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Original Article

Critical Success Factors for Successful Completion of Sustainable Public Sanitary Projects in Smart City

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Abstract *- In the era of smart cities, the problem of insufficient upkeep and cleanliness in public restrooms remains, discouraging people from utilizing them despite their availability. This article investigates using smart features in public toilets to solve this problem while promoting sustainability, public health, and user experience. Automated flushing, remote monitoring, and real-time occupancy status displays are examples of smart features that improve efficiency and cleanliness. The research divides project management, procurement, client, design team, and contractor-related factors into essential aspects that influence the successful completion of smart, sustainable toilet projects. Then, the relative relevance of these aspects will be assessed through a thorough survey and statistical analysis, establishing a framework for implementing smart, sustainable toilet projects. The research employs a structured questionnaire and statistical analysis with SPSS software to ensure the reliability and validity of the results. The study evaluates dependability, model fit, and the relative relevance index.*

Keywords *- Smart Public Toilet, Smart City, Project Management, Critical Success Factors, SPSS.*

1. Introduction

Creating "smart cities" has been a goal for several governments in recent years as a means of enhancing the lives of their residents [1]. This action raises living conditions and promotes long-term sustainability by making cutting-edge ICTs more accessible to the general public. Despite their many advantages, smart cities confront significant hurdles in terms of trust, dependability, privacy, and security [2]. Public restrooms have always been a subject of debate.

In today's cutting-edge world, where every nation is expanding and building smart cities, sanitation and hygiene are under threat. Despite the existence of public restrooms across the country, their maintenance is inadequate. As a result, many people refuse to use the bathrooms, even though they are available. Smart toilets are a vital component of smart cities since they promote sustainability, improve public health, and enhance user experience.

Cities may seek to ensure the safety, accessibility, and quality of public bathrooms by incorporating smart toilets into their infrastructure. Smart public toilets will have features such as automated flushing, remote monitoring via mobile phones, automatic wall and floor cleaning, and occupancy status display. As a result, residents will profit, and their health will improve. According to an international survey, several large nations have already developed fully automated smart toilets that can perform all functions, including data collection and automatic toilet cleaning, without requiring human interaction, except for system maintenance. Building this fully automated system is expensive, and not all public bathrooms can utilize it. [3] According to the literature review, contractors in India often hire cleaners or labourers to physically clean restrooms since no technology exists to automate the process.

The Smart City Mission is an Indian government initiative that seeks to rehabilