This functional-oriented technique of value engineering has demonstrated its effectiveness as a management tool for achieving improved design and cost-effectiveness across various construction and maintenance projects. Traditionally, the application of value engineering leads to additional benefits beyond design improvements, such as updating standards and policies and integrating new materials, methods, and techniques to enhance value. Insights and opinions on specific topics can be gleaned from a group of relevant experts, as outlined by Delphi analysis. In this study, Delphi analysis procedures were employed with a panel of 10 experts from mainland Tanzania, comprising engineers, quantity surveyors, and value engineering specialists to generate VE principles and activities alongside with maintenance performance indicators. The procedure encompassed three stages: expert selection based on expertise and knowledge, generation of responses and feedback through rounds 1 and 2, and VE expert in order to group gathered information into VE phases to highlight key insights. The VE principles, activities, and maintenance performance indicators are outlined in Tables 1 and 2 as a result of Delphi analysis. Khalid *et al.,* (2019), stated that from the designer's perspective, maintenance problems are traceable, and are limited with pre and post-contract activities. Lack of integration of construction processes such as value engineering into the designer's team has been found to increase maintenance problems (Khalid *et al*., 2019). To ensure sustainability, this study incorporated all value engineering and performance aspects as dependent and independent variables in constructing the structural equation model. The Value Engineering (VE) approach is a functional-oriented technique renowned for its effectiveness as a management tool in attaining optimal value across various construction and maintenance projects. Traditionally, VE not only enhances design but also yields additional benefits such as the revision of standards and policies, as well as the integration of innovative materials, methodologies, and techniques to enhance value. Specifically concerning gravel roads (GR), VE encompasses meticulously crafted policy directives governing planning, design, construction, maintenance, and the sustained enhancement of value. In the context of Tanzania, the Annual Performance Agreement (APA) of 2023 between the Roads Fund Board (RFB) and roads development and maintenance implementing agencies (TARURA and TANROADS) delineates maintenance as one of the core functional groups under the recurrent budget. This maintenance umbrella includes routine maintenance (RM), periodic maintenance (PM), emergency maintenance (EM), spot improvement (SI), and bridge maintenance. The selection of appropriate maintenance interventions and activities hinges upon the data pertaining to road inventory and conditions.

Table 1*:* VE Phases and indicators for gravel roads maintenance projects

VE (Phases)	CODE	Indicator's name
Information Phase (Areas of study to provide information base)	IP1	Gravel materials thickness on road surface
	IP2	Rutting
	IP3	Corrugation
	IP4	Potholes
	IP5	Stoniness
	IP6	Gravel materials lost
	IP7	Drain condition
	IP8	Vegetation type (Open, medium, dense)
	IP9	Road signs conditions
	IP10	Borrow pit gravel materials quality
	IP11	Maintenance records (Costs and interventions)
	IP12	Travel times between points
	IP13	Extent of damage of drainage structures
	IP14	Population served by the road
	IP15	Access to economic centers
	IP16	Access to social centers
	IP17	Traffic class
	IP18	Connectivity
	IP19	Agricultural output of the area served
	IP20	Prevalence condition level of the road
	IP21	Political influence
	IP22	Mobility
	IP23	Maintenance cost
	IP24	Change of land use
	IP25	Rate of road deterioration
	IP26	Vehicle operating costs
	IP27	Societal riot
Functional Phase **(**Explore project details to find opportunities for changes by generating alternatives for problem solving)	FP1	Change in material prices
	FP2	Change in the road's requirements of beneficiaries
	FP3	Corruption
	FP4	Limited construction materials
	FP5	Erroneous in maintenance cost estimation
	FP6	Lack of new maintenance information
	FP7	Absence of ties or good coordination
	FP8	Poor Project timing
	FP9	Contract conditions changes during implementation
	FP10	Delay of payments of raised payment certificates
	FP11	Use of low cost and non-standard materials
	FP12	Delay in issuing works certification
	FP13	Design changes
	FP14	Poor quality control
Creativity Phase (Brainstorming improvement areas to meeting the needs)	CP1	Awareness of value increment techniques
	CP2	Introducing new management techniques
	CP3	Maintaining life cycle value
	CP4	Equitable allocation of risks
	CP5	Continuous learning from experience of past projects
	CP6	Socially responsible designs
	CP7	Continual quality of maintenance management system
	CP8	Regular training of technical staffs and communities involved in road sector
	CP9	Integrated follow up of maintenance plans by all key stakeholders
Evaluation Phase (Benefits of the VE ideas)	EP1	Coordination of road condition survey activity and its reports
	EP2	Proper road inventory records
	EP3	Appropriate gravel roads maintenance prioritization
	EP4	Identifying road maintenance planning processes
	EP5	Engaging environmental considerations and community needs for gravel roads maintenance implementation
	EP6	Timely measurement and payment certification of works
	EP7	Reducing time for tendering procedures
	EP8	Facilitating maintenance works funding timeline
Development and Presentation Phase (Options to improve value)	DP1	Management strategy
	DP2	Document quality strategy
	DP3	Construction materials strategy
	DP4	Scope and schedule strategy
	DP5	Risk strategy
	DP6	Delivery and procurement strategy
	DP7	Estimate quality strategy
	DP8	Integrity strategy
	DP9	Off-Prism strategy
	DP10	Maintenance fund disbursement strategy

Note: VE =value engineering; IP = information phase; FP =function phase; CP =creativity phase; EP =evaluation phase, DP =development and presentation phase

Performance measurements of gravel roads maintenance projects: Establishing quantifiable performance metrics is imperative for assessing the success of maintenance projects across all categories of roads, including gravel roads. Key objectives of effective construction or maintenance work, such as quality, time, and cost, as outlined by Chua *et al*., (1999), constitute fundamental hard performance measures. While much research has concentrated on evaluating project performance based on these hard criteria, the softer aspects related to social, relational, and environmental considerations have often been overlooked. To date, a comprehensive model encompassing both hard and soft performance measures for gravel road maintenance projects in Tanzania remains absent from the literature. Luvara (2020) asserted that the cost, time, and quality of a completed project are the primary goals of construction projects. Factors such as minimizing cost variations, adhering to project timelines, and enhancing compliance with specifications are crucial determinants of project performance. This study investigated both hard and soft criteria for project performance measurement, leveraging the insights gained from Delphi analysis on implementing value engineering (VE) principles. Accordingly, the performance indicators encompassing quality, time, cost, social, relational, and environmental factors for gravel roads are described in Table 2.

