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The Role of Integrated Project Management Techniques in Enhancing Infrastructure Project Performance in the Greater Cairo Metro

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Abstract

Infrastructure projects frequently encounter challenges related to cost overruns, schedule delays, scope deviations, and quality deficiencies, particularly in complex rehabilitation projects operating under strict operational constraints. This paper investigates the Impact of Integrating Project Management Techniques on Improving the Performance of Infrastructure Projects, with an application to Greater Cairo Metro. A quantitative descriptive-analytical approach was adopted using data collected through a structured questionnaire from 242 valid respondents drawn from a population of 650 participants involved in the Fire Protection System Rehabilitation Project on Greater Cairo Metro Line 1. The data were analyzed using the Statistical Package for the Social Sciences (SPSS) 25 and Analysis of Moment Structures (AMOS) through reliability and validity tests, Confirmatory Factor Analysis (CFA), Structural Equation Modeling (SEM), and Path Analysis. The results revealed a statistically significant positive effect of integrating project management techniques on infrastructure project performance. The findings also demonstrated statistically significant positive effects for each of the four techniques investigated individually. Among the standardized path coefficients, Earned Value Management (EVM) had the numerically largest coefficient, followed by Program Evaluation and Review Technique (PERT), Six Sigma, and Work Breakdown Structure (WBS). The integrated application of these complementary techniques was associated with improvements in budget control, schedule adherence, scope adherence, and quality improvement. This study contributes by empirically examining both the overall integrated relationship and the individual relationships of EVM, WBS, PERT, and Six Sigma with infrastructure project performance within a real-world infrastructure rehabilitation project and provides practical guidance for improving the performance of similar projects operating under safety and operational constraints.

Keywords

Earned Value Management; Six Sigma; Work Breakdown Structure; Program Evaluation and Review Technique; Infrastructure Rehabilitation

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1. INTRODUCTION

Infrastructure projects are fundamental to sustainable economic and social development, providing essential services such as transportation, energy, water, and communication that enhance productivity, connectivity, and quality of life. As urbanization accelerates and populations grow, the demand for resilient and sustainable infrastructure continues to increase. Governments and institutions therefore seek to rehabilitate aging infrastructure while balancing economic, environmental, and social objectives

to support long-term sustainable development.

Project management has evolved into a strategic discipline that enables organizations to deliver complex projects efficiently through systematic planning, resource allocation, risk management, and performance monitoring. In infrastructure projects, where budget, schedule, scope, and stakeholder expectations are critical, project management techniques provide structured frameworks that improve decision-making, optimize workflows, and enhance project control [1],[2].

Infrastructure rehabilitation projects require an integrated management approach that combines technical, environmental, and stakeholder considerations. Previous research has demonstrated that approaches such as phased implementation, stakeholder engagement, hybrid Agile-Waterfall models, Integrated Management Systems (IMS), and the United Nations Principles of Effective Governance improve transparency, coordination, risk management, innovation, and long-term value creation in rehabilitation projects [3],[4],[5].

Despite these advances, infrastructure projects continue to experience persistent challenges related to cost overruns, schedule delays, scope deviations, and quality deficiencies, particularly in large-scale and resource-intensive environments. Global evidence indicates that infrastructure projects frequently exceed planned budgets and schedules, while stakeholder coordination, communication deficiencies, and organizational constraints continue to undermine project performance [6],[7]. Previous studies have further demonstrated that fragmented implementation of project management practices, rather than an integrated management framework, significantly increases the likelihood of schedule delays, budget overruns, scope deviations, and reduced stakeholder satisfaction [8],[9].

The Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1 represents a particularly challenging infrastructure rehabilitation project because all rehabilitation activities must be completed during the limited daily operational downtime of the metro while maintaining uninterrupted passenger services and complying with the latest international fire protection standards. The restricted working windows, the complexity of the operating environment, and the interdependence of project activities require a highly coordinated management approach. Previous rehabilitation projects implemented on Metro Line 1 experienced scope changes, schedule delays, budget overruns, and quality-related shortcomings, demonstrating the need for an integrated project management framework capable of coordinating planning, scheduling, cost control, and quality management throughout the project lifecycle.

Against this background, this paper investigates the impact of integrating project management techniques on improving the performance of infrastructure projects, with an application to the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. Specifically, it examines how the integration of EVM, WBS, PERT, and Six Sigma influences budget control, scope adherence, schedule adherence, and quality improvement. By providing empirical evidence from a complex infrastructure rehabilitation project operating under strict operational constraints, this paper contributes to the growing body of knowledge on integrated project management and offers practical guidance for improving the performance of similar infrastructure rehabilitation projects.

2. LITERATURE REVIEW

2.1 Project planning, scheduling, monitoring, and quality management

Effective infrastructure project performance depends on coordinated planning, scope definition, scheduling, performance monitoring, and quality management. WBS provides a systematic basis for decomposing complex projects into manageable work packages, clarifying responsibilities, supporting resource coordination, and establishing a framework for monitoring and control. Previous studies demonstrated that structured project decomposition improves scope definition, resource allocation, stakeholder communication, and managerial control, whereas recognized project management standards contribute to work structuring, responsibility assignment, and coordination [10],[11]. They likewise highlighted the value of structured planning in public infrastructure projects with multiple stakeholders and operational constraints [12]. Further studies showed weak project decomposition contribute to delays and cost overruns and recommended structured methodologies and stronger integration between planning and execution [13]. Collectively, these findings support WBS as both a scope-definition mechanism and a foundation for subsequent scheduling, cost estimation, progress monitoring, and risk management. However, limited attention has been given to its interaction with complementary techniques, particularly in infrastructure rehabilitation projects.

Schedule adherence is critical because delays may generate cost overruns, inefficient resource utilization, contractual difficulties, and reduced stakeholder satisfaction, especially where rehabilitation work is performed within limited maintenance windows. PERT addresses uncertainty in activity durations through optimistic, most likely, and pessimistic estimates, supporting expected-duration calculation, schedule-risk assessment, activity dependency analysis, and critical-path identification. Previous studies emphasized PERT's contribution to understanding interdependencies, focusing managerial attention on critical activities, anticipating delays, and improving resource allocation [14],[15],[16],[17]. Empirical evidence further indicates that structured and network-based scheduling improves sequencing, forecasting accuracy, schedule adherence, and project-management effectiveness [18]. Nevertheless, PERT alone does not address the broader requirements of scope control, performance monitoring, and quality assurance, indicating the importance of combining it with complementary techniques.

Effective project monitoring and control require continuous comparison of actual performance with planned performance to identify deviations and support corrective action. EVM integrates scope, schedule, and cost by comparing Planned Value (PV), Earned Value (EV), and Actual Cost (AC), while providing indicators such as Cost Performance Index (CPI), Schedule Performance Index (SPI), Cost Variance (CV), and Schedule Variance (SV). EVM was described as a comprehensive methodology integrating planning, budgeting, scheduling, and performance measurement; its value in relating physical progress to financial expenditure was highlighted; and the continuous integration of planning information with performance indicators was emphasized [19],[20],[21]. Empirical studies further reported improvements in budget control, forecasting, risk-informed performance assessment, decision-making, and project control [22],[23]. However, traditional EVM may not fully capture localized delays, uncertainty, or quality-related issues, reinforcing the need for complementary planning, scheduling, and quality-management techniques.

Quality is another critical performance dimension in infrastructure rehabilitation because execution errors may cause additional cost and schedule effects, operational disruption, and safety risks. Six Sigma provides a structured, data-driven approach to reducing process variation and defects through statistical analysis and root-cause identification. Its DMAIC cycle supports improvement of existing processes, while DMADV supports the design or redesign of processes and systems. Six Sigma can improve construction performance through defect reduction, waste minimization, sustainability, and operational efficiency, while organizational improvements in the road infrastructure sector were reported, with

emphasis on leadership, training, resources, and strategic alignment [24],[25]. Effective implementation of Project Management Institute (PMI) knowledge areas-including integration, scope, time, cost, quality, risk, communication, procurement, and human resource management-supports project quality and organizational effectiveness [26].

Overall, the literature indicates that WBS, PERT, EVM, and Six Sigma address complementary requirements and that their combined application can provide a more comprehensive basis for improving scope, schedule, cost, and quality performance.

2.2 Theoretical foundation of integrating project management techniques

The theoretical foundation of this study is primarily informed by Systems Theory, which views a project as an integrated system composed of interdependent elements whose collective performance cannot be fully understood by examining each element in isolation. Planning, scheduling, cost control, scope management, and quality improvement are interconnected managerial functions whose interactions extend throughout the project life cycle. Project performance therefore depends not only on the effectiveness of individual practices but also on coordination and integration among them. This systems perspective is particularly relevant to project management because interdependencies among activities, organizational functions, information flows, and control processes require a holistic rather than fragmented approach.

Consistent with this perspective, the study conceptualizes Integrating Project Management Techniques as the coordinated and simultaneous application of EVM, WBS, PERT, and Six Sigma within the same project management system. WBS supports scope and activity organization; PERT supports sequencing and schedule planning under uncertainty; EVM integrates scope, schedule, and cost information for performance monitoring and control; and Six Sigma supports process improvement and quality enhancement. Their coordinated application allows decisions affecting one performance area to be considered in relation to their potential consequences for other areas. This perspective is especially relevant to complex infrastructure rehabilitation projects in which operational constraints and interdependencies may simultaneously affect scope, schedule, cost, quality, and service continuity.

Contingency Theory provides a complementary perspective by recognizing that the effectiveness of management structures and practices depends on the characteristics of the environment in which they are applied. Accordingly, there is no universally optimal combination of management practices independent of project conditions. The value of an integrated approach may therefore be particularly relevant to projects characterized by high complexity, uncertainty, operational constraints, and multiple interdependencies. In the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1, activities must be coordinated within an existing transportation system, limited maintenance windows, continuing passenger services, and stringent safety requirements. A systems and contingency perspective therefore provides a theoretical basis for examining whether the coordinated application of EVM, WBS, PERT, and Six Sigma can contribute to improved budget control, scope adherence, schedule adherence, and quality improvement.

2.3 Integrating project management techniques for infrastructure project performance

Infrastructure projects increasingly involve multiple stakeholders, technological complexity, stringent safety requirements, limited resources, and uncertainty. Under such conditions, relying on a single project management technique may be insufficient, whereas integrated approaches combine complementary practices for planning, scheduling, monitoring, and quality management. Project

performance is influenced by interactions among managerial practices, while the contribution of comprehensive project management frameworks to coordination, communication, decision-making, and organizational learning was highlighted [27],[28]. Infrastructure performance requires integrated planning, resource coordination, and continuous oversight; systematic project management practices across the project life cycle were emphasized; and integrated management practices were linked with improved communication, coordination, decision-making, organizational efficiency, and project performance [29],[30],[31]. The importance of combining planning, monitoring, quality management, and risk control was highlighted, while the value of integrating performance measurement with scheduling and forecasting for proactive decision-making was demonstrated [32],[33].

Within this study, integration refers specifically to the simultaneous and complementary application of EVM, WBS, PERT, and Six Sigma within the same infrastructure project. It does not require a unified information platform or mandatory joint meetings; rather, the four techniques are applied collectively within the project management process, with EVM supporting budget control, WBS supporting scope adherence, PERT supporting schedule adherence, and Six Sigma supporting quality improvement. The literature remains fragmented because most studies examine techniques separately, relatively few investigate their synergistic relationships within a unified framework, and limited attention has been given to infrastructure rehabilitation under continuous operational and safety constraints, particularly in developing-country public transportation systems.

