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A Comprehensive Evaluation of Key Performance Indicators (KPIs) for Enhanced Decision Support in Infrastructure Projects

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Abstract: Improving the efficiency and performance of infrastructure projects by contractors and owners is essential. The performance of a construction project significantly impacts its success, particularly given the inherently protracted nature of construction activities. Thus, there is a need for an efficient monitoring tool to evaluate the performance of specific types of infrastructure projects throughout the construction phase. This study aims to identify the Key Performance Indicators (KPIs) affecting sanitation infrastructure projects in the construction industry and to develop a generic model for measuring and evaluating their sustainable performance. Using semi-structured interviews and a review of the literature, the study identified 7 indicators that enhance the performance of construction projects related to sanitation infrastructure. Subsequently, a questionnaire survey was conducted to assess the impact of these KPIs on sanitation projects, ranking and prioritizing their significance. The Analytic Network Process (ANP) approach was then applied to analyze project performance and explore the linkages between various KPIs. Management of the number of KPIs, their classification, and selection for suitable projects are crucial considerations addressed in this study. The objective of this study is to develop a comprehensive model that can measure and evaluate sanitation project performance.

1. Introduction

The construction industry is a major sector that contributes significantly to the economic growth worldwide including developed and developing countries (Ali et al., 2023)., (Ali et al., 2023b); (Horta, 2014). In advanced industrial nations, construction investment as a percentage of gross national product varies, with around 4% in the United States, 6% in Canada, 7% in the United Kingdom, and 10% in Japan. In contrast, in developing countries,

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significant construction activities constitute approximately 80% of total capital assets and 10% of their GDP. (Moutawei, 2017). Hence, there is a growing need for the development of civil infrastructure and buildings to meet the demands of society due to continuous population growth and economic expansion. The construction sector, which currently accounts for 13% of the world's GDP, is projected to reach 14.7% by 2030 (Pervez et al., 2021). It is noteworthy that the construction industry is highly complex, involving multiple participants primarily clients, contractors and engineers. (Helen et al., 2015); (Ingle, 2022). The objective of this study is to develop a comprehensive model that can measure and evaluate sanitation project performance. In section 2, we delved into the Literature Review, which served as the foundation for gathering pertinent factors. Subsequently, in section 3, we expound upon our approach to gauging expert consensus on the validity of factors extracted from the literature review. Section 4 offers a comprehensive overview of our research methodology, outlining the steps taken to conduct our study. Finally, the paper concludes with a summary of findings and directions for future research.

2. Literature Review for collecting factors.

A successful construction project is characterized by the fulfillment of its specified criteria, timely completion, adherence to budget constraints, and achievement of high-quality outcomes. This section highlights the necessity of expanding definition of (KPIs) beyond original performance indicators which are cost, time, and quality. Additional KPIs, including sustainability, stakeholder management, environmental aspects, social aspects, project procurement, etc. are explored to provide a more comprehensive evaluation of construction projects. An intensive review of relevant literature (from 2010 to 2023) was conducted to firstly identify (KPIs) influencing construction projects. Then success and failure factors affecting the performance of the projects were examined, in addition to other sustainable KPIs.

2.1 Key performance indicators in construction projects

(Ingle, 2022) identified more (KPIs) than the typical ones used in construction projects, such as cost, time, and quality. Through an extensive literature review, 93 key performance factors were identified as influencing construction projects performance. (Belassi, 1996) suggested a new scheme that classifies the critical factors, and describes the impacts of these factors on project performance. (Toor, 2010) investigated the perception of the KPIs from the viewpoint of different construction stakeholders, including clients, consultants, and contractors,, where it was indicated only the traditional measures (time, cost and quality). (Masrom, 2015) identified and categorized the factors affecting the success of a project under 6 categories related to the following: (i) Project management, (ii) Characteristics of key stakeholders, (iii) Project characteristics, (iv) Project Procurement, (v) Client & Project team, and (vi) External factors. (Maya, 2023) developed an artificial neural network (ANN) model to predict construction projects performance based on 6 factors and used ANN due to its capability to model complex nonlinear relationships in data, making it especially suitable for tasks like pattern recognition and prediction. (Abu Oda et al., 2022) identified the performance indicators to evaluate the contractor’s performance in number of projects in Gaza strip (Palestine) from both perspectives’; Employers & Consultants. (Ingle, 2022) determined the 10 performance areas affecting the Indian construction industry through a survey instrument, using principal component analysis (PCA). The PCA methodology is used to reduce the dimensionality of data while preserving its essential features, thereby enabling simpler visualization, interpretation, and analysis of intricate datasets. (Ali, 2013) identified a set of 10 Construction executives in Saudi Arabia might use KPIs to gauge performance at the corporate level. Then, success and failure factors that play a critical role in determining the overall performance of construction projects will be examined.

2.2 Success and Failure factors affecting performance in construction projects

(Banihashemi, 2017) identified 56 initial Critical Success Factors (CSFs) affecting integration of sustainability into project management practices of construction projects in developing countries. (Sinesilassie et al., 2017) determined the factors responsible for impacting performance of Ethiopian public construction projects. (Chan, 2002) determined project success criteria for design/build construction project by locating pertinent project success metrics for a construction project in previous research. (Alias, 2014) identified the extent of the relationship between Critical success factors CSFs and project performance in the same vein sustainable KPIs in construction project.