Table 2: Gravel roads maintenance projects performance measurements

Performance Criteria	CODE	Indicator's name
Hard performance criteria (Cost, time and quality)	C1	No addition works and variations
	C2	Accurate budgets estimate as per roads condition survey reports
	C3	No maintenance scope creep
	C4	No maintenance scope changes
	C5	Adequate funds allocation considering actual maintenance needs
	T1	Minimum or no disputes for maintenance projects
	T2	Adequate timing of maintenance activities
	T3	Timely payments for works dully executed by clients
	Q1	No hike in construction materials due to inflation
	Q2	Proper project planning and control
	Q3	Good risk management
	Q4	Quality and conditions of construction materials
Soft performance criteria (Social, relational and environmental)	R1	Overall, personal relationships among members (employee-employee, Management employee relationships) are continually good
	R2	Overall achievement on adherence to health and safety measures on gravel roads projects well maintained
	R3	Overall satisfaction of road users and other stakeholders
	E1	Overall achievement of influence by local communities on environmental improvement for gravel roads maintenance projects sites
	E2	Overall achievement of training programs on environmental issues related to gravel roads management
	E3	Overall achievement of completed gravel roads maintenance projects' sites being environmentally protected
	E4	Overall achievement of compliance with implementing environmental management practices for gravel roads maintenance projects

Note: C = cost; T=Time; Q =quality; R =relational; E =environmental aspects

Relationship between VE principles implementation and Maintenance Performance: Several studies have explored value engineering (VE) to develop frameworks and assess its benefits. For instance, Palmera *et al.*, (1996) examined VE benefits within the construction industry in the United States by scrutinizing value engineering workshops and establishing an appraisal of the technique. In the UK construction sector, Dean *et al.*, (2002) sought to reveal the connection between value engineering theory and project practice, noting the limited extension of VE beyond the tendering stage. Leung *et al.,* (2014) emphasized the direct influence of performance on organizational efficiency and effectiveness. The utilization of appropriate performance assessment methods holds the potential to meet organizational and individual requirements and enhance the cost-effectiveness of training initiatives. Despite several studies focusing on individual phases of VE implementation (VE-IMP phases), scant attention has been given to its impact on the overall performance of projects or systems, particularly in terms of evaluating the effectiveness of performance indicators and targets.

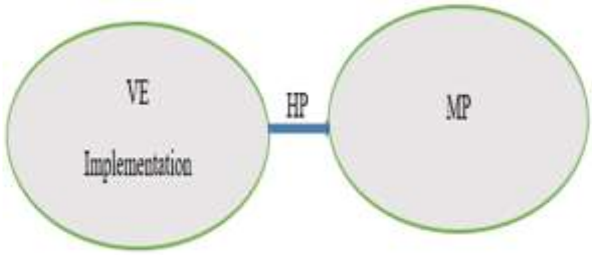

Fig.1: Effect of VE principles implementation on GR projects maintenance performance

Thus, this paper seeks to investigate the relationship between VE implementation and the overall maintenance performance of gravel roads projects, contributing to previously unidentified areas of inquiry. According to Brown and Dant (2008), VE implementation holds the promise of significant contributions to the construction industry. Consequently, a conceptual model depicting the hypothesized pathway (HP) of the study was developed, as illustrated in Figure 1.

In this the conceptual model based on theories (hypotheses) was derived from extensive literature reviews (Shields *et al.*, 2006). The modeling process involved several key steps, including the identification of constructs within the model, categorization of these constructs, and specification of the relationships between constructs and their respective indicators. Table 1 provides an overview of the indicators or activities that classify the SEM constructs. To gather information on these VE activities and classify them into phases, a questionnaire survey was administered to 385 professionals within the roads sector. The concept of maintenance performance factors was derived solely from documentary review and Delphi analysis. These performance measures were subsequently grouped into model constructs encompassing both hard and soft performance criteria in terms of quality, time, cost, relational, and environmental aspects. To ensure the strength of the research methodology, a two-stage questionnaire survey was conducted.

The first stage involved a pilot study conducted in Dar es Salaam City, Tanzania. Conducting a pilot study is considered a best practice for evaluating the measurement instrument's validity before its implementation in the main study (Van Teijlingen and Hundley, 2010). The second stage comprised the main study conducted in mainland Tanzania, where the theoretical hypotheses were tested based on the findings from the pilot study. The research design and approach are depicted in Figure 2.

Pilot Study: A pilot study was conducted to examine the groups identified in the research approach. Initially, 40 questionnaires were distributed to professionals in the road sector operating under either TANROADS or TARURA in the Dar es Salaam Region of Tanzania. Structural equation modeling using the partial least squares method, a sample size of 200 or more is necessary. Given that the study adopted the structural equation modeling approach with partial least squares, the population proportion considered for main survey was 50%, resulting in a sample size of 385, as determined by equation 1.

$$Sample\ size\ (n) = \frac{N}{(1+Ne)^2} \quad (1)$$

Where n is the corrected sample size or minimum number of required respondents; N is the population size identified and e is the margin of error which is the level of acceptance or precision.

Other assumed parameters with regard to calculating sample size are; 95% confidence level, 50% population proportion and 5% margin of error e. 213 respondents returned the questionnaire giving a response rate of 55.3%. Therefore, the sample size used fitted the purpose as a representative sample and is within an acceptable range of 150-300 (Tabachnick *et al.*, 2007). This pilot study aimed to test and identify errors, ambiguous terms and any other thing that could make the research unsuccessful or hinder further steps.