2.4 Research gap and research contribution

Previous research provides substantial evidence regarding the contribution of individual project management techniques, but important gaps remain in examining their combined application. Relatively few studies investigate the synergistic relationships among multiple techniques operating within a unified management framework, and comparatively limited research addresses infrastructure rehabilitation projects conducted under continuous operational and safety constraints. Empirical evidence from developing countries and large public transportation systems is also relatively limited. Furthermore, limited empirical research has employed SEM to evaluate the collective relationships between integrated project management techniques and multiple project performance dimensions simultaneously. Accordingly, this paper addresses these gaps by proposing and empirically examining an integrated framework combining WBS, PERT, EVM, and Six Sigma and by assessing their collective relationship with budget control, schedule adherence, scope adherence, and quality improvement in the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. The study therefore contributes empirical evidence and practical guidance on the integrated management of multiple performance dimensions within a complex infrastructure rehabilitation context.

3. RESEARCH METHODOLOGY

3.1 Research design

This paper adopted a quantitative research design to investigate the impact of integrating project management techniques on improving the performance of infrastructure projects. A descriptive-analytical approach was employed to examine the relationships between the research variables and to empirically test the proposed conceptual framework. The empirical investigation was conducted through a cross-sectional survey of professionals involved in the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1.

3.2 Conceptual framework

The conceptual framework was developed based on the literature review and previous empirical studies. The study conceptualizes Integrating Project Management Techniques as the independent construct, represented by four dimensions: EVM, WBS, PERT, and Six Sigma. The dependent construct, Infrastructure Project Performance, was measured through four performance dimensions: Budget Control, Scope Adherence, Schedule Adherence, and Quality Improvement.

Figure 1 illustrates the conceptual framework of the study, showing the relationship between the independent construct, Integrating Project Management Techniques, and the dependent construct, Improving the Performance of Infrastructure Projects, together with their respective dimensions.

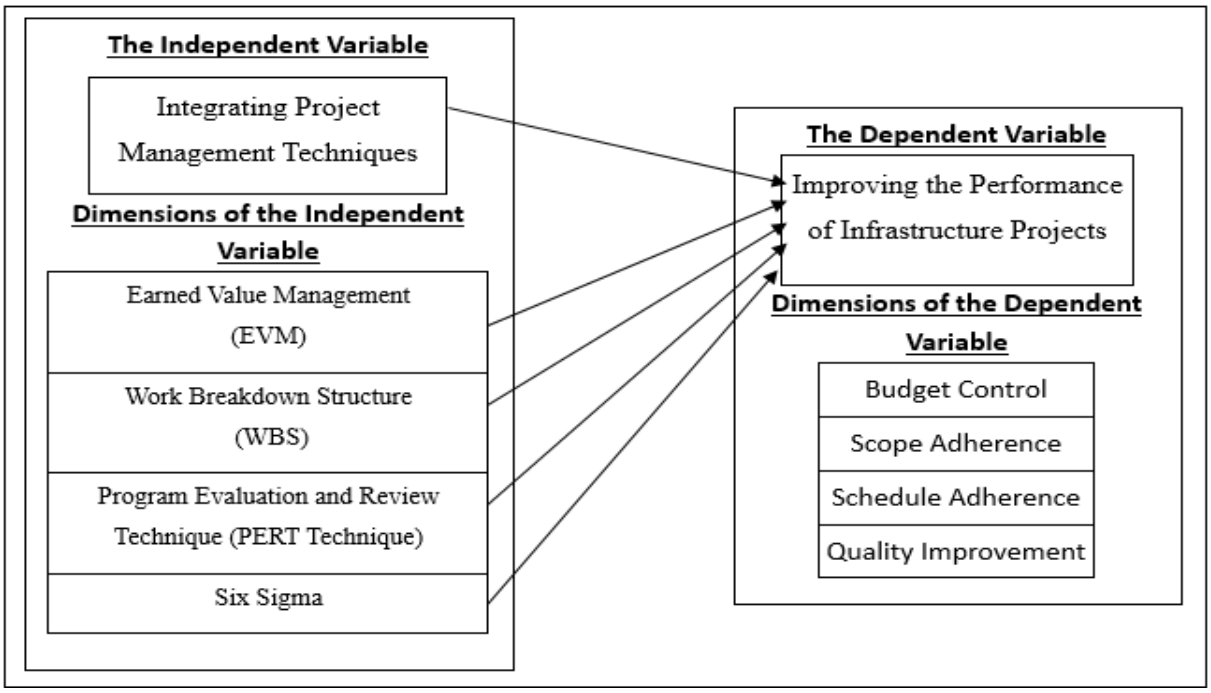


Figure 1. Conceptual framework of the study

As illustrated in Figure 1, the study examines the relationship between the integrated application of EVM, WBS, PERT, and Six Sigma and infrastructure project performance across budget control, scope adherence, schedule adherence, and quality improvement.

3.3 Research hypotheses

Based on the proposed conceptual framework, one main hypothesis and four sub-hypotheses were formulated to examine the relationships between project management techniques and infrastructure project performance.

Main Hypothesis

H1: Integrating Project Management Techniques has a statistically significant effect on Improving the Performance of Infrastructure Projects.

Sub-Hypotheses

H1a: EVM has a statistically significant effect on Improving the Performance of Infrastructure

Projects.

H1b: WBS has a statistically significant effect on Improving the Performance of Infrastructure Projects.

H1c: PERT has a statistically significant effect on Improving the Performance of Infrastructure Projects.

H1d: Six Sigma has a statistically significant effect on Improving the Performance of Infrastructure Projects.

3.4 Population and sampling

The target population comprised managers, engineers, planners, supervisors, accountants, and technical personnel participating in the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. The target population was identified according to the main job categories involved in the project, including project managers, engineers, planners, accountants, supervisors, and other personnel. These categories were used to describe the composition of the study population and the obtained sample. The questionnaire was distributed across the identified target population. The specific determination of the required sample size and the characteristics of the final valid sample are presented in Section 4.4.

3.5 Data collection instrument

Primary data were collected using a structured questionnaire designed according to the research objectives and supported by previous literature. The questionnaire consisted of three sections. The first collected respondents' demographic information, while the second and third measured the study constructs using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

The independent construct was measured through four dimensions (EVM, WBS, PERT, and Six Sigma), whereas the dependent construct was measured through Budget Control, Scope Adherence, Schedule Adherence, and Quality Improvement.

3.6 Data analysis

The collected data were coded and analyzed using IBM SPSS Statistics 25 and AMOS. SPSS was employed for data preparation and descriptive statistical analysis, whereas AMOS was used to estimate the measurement and structural models using SEM.

The empirical procedures, including respondent profile analysis, reliability and validity assessment, CFA, model fit evaluation, structural model assessment, and hypothesis testing, are presented in the following section (Empirical Study).

4. EMPIRICAL STUDY

4.1 Variable operationalization and measurement modeling

The variables examined in the empirical study were operationalized based on the conceptual framework presented in Section 3.2 and the research hypotheses formulated in Section 3.3. The

independent variable, Integrating Project Management Techniques, was operationalized through four dimensions: EVM, WBS, PERT, and Six Sigma. The dependent variable, Improving the Performance of Infrastructure Projects, was operationalized through four dimensions: Budget Control, Scope Adherence, Schedule Adherence, and Quality Improvement.

The proposed relationships between these variables were examined using the hypotheses previously formulated in Section 3.3. The measurement of the study variables was subsequently incorporated into the research instrument and assessed through the empirical procedures presented in the following sections.

4.2 Statistical analysis

Data was analyzed using IBM SPSS Statistics and AMOS. The analysis comprised three stages. First, reliability and validity were assessed using Cronbach's Alpha and validity coefficients. Second, descriptive statistics, including frequencies, weighted means, standard deviations, and coefficients of variation, were calculated to summarize respondents' perceptions. Finally, SEM was employed to test the proposed research model. CFA was conducted to evaluate the measurement model, followed by Path Analysis (PA) to examine the hypothesized relationships among the study variables. The structural model was evaluated using standard goodness-of-fit indices in accordance with the recommendations of previous studies [34],[35].

4.3 Research instrument

A structured closed-ended questionnaire was developed based on the literature review, field observations, and interviews with professionals involved in infrastructure rehabilitation projects. The questionnaire consisted of three sections. The first section collected respondents' demographic information. The second measured Integrating Project Management Techniques using 20 items distributed across four dimensions (EVM, WBS, PERT, and Six Sigma). The third measured Improving the Performance of Infrastructure Projects using 20 items covering Budget Control, Scope Adherence, Schedule Adherence, and Quality Improvement. Accordingly, the questionnaire comprised 40 measurement items.

4.4 Population and sample

The study population comprised 650 participants involved in the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. The target population and its main job categories were described in Section 3.4. The required sample size was determined using the sampling formula described below.

The required sample size was determined using a sample size calculation formula based on simple random sampling, with a population size of 650, a confidence level of 95%, a permissible error rate of 5%, and an assumed population proportion of 0.50, as follows:

$$n = \frac{N * p(1-p)}{\left[(N-1) * \left[\frac{d^2}{z^2}\right] + p(1-p)\right]} \quad (1)$$

where N is the population size, d is the permissible error rate, Z is the standard score corresponding to the selected confidence level, and P is the assumed population proportion. With N=650, d=0.05, Z=1.96, and P=0.50, the minimum required sample size was 242 respondents [36].

The questionnaire was prepared electronically using Google Forms. Google Forms was used solely as an electronic tool for distributing and collecting questionnaire responses and did not constitute a separate sampling technique. After collecting and reviewing the survey forms, the researcher coded the survey statements within each dimension of the study and assigned weights according to the five-point Likert scale. The five-point Likert scale used in the study assigns numerical grades from 1 to 5 to the respondents' responses. Specifically, "Strongly Agree" corresponds to a grade of 5, "Agree" to 4, "Neutral" to 3, "Disagree" to 2, and "Strongly Disagree" to 1. Thus, the relative weight of each response score is 20%, corresponding to the assigned response category. The five-point scale range used for the overall axis in the study was calculated, with the length of each category equal to 0.80. Accordingly, the five-point Likert scale and its evaluation criteria were applied as presented by [37]. After ensuring the completeness and validity of the questionnaires, the data were entered into the computer. SPSS, version 25.0, was used to perform the relevant statistical analyses. The positive survey items were recorded using the numerical codes assigned to the five-point Likert scale. The study categories can be evaluated based on the weighted average and the corresponding criteria of agreement and disagreement within the five-point Likert scale, as shown in the following table.

Table 1. The range of measurement averages within the Likert scale

Likert scale	Interval	Direction
1	1-1.79	Trends tend to (Strongly disagree)
2	1.8-2.59	Trends tend to (disagree)
3	2.6-3.39	Trends tend to (neutral)
4	3.4-4.19	Trends tend to (agree)
5	4.2-5	Trends tend to (Strongly agree)

The measurement intervals presented in Table 1 were used to interpret the weighted mean values obtained from the questionnaire responses.