2.3 Sustainable Key performance indicators in project

(Ugwu et al., 2006) proposed an analytical decision model and a structured methodology for sustainability appraisal in infrastructure projects. (FernÃ¡ndez-SÃ¡nchez, 2010) established methodological process, developed by stakeholders, to identify and select sustainability indicators by considering them as opportunities, which were identified in a sustainable breakdown structure then classified in an orderly manner into a list of 30 opportunities (positive risks). (Rajabi, 2022) identified and assessed 22 sustainability KPIs for construction projects during the construction phase, where they were shortlisted and grouped. (Stanitsas, 2021) explored the integration of sustainability indicators into project management practices of construction projects. (Agyekum, 2022) used an explanatory sequential design with an initial quantitative instrument phase, followed by a qualitative data collection phase, resulted in the identification of 10 environmental sustainability KPIs for projects in Ghana. Additionally, (Oghomwen et al., 2022) highlighted various elements influencing project performance, including construction errors, inconsistencies in contract documents, changes in design, a shortage of skilled and experienced workers, and growing material costs.

2.4 Summary of Key Findings in Literature Review

Based on the extensive literature review conducted, it is evident that there exists a diverse range of factors and (KPIs) that significantly influence the performance of construction projects. The findings from various studies emphasize the necessity of expanding beyond traditional KPIs like cost, time, and quality to incorporate a more comprehensive set of indicators that encompasses aspects such as sustainability, stakeholder management, and project procurement. The identification of 93 factors and KPIs underscores the complexity and multifaceted nature of project performance evaluation. This comprehensive understanding is crucial for enhancing project management practices and ensuring successful project outcomes. Therefore, the analysis presented in this study is justified by the wealth of evidence highlighting the need for a broader perspective on project performance assessment in the construction industry. These extensively listed factors encompass fundamental project aspects such as cost, time, quality, and scope, along with broader dimensions including environmental concerns, occupational health and safety, stakeholders, and procurement. The exhaustive list of these 93 factors is detailed in Table 1

Table 1 provides a summary of the literature review, listing the essential factors that influence the performance of construction projects

Number	**Factors**	**Author**
1	Project Management Action	(Masrom et al., 2015)
2	Project Procedures	
3	Human Related Factors	
4	External Issues	
5	Project Related Factors	
6	Environment	(Ugwu et al., 2006)
7	Health and safety	
8	Budget	(Toor and Ogunlana, 2010)
9	Societal	(Ugwu et al., 2006)
10	Resource Utilization	
11	Project Administration	
12	Time deviation indicator	(Maya et al., 2021)
13	Cash flow	(Ali et al., 2013)
14	Quality indicator	(Maya et al., 2021)
15	Construction cost	(Alias et al., 2014)
16	Time	(Abu Oda et al., 2022)
17	Cost	
18	Quality	
19	Health & Safety	
20	Relationship	
21	Environment	
22	Innovation	
23	Project Management	

Number	Factors	Author
24	Qualification	
25	Environmental	(Rajabi et al., 2022)
26	Cost	(Elhegazy et al., 2022)
27	Construction and demolition waste management	(Agyekum et al., 2021)
28	Effect on air quality	
29	Effect on water quality	
30	Energy use and conservation	
31	Environmental Compliance and Management	
32	Impact on ecology and biodiversity	
33	Impact on soil/land resources	
34	Light pollution	
35	Noise pollution	
36	Water use and conservation	
37	Time	(Toor and Ogunlana, 2010)
38	Cost deviation indicator	(Maya et al., 2021)
39	Meets specifications	(Toor and Ogunlana, 2010)
40	Efficiently (use of resources)	
41	Doing the right thing (effectiveness)	
42	Safety	
43	Free from defects (high quality of workmanship)	
44	Conforms to stakeholders' expectations	
45	Minimized construction aggravation, disputes, and conflicts	
46	Quality	(Ingle and Mahesh, 2022)
47	Schedule	(Ingle and Mahesh, 2022)
48	Environment and stakeholder satisfaction	(Ingle and Mahesh, 2022)
50	Productivity	(Ingle and Mahesh, 2022)
51	Safety	(Ingle and Mahesh, 2022)
52	Communication	(Ingle and Mahesh, 2022)
53	Customer	(Ingle and Mahesh, 2022)
54	Economy	(Ugwu et al., 2006)
55	Evaluation	(Banihashemi et al., 2017)
56	Preparation in organization	(Banihashemi et al., 2017)
57	Preparation on project	(Banihashemi et al., 2017)
58	Identification	(Banihashemi et al., 2017)
59	Implementation	(Banihashemi et al., 2017)