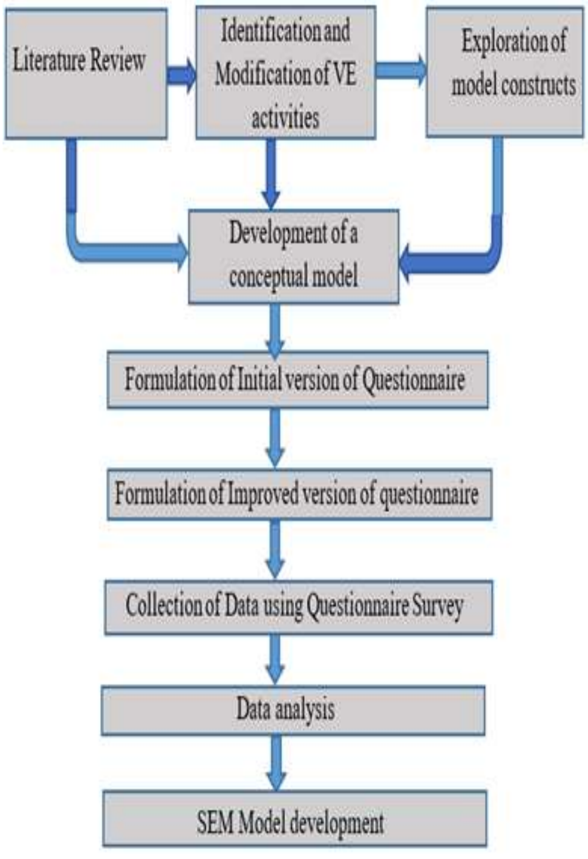

Fig. 2: Research design and approach

Main Survey Design: Based on the literature review, a structured questionnaire was developed to gather data on maintenance activities related to value engineering (VE) in gravel roads, as well as factors influencing maintenance performance. These activities, or indicators, were systematically categorized into VE phases: information, function, creativity, evaluation, and development and presentation, with the overarching goal of enhancing overall maintenance performance. The research was conducted across all regions of mainland Tanzania. Respondents were tasked with providing insights into VE-related maintenance activities and performance indicators for gravel road projects. This involved categorizing information on VE constructs and performance indicators into hard criteria, namely quality, time, and cost, alongside soft criteria, including social and relational factors. Table 3 illustrates the diverse array of organizations from which respondents were drawn, including the Tanzania National Roads Agency (TANROADS), Tanzania Rural and Urban Roads Agency (TARURA), Local Government Authorities (LGAs), Private Construction Companies (PCC).

The findings revealed a concerning lack of awareness regarding VE principles among respondents, with 74.2% reporting no familiarity with the fundamental understanding of VE in road construction and maintenance projects. However, the majority of respondents (75.7%) had three or more years of experience in gravel road maintenance, instilling confidence in the validity of the study findings. In terms of academic credentials, the majority of respondents (86.5%) held basic degrees, with 70.6% holding Bachelor's degrees (BSc), 15.9% holding Master's degrees (MSc), 11.7% holding diplomas, and 1.9% holding PhDs. Furthermore, the distribution of respondents' professional fields and organizational affiliations was fairly proportionate, with civil engineering being the predominant field (79.4%) and TARURA being the primary organizational affiliation (59.2%). Responses were collected using a Likert 5-point scale, with participants indicating their level of agreement or disagreement with various statements. The sample size of 385 was determined based on the aim of the analysis, ensuring that it met the requirements for statistical analysis, as recommended by previous studies. This study employed partial least squares algorithm structural equation modeling (PLS Alg - SEM) due to its ability to handle numerous observed and latent variables. A total of 213 returned participants' responses were included in the SEM analysis, resulting in a response rate of 55.3%. This high response rate was attributed to the ample time interval provided for data collection and the convenience of the Google Form method, which required respondents to complete all questions before submission. In conclusion, the correlation observed between experience and education level highlights the intricate relationship between theoretical knowledge and practical application. Similarly, the significance of professional qualifications and the relevance of organizations' roadworks underscore the credibility of the information gathered from authoritative sources. Consequently, this data is presumed to furnish a solid grounding in concepts and principles, as well as furnish invaluable understandings suitable for analysis and model development.

Table 3*:* Demographic profile results summary

Demographic profile		Frequency	Percent	Valid percent	Cumulative percent
Experience	Less than 3 years	52	23.9	23.9	23.9
	3-5 years	49	23.0	23.0	46.9
	5-10 years	47	22.1	22.1	69.0
	10-20 years	47	22.1	22.1	91.1
	More than 20 years	19	8.9	8.9	100
	Total	**213**	**100**	**100**	
Education	PhD	4	1.9	1.9	1.9
	Master	34	16.0	16.0	17.8
	Bachelor	150	70.4	70.4	88.3
	FTC/ordinary diploma	25	11.7	11.7	100
	Total	**213**	**100**	**100**	
Professional qualification	Civil Engineer	169	79.3	79.3	79.3
	Quantity Surveyor	15	7.0	7.0	86.3
	Architect	3	1.4	1.4	87.7
	Environmental Engineer	2	0.9	0.9	88.6
	Civil Technician	24	11.3	11.3	100
	Total	**213**	**100**	**100**	
Organization or firm	Tanzania National Roads Agency (TANROADS)	22	10.3	10.3	10.3
	Tanzania Rural and Urban Roads Agency (TARURA)	126	59.2	59.2	69.5
	Local Government Authority	15	7.0	7.0	76.5
	Private Construction Company	50	23.5	23.5	100
	Total	**213**	**100**	**100**	

Structural equation modeling approach: Given the complex nature of the study, which aims to assess the impact of value engineering implementation on the overall maintenance performance of GR, Structural Equation Modeling (SEM) proves invaluable. SEM is well-suited for this purpose as it accommodates various factors, including interactions, nonlinearities, correlated independent variables, measurement error, correlated error terms, multiple latent independent variables each measured by multiple indicators, and one or more latent dependent variables, each with multiple indicators. This approach contrasts with linear or multiple regression techniques, which cannot adequately address the relationship between observed and latent variables, particularly nonlinearities, as highlighted by Oke *et al*., (2015). Thus, SEM enabled the description of relationships among numerous measurable endogenous and exogenous variables. The equation 2 provided below offers a simplified illustration of SEM's characteristics.

$$a_1y_1+a_2y_2+a_3y_3+\ldots+a_ny_n = b_1x_1+b_2x_2+b_3x_3+\ldots+b_nx_n \quad (2)$$

Where y_1, y_2, y_3... y_n are endogenous (dependent) variables and; x_1, x_2, x_3……. x_n are exogenous (independent) variables.