4.5 Test reliability and validity

To determine the degree of validity and the extent of reliance on the tool used to measure the responses of the sample items, the researcher relied on Cronbach's Alpha coefficient as a measure of internal consistency to assess the reliability and validity of the statements and dimensions of the survey, as shown in the following Table 2:

Table 2. Reliability and validity for all statements

Statements	Number of statements	Reliability	Validity
Dimension 1: Earned Value Management (EVM)	5	0.948	0.974
Dimension 2: Work Breakdown Structure (WBS)	5	0.952	0.976
Dimension 3: Program Evaluation and Review Technique (PERT)	5	0.962	0.981
Dimension 4: Six Sigma	5	0.963	0.981
Section 2: independent variable (integrating project management techniques)	20	0.984	0.992
Dimension 1: budget control	5	0.963	0.981
Dimension 2: scope adherence	5	0.958	0.979
Dimension 3: schedule adherence	5	0.969	0.984
Dimension 4: quality improvement	5	0.969	0.984
Section 3: dependent variable (improving the performance of infrastructure projects)	20	0.988	0.994
Survey	40	0.992	0.996

The Cronbach's Alpha coefficient is greater than (94%) for all dimensions of the study. In addition, the Cronbach's Alpha coefficient for the scale as a whole is greater than (99%); therefore, it can be relied upon in measuring the dimensions of the study. This confirms that the questionnaire measures what it was designed to measure, that all items and dimensions are clear to the respondents, and that there is no ambiguity in them. If the questionnaire is applied again to the same sample, it will give almost the same results. The validity of all the elements and dimensions of the study was confirmed through the validity coefficients, which ranged from 0.974 to 0.996. From the results of the above table, it is clear that all the elements are valid for measurement, meaning that this list is valid in measuring what it was designed to measure.

4.6 Descriptive statistical analysis for demographic data

Descriptive statistics for demographic data were calculated by determining frequencies and percentages for the demographic data of the research study.

4.6.1 Gender

Table 3 presents the frequencies and percentages of the participants according to gender.

Table 3. Frequencies and percentages for participants' gender

Gender	Frequency	Percentage
Male	196	81.0
Female	46	19.0
Total	242	100

Figure 2 illustrates the gender distribution of the study participants.

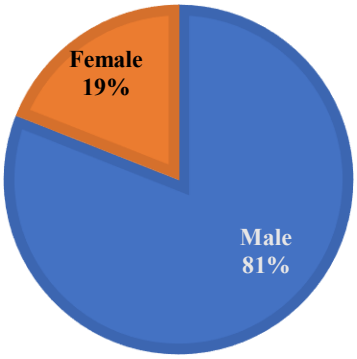


Figure 2. Participants' gender distribution

In the previous table and figure, it is observed that the study consisted of (81%) males, representing the majority of the sample, and (19%) females.

4.6.2 Age group

Table 4 presents the frequencies and percentages of the participants according to age group.

Table 4. Frequencies and percentages for participants' age group

Age group	Frequency	Percentage
Under 30 years old	47	19.4
From 30 to under 40 years old	52	21.5
From 40 to under 50 years old	73	30.2
50 years old and above	70	28.9
Total	242	100

Figure 3 illustrates the distribution of the study participants across different age groups.

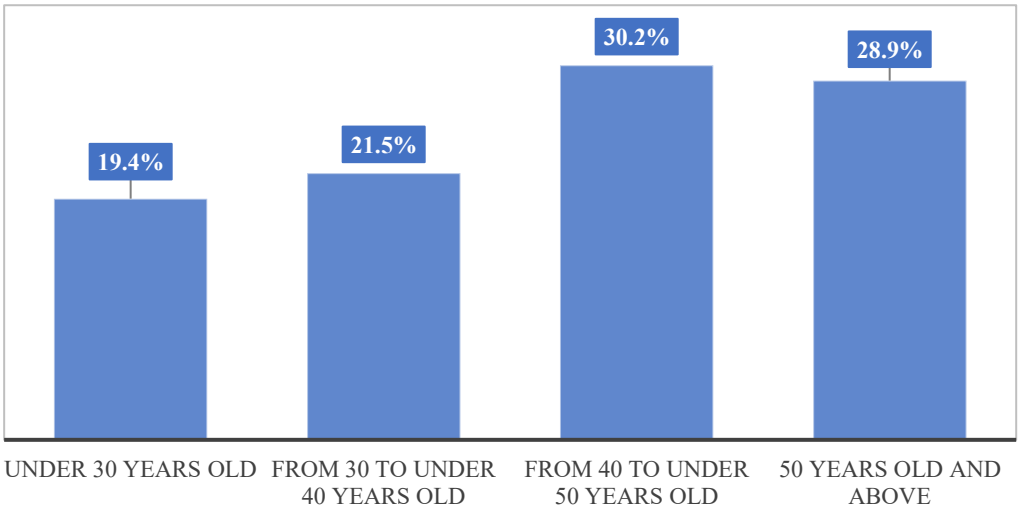


Figure 3. Participants' age group distribution

The data presented in the previous table and figure indicate that, within the study sample categorized by age group, (30.2%) of participants were from 40 to under 50 years old. Additionally, (28.9%) were 50 years old and above, (21.5%) were from 30 to under 40 years old, and (19.4%) were under 30 years old.

4.6.3 Educational qualification

Table 5 presents the frequencies and percentages of the participants according to educational qualification.

Table 5. Frequencies and percentages for participants' educational qualification

Educational qualification	Frequency	Percentage
Diploma	4	1.7
Bachelor's	204	84.3
Master's	18	7.4
Doctorate	16	6.6
Total	242	100

Figure 4 illustrates the educational qualification distribution of the study participants.

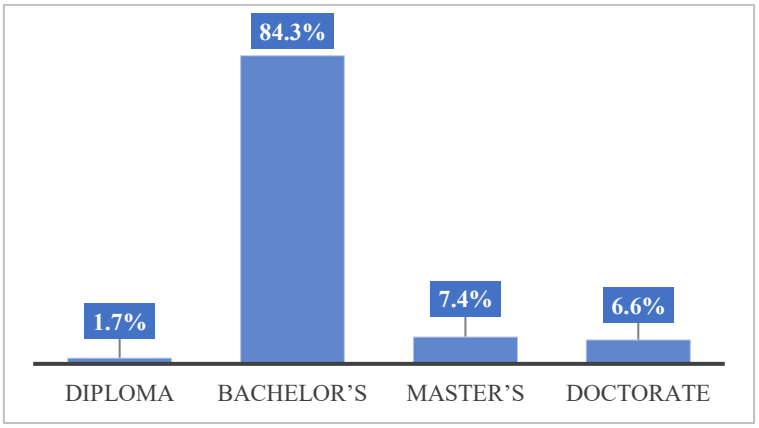


Figure 4. Participants' educational qualification distribution

The data presented in the previous table and figure indicate that, within the study sample categorized by educational qualification, (84.3%) held a bachelor's degree, representing the majority of the sample. In addition, (7.4%) had a master's degree, (6.6%) had a Doctorate, and lastly, (1.7%) had a Diploma degree.

4.6.4 Job title

Table 6 presents the frequencies and percentages of the participants according to job title.

Table 6. Frequencies and percentages for participants' job title

Job title	Frequency	Percentage
Engineer	165	68.2
Planner	25	10.3
Accountant	25	10.3
Project manager	18	7.5
Supervisor	9	3.7
Total	242	100

Figure 5 illustrates the distribution of the study participants according to job title.

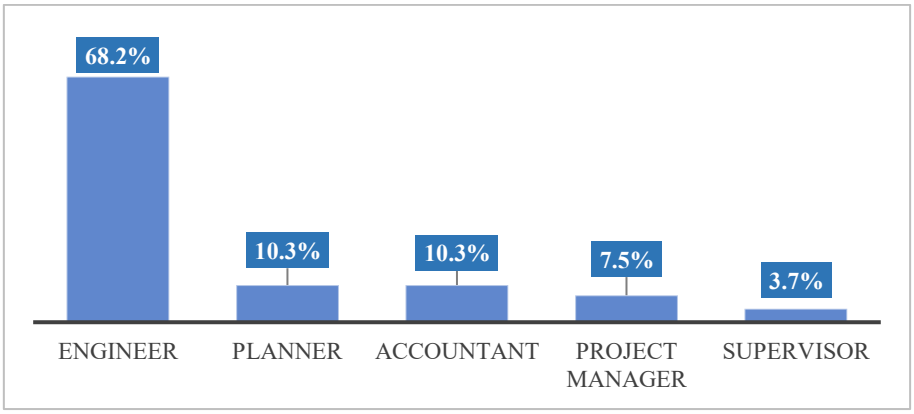


Figure 5. Participants' job title distribution

The data presented in the previous table and figure indicate that, within the study sample categorized by job title, (68.2%) were Engineers, representing the majority of the sample. In addition, (10.3%) were Planners, while (10.3%) were Accountants. Furthermore, (7.5%) were Project Managers, and lastly, (3.7%) were Supervisors.

4.6.5 Years of experience

Table 7 presents the frequencies and percentages of the participants according to years of professional experience.

Table 7. Frequencies and percentages for participants' years of experience

Years of experience	Frequency	Percentage
Less than 5 years	5	2.1
From 5 to under 10 years	48	19.8
From 10 to under 15 years	104	43.0
15 years and above	85	35.1
Total	242	100

Figure 6 illustrates the distribution of the study participants according to years of professional experience.

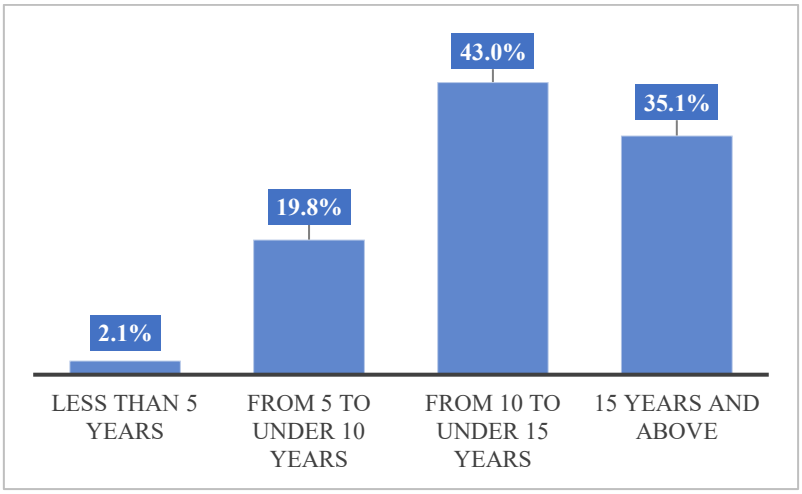


Figure 6. Participants' years of experience distribution

The data presented in the previous table and figure indicate that, within the study sample categorized by years of experience, (43.0%) had from 10 to under 15 years of experience. Additionally, (35.1%) were 15 years and above. Furthermore, (19.8%) had from 5 to under 10 years of experience, and finally, (2.1%) had less than 5 years of experience.

4.6.6 Organization type

Table 8 presents the frequencies and percentages of the participants according to organization type.

Table 8. Frequencies and percentages for participants' organization type

Organization type	Frequency	Percentage
Governmental organization	66	27.2
Contracting company	118	48.8
Consulting office	58	24.0
Total	242	100

Figure 7 illustrates the distribution of the study participants according to organization type.