Number	Factors	Author
60	Commitment	(Banihashemi et al., 2017)
61	Organization's attitude towards the project	(Belassi and Tukel, 1996)
62	Preliminary Estimates	(Belassi and Tukel, 1996)
63	Availability of resources	(Belassi and Tukel, 1996)
64	Client Consultation	(Belassi and Tukel, 1996)
65	Project Management Performance	(Belassi and Tukel, 1996)
66	Top management Support	(Belassi and Tukel, 1996)
67	Finance	(Ingle and Mahesh, 2022)
49	Economic	(Rajabi et al., 2022)
68	Environment	(Rajabi et al., 2022)
69	Social/management	(Rajabi et al., 2022)
70	Health and Safety	(Scott and Lam, 2002)
71	Quality	(Scott and Lam, 2002)
72	Profitability	(Scott and Lam, 2002)
73	Technical Performance	(Scott and Lam, 2002)
74	Functionality	(Scott and Lam, 2002)
75	Subjective	(Scott and Lam, 2002)
76	Productivity	(Scott and Lam, 2002)
77	Satisfaction	(Scott and Lam, 2002)
78	Environmental Sustainability	(Scott and Lam, 2002)
79	Financial stability	(Ali et al., 2013)
80	Construction time	(Alias et al., 2014)
81	Quality	(Alias et al., 2014)
82	Construction predictability, Time predictability, Defects	(Alias et al., 2014)
83	predictability, Client satisfaction with the service	(Alias et al., 2014)
84	Client satisfaction with the product	(Alias et al., 2014)
85	Profitability	(Ali et al., 2013)
86	Market share	(Ali et al., 2013)
87	Profit indicator	(Maya et al., 2021)
88	Quality of service and work	(Ali et al., 2013)
89	External customer satisfaction	(Ali et al., 2013)
90	Socio-Economic	(Rajabi et al., 2022)
91	Safety (Excellence)	(Ali et al., 2013)
92	Business efficiency	(Ali et al., 2013)
93	Effectiveness of planning	(Ali et al., 2013)

3. Research Methodology

The process begins by identifying issues and pinpointing 93 factors affecting construction project performance through literature review. These factors are condensed to 70 and then categorized into 12 KPIs through interviews. Following this, the factors are further grouped into 37 across 7 KPIs, specifically for sanitation projects, using expert questionnaires. Next, the 7 KPIs are evaluated and ranked to identify the most effective ones. Finally, an ANP model is developed using the top-ranked KPIs to assess sanitation project performance. This section describes the approach utilized to accomplish the goals of the paper, with specific steps outlined in subsequent sections as follows:

Step 1, Involves initially identifying the issue at hand and then proceeding to identify the 93 factors that impact the performance of construction projects through a comprehensive literature review.

Step 2, Duplication, merging and categorization techniques were applied to streamline the 93 factors, resulting in a reduction to 70 factors classified into 12 (KPIs) through interviews.

Step 3, These factors were then categorized into 37 factors across 7 KPIs, specifically targeting sanitation infrastructure projects, using a questionnaire administered to subject matter experts (SMEs) in step two.

Step 4, The evaluation and ranking of these 7 KPIs were conducted using a semi-structured questionnaire to identify the most effective ones.

Step 5, Developing an Analytic Network Process (ANP) model utilizing the highest-ranked (KPIs) to assess the performance of sanitation infrastructure projects (7 KPIs). Figure 4 presents the flowchart for research methodology.

3.1 Literature Review to Identify the Performance factors (PF) & Key Performance Indicators (KPIs) in Construction Projects

An exhaustive review of relevant literature was conducted to identify the factors influencing construction projects in general, as well as success and failure factors affecting project performance, along with other sustainable factors. Various sources were consulted in this literature review, including studies by (Eleni Moschouli1 et al., 2018), (Abdelnaser omran, 2010), (S Meeampol et al., 2006), among others, to pinpoint factors affecting project costs. Additional sources, such as (Ephrem Girma Sinesilassie, 2017), (Chen Shih-Pin, 2007), and (Arshi Shakeel Faridi a et al., 2007), were examined to identify factors impacting project schedules. Furthermore, works by (K. N. JHA et al., 2006) and (Grigoroudis Evangelos et al., 2006) were analyzed to uncover factors influencing project quality, while sources like (Abdelnaser omran1, 2015), (Florence Yean Yng Ling1 and Thi Thuy Dung Bui2, 2010), and (Adnan Enshassi1 et al., 2009) were reviewed to identify a mix of factors affecting the project management triangle. The literature review yielded a total of 93 Performance Factors & KPIs, primarily focusing on the client's perspective, as detailed in Table1 above.