In this study the indicators and VE constructs are exogenous variables while the maintenance performance constructs and indicators are endogenous variables. Amaratunga *et al*., (2010) highlighted SEM as a valuable tool for handling errors in variables, while Byne (2010) characterized SEM as a non-experimental research technique. Furthermore, Yuan *et al*., (2011) concluded that SEM is widely recognized as a favored data analysis technique. Within the context of PLS Algorithmic Structural Equation Modeling (SEM), the measurement model delineates the relationship between constructs and their observable indicators (Sarstedt *et al*., 2014). Building upon these understandings, this study employed the PLS Algorithmic SEM approach to assess the impact of implementing value engineering principles and activities on GR maintenance performance indicators. Five value engineering constructs and their associated activities/indicators were analyzed using Partial Least Squares (PLS), which is one approach to SEM. Concurrently, gravel roads maintenance performance indicators underwent similar analysis to culminate in final results, demonstrating the overall coefficient of determination (R^2). Partial Least Squares focuses on variance analysis and can be executed using various tools such as ADANCO, PLS-Graph, VisualPLS, SmartPLS, and WarpPLS. This study utilized SmartPLS for analysis and model development. In developing the structural equation model, the study delineated two sub-models: the inner and outer models. The inner model outlined the relationship between independent and dependent latent variables (VE and MP constructs), while the outer model specified the latent variables and their observed indicators (VE constructs vs. VE indicators) and (MP constructs vs. MP indicators). Factor loadings were employed to assess whether observed variables (VE indicators) effectively measured latent variables (VE constructs), while path coefficients (weights) determined how independent variables predicted dependent variables, referred to as 'model outcomes' within this study. The overall results, denoting the total effect of value engineering principles and activities on maintenance performance, were quantified by the coefficient of determination (R^2). An R^2 value exceeding 0.20 was deemed acceptable, indicating the proportion of an endogenous construct's variance explained by its predictor constructs.

RESULTS AND DISCUSSION

The analysis involved scrutinizing sixty-eight (68) variables related to value engineering activities/indicators and nineteen (19) items pertinent to gravel roads (GR) maintenance performance. To determine the model path coefficients and their significance levels (p-values), the Partial Least Squares (PLS) algorithm and bootstrapping techniques were employed. Following established criteria, p-values ≤ 0.02 were deemed acceptable, while an Average Variance Extracted (AVE) of ≥ 0.5 was considered satisfactory (Henseler, 2015). Understanding the theoretical framework of the model relied heavily on the sizes of model path coefficients, indicative of variable relationships' strength, and the associated p-values denoting statistical significance. Results from the PLS algorithm and bootstrapping revealed that among the sixty-eight VE activities/indicators analyzed, twenty-seven items displayed p-values >0.02 and outer loadings values <0.7, resulting in the exclusion of 39.7% of total items. Contrariwise, for GR maintenance performance indicators, only one item (C4 - No maintenance scope changes) out of nineteen items, representing 5.3% of the total items, was excluded. Results revealed that all model constructs exhibited statistically significant p-values for path coefficients, total indirect effects, specific indirect effects, and total effects, with p-values of 0.000, meeting the criterion of ≤ 0.02. The twenty-nine indicators were omitted from the final modified model due to their insignificant outer loadings and outer weights values, with p-values exceeding 0.02. Upon further scrutiny, it was found that all model construct paths remained statistically significant based on the original data, as outlined in Table 4. Table 5 provides a summary of the gravel roads-value engineering model indicators considered for inclusion and exclusion due to cross-loading in building the Structural Equation Model (SEM), with twenty-nine items, equivalent to 33.3% of overall items, designated for exclusion.

Table 4: Structural equation model constructs path coefficients

Path Name	Original sample (O)	Sample Mean (M)	Standard Deviation(STDEV)	T Statistics (IO/STDEVI)	P-Values
CP->VE-IM	0.341	0.338	0.028	12.320	0.000
DP->VE-IM	0.170	0.169	0.017	10.245	0.000
EP->VE-IM	0.291	0.286	0.025	11.743	0.000
FP->VE-IM	0.114	0.113	0.022	5.121	0.002
IP->VE-IM	0.390	0.388	0.033	11.745	0.000
MP->C	0.746	0.749	0.040	18.800	0.000
MP->E	0.724	0.725	0.045	16.113	0.000
MP->Q	0.749	0.751	0.038	19.944	0.000
MP->R	0.776	0.776	0.041	19.092	0.000
MP->T	0.659	0.660	0.051	12.952	0.000
VE-IM->MP	0.892	0.897	0.013	67.376	0.000

Note: VE-IM =Value engineering implementation, MP =Maintenance performance

Table 5: Indicators for inclusion and exclusion in the model

Construct name	Indicators' codes for inclusion	Indicators' codes for exclusion
Information Phase	IP1, IP7, IP11, IP14, IP15, IP16, IP17, IP18, IP19, IP20, IP22, 1P25	IP2, IP3, IP4, IP5, IP6, IP8, IP9, IP10, IP12, IP13, IP21, IP23, IP24, IP26, IP27
Functional Phase	FP1, FP8, FP9, FP10	FP2, FP3, FP4, FP5, FP6, FP7, FP11, FP12, FP13, FP14
Creativity Phase	CP1, CP2, CP3, CP4, CP5, CP6, CP7, CP8, CP9	-
Evaluation Phase	EP1, EP2, EP3, EP4, EP5, EP6, EP7, EP8	-
Development and presentation Phase	DP1, DP2, DP3, DP5, DP6, DP7, DP8, DP10	DP4, DP9
Time	T1, T2, T3	-
Cost	C1, C2, C3, C5	C4
Quality	Q1, Q2, Q3, Q4	-
Social and relational	R1, R2, R3	-
Environment	E1, E2, E3, E4	-

Building the Inner and Outer Models: From the conceptual model derived, the structural equation model (SEM) depicted in Figure 3 reflects the hypothesized pathway illustrated in Figure 1, delineating the anticipated effects of implementing value engineering principles on overall gravel roads (GR) maintenance performance. Tables 1 and 2 categorize each value engineering and maintenance performance construct within the model, derived from activities (indicators) identified through Delphi analysis. In the context of SmartPLS, the SEM model elucidates the complex relationships among the variables under study, particularly the nexus between value engineering implementation constructs and their observable indicators or activities (Sarstedt *et al.*, 2014). Within the Partial Least Squares (PLS) framework, the SEM's inner models were constructed by identifying appropriate latent variables gleaned from Delphi analysis. The outer models were developed by linking the indicators (activities) to the latent variables. As articulated by Hair *et al.,* (2016), assessing the measurement model necessitates evaluating several criteria, including the reliability of each indicator, composite reliability, average variance extracted (AVE), discriminant validity, Rho-A ratio, Cronbach's alpha value, coefficient of determination (R^2), and predictive relevance of the model (Q^2). This study adhered to all eight measurement model assessment requirements, with results presented in Tables 6-9. The modified model's Cronbach's alpha value for the cost construct, as indicated in Table 6, stands at 0.696, slightly below the threshold of 0.7. However, for newly developed model measurements, a Cronbach's alpha value >0.6 is considered acceptable, while values above 0.8 are deemed highly reliable (*Hair et al.,* 2016). Thus, all Cronbach's alpha values in Table 6 are deemed acceptable, indicating consistent internal variables. As suggested by Henseler *et al.*, (2009), indicators with outer loadings should only be considered for exclusion if their removal significantly improves composite reliability and average variance extracted. Figure 4 presents the outer loadings values for all variables in the modified measurement model. Results reveal that VE variables with the highest outer weights/loadings values for VE constructs include IP14 (Population served by the road) and FP1 (Change in materials prices), among others. Based on these findings, an implementation model for VE phases and activities, along with performance factors, incorporating five main dimensions and subscales of cost, time, quality, relational, and environment, has been developed, as elucidated in Figures 3 and 4. Further evaluation was done after excluding statistically insignificant variables. Assessing the internal consistency of composite reliability (CR) was imperative due to Cronbach alpha limits, as it measures sensitivity toward the number of elements involved (Hair *et al.*, 2016). All models surpassed the CR>0.70 threshold, indicative of their appropriateness for analysis. The convergent validity of constructs was evaluated using average variance extracted (AVE), with values above