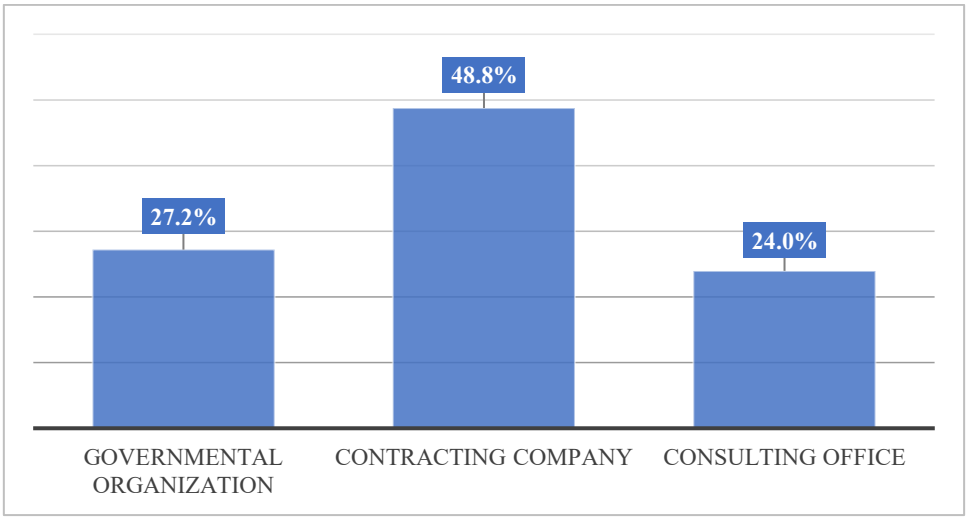


Figure 7. Participants' organization type distribution

The data from the previous table and figures show that, within the study sample categorized by their organization type, (48.8%) were Contracting Companies. Additionally, (27.2%) were Governmental Organizations. Finally, (24.0%) were Consulting Offices.

4.7 Descriptive statistics of the study variables

Descriptive statistics for the independent variable "Integrating Project Management Techniques" and the dependent variable "Improving the Performance of Infrastructure Projects" were conducted by calculating frequencies, percentages, means, standard deviations, and coefficients of variation.

First: independent variable (integrating project management techniques)

Table 9 presents the frequencies, percentages, weighted means, standard deviations, coefficients of variation, trends, and ranks of the questionnaire items measuring Integrating Project Management Techniques.

Table 9. Frequencies, percentages, and descriptive statistics for the independent variable (integrating project management techniques)

Num	Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean	Std. D	C.V	Trend	Rank
1	Earned value management is regularly used to monitor project progress.	1 (.4%)	3 (1.2%)	5 (2.1%)	137 (56.6%)	96 (39.7%)	4.34	0.625	14%	Strongly agree	4
2	EVM helps in early detection of cost deviations.	1 (.4%)	6 (2.5%)	4 (1.7%)	118 (48.8%)	113 (46.7%)	4.39	0.686	16%	Strongly agree	1
3	Applying EVM improves the accuracy of forecasting final project costs.	1 (.4%)	6 (2.5%)	3 (1.2%)	127 (52.5%)	105 (43.4%)	4.36	0.675	15%	Strongly agree	3
4	EVM reports support managerial decisions related to budget control.	1 (.4%)	6 (2.5%)	3 (1.2%)	123 (50.8%)	109 (45.0%)	4.38	0.678	15%	Strongly agree	2
5	Implementing EVM enhances financial control during execution.	1 (.4%)	3 (1.2%)	7 (2.9%)	137 (56.6%)	94 (38.8%)	4.32	0.634	15%	Strongly agree	5
	Dimension 1: Earned Value Management (EVM)						4.36	0.601	14%	Strongly agree	
6	The project is divided into clear work packages using WBS.	1 (.4%)	6 (2.5%)	6 (2.5%)	131 (54.1%)	98 (40.5%)	4.32	0.683	16%	Strongly agree	1
7	WBS clarifies scope and prevents overlapping between activities.	1 (.4%)	6 (2.5%)	4 (1.7%)	139 (57.4%)	92 (38.0%)	4.30	0.666	15%	Strongly agree	4
8	WBS clearly assigns responsibilities among project teams.	1 (.4%)	7 (2.9%)	3 (1.2%)	138 (57.0%)	93 (38.4%)	4.30	0.679	16%	Strongly agree	3
9	WBS helps monitor work progress against the approved plan.	2 (.8%)	6 (2.5%)	4 (1.7%)	136 (56.2%)	94 (38.8%)	4.30	0.701	16%	Strongly agree	5
10	WBS reduces unjustified scope changes.	1 (.4%)	7 (2.9%)	3 (1.2%)	136 (56.2%)	95 (39.3%)	4.31	0.681	16%	Strongly agree	2
	Dimension 2: Work Breakdown Structure (WBS)						4.31	0.625	15%	Strongly agree	
11	PERT is used to estimate activity durations under uncertainty.	1 (.4%)	5 (2.1%)	6 (2.5%)	127 (52.5%)	103 (42.6%)	4.35	0.672	15%	Strongly agree	2
12	PERT helps identify the project critical path.	2 (.8%)	5 (2.1%)	5 (2.1%)	126 (52.1%)	104 (43.0%)	4.34	0.701	16%	Strongly agree	3
13	PERT contributes to better schedule adherence.	2 (.8%)	5 (2.1%)	5 (2.1%)	132 (54.5%)	98 (40.5%)	4.32	0.695	16%	Strongly agree	5

14	PERT helps analyze the impact of potential delays.	1 (.4%)	6 (2.5%)	6 (2.5%)	130 (53.7%)	99 (40.9%)	4.32	0.684	16%	Strongly agree	4
15	Using PERT enhances time management efficiency.	1 (.4%)	4 (1.7%)	6 (2.5%)	130 (53.7%)	101 (41.7%)	4.35	0.653	15%	Strongly agree	1
	Dimension 3: Program Evaluation and Review Technique (PERT)						4.34	0.635	15%	Strongly agree	
16	Six Sigma principles are applied to reduce execution errors.	3 (1.2%)	3 (1.2%)	5 (2.1%)	125 (51.7%)	106 (43.8%)	4.36	0.704	16%	Strongly agree	1
17	Six Sigma tools contribute to improving work quality.	2 (.8%)	4 (1.7%)	5 (2.1%)	129 (53.3%)	102 (42.1%)	4.34	0.683	16%	Strongly agree	2
18	Six Sigma methodology is used to analyze root causes.	4 (1.7%)	3 (1.2%)	5 (2.1%)	134 (55.4%)	96 (39.7%)	4.30	0.726	17%	Strongly agree	5
19	Applying Six Sigma reduces rework.	3 (1.2%)	4 (1.7%)	4 (1.7%)	137 (56.6%)	94 (38.8%)	4.30	0.703	16%	Strongly agree	4
20	Six Sigma supports continuous quality improvement.	2 (.8%)	6 (2.5%)	3 (1.2%)	136 (56.2%)	95 (39.3%)	4.31	0.698	16%	Strongly agree	3
	Dimension 4: Six Sigma						4.32	0.656	15%	Strongly agree	
	Section 2: Independent variable (integrating project management techniques)						4.33	0.597	14%	Strongly agree	

First, the study sample tended to Strongly Agree with Dimension 1: EVM, according to the Likert five-point scale, where the weighted average value was 4.36, the coefficient of variation was 14%, and the standard deviation was 0.601. It is also clear that the response to the statement “EVM helps in early detection of cost deviations” was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 1: EVM, as it came in first place with a weighted average value of 4.39.

Second, the study sample tended to Strongly Agree with Dimension 2: WBS, according to the Likert five-point scale, where the weighted average value was 4.31, the coefficient of variation was 15%, and the standard deviation was 0.625. It is also clear that the response to the statement “The project is divided into clear work packages using WBS” was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 2: WBS, as it came in first place with a weighted average value of 4.32.

Third, the study sample tended to Strongly Agree with Dimension 3: PERT, according to the Likert five-point scale, where the weighted average value was 4.34, the coefficient of variation was 15%, and the standard deviation was 0.635. It is also clear that the response to the statement “Using PERT enhances

time management efficiency" was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 3: PERT, as it came in first place with a weighted average value of 4.35.

Fourth, the study sample tended to Strongly Agree with Dimension 4: Six Sigma, according to the Likert five-point scale, where the weighted average value was 4.32, the coefficient of variation was 15%, and the standard deviation was 0.656. It is also clear that the response to the statement "Six Sigma principles are applied to reduce execution errors" was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 4: Six Sigma, as it came in first place with a weighted average value of 4.36.

Finally, the study sample tended to strongly agree with the independent variable: Integrating Project Management Techniques, according to the Likert five-point scale, where the weighted average value was 4.33, the coefficient of variation was 14%, and the standard deviation was 0.597.

Second: dependent variable (improving the performance of infrastructure projects)

Table 10 presents the frequencies, percentages, weighted means, standard deviations, coefficients of variation, trends, and ranks of the questionnaire items measuring Improving the Performance of Infrastructure Projects.

Table 10. Frequencies, percentages, and descriptive statistics for the dependent variable (improving the performance of infrastructure projects)

Num	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree	Mean	Std. D	C.V	Trend	Rank
1	Applying budget control using Earned Value Management (EVM) improves compliance with the approved project budget.	1 (.4%)	7 (2.9%)	3 (1.2%)	127 (52.5%)	104 (43.0%)	4.35	0.690	16%	Strongly agree	4
2	Budget control through Earned Value Management indicators helps manage actual expenditures against planned costs.	1 (.4%)	7 (2.9%)	3 (1.2%)	124 (51.2%)	107 (44.2%)	4.36	0.693	16%	Strongly agree	3
3	Applying budget control techniques contributes to reducing cost overruns during project execution.	1 (.4%)	8 (3.3%)	2 (.8%)	127 (52.5%)	104 (43.0%)	4.34	0.701	16%	Strongly agree	5
4	Relying on budget control techniques like (EVM) enhances the accuracy of future cost estimations for the project.	2 (.8%)	4 (1.7%)	5 (2.1%)	109 (45.0%)	122 (50.4%)	4.43	0.697	16%	Strongly agree	1
5	Continuous financial performance analysis in budget control enables effective corrective actions when deviations occur.	3 (1.2%)	5 (2.1%)	2 (.8%)	118 (48.8%)	114 (47.1%)	4.38	0.727	17%	Strongly agree	2

	Dimension 1: budget control						4.37	0.655	15%	Strongly agree	
6	Adhering to the project scope through the Work Breakdown Structure (WBS) ensures execution according to the approved scope.	2 (.8%)	5 (2.1%)	6 (2.5%)	119 (49.2%)	110 (45.5%)	4.36	0.711	16%	Strongly agree	1
7	Using the WBS limits unnecessary changes to the project scope.	1 (.4%)	4 (1.7%)	9 (3.7%)	123 (50.8%)	105 (43.4%)	4.35	0.673	15%	Strongly agree	2
8	Adhering to the predefined project scope enables effective control of change orders.	1 (.4%)	7 (2.9%)	6 (2.5%)	123 (50.8%)	105 (43.4%)	4.34	0.706	16%	Strongly agree	3
9	Clear scope definition through the WBS improves coordination among project stakeholders.	2 (.8%)	7 (2.9%)	5 (2.1%)	130 (53.7%)	98 (40.5%)	4.30	0.726	17%	Strongly agree	5
10	Strict scope adherence reduces conflicts and disputes during project execution.	1 (.4%)	7 (2.9%)	5 (2.1%)	132 (54.5%)	97 (40.1%)	4.31	0.693	16%	Strongly agree	4
	Dimension 2: Scope Adherence						4.33	0.650	15%	Strongly agree	
11	Following the schedule using PERT ensures work is executed according to the approved timeline.	2 (.8%)	7 (2.9%)	4 (1.7%)	121 (50.0%)	108 (44.6%)	4.35	0.731	17%	Strongly agree	2
12	Applying scheduling techniques such as PERT helps minimize delays in activity execution.	3 (1.2%)	6 (2.5%)	3 (1.2%)	123 (50.8%)	107 (44.2%)	4.34	0.742	17%	Strongly agree	3
13	Adherence to the schedule based on critical path analysis enables effective handling of time deviations.	2 (.8%)	6 (2.5%)	5 (2.1%)	118 (48.8%)	111 (45.9%)	4.36	0.723	17%	Strongly agree	1
14	Accurate scheduling using PERT ensures optimal utilization of limited working periods.	4 (1.7%)	4 (1.7%)	4 (1.7%)	127 (52.5%)	103 (42.6%)	4.33	0.743	17%	Strongly agree	4