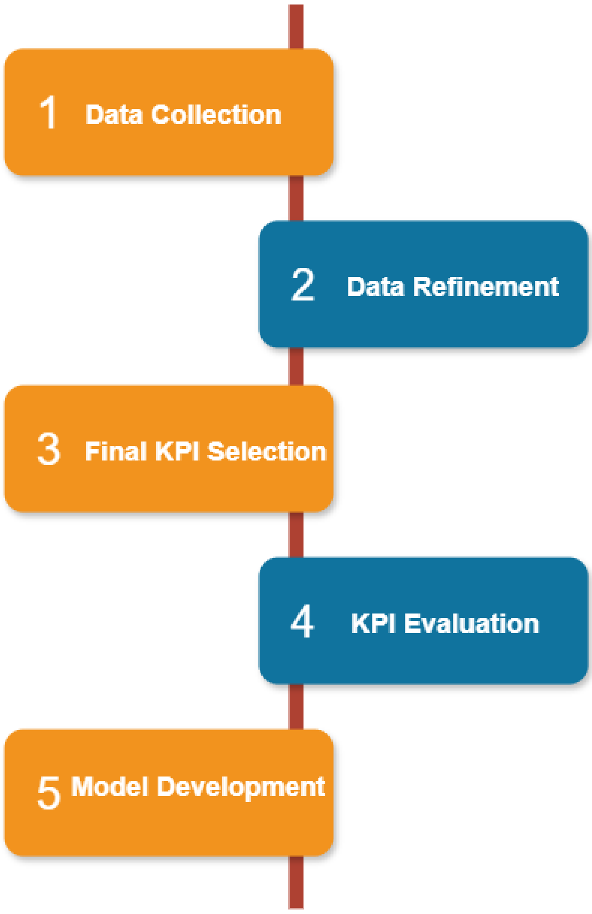

Figure 4 The flowchart of Research Methodology Steps

3.2 Semi structured Interviews to Identifying major categorization and duplication for Construction Projects

Following this interview, an initial list of the KPIs was prepared as a result of SMEs online questionnaire, classifying the 93 factors identified under the main knowledge area stated in the PMBook as reference, e.g.: Cost, Time, Quality, Risk, etc., in addition to the other categories suggested by the target group of SMEs.

3.2.1 Sample size

Before distributing the questionnaire, it is necessary for us to determine the number of experts among the staff, consultants, and contractors by applying the appropriate sample size methodology. (Assaf et al., 2001) argued that Equation 1 can be used to find the proper sample size for various entities.

$$n = n' / [1 + (n'/N)] \qquad (1)$$

where S' is the sample size from infinite entities = S^2/V^2, where (N) is the number of entities (owner, consultant, and contractor), (n) is the sample size of entities (number of experts to be interviewed), and (V) is the standard error of sampling entities (usually S = 0.5 and V = 0.06).

It is absolutely essential to identify the total population (N) of experts and professionals in Egypt's sanitation infrastructure sector as a crucial step towards determining the most appropriate sample size for the survey. These experts can be classified into various categories based on their roles and responsibilities, including but not limited to:

(1) Contractors: The sample consists of 63 contracting firms that are classified as first rank by the Egyptian Federation for Construction and Building Contractors, primarily due to their participation in ongoing mega infrastructure sanitation projects.

(2) Consultants: The sample consisted of nine firms categorized as (A) rank, which included engineering consulting firms and construction companies classified as first rank.

(3) Owner/Employer: The sample included 28 governmental agencies, including the three largest organizations specializing in Water and Wastewater Infrastructure Projects. The sample size was determined using the equation by Assaf et al. (2001).

The total sample consisted of 61 participants divided into three main categories:

Owners: 20 participants from government agencies.

Consultants: 8 participants from consulting firms.

Contractors: 33 participants from first-tier contracting companies.

The experts were consulted in two phases: initially to identify key factors and later to evaluate and rank the Key Performance Indicators (KPIs), referring to Table No. 2, the results of n are presented.

Table 2 Sample size results

Category	N	n
Owner/Employer	28	20
Consulting	9	8
Contractors	63	33

3.2.2 Refinement and Categorization of (KPIs) through Expert Interviews

The purpose of these interviews was to address any duplication and categorization issues within the extensive list of factors, ensuring clarity and coherence in their context or meaning. Consequently, the initial 93 factors were reduced to 70 factors organized into 12 (KPIs) as depicted in table 3.

Table 3 list of 12 Main KPIs affecting construction projects, with the corresponding factors

Nr	KPIs (12)	Factors (70)	Author
1	**Communication**	Communication	(Ingle and Mahesh, 2022)
		Minimized construction aggravation, disputes, and conflicts	(Toor and Ogunlana, 2010)
2	**Cost**	Budget	(Toor and Ogunlana, 2010)
		Cash flow	(Ali et al., 2013)

Nr	KPIs (12)	Factors (70)	Author
		Construction cost	(Alias et al., 2014)
		Cost	(Chakraborty et al., 2020)
		Cost deviation indicator	(Maya et al., 2021)
		Economy	(Ugwu et al., 2006)
		Finance	(Ingle and Mahesh, 2022)
		Market share	(Ali et al., 2013)
		Profitability	(Ali et al., 2013)
		Socio-Economic	(Rajabi et al., 2022)
3	**Environmental**	Construction and demolition waste management	(Agyekum et al., 2021)
		Effect on air quality	(Agyekum et al., 2021)
		Effect on water quality	(Agyekum et al., 2021)
		Energy use and conservation	(Agyekum et al., 2021)
		Environment	(Ugwu et al., 2006)
		Environmental Sustainability	(Scott and Lam, 2002)
		Impact on ecology and biodiversity	(Agyekum et al., 2021)
		Impact on soil/land resources	(Agyekum et al., 2021)
		Light pollution	(Agyekum et al., 2021)
		Noise pollution	(Agyekum et al., 2021)
		Water use and conservation	(Agyekum et al., 2021)
4	**Health and safety**	Health and Safety	(Scott and Lam, 2002)
5	**Innovation**	Innovation	(Abu Oda et al., 2022)
		Evaluation	(Banihashemi et al., 2017)
		Organization's attitude towards the project	(Belassi and Tukel, 1996)
		Preliminary Estimates	(Belassi and Tukel, 1996)
		Preparation in organization	(Banihashemi et al., 2017)
		Preparation on project	(Banihashemi et al., 2017)
		Project Procedures	(Masrom et al., 2015)
6	**Quality**	Business efficiency	(Ali et al., 2013)
		Doing the right thing (effectiveness)	(Toor and Ogunlana, 2010)
		Effectiveness of planning	(Ali et al., 2013)
		Free from defects (high quality of workmanship)	(Toor and Ogunlana, 2010)
		Functionality	(Scott and Lam, 2002)
		Quality	(Abu Oda et al., 2022)
		Subjective	(Scott and Lam, 2002)
		Technical Performance	(Scott and Lam, 2002)
7	**Resource**	Availability of resources	(Belassi and Tukel, 1996)
		Efficiently (use of resources)	(Toor and Ogunlana, 2010)
		Resource Utilization	(Ugwu et al., 2006)
8	**Schedule**	Construction predictability, Time predictability, Defects	(Alias et al., 2014)