0.50 considered appropriate (Wong, 2013). Results presented in Table 6 demonstrate that all constructs pass this test, as their AVE values exceed 0.5. The discriminatory validity of the model constructs was examined through the Heterotrait-Monotrait (HTMT) ratio, with Hair *et al.,* (2010) suggesting a threshold value of ≤0.85. Results in Table 9 indicate that a substantial proportion of correlated constructs exhibit an HTMT ratio below 0.85, indicating satisfactory discriminatory validity. In conclusion, the Fornell and Larker's (1981) criterion was employed to assess the discriminating validity of model constructs, with results detailed in Tables 6 and 11. The square roots of AVEs surpass the correlations of the constructs, in line with Fornell and Larker's stipulations (1981), thus affirming the model's discriminating validity.

Table 6: Construct reliability and validity test results summary

Constructs name	Item code	Rho-A	Cronbach's alpha	Composite reliability	AVE
Information	IP	0.930	0.912	0.925	0.512
Function	FP	0.839	0.716	0.807	0.513
Creativity	CP	0.984	0.983	0.986	0.884
Evaluation	EP	0.985	0.984	0.986	0.899
Development/presentation	DP	0.896	0.868	0.894	0.515
Time	T	0.794	0.791	0.878	0.707
Cost	C	0.717	0.696	0.811	0.520
Quality	Q	0.763	0.759	0.847	0.581
Relational	R	0.942	0.941	0.962	0.894
Environment	E	0.979	0.978	0.984	0.938
VE-implementation	VE-IM	0.965	0.980	0.969	0.509
Maintenance performance	MP	1.000	1	1	1
Acceptable value		≥ 0.70	≥ 0.70	≥ 0.70	≥ 0.50

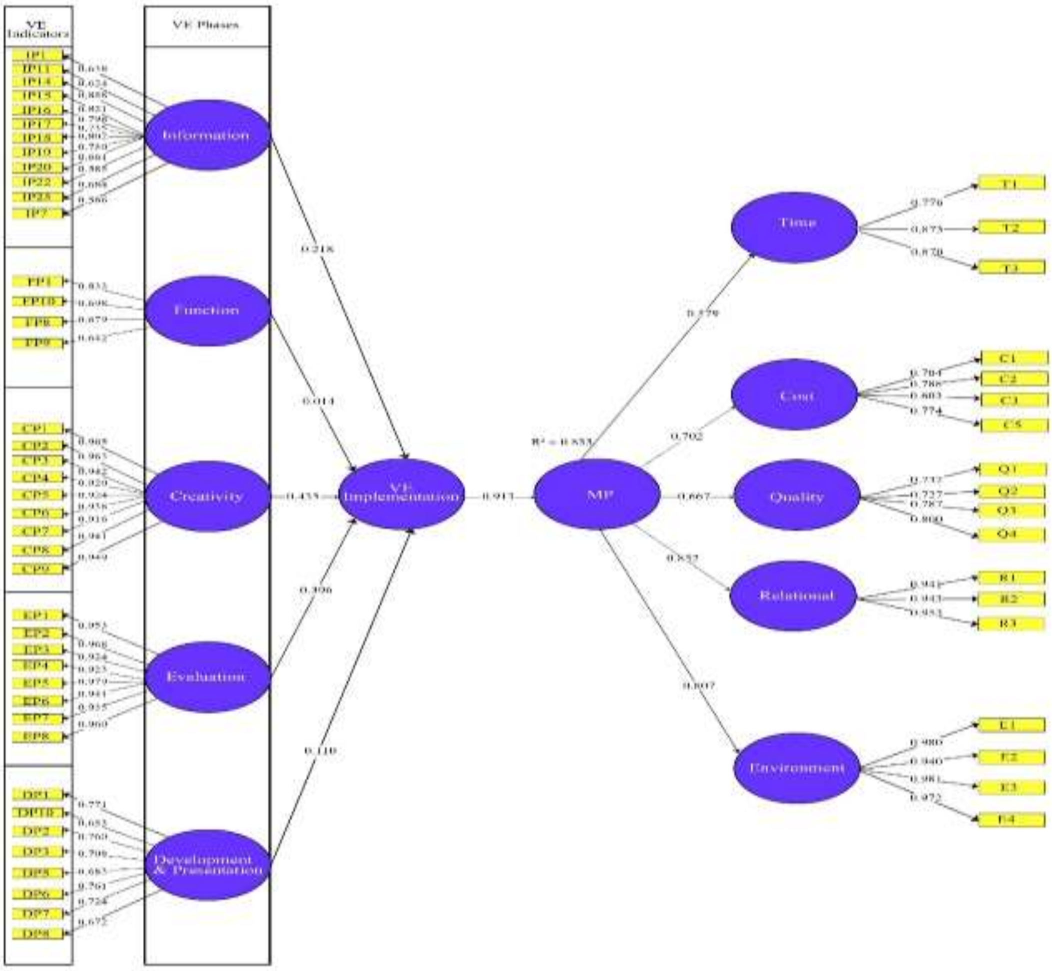

Fig. 3: Structural equation model with path coefficients and coefficient of determination R^2