15	Schedule adherence contributes to improving on-time project delivery efficiency.	2 (.8%)	5 (2.1%)	5 (2.1%)	134 (55.4%)	96 (39.7%)	4.31	0.693	16%	Strongly agree	5
	Dimension 3: schedule adherence						4.34	0.685	16%	Strongly agree	
16	Applying quality improvement methodologies like Six Sigma ensures compliance with approved technical standards and specifications.	1 (.4%)	6 (2.5%)	6 (2.5%)	119 (49.2%)	110 (45.5%)	4.37	0.695	16%	Strongly agree	1
17	Applying Six Sigma for quality improvement enhances the operational efficiency of the project.	1 (.4%)	7 (2.9%)	4 (1.7%)	129 (53.3%)	101 (41.7%)	4.33	0.692	16%	Strongly agree	4
18	Quality improvement using Six Sigma tools reduces technical defects during execution.	1 (.4%)	7 (2.9%)	4 (1.7%)	126 (52.1%)	104 (43.0%)	4.34	0.695	16%	Strongly agree	2
19	Six Sigma-based quality improvement enhances project safety levels.	1 (.4%)	6 (2.5%)	5 (2.1%)	132 (54.5%)	98 (40.5%)	4.32	0.678	16%	Strongly agree	5
20	Quality improvement through Six Sigma contributes to achieving stakeholder satisfaction.	2 (.8%)	5 (2.1%)	4 (1.7%)	130 (53.7%)	101 (41.7%)	4.33	0.693	16%	Strongly agree	3
	Dimension 4: quality improvement						4.34	0.652	15%	Strongly agree	
	Section 3: dependent variable (improving the performance of infrastructure projects)						4.35	0.636	15%	Strongly agree	

First, the study sample tended to Strongly Agree with Dimension 1: Budget Control, according to the Likert five-point scale, where the weighted average value was 4.37, the coefficient of variation was 15%, and the standard deviation was 0.655. It is also clear that the response to the statement “Relying on budget control techniques like EVM enhances the accuracy of future cost estimations for the project” was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 1: Budget Control, as it came in first place with a weighted average value of 4.43.

Second, the study sample tended to Strongly Agree with Dimension 2: Scope Adherence, according to the Likert five-point scale, where the weighted average value was 4.33, the coefficient of variation was 15%, and the standard deviation was 0.650. It is also clear that the response to the statement "Adhering to the project scope through WBS ensures execution according to the approved scope" was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 2: Scope Adherence, as it came in first place with a weighted average value of 4.36.

Third, the study sample tended to Strongly Agree with Dimension 3: Schedule Adherence, according to the Likert five-point scale, where the weighted average value was 4.34, the coefficient of variation was 16%, and the standard deviation was 0.685. It is also clear that the response to the statement "Adherence to the schedule based on Critical Path Analysis enables effective handling of time deviations" was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 3: Schedule Adherence, as it came in first place with a weighted average value of 4.36.

Fourth, the study sample tended to Strongly Agree with Dimension 4: Quality Improvement, according to the Likert five-point scale, where the weighted average value was 4.34, the coefficient of variation was 15%, and the standard deviation was 0.652. It is also clear that the response to the statement "Applying quality improvement methodologies like Six Sigma ensures compliance with approved technical standards and specifications" was, in the opinion of the study sample, one of the important points that must be paid attention to within the statements of Dimension 4: Quality Improvement, as it came in first place with a weighted average value of 4.37.

Finally, the study sample tended to Strongly Agree with the dependent variable: Improving the Performance of Infrastructure Projects, according to the Likert five-point scale, where the weighted average value was 4.35, the coefficient of variation was 15%, and the standard deviation was 0.636.

4.8 Confirmatory factor analysis

CFA was conducted using AMOS to evaluate the measurement model and examine the construct validity of the study variables. The analysis assessed the adequacy of the measurement model for the two latent constructs: Integrating Project Management Techniques and Improving the Performance of Infrastructure Projects.

The measurement model was evaluated using standardized factor loadings together with commonly accepted goodness-of-fit indices, including the Chi-square/degrees of freedom ratio (χ^2/df), Goodness-of-Fit Index (GFI), Comparative Fit Index (CFI), Root Mean Square Residual (RMR), and Root Mean Square Error of Approximation (RMSEA), following the recommendations of [38],[39],[40]. Standardized factor loadings greater than 0.30 were considered acceptable, while overall model fit was assessed using the recommended threshold values for each fit index.

The CFA results confirmed that the measurement model demonstrated satisfactory construct validity and an acceptable level of fit between the proposed model and the observed data, providing an appropriate basis for testing the structural relationships among the study variables.

The following Table 11 presents the most important indicators of structural model fit and their corresponding ideal acceptance limits.

Table 11. Model indicators

Index	Ideal limits
Chi square /DF	Less than 5
RMSEA	Less than 0.09
RMR	Less than 0.09
GFI	0.9 -1
CFI	0.9 -1

These indicators provide the criteria used to assess the overall fit of the structural models examined in the study.

4.8.1 Confirmatory factor analysis of integrating project management techniques

Figure 8 presents the CFA model for Integrating Project Management Techniques, showing the relationships among the latent construct, its dimensions, and the associated measurement items.

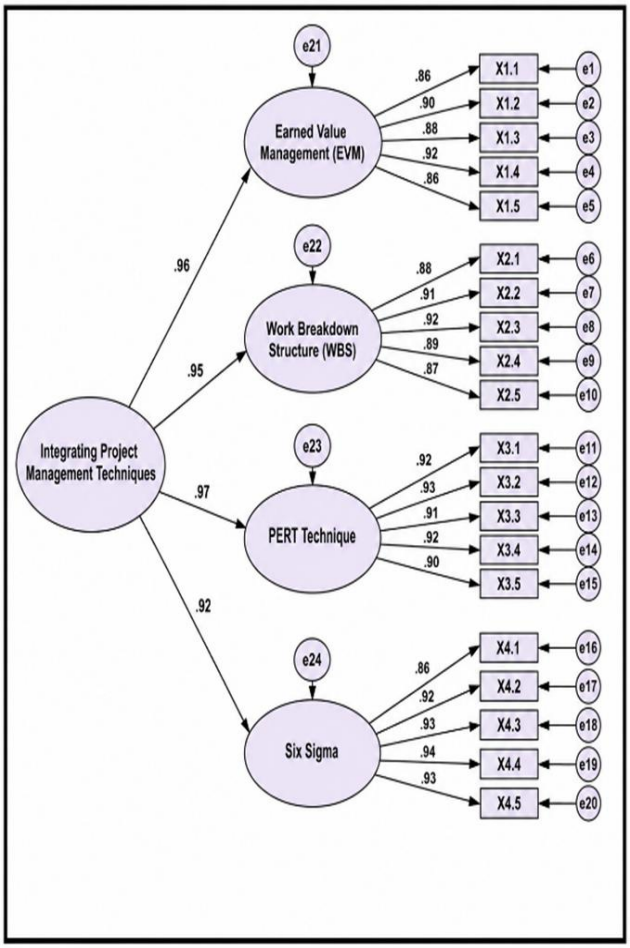


Figure 8. Confirmatory factor analysis of integrating project management techniques

The model presented in Figure 8 was evaluated using the standardized factor loadings, standard errors, critical ratios, and P-values reported in Table 12.

Table 12. Confirmatory factor analysis estimate of integrating project management techniques

	Path		Estimate	S.E.	C.R.	P
F1	<---	F5	0.96	-	-	-
F2	<---	F5	0.949	0.067	16.523	0.001
F3	<---	F5	0.971	0.064	18.161	0.001
F4	<---	F5	0.919	0.07	15.25	0.001
x1.1	<---	F1	0.861	-	-	-
x1.2	<---	F1	0.901	0.058	19.874	0.001
x1.3	<---	F1	0.882	0.058	19.044	0.001
x1.4	<---	F1	0.923	0.056	20.95	0.001
x1.5	<---	F1	0.862	0.056	18.214	0.001
x2.1	<---	F2	0.883	-	-	-
x2.2	<---	F2	0.91	0.047	21.597	0.001
x2.3	<---	F2	0.921	0.047	22.268	0.001
x2.4	<---	F2	0.888	0.051	20.402	0.001
x2.5	<---	F2	0.868	0.05	19.406	0.001
x3.1	<---	F3	0.918	-	-	-
x3.2	<---	F3	0.926	0.041	25.493	0.001
x3.3	<---	F3	0.912	0.042	24.318	0.001
x3.4	<---	F3	0.918	0.041	24.859	0.001
x3.5	<---	F3	0.896	0.041	23.114	0.001
x4.1	<---	F4	0.857	-	-	-
x4.2	<---	F4	0.919	0.05	20.667	0.001

x4.3	<---	F4	0.935	0.052	21.432	0.001
x4.4	<---	F4	0.942	0.05	21.809	0.001
x4.5	<---	F4	0.933	0.051	21.349	0.001

It is clear from Figure 8 and Table 12 that the standard loading coefficients for the expressions ranged between (0.857–0.971), which are greater than (0.5), and the critical ratio (C.R.) values are also greater than (1.96).

Table 13 presents the goodness-of-fit indicators of the measurement model for Integrating Project Management Techniques and their corresponding ideal limits.

Table 13. Measured indicators of integrating project management techniques

Index	Actual limits	Ideal limits
Chi square /DF	3.416	Less than 5
RMSEA	.089	Less than 0.09
RMR	.014	Less than 0.09
GFI	.90	0.9-1
CFI	.941	0.9-1

Based on all of the above, it can be judged that Integrating Project Management Techniques has a high degree of validity in data representation and a high quality of model fit.

4.8.2 Confirmatory factor analysis of improving the performance of infrastructure projects

Figure 9 presents the CFA model for Improving the Performance of Infrastructure Projects, showing the relationships among the latent construct, its dimensions, and the associated measurement items.

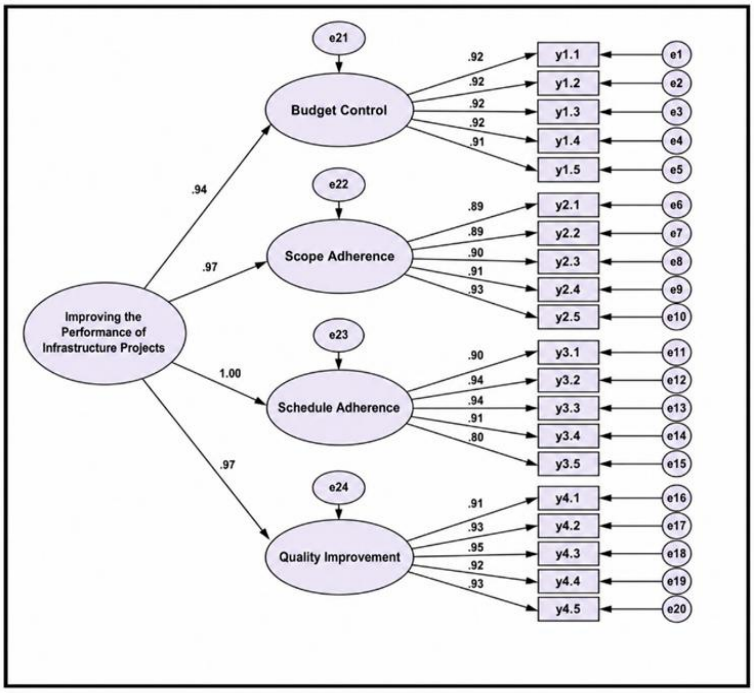


Figure 9. Confirmatory factor analysis of improving the performance of infrastructure projects

The model presented in Figure 9 was evaluated using the standardized factor loadings, standard errors, critical ratios, and P-values reported in Table 14.