Nr	KPIs (12)	Factors (70)	Author
		Construction time	(Alias et al., 2014)
		Schedule	(Ingle and Mahesh, 2022)
		Time	(Abu Oda et al., 2022)
9	**Scope**	Identification	(Banihashemi et al., 2017)
		Implementation	(Banihashemi et al., 2017)
		Meets specifications	(Toor and Ogunlana, 2010)
		Productivity	(Ingle and Mahesh, 2022)
10	**Social**	Social/management	(Rajabi et al., 2022)
		Societal	(Ugwu et al., 2006)
11	**Stakeholder**	Client Consultation	(Belassi and Tukel, 1996)
		Client satisfaction with the product	(Alias et al., 2014)
		Commitment	(Banihashemi et al., 2017)
		Conforms to stakeholders' expectations	(Toor and Ogunlana, 2010)
		External customer satisfaction	(Ali et al., 2013)
		External Issues	(Masrom et al., 2015)
		Human Related Factors	(Masrom et al., 2015)
		predictability, Client satisfaction with the service	(Alias et al., 2014)
		Project Administration	(Ugwu et al., 2006)
		Project Management	(Abu Oda et al., 2022)
		Project Management Action	(Masrom et al., 2015)
		Project Management Performance	(Belassi and Tukel, 1996)
		Project Related Factors	(Masrom et al., 2015)
		Qualification	(Abu Oda et al., 2022)
		Relationship	(Abu Oda et al., 2022)
		Satisfaction	(Scott and Lam, 2002)
		Top management Support	(Belassi and Tukel, 1996)
12	**Procurement**	Diversifying suppliers	(Ingle and Mahesh, 2022)

It has been determined that there is no mathematical relationship linking the factors to (KPIs), and the factors have been classified according to KPIs for that we have grouped them under the umbrella of KPIs. Upon completing step 2, where we identified 70 factors categorized into 12 KPIs, the lingering question remains: are these factors, derived from the literature review, actually utilized by professionals in the sanitation infrastructure sector? To address this inquiry, we conducted step 3.

3.3 Personal Interviews to Identify Key Performance Indicators in Sanitation Infrastructure Projects

Another survey was conducted following the previous one, targeting Subject Matter Experts (SMEs) in the sanitation infrastructure sector across various countries. This survey aimed to identify, from industrial point of view, the most relevant (KPIs) affecting the performance of sanitation infrastructure projects. Personal interviews with SMEs were also conducted in certain cases, widely recognized as one of the most effective fact-finding methods and commonly employed. Interviews prove useful when the study's objectives involve understanding perceptions, thoughts, behaviors, beliefs, and processes (Rowley, 2012). Based on the survey results and SME interviews, a list of 12 KPIs was compiled and ranked according to the frequency of selection for each KPI. The KPIs were reviewed to ensure their applicability to sanitation projects. Only relevant KPIs were retained, such as environmental considerations, site safety, and long-term operational costs as illustrated in Table 4 below. Table 4 presents the results of the semi-structured interviews conducted.

Table 4 list of 7 Main KPIs affecting construction projects, between the 12 identified in step2

#	KPIs	Coding	Interview	Count	Count/ Total surveys done
1	**Cost**	KPI. 1	Selected	72	100%
2	**Environmental**	KPI. 2	Selected	57	79%
3	**Health and safety**	KPI. 3	Selected	54	75%
4	**Quality**	KPI. 4	Selected	70	97%
5	**Schedule**	KPI. 5	Selected	72	100%
6	**Social**	KPI. 6	Selected	55	76%
7	**Procurement**	KPI. 7	Selected	60	83%
8	**Communication**	KPI. 8	Not Selected	10	14%
9	**Innovation**	KPI. 9	Not Selected	3	4%
10	**Resource**	KPI. 10	Not Selected	20	28%
11	**Scope**	KPI. 11	Not Selected	15	21%
12	**Stakeholder**	KPI. 12	Not Selected	19	26%

Upon concluding step 3, where 7 KPIs were identified, uncertainties persist regarding potential interactions among these KPIs and the factors influencing sanitation project performance. In order to unveil these potential relationships, we initiated step 4.