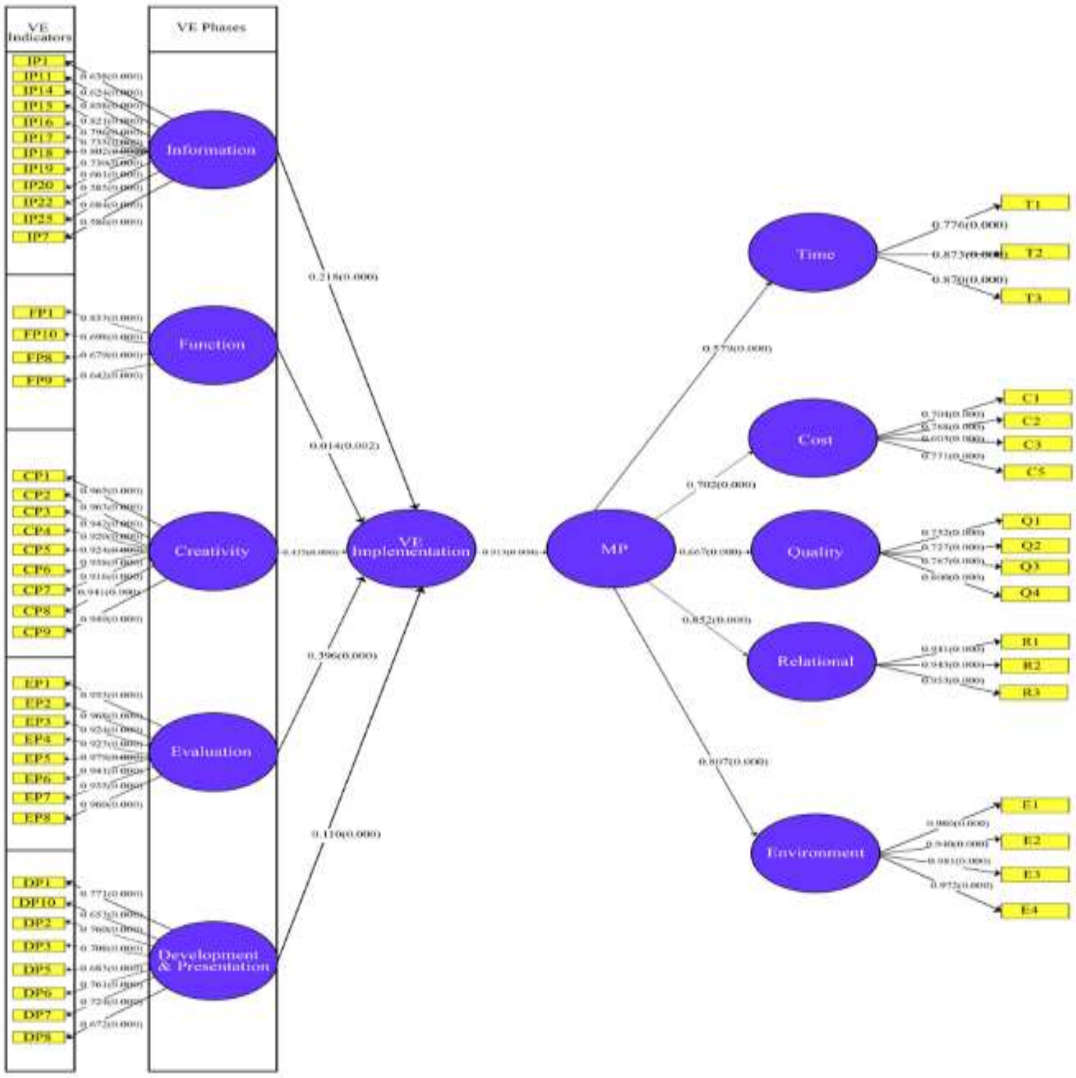

Fig. 4: Structural equation model with path coefficients and p-values on inner model and outer weights/loadings and p-values on outer model.

Structural Equation Model Path Coefficients and Power: The analysis of path coefficients is a common method for examining complex relationships, and Structural Equation Modeling (SEM) analysis is no exception (Tabachnick *et al.*, 2007). The structural model serves to evaluate the intricate relationship between input and output constructs in the research. In this study, path coefficients and power analysis were conducted after fitting the model, assessing standardized root mean squared residual (SRMR), and unweighted least squares discrepancy (d_ULS) using SmartPLS. The SRMR is deemed acceptable when it is 0.08 or lower, while a lower d_ULS indicates a better model fit. The assessment of the structural model primarily relies on total model fit, where results are tested and compared against predefined ranges, with hypothesized parameter estimates followed by size, direction, and importance (Hair *et al.*, 2006). As summarized in Table 7, both the saturated and estimated models met the requirements, and Table 4 displays the significant path coefficients between construct variables, indicating the strength of their relationship. In this research, in line with the PLS assessment model's fit results, the total effect (f^2) of implementing value engineering on gravel roads maintenance performance is substantial, with an f^2 value of 0.931, exceeding the threshold of 0.35. The overall impact or power of implementing value engineering principles on gravel roads maintenance projects, as assessed within the context of PLS Algorithm, bootstrapping, and blindfolding, yields a coefficient of determination (R^2) of 0.833. An acceptable R^2 value is defined as $R^2 > 0.20$, indicating the proportion of endogenous constructs explained by predictor constructs. Hence, the coefficient of determination results of 0.833 (83.3%), along with corresponding path coefficients and p-values, elucidate the impact of VE principles on GR maintenance project performance. Since all R^2 and adjusted R^2 values in Table 9 exceed 0.2, they are considered acceptable.

Table 7*:* Model fit test result summary

Fitness test	Saturated Model	Estimated Model
SRMR	0.164	0.182
d_ULS	166.415	206.864

Predictive Relevance of the Structural Equation Model: To assess the accuracy of the adjusted model, it is imperative to evaluate the predictive relevance Q^2, as emphasized by Hair *et al*., (2014). In this study, blindfolding was employed to examine the cross-validated redundancy measures of the model constructs. The findings revealed a predictive relevance Q^2 value of 0.332 for gravel roads maintenance performance and 0.502 for value engineering implementation. According to Hair *et al.*, (2014), an acceptable predictive relevance Q^2 is greater than 0. These results suggest that the independent constructs hold significant predictive relevance for the dependent constructs, namely maintenance performance, as the Q^2 values exceed zero. The summary of the Q^2 results is presented in Table 12. The cross-validated redundancy values of the maintenance performance outcomes are 0.221, 0.632, 0.242, 0.597, and 0.234 for timeframe, social and relational aspects, quality, environment, and project cost, respectively. Consequently, the structural model equation exhibits excellent predictive relevance.