Table 14. Confirmatory factor analysis estimate of improving the performance of infrastructure projects

	Path		Estimate	S.E.	C.R.	P
F1	<---	F5	0.939	-	-	-
F2	<---	F5	0.973	0.055	19.028	0.001
F3	<---	F5	0.996	0.055	20.294	0.001
F4	<---	F5	0.966	0.053	19.661	0.001
y1.1	<---	F1	0.915	-	-	-
y1.2	<---	F1	0.919	0.041	24.709	0.001
y1.3	<---	F1	0.924	0.041	25.125	0.001
y1.4	<---	F1	0.916	0.041	24.503	0.001
y1.5	<---	F1	0.909	0.044	23.918	0.001
y2.1	<---	F2	0.894	-	-	-

y2.2	<---	F2	0.89	0.044	21.263	0.001
y2.3	<---	F2	0.901	0.046	21.89	0.001
y2.4	<---	F2	0.913	0.046	22.634	0.001
y2.5	<---	F2	0.932	0.042	23.986	0.001
y3.1	<---	F3	0.904	-	-	-
y3.2	<---	F3	0.943	0.041	25.966	0.001
y3.3	<---	F3	0.937	0.041	25.423	0.001
y3.4	<---	F3	0.908	0.041	23.211	0.001
y3.5	<---	F3	0.8	0.046	17.306	0.001
y4.1	<---	F4	0.914	-	-	-
y4.2	<---	F4	0.932	0.039	25.854	0.001
y4.3	<---	F4	0.946	0.038	27.222	0.001
y4.4	<---	F4	0.92	0.04	24.889	0.001
y4.5	<---	F4	0.935	0.039	26.132	0.001

It is clear from Figure 9 and Table 14 that the standard loading coefficients for the expressions ranged between (0.800–0.996), which are greater than (0.5), and are statistically significant at the level (P-value < 0.001). The critical ratio (C.R.) values are also greater than (1.96).

Table 15 presents the goodness-of-fit indicators of the measurement model for Improving the Performance of Infrastructure Projects and their corresponding ideal limits.

Table 15. Measured indicators for improving the performance of infrastructure projects

Index	Actual limits	Ideal limits
Chi square /DF	3.603	Less than 5
Root Mean Square Error of Approximation (RMSEA)	.089	Less than 0.09
Root Mean Square Residual (RMR)	.013	Less than 0.09
Goodness-Of-Fit Index (GFI)	.90	0.9 -1
Comparative Fit Index (CFI)	.942	0.9 -1

The study notes that the quality indicators are within the optimal limits. Based on these results, it can be concluded that the model has a high degree of validity in representing the data and a high quality of model fit.

Based on all of the above, the model can be considered acceptable in terms of compatibility with the research sample data.

4.9 Structural model assessment

Following the satisfactory results of the measurement model, the structural model was evaluated using SEM in AMOS to examine the hypothesized causal relationships between the study variables. The model included Integrating Project Management Techniques as the exogenous (independent) construct and Improving the Performance of Infrastructure Projects as the endogenous (dependent) construct.

The structural model was assessed using standardized path coefficients, critical ratios (C.R.), significance levels (p-values), and the overall goodness-of-fit indices. The estimated path coefficients were used to evaluate the strength and direction of the relationships between the latent constructs and to test the proposed research hypotheses.

4.9.1 Structural model for the main hypothesis

There is a statistically significant effect of applying Integrating Project Management Techniques on Improving the Performance of Infrastructure Projects.

This analysis aimed to examine the effect of applying Integrating Project Management Techniques on Improving the Performance of Infrastructure Projects.

Figure 10 presents the final structural model used to examine the main hypothesis concerning the relationship between Integrating Project Management Techniques and Improving the Performance of Infrastructure Projects.

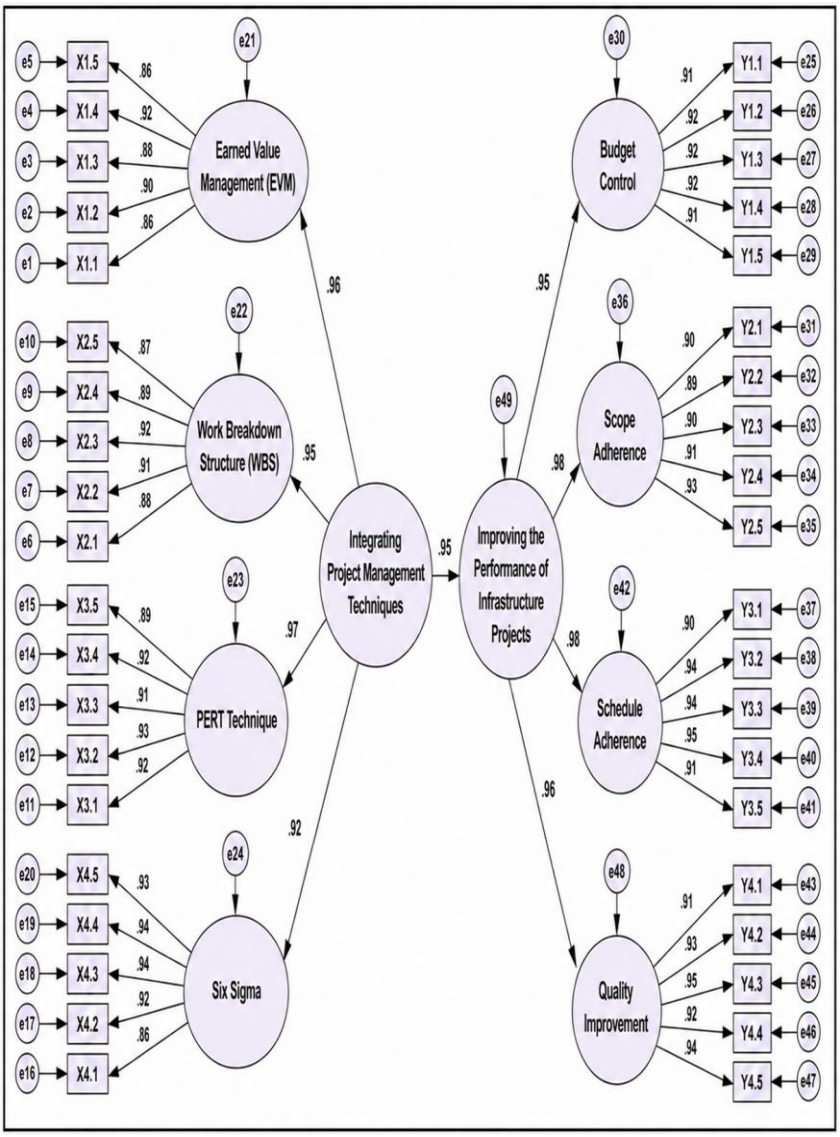


Figure 10. The model answer to the main hypothesis

The overall fit of the final structural model presented in Figure 10 was evaluated using the goodness-of-fit indicators shown in Table 16.

Table 16. Quality indicators of the model answer to the main hypothesis

Index	Actual limits	Ideal limits
Chi square /DF	3.416	Less than 5
Root Mean Square Error of Approximation (RMSEA)	.089	Less than 0.09
Root Mean Square Residual (RMR)	.014	Less than 0.09
Goodness-Of-Fit Index (GFI)	.900	0.9 -1
Comparative Fit Index (CFI)	.900	0.9 -1

From the previous table, the quality and validity of the proposed final structural model are clear, as the value of the standard Chi-square ($\chi 2/DF$) is equal to (3.416). The quality of fit indicators for the proposed model reached ideal levels or close to them, as the Goodness-of-Fit Index reached (GFI = .900), the Comparative Fit Index reached (CFI = .900), the Root Mean Square Residual reached (RMR = .014), and the Root Mean Square Error of Approximation reached (RMSEA = .089). This indicates that the proposed final structural model is compatible with the study data and its indicators. Therefore, it is possible to move to the stage of testing the causal relationships between the study variables.

4.9.2 Testing the validity of the main hypothesis and interpreting its result

Table 17 presents the path analysis estimates used to test the main hypothesis, including the standardized path coefficient, standard error, critical ratio, and P-value.

Table 17. The path analysis estimate of the main hypothesis

	Path		Estimate	S.E.	C.R	P-value
Integrating project management techniques	→	Improving the performance of infrastructure projects	0.949	0.066	16.52	0.001

The main hypothesis: "There is a statistically significant effect of applying Integrating Project Management Techniques on Improving the Performance of Infrastructure Projects."

The path shown in the structural model of the study in Table 17 represents the main hypothesis and explains the significant effect of applying Integrating Project Management Techniques on Improving the Performance of Infrastructure Projects at a significance level less than 0.05, where (Beta = .949, t = 16.52, P-Value = .001).

The main hypothesis was accepted, indicating that there is a positive and statistically significant effect of applying Integrating Project Management Techniques on Improving the Performance of Infrastructure Projects.

4.9.3 Structural model for the Sub-Hypotheses

Figure 11 presents the final structural model used to examine the effects of the four dimensions of Integrating Project Management Techniques-EVM, WBS, PERT, and Six Sigma-on Improving the Performance of Infrastructure Projects.