3.4 Questionnaire Survey evaluating efficacy of KPIs

A questionnaire survey was conducted to determine relation between the 7 KPIs affecting performance of sanitation projects in terms of the kind and degree of influence of each KPI with respect to other KPI. Table 5 determines the relationship between KPIs, serving as a step in applying the ANP methodology.

Table 5: Survey Template for Organizing Seven Performance KPIs Using ANP Methodology

Ser	KPI	Social	Schedule	Environmental	Health and Safety	Procurement	Quality
KPI.1	Cost						
KPI.2	Quality						
KPI.3	Procurement						
KPI.4	Health and Safety						

KPI.5	Environmental
KPI.6	Schedule
KPI.7	Social

4. Data Analysis and Results

This section presents the analysis of collected data, and the results derived from the expert evaluations. The findings provide insights into the background of Subject Matter Experts (SMEs), the evaluation of Key Performance Indicators (KPIs), and the application of the Analytic Network Process (ANP) approach for ranking these indicators. The consistency of judgments and the reliability of the results are also assessed to ensure the validity of the proposed performance evaluation model.

4.1 Subject Matter Experts (SMEs) Analysis

The Subject Matter Experts (SMEs) with experience in sanitation projects who were targeted in the questionnaires encompassed a diverse set of (individuals) SMEs covering various roles within the relevant project stakeholders, including Chairman/CEO, General Managers, Project Managers, Senior Engineers, and Site Engineers. According to Figure 3.2, the majority held the position/role of project manager. The total number of SMEs involved in the study was 98, which exceeds the sample size, ensuring a broader range of expert opinions and insights. The experiences of experts in construction projects are categorized as follows: (1) Less than 5 years, (2) over 5 up to 15 years, (3) over 15 up to 20 years, (4) over 20 up to 25 years, and (5) over 25 years. Most experts have experience ranging from over 20 years to up to 25 years, as illustrated in Figure 2

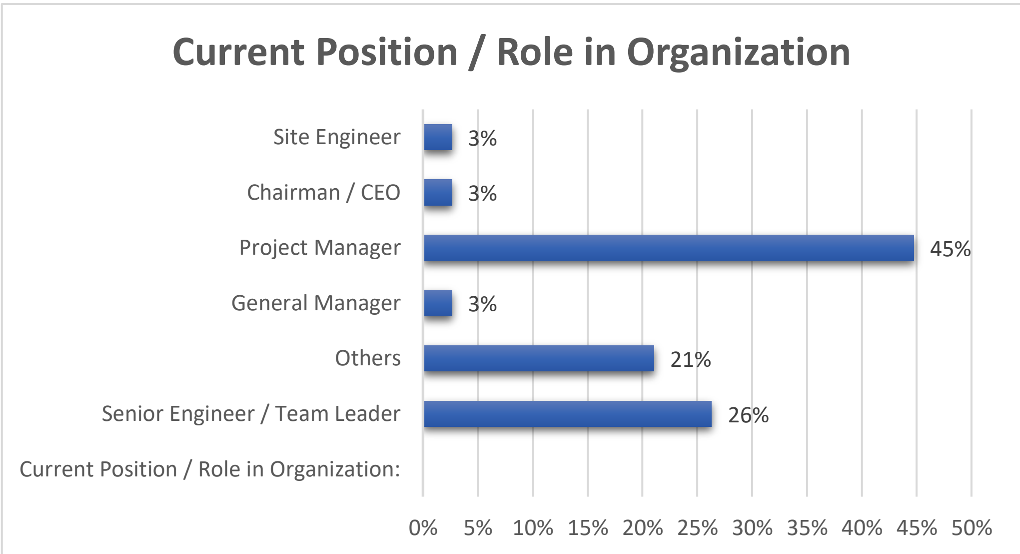

Figure1 Percentage of Frequency for the Experts Position / Role in Organization

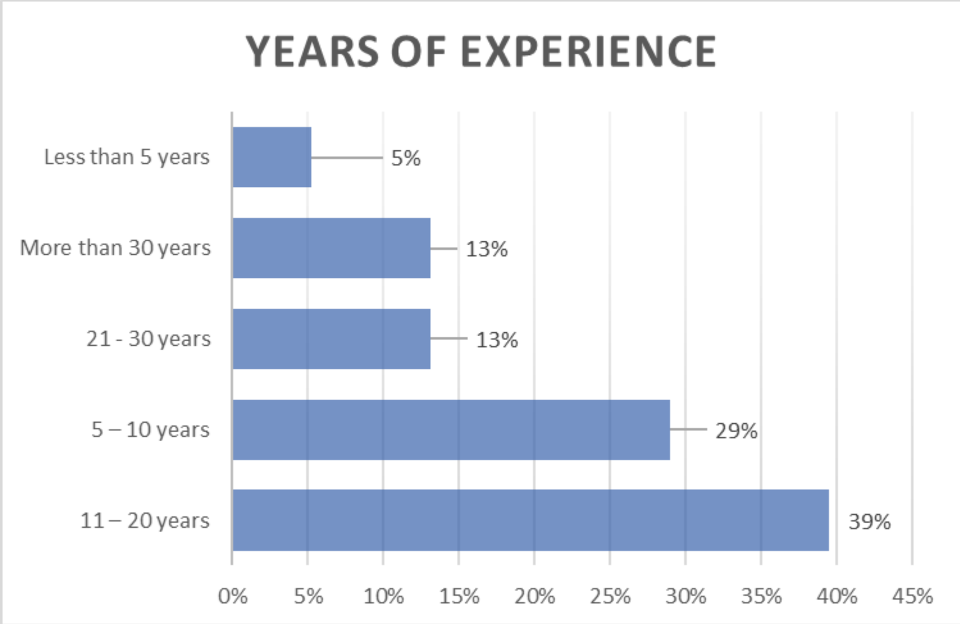

Figure 2 Percentage of Frequency for the Experts' Years of Experience the Role of Experts