Importance-Performance Matrix Analysis: The Importance-Performance Matrix Analysis (IPMA) enhances the findings derived from Partial Least Squares Structural Equation Modeling (PLS-SEM) by evaluating both the importance and performance of each variable incorporated in constructing the structural equation model. IPMA provides insights into the relative value of independent variables in explicating the dependent variable in the path model (Hair *et al.*, 2016).

The results of IPMA can be illustrated in two dimensions: importance and performance, with particular emphasis on identifying the most crucial variables for guiding management actions. In this study, decision-making processes can be informed by judiciously selecting the flow of gravel roads maintenance planning, prioritizing paths with high importance values. To pinpoint critical areas for enhancing gravel roads management activities, the structural model's total effects are examined. In this context, the importance of value engineering GR maintenance activities (indicators) and the latent variables (performances) representing value engineering phases are assessed. The comprehensive findings, as presented in Table 13, outline the significance and performance of exogenous variables. It is therefore pertinent to conclude that the degree of importance attributed to value engineering implementation is 0.913, while the total effects on performance amount to 74.1%. These results underscore the pivotal role of value engineering in enhancing gravel roads maintenance activities. The integration of value engineering (VE) principles can significantly enhance the maintenance performance of gravel roads projects.

Through a thorough examination of the correlations between model constructs, namely value engineering phases/activities and GR maintenance performance, a comprehensive understanding has been achieved within the structural equation model, complemented by pertinent statistical values. In summarizing the research findings gleaned from the analysis, several compelling understandings emerge regarding the impact of VE implementation on the overall performance of gravel roads maintenance projects.

Table 13*:* Importance-Performance Map Analysis (IPMA) on GR maintenance projects

Predictor	Importance	Performances
VE Implementation	0.913	74.100

Identifying the performance factors of gravel roads maintenance projects: This research considered project performance measures in terms of both hard and soft criteria. While hard criteria typically focus on time, cost, and quality commonly emphasized in construction and management studies, this study also delved into soft criteria, encompassing social, relational, and environmental aspects. Among the hard criteria performance measures, cost emerged as the top-ranking factor, with an outer loading score of 0.702.

This underscores the significance of cost management within the gravel roads maintenance cycle, with value engineering implementation offering potential cost reduction and added value.

The indicator "accurate budgets estimate as per roads conditions survey reports" (C2) received substantial support, highlighting the pivotal role of precise budgeting in project performance. Supporting this stance, Ellis *et al*., (2005) affirmed that satisfactory application of value engineering could reduce construction project costs by up to 10%-25%.

Table 8: VE constructs path coefficients values ranking results summary

Construct name	Information	Function	Creativity	Evaluation	Development and presentation
Path coefficient	0.218	0.014	0.435	0.396	0.110
Rank	3	5	1	2	4

Table 9: Coefficient of determination (R^2) results of the model

Construct name	Code	R^2	R^2 adjusted
VE-Implementation	VE-IM	0.999	0.999
Maintenance performance	MP	0.833	0.832
Time	T	0.336	0.332
Cost	C	0.492	0.490
Quality	Q	0.444	0.442
Relational	R	0.726	0.725
Environment	E	0.652	0.650

Table 10: The Heterotrait-Monotrait (HTMT) ratio values

Constructs name	Cost	Creativity	Development	Environment	Evaluation	Function	Information	Quality	Relational	Time	VE-Implementation
Creativity	0.360										
Development	0.764	0.345									
Environment	0.267	0.975	0.290								
Evaluation	0.308	1.004	0.307	0.994							
Function	0.663	0.185	0.570	0.129	0.157						
Information	0.752	0.418	0.809	0.332	0.370	0.589					
Quality	1.033	0.280	0.812	0.203	0.236	0.712	0.714				
Relational	0.361	1.025	0.354	1.008	1.014	0.183	0.423	0.272			
Time	0.848	0.179	0.685	0.119	0.154	0.560	0.660	0.933	0.186		
VE-Implementation	0.628	0.924	0.697	0.866	0.901	0.427	0.780	0.561	0.934	0.452	-

Table 11: Correlation of latent variables and discriminant validity (Fornell-Larcker)

Constructs	Cost	Creativity	Development and presentation	Environment	Evaluation	Function	Information	Maintenance performance	Quality	Relational	Time	VE Implementation
Cost	0.721	-	-	-	-	-	-	-	-	-	-	-
Creativity	0.315	0.940	-	-	-	-	-	-	-	-	-	-
Development/ presentation	0.630	0.357	0.718	-	-	-	-	-	-	-	-	-
Environment	0.236	0.957	0.301	0.969	-	-	-	-	-	-	-	-
Evaluation	0.272	0.988	0.320	0.975	0.948	-	-	-	-	-	-	-
Function	0.502	0.193	0.481	0.141	0.168	0.716	-	-	-	-	-	-
Information	0.611	0.427	0.729	0.346	0.382	0.505	0.716	-	-	-	-	-
Maintenance performance	0.702	0.848	0.630	0.807	0.827	0.429	0.648	-	-	-	-	-
Quality	0.753	0.246	0.666	0.181	0.209	0.543	0.583	0.667	0.762	-	-	-
Relational	0.310	0.986	0.356	0.968	0.976	0.190	0.424	0.852	0.234	0.946	-	-
Time	0.639	0.159	0.570	0.106	0.136	0.423	0.550	0.579	0.726	0.162	0.841	-
VE Implementation	0.456	0.961	0.557	0.913	0.947	0.327	0.642	0.913	0.396	0.950	0.309	0.713

Table 12*:* Predictive relevance (Q^2) results of the model

Endogenous latent variables	SSO	SSE	Q^2 (=1-SSE/SSO)
VE -Implementation	7242.000	3603.512	0.502
Maintenance performance	3834.000	2562.963	0.332