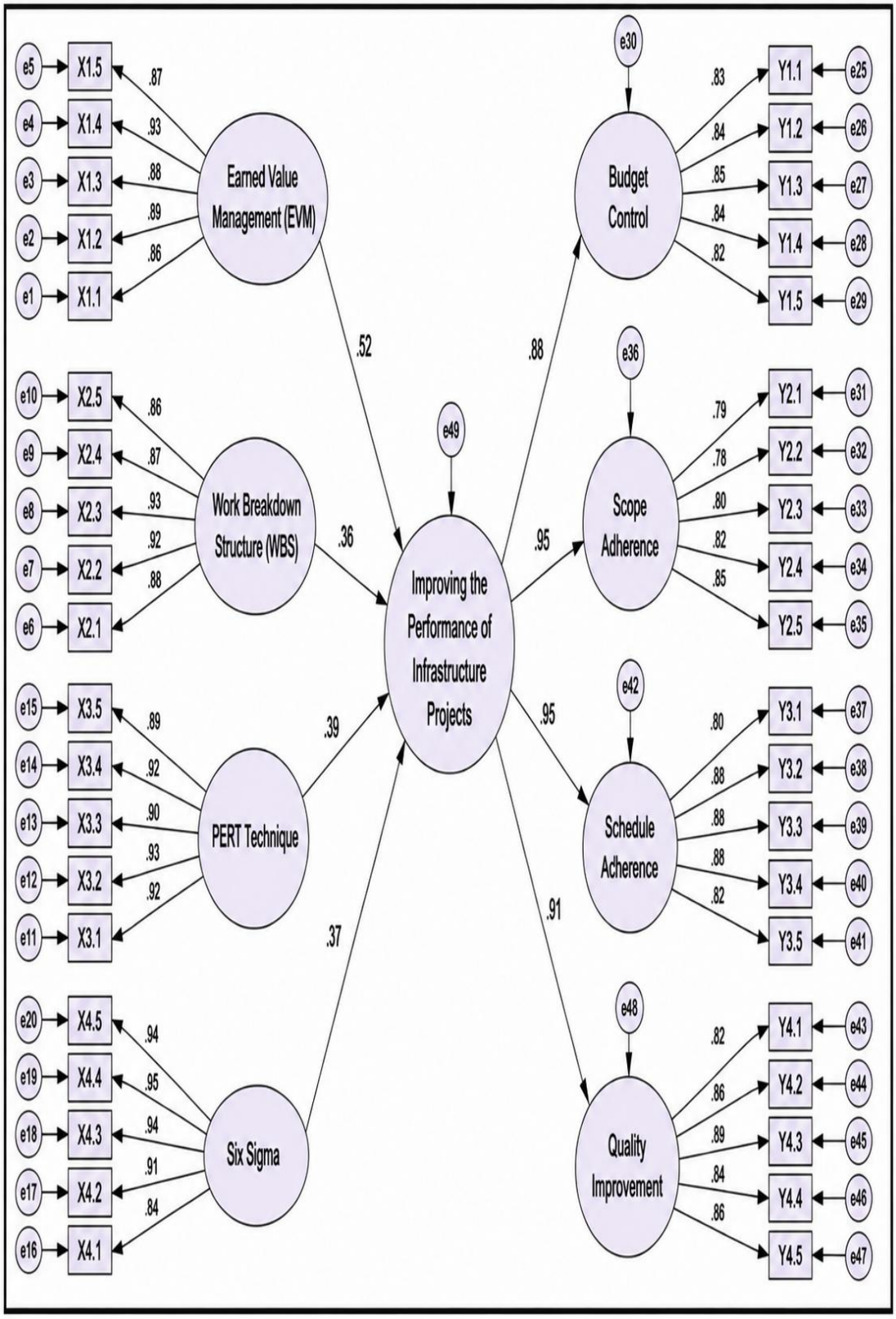


Figure 11. The model answer to the Sub-Hypotheses

The goodness-of-fit indicators of the structural model presented in Figure 11 are summarized in Table 18.

Table 18. Quality indicators of the model answer to the Sub-Hypotheses

Index	Actual value	Ideal limits
Chi-square /DF	4.864	Less than 5
Root Mean Square Error of Approximation (RMSEA)	.089	Less than 0.09
Root Mean Square Residual (RMR)	.088	Less than 0.09
Goodness-Of-Fit Index (GFI)	.900	0.9 -1
Comparative Fit Index (CFI)	.900	0.9 -1

From the previous table, the quality and validity of the proposed final structural model are clear, as the value of the standard Chi-square ($\chi 2/DF$) is equal to (4.864). The quality of fit indicators for the proposed model reached ideal levels or close to them, as the Goodness-of-Fit Index reached (GFI = .900), the Comparative Fit Index reached (CFI = .900), the Root Mean Square Residual reached (RMR = .088), and the Root Mean Square Error of Approximation reached (RMSEA = .089). This indicates that the proposed final structural model is compatible with the study data and its indicators. Therefore, it is possible to move to the stage of testing the causal relationships between the study variables.

4.9.4 Testing the validity of the Sub-Hypotheses and interpreting their results

Table 19 presents the path analysis estimates used to test the four sub-hypotheses, including the standardized path coefficients, standard errors, critical ratios, and P-values for the four project management techniques.

Table 19. The path analysis estimate of the Sub-Hypotheses

Path			Estimate	S.E.	C.R.	P- value
Earned Value Management (EVM)	→	Improving the performance of infrastructure projects	0.519	0.038	9.476	0.001
Work Breakdown Structure (WBS)	→	Improving the performance of infrastructure projects	0.359	0.03	7.432	0.001
Program Evaluation and Review Technique (PERT)	→	Improving the performance of infrastructure projects	0.389	0.029	8.039	0.001
Six Sigma	→	Improving the performance of infrastructure projects	0.366	0.03	7.468	0.001

Sub-Hypothesis I: “There is a statistically significant effect of applying EVM on Improving the Performance of Infrastructure Projects.”

The paths shown in the structural model of the study in Table 19 indicate that the first path represents the first sub-hypothesis and explains the significant effect of applying EVM on Improving the Performance of Infrastructure Projects at a significance level less than 0.05, where (Beta (Estimate)

= .519, t = 9.476, P-Value = .001).

Therefore, the first sub-hypothesis was accepted, indicating that there is a positive and statistically significant effect of applying EVM on Improving the Performance of Infrastructure Projects.

Sub-Hypothesis II: "There is a statistically significant effect of applying WBS on Improving the Performance of Infrastructure Projects."

The paths shown in the structural model of the study in Table 19 indicate that the second path represents the second sub-hypothesis and explains the significant effect of applying WBS on Improving the Performance of Infrastructure Projects at a significance level less than 0.05, where (Beta (Estimate) = .359, t = 7.432, P-Value = .001).

Therefore, the second sub-hypothesis was accepted, indicating that there is a positive and statistically significant effect of applying WBS on Improving the Performance of Infrastructure Projects.

Sub-Hypothesis III: "There is a statistically significant effect of applying PERT on Improving the Performance of Infrastructure Projects."

The paths shown in the structural model of the study in Table 19 indicate that the third path represents the third sub-hypothesis and explains the significant effect of applying PERT on Improving the Performance of Infrastructure Projects at a significance level less than 0.05, where (Beta (Estimate) = .389, t = 8.039, P-Value = .001).

Therefore, the third sub-hypothesis was accepted, indicating that there is a positive and statistically significant effect of applying PERT on Improving the Performance of Infrastructure Projects.

Sub-Hypothesis IV: "There is a statistically significant effect of applying Six Sigma on Improving the Performance of Infrastructure Projects."

The paths shown in the structural model of the study in Table 19 indicate that the fourth path represents the fourth sub-hypothesis and explains the significant effect of applying Six Sigma on Improving the Performance of Infrastructure Projects at a significance level less than 0.05, where (Beta (Estimate) = .366, t = 7.468, P-Value = .001).

Therefore, the fourth sub-hypothesis was accepted, indicating that there is a positive and statistically significant effect of applying Six Sigma on Improving the Performance of Infrastructure Projects.

5. CONCLUSION

5.1 Main findings and overall conclusion

This study investigated the impact of integrating project management techniques on improving infrastructure project performance, with an application to the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. The study was developed around an integrated framework combining EVM, WBS, PERT, and Six Sigma, with the objective of examining their collective contribution to budget control, schedule adherence, scope adherence, and quality improvement. Using SEM, the study examined the proposed relationships within a complex infrastructure rehabilitation context characterized by strict safety and operational constraints.

The findings provide empirical evidence of a positive and statistically significant association between integrating project management techniques and infrastructure project performance. The coordinated application of EVM, WBS, PERT, and Six Sigma was significantly associated with budget control, schedule adherence, scope adherence, and quality improvement, supporting the need for an integrated framework in complex rehabilitation projects where planning, scheduling, monitoring, scope control, and quality management are interdependent. The reliability and validity results also support the measurement quality of the study: Cronbach's Alpha ranged from 0.948 to 0.992 and validity coefficients from 0.974 to 0.996.

Further evidence regarding the observed relationships was obtained from the descriptive analysis. Respondents strongly agreed on the importance of integrating project management techniques, with an overall weighted mean of 4.33. Among the techniques investigated, EVM had the highest means, followed by PERT, Six Sigma, and WBS. Similarly, respondents strongly agreed on infrastructure project performance, with an overall weighted mean of 4.35. Within the performance dimensions, budget control ranked highest, followed by schedule adherence, quality improvement, and scope adherence. These descriptive results therefore provide an overall indication of the perceived importance of both the integrated project management techniques and the resulting infrastructure project performance dimensions.

The measurement models were further examined through CFA, which provided additional support for the adequacy of the measurement constructs. The standardized factor loadings ranged from 0.857–0.971 for integrated project management techniques and from 0.800–0.996 for infrastructure project performance, together with acceptable fit indices. These results support the adequacy of the measurement models and provide a basis for interpreting the relationships examined through the principal structural model.

Building on the measurement results, the principal structural model showed $\beta = 0.949$, C.R. = 16.52, $p = 0.001$, indicating a strong positive statistical association between the integration of project management techniques and overall infrastructure project performance. The structural model also showed acceptable fit ($\chi^2/df = 3.416$, RMSEA = 0.089, RMR = 0.014, GFI = 0.900, CFI = 0.900). Taken together, these results confirm the proposed positive relationship between the integrated application of EVM, WBS, PERT, and Six Sigma and improvements in budget control, schedule adherence, scope adherence, and quality improvement.

The examination of the individual techniques provided further insight into the contribution of each component of the integrated framework. EVM had the largest standardized path coefficient ($\beta = 0.519$, C.R. = 9.476, $p = 0.001$). Its ability to combine scope, schedule, cost, and actual-progress information and identify deviations early is particularly relevant to rehabilitation projects subject to budget constraints, contractual complexity, restricted work windows, and operational interruptions. PERT also had a positive significant relationship ($\beta = 0.389$, C.R. = 8.039, $p = 0.001$), supporting probabilistic duration estimation, critical-path identification, and schedule forecasting under uncertainty and restricted operational downtime. Six Sigma showed a positive significant relationship ($\beta = 0.366$, C.R. =7.468, p=0.001), supporting defect reduction, process-variation control, lower rework, and compliance with specifications. Its DMAIC and DMADV approaches are particularly relevant to fire-protection rehabilitation where quality affects safety, reliability, and service continuity. WBS also showed a positive significant relationship (β=0.359, C.R.=7.432, p=0.001). It structures scope into work packages, assigns responsibilities, defines deliverables, and links activities with cost and schedule planning. Its numerically smaller coefficient does not diminish its managerial importance and may reflect its

foundational role relative to techniques that directly support continuous measurement, forecasting, and quality improvement.

The numerical ranking of the investigated techniques was therefore EVM, followed by PERT, Six Sigma, and WBS. However, this numerical ranking should be interpreted as a comparison of the estimated standardized path coefficients rather than as evidence that the differences between the coefficients are statistically significant. Accordingly, the results should not be interpreted as indicating that one technique is universally superior to the others; rather, the findings highlight the different and complementary roles that the techniques play within an integrated project management framework.

In this context, the findings indicate complementary rather than substitutable capabilities: WBS structures scope and work, PERT supports scheduling under uncertainty, EVM monitors cost and schedule performance, and Six Sigma supports quality and process improvement. Their integration therefore supports simultaneous management of cost, time, scope, and quality. This integrated perspective is particularly important for complex infrastructure rehabilitation projects, where these performance dimensions are interdependent and where decisions related to one dimension can directly affect the others. The study therefore extends the literature by empirically examining these complementary techniques within a complex infrastructure rehabilitation project subject to strict safety and operational constraints.

At the same time, alternative causal interpretation should also be acknowledged. Better-performing projects may be more likely to adopt or consistently apply integrated techniques because their teams have greater organizational capacity, managerial maturity, or confidence. This potential reverse-causality explanation cannot be completely excluded by the cross-sectional design and should therefore be considered when interpreting the observed relationship. Nevertheless, the proposed direction is grounded in the theoretical framework and hypotheses developed in this study.

From a broader project management perspective, the findings contribute to project management literature by empirically validating an integrated framework that combines planning, scheduling, project control, and quality management within a single structural model, particularly in complex infrastructure rehabilitation projects operating under strict technical and operational constraints. The proposed framework and action plan also provide infrastructure owners, governmental authorities, project management offices, contractors, and consulting organizations with practical guidance for strengthening project planning, cost and schedule control, quality management, decision-making, and risk reduction throughout the project life cycle.