The organizations were categorized into one of the following three types: (1) owner, (2) contractor, and (3) consultant/project management. Owners were the most frequent type, as illustrated in Figure 3.

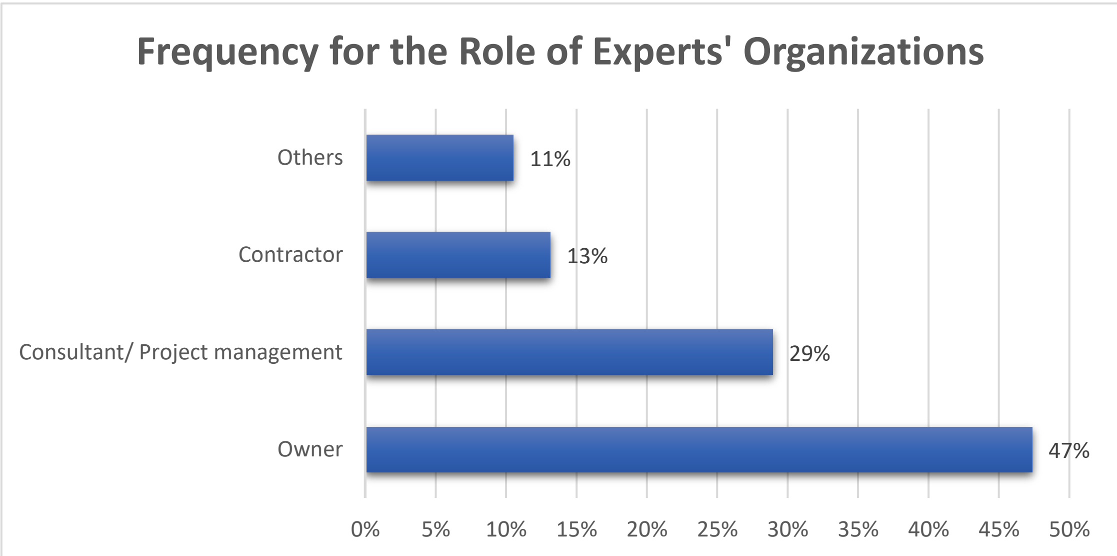

Figure 3 Percentage of Frequency for the Role of Experts' Organizations

4.2 Results Assessing the Evolution and Ranking of KPIs Using the (Analytic Network Process) ANP Approach

The intricacies and interdependencies among KPIs are examined by the ANP model.to establish the weight for each KPI, the decision network examined in this study consists of both hierarchical and interdependent links.

4.2.1 Pairwise Comparisons Matrix

Below is the geometric mean of the pairwise comparison matrices, which shows how relevant they are to the total project performance.

		KPI. 1	**KPI. 2**	**KPI. 3**	**KPI. 4**	**KPI. 5**	**KPI. 6**	**KPI. 7**
	KPI. 1	1.00	1.00	4.00	0.50	2.58	2.50	0.96
	KPI. 2	1.00	1.00	1.38	0.95	3.46	0.66	1.10
	KPI. 3	0.25	1.06	1.00	0.36	1.25	0.38	0.37
	KPI. 4	1.99	1.06	2.76	1.00	3.13	1.27	3.41
X =	**KPI. 5**	0.39	0.29	0.80	0.32	1.00	0.59	0.46
	KPI. 6	0.40	1.51	2.61	0.79	1.69	1.00	1.37
	KPI. 7	1.04	0.91	2.72	0.29	2.17	0.73	1.00
	Sum	**6.08**	**6.82**	**15.27**	**4.21**	**15.28**	**7.14**	**8.67**

4.2.2 Normalization of the Key Performance Indicators

This phase entailed computing the normalized matrix and then the weighted matrix in accordance with the procedural procedures previously outlined in the approach (Odu, 2019). This procedure was used to normalize the KPI metrics from a standard ratio scale to a relative ratio scale. Below are the weighted matrix and normalized eigenvectors for each KPI included in the model.