Quality factor followed closely, garnering an outer loading value of 0.667. Sub-indicator Q4, pertaining to the quality and conditions of construction materials, received notable attention, suggesting that value engineering can contribute to quality enhancement in gravel roads maintenance processes. Quality, defined as the amalgamation of attributes requisite for road service, forms the bedrock for functionality, fitness assessment, and customer satisfaction. Time, although ranked last among hard criteria, remains crucial, with an outer loading value of 0.579. Notably, sub-indicator T2 -"Adequate timing of maintenance activities" emerged as the most significant activity time factor, integral to GR project performance. Time considerations extend to planning, order implementation, resource accessibility, with value engineering potentially streamlining project implementation timelines. Soft criteria performance measures placed social and relational aspects at the forefront, boasting an outer loading value of 0.852. Sub-factor R3, focusing on overall satisfaction of road users and stakeholders, emerged as paramount. Regular assessment and proactive measures, facilitated by performance indicators and feedback mechanisms, play a pivotal role in enhancing gravel road maintenance projects over time and the environmental aspects, constituting the last soft criterion, attained an outer loading value of 0.807. Notably, factor E3-"Completed gravel roads maintenance projects' sites being environmentally protected" held significant sway, highlighting the importance of environmental compliance alongside other performance factors to bolster overall project performance. In conclusion, this research highlights the multifaceted nature of project performance evaluation, emphasizing the interplay between hard and soft criteria. From cost management and quality enhancement to stakeholder satisfaction and environmental stewardship, a comprehensive understanding of these factors is essential for optimizing gravel roads maintenance project outcomes.

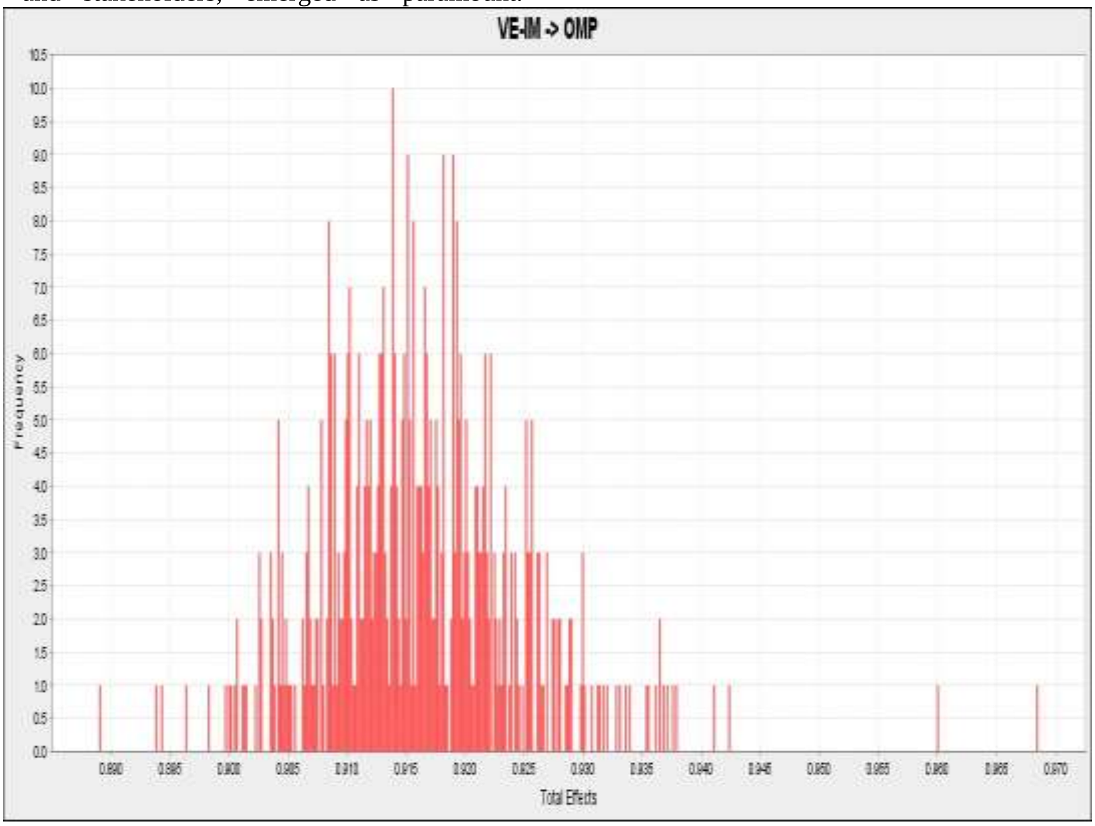

Fig. 5: Total effects of implementing VE on GR overall maintenance performance

*Identifying the impact of VE on GR Maintenance Performance***:** Examining the impact of value engineering (VE) on enhancing the performance of gravel roads maintenance projects is paramount. The findings highlight the significant contribution of VE implementation, amounting to 83.3% towards enabling gravel roads maintenance projects to attain their desired performance levels. Moreover, the VE implementation's correlation with gravel roads maintenance performance is robust, evident from its path coefficient of 0.913, a p-value of 0.000, and a performance value of 74.1%, all of which meet acceptable standards, indicative of an excellent correlation. A visual representation of the total effects of VE implementation (VE-IM) on overall maintenance performance (OMP) is depicted in Figure 5. Based on the aforementioned results, we can conclude that the outcomes of value engineering (VE) implementation will indeed influence maintenance performance, as delineated with regard to both hard and soft criteria encompassing time, cost, quality, social and relational, and environmental aspects. All performance factors aligned with the expectations of this study, which aimed to optimize the performance of gravel roads maintenance projects. The fulfillment of these expectations is substantiated by the widespread utilization of VE as a supportive methodology to address challenges such as rigorous planning within the construction industry (Lin *et al.*, 2011).

Conclusion: The research significantly contributes to the knowledge base on Value Engineering (VE) by demonstrating its effectiveness in enhancing the performance of gravel roads maintenance projects. It highlights the crucial impact of the creativity phase (CP) on VE implementation, especially the activity "Awareness of value increment techniques" (CP1). Additionally, the evaluation and information phases also play substantial roles, while the development and presentation (DP) and function (FP) phases exhibit more moderate impacts. This study advances academic understanding by establishing key causal relationships between various VE activities and methods pertinent to managing pertinent to enhancing performance of gravel roads maintenance projects. It further provides a comprehensive framework that can guide road management authorities and civil engineering contractors in effectively applying VE principles. The research also underscores the importance of reviewing institutional setups in the road sector to better integrate multidisciplinary VE teams, including maintenance engineers and other professionals. Moreover, the developed model offers a clear hierarchy of activity flow rankings, elucidating their relative significance and strength. This study's findings are pivotal in shaping effective implementation strategies, thereby enriching both theoretical and practical aspects of VE in project management. The research not only enhances the academic discourse on VE but also delivers practical insights and solutions for improving gravel road maintenance projects, with broader implications for similar regions globally.

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Data availability statement: Data utilized for analysis in this study are accessible from the corresponding author upon request.

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