Overall, the findings support a shift from the isolated application of individual project management techniques toward an integrated management approach in which planning, scheduling, project control, scope, and quality operate as complementary components of a unified decision-making framework. Such integration provides a practical pathway for delivering infrastructure rehabilitation projects more efficiently, reliably, and sustainably while strengthening organizations' ability to manage increasing technical and operational complexity.

5.2 Practical implications

The findings support adoption of an integrated project management framework combining EVM, WBS, PERT, and Six Sigma throughout the project lifecycle, linking planning, scheduling, monitoring, scope management, and quality improvement. EVM indicators can be incorporated into routine performance reporting to identify cost and schedule deviations early; PERT can strengthen probabilistic

duration estimation, critical-path analysis, and forecasting where activities are uncertain or implementation windows are restricted; and Six Sigma can embed continuous improvement to reduce variation, technical errors, rework, and non-compliance, particularly for safety-critical systems. WBS should remain standardized as the basis for work-package definition, responsibility assignment, scope control, and integration with schedule, cost, and quality planning.

Because budget control was the highest-rated performance dimension, integrated financial monitoring can combine EVM indicators with current cost reporting to support resource allocation and timely corrective decisions. Owners, contractors, consultants, and governmental authorities should also provide multidisciplinary training that develops a common understanding of integrated practices and strengthens stakeholder collaboration.

Overall, the framework provides a practical evidence-based approach for managing infrastructure rehabilitation under complex technical and operational conditions.

5.3 Action plan

Based on the empirical findings, an action plan was developed to translate the statistically significant relationships identified in this paper into practical managerial initiatives. The proposed framework provides implementation guidance by specifying recommended actions, implementation mechanisms, responsible entities, implementation priorities, indicative time frames, and typical cost examples for infrastructure organizations.

Result	Recommendation	Implementation mechanism	Responsible entity	Time frame	Priority	Typical cost examples
The study confirmed a strong direct effect of applying integrating project management techniques on improving the performance of infrastructure projects.	Adopt an integrated institutional framework for applying integrating project management techniques within infrastructure projects.	Develop unified operational procedures integrating EVM, WBS, PERT, and Six Sigma within all project phases.	Governmental authorities, infrastructure project management departments, consulting offices.	Medium-Term	Critical	External consultant fees; workshops and meeting facilities for project management techniques integration; standard operating procedures (SOPs) preparation.
EVM had the numerically largest standardized path coefficient among the investigated techniques, contributing significantly to budget control and cost performance improvement.	Prioritize the activation of EVM in project monitoring and performance control.	Establish integrated cost and schedule tracking systems based on EVM indicators and periodic performance reporting.	Project Management Offices (PMOs), financial control departments.	Short-Term	Critical	EVM software license; Project Controls Engineer labor cost; EVM implementation consultancy fees.
PERT showed a significant positive effect on improving adherence to project schedules.	Enhance the use of PERT in project scheduling and critical path analysis.	Apply advanced scheduling software and periodic schedule forecasting techniques for infrastructure projects.	Planning and scheduling departments, project managers.	Short-Term	Important	PERT three-point estimation workshops; Subject Matter Expert (SME) consultation fees for PERT duration estimates; Planning Engineer labor cost.

Six Sigma demonstrated a significant role in improving execution quality and reducing technical errors.	Expand the implementation of Six Sigma methodology in quality management processes.	Conduct continuous quality improvement programs and implement DMAIC and DMADV methodologies in project execution.	Quality assurance departments, technical management teams.	Medium-term	Important	Six Sigma consultant fees; Green Belt/Black Belt certification fees; Quality audit fees.
WBS showed a statistically significant effect on improving project scope organization and responsibility.	Strengthen the application of WBS in infrastructure projects.	Standardize WBS templates and integrate them with scope, schedule, and responsibility planning processes.	Project planning departments, engineering management teams.	Short-Term	Important	Planning Engineer labor cost; WBS development workshops facilities; WBS documentation preparation cost.
Budget Control emerged as the highest-rated dimension within Improving the Performance of Infrastructure Projects.	Focus on enhancing budget control systems in infrastructure projects.	Create periodic financial dashboards linked with EVM indicators to monitor project expenditures and deviations.	Financial management departments, PMOs.	Short-Term	Critical	Cost control engineer labor cost; financial dashboard software license; financial analyst labor cost; budget review workshop facilities.
The effectiveness of integration between project management techniques requires unified procedural understanding among project stakeholders.	Develop joint training programs on integrated project management techniques.	Organize specialized workshops and training programs for governmental entities, contractors, and consultants.	Human resource departments, training centers, infrastructure authorities.	Medium-Term	Supportive	Training provider fees; training materials; participant certification fees; training venue or e-learning platform fees.
The study confirmed the importance of continuous monitoring and evaluation in supporting the improvement of infrastructure project performance.	Adopt periodic performance measurement systems for infrastructure projects.	Develop standardized Key Performance Indicators (KPIs) and periodic evaluation systems to continuously monitor project cost, time, quality, and scope performance.	Monitoring and evaluation departments, Project Management Offices (PMOs).	Long-Term	Critical	KPIs management software license; External performance audit fees; Performance Analyst labor cost.
Improving infrastructure project performance requires linking scope adherence, schedule adherence, quality improvement, and budget control within one integrated framework.	Establish unified performance management matrices for infrastructure projects.	Integrate project scope, schedule, cost, and quality indicators into centralized project performance systems.	Senior management, strategic planning departments.	Long-term	Critical	PMO implementation consultancy fees; Enterprise Performance Management (EPM) software license; executive training fees; system implementation contractor fees.

Note (1): The “Typical Cost Examples” identify the principal cost items associated with implementing each recommendation. These cost elements are indicative and intended to support implementation planning and budgeting. They represent the main sources of expenditure rather than actual project costs, which may vary depending on the project’s size, scope, complexity, organizational context, existing resources, procurement arrangements, and prevailing market conditions.

Note (2): The Key Performance Indicators (KPIs) for each action should be defined according to the objective of the corresponding recommendation and the relevant project performance dimension. Each KPI should be calculated using an appropriate quantitative formula that compares actual performance with the established baseline, planned target, or reference value. KPI results should be measured periodically using verified project data and reviewed by the responsible entity to evaluate the effectiveness of the implemented action and determine whether corrective measures are required. Depending on the nature of each action, KPIs may include achievement rates, cost or schedule variances, compliance rates, defect rates, process improvement rates, or other relevant performance measures. The baseline, target, formula, measurement frequency, and data source should be established prior to implementation based on the project size, complexity, and organizational context.

5.4 Limitations

First, the empirical investigation concerned one infrastructure rehabilitation project, the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. Although it represents a complex and operationally constrained environment, its scale and organizational complexity may differ from large-scale new construction; therefore, generalization to other sectors or projects with different sizes, organizational structures, contractual arrangements, or operating

conditions should be made cautiously. Second, the cross-sectional design collected data at one point in time. Thus, although SEM identified statistically significant relationships, it cannot definitively establish temporal or causal direction or fully exclude reverse causality. Longitudinal designs and, where appropriate, instrumental-variable approaches could address these issues and potential endogeneity. Third, the analysis relied on questionnaire responses from project managers, engineers, planners, supervisors, and other project professionals. Despite their practical experience and the instrument's high reliability and validity, the results remain dependent on perceptions rather than direct longitudinal observations of project performance. Fourth, 242 valid respondents were unevenly distributed: engineers represented 68.2% while project managers represented 7.5%. This may give greater weight to technical and execution perspectives than higher-level management perspectives and may influence evaluations of management-oriented techniques such as EVM; future studies should seek more balanced job-category representation. Finally, the framework examined only four techniques—EVM, WBS, PERT, and Six Sigma-and four performance dimensions-budget control, schedule adherence, scope adherence, and quality improvement. Other factors, including leadership, organizational culture, digital transformation, stakeholder engagement, and risk management, were outside the scope and may also affect infrastructure project performance. These limitations define the context of interpretation and provide opportunities to test and extend the framework across different infrastructure and organizational settings.

5.5 Future research

Future research may validate the framework across railways, airports, seaports, highways, power systems, and water utilities to examine generalizability under different technical and organizational conditions. The model may also be extended with project risk management, digital transformation, Building Information Modeling (BIM), organizational culture, leadership, stakeholder engagement, communication effectiveness, and top-management support to provide a broader explanation of performance. Longitudinal studies should examine how integration and performance change across project life-cycle phases and can strengthen understanding of dynamic relationships and causal direction. Mixed-methods research combining quantitative analysis with interviews, case studies, and field observations could explain how integrated techniques are implemented and identify organizational factors that facilitate or hinder adoption. Finally, future studies could examine implementation costs against operational benefits, including cost reduction, schedule optimization, quality improvement, productivity enhancement, and long-term asset performance, thereby providing stronger economic evidence for investment in integrated project management systems.

Abbreviations

AC, Actual Cost;

AMOS, Analysis of Moment Structures;

BIM, Building Information Modeling;

C.R., Critical Ratio;

CFA, Confirmatory Factor Analysis;

CFI, Comparative Fit Index;

CPI, Cost Performance Index;

CV, Cost Variance;

df / DF, Degrees of Freedom;

DMADV, Define-Measure-Analyze-Design-Verify;

DMAIC, Define-Measure-Analyze-Improve-Control;

EPM, Enterprise Performance Management;

EV, Earned Value;

EVM, Earned Value Management;

GFI, Goodness-of-Fit Index;

IMS, Integrated Management Systems;

KPI / KPIs, Key Performance Indicator(s);

PA, Path Analysis;

PERT, Program Evaluation and Review Technique;

PMI, Project Management Institute;

PMO/PMOs, Project Management Office(s);

PV, Planned Value;

RMR, Root Mean Square Residual;

RMSEA, Root Mean Square Error of Approximation;

SEM, Structural Equation Modeling;

SME, Subject Matter Expert;

SPI, Schedule Performance Index;

SPSS, Statistical Package for the Social Sciences;

SV, Schedule Variance;

WBS, Work Breakdown Structure;

χ^2, Chi-square.

Supplementary Material

Not applicable.

Appendix

Not applicable.

Ethics approval and consent to participate.

The study was conducted with official administrative authorization from the National Authority for Tunnels (NAT), the administrative authority responsible for the project addressed in this study, to conduct the questionnaire survey among personnel involved in the Rehabilitation Project of the Fire Protection System on Greater Cairo Metro Line 1. The authorization was granted by the Chairman of the National Authority for Tunnels. The authorization document is available in the Figshare repository at https://doi.org/10.6084/m9.figshare.34056603

For verification of the authorization, the National Authority for Tunnels may be contacted through its official communication channels: National Authority for Tunnels, Ministry of Transport Building, Government District, New Administrative Capital, Egypt; Tel.: +20 2 20545335, +20 2 20545336, +20 2 20545337; Fax: +20 2 20545318; Email: chairman@nat.gov.eg; Website: www.nat.gov.eg.

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Competing interests

The author declares that he has no financial or personal relationships that may have inappropriately influenced him in writing this article.

Author contributions

The author has read and agreed to the published version of the manuscript. The author's contributions are specified as follows: **H.S.:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

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Data availability

The datasets generated during and/or analyzed during the current study are available in the Figshare repository, https://doi.org/10.6084/m9.figshare.34056603

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Declaration of AI and AI-assisted Technologies in the Writing Process

During the writing of this article, the author used AI-assisted technologies for spelling and grammar checking. After using these technologies, the author reviewed and edited the content as needed and assumed full responsibility for the final published content.

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