	KPI. 1	KPI. 2	KPI. 3	KPI. 4	KPI. 5	KPI. 6	KPI. 7	Sum
KPI. 1	0.165	0.147	0.262	0.119	0.169	0.350	0.111	1.321
KPI. 2	0.165	0.147	0.091	0.225	0.226	0.093	0.127	1.073
KPI. 3	0.041	0.155	0.065	0.086	0.082	0.054	0.042	0.526
KPI. 4	0.328	0.155	0.181	0.238	0.205	0.178	0.394	1.678
KPI. 5	0.064	0.042	0.052	0.076	0.065	0.083	0.053	0.436
KPI. 6	0.066	0.221	0.171	0.187	0.111	0.140	0.158	1.053
KPI. 7	0.172	0.133	0.178	0.070	0.142	0.103	0.115	0.913
Sum	1	1	1	1	1	1	1	

Eigen vector matrix (i.e. relative weights vector) V1

KPI. 1	0.189
KPI. 2	0.153
KPI. 3	0.075
KPI. 4	0.240
KPI. 5	0.062
KPI. 6	0.150
KPI. 7	0.130

4.2.3 Estimate of Consistency Ratio

Equation 6 is used as the first step of consistency analysis to produce the weighted sum vector. In this procedure, the vector of relative weights (w) is multiplied by the comparison matrix (A). Equation 7, which involves dividing the weighted sum vector by the eigenvector (weighted matrix), is then used to get the consistency vector.

$$\textbf{Weighted Sum Vector (V2)} = \begin{vmatrix} 1 & 1 & 4 & 0.50 & 2.58 & 2.50 & 0.96 \\ 1 & 1 & 1.38 & 0.95 & 3.46 & 0.66 & 1.10 \\ 0.25 & 1.06 & 1 & 0.36 & 1.25 & 0.38 & 0.37 \\ 1.99 & 1.06 & 2.76 & 1 & 3.13 & 1.27 & 3.41 \\ 0.39 & 0.29 & 0.80 & 0.32 & 1 & 0.59 & 0.46 \\ 0.40 & 1.51 & 2.61 & 0.79 & 1.69 & 1 & 1.37 \\ 1.04 & 0.91 & 2.72 & 0.29 & 2.17 & 0.73 & 1 \end{vmatrix} \times \overset{\text{V1}}{\begin{vmatrix} 0.189 \\ 0.153 \\ 0.075 \\ 0.240 \\ 0.062 \\ 0.150 \\ 0.130 \end{vmatrix}} = \overset{\text{V2}}{\begin{vmatrix} 1.4218 \\ 1.13 \\ 0.5534 \\ 1.8132 \\ 0.4652 \\ 1.1249 \\ 0.9834 \end{vmatrix}}$$

V3 = V2 / V1

Consistency vector =

KPI. 1	11.832
KPI. 2	11.589
KPI. 3	11.857
KPI. 4	11.824
KPI. 5	11.879
KPI. 6	11.807
KPI. 7	11.660

The final step is to calculate λ max, which involves averaging the values in the consistency vector according to Equation 8. This step is essential to the technique because it enables decision-makers to gauge the quality of the decision-making process and the degree of consistency in their assessments. In the fourth and fifth steps, the Random Consistency Index Table and the consistency index (CI) equation are used to compute the CI and RI, respectively (Saaty et al., 2013). the CR by dividing the CI by the RI, which entails doing so for a comparison matrix of the same size.

- $\lambda_{max} = 7.475$
- $CI = \frac{7.45-7}{7-1} = 0.079$
- RI = 0.13
- $CR = \frac{0.079}{0.13} = 0.05938$

One important indicator of the dependability of the computed relative weights is the ANP's CR (Navarro et al., 2022). Given that the calculated CR in this instance is 0.05938, which is less than the generally recognized cutoff of 0.1, it can be concluded that the rulings are reasonable and consistent. This discovery highlights the strength of the decision-making process and boosts decision-makers' confidence in the results. In conclusion, we have obtained the weights for each performance indicator after applying the ANP approach and conducting the necessary checks, as depicted in the table below.

Table 6: Overall Performance Weights

Ser	(KPIs)	Weight n = 7	Weight n = 1	Percentage weight
KPI. 1	Cost	1.329	0.190	19%
KPI. 2	Quality	1.080	0.154	15%
KPI. 3	Procurement	0.482	0.069	7%
KPI. 4	Health and Safety	1.686	0.241	24%
KPI. 5	Environmental	0.438	0.063	6%
KPI. 6	Schedule	1.064	0.152	15%
KPI. 7	Social	0.919	0.131	13%
Total		**7**	**1**	**100%**

5. Conclusion and future works

Improving the performance of infrastructure projects is crucial for contractors and facilities owners, particularly in achieving optimal wastewater service coverage. This necessitates continual enhancements driven by vigilant monitoring and control of project performance. Through an extensive review of literature, we identified 93 factors, which were then analyzed through semi-structured interviews, resulting in 73 factors applicable to all types of projects. Additionally, our study identified 37 factors specifically relevant to sanitation projects. However, using all these factors directly for project performance evaluation presents challenges. Therefore, we identified 7 (KPIs) that significantly enhance construction project performance. Through a survey, we established the impact of these KPIs on sanitation project performance and determined the top-ranked KPIs to focus on, resulting in the identification of 7 key ones. Moreover, we proposed an integrated Analytic Network Process (ANP) model for assessing and appraising the performance of sanitation infrastructure projects, assigning weights to each KPI.
After obtaining the 7 KPIs, a model was developed to measure and evaluate performance. Future research will focus on developing a model that encompasses the entire construction phase cycle. Since all projects, regardless of size or type, show similar evolutionary trends, this model must be generic in nature. In order to better understand how performance KPIs interact with one another, the suggested model will replicate current dependencies among sanitation infrastructure project KPIs and their changes over time.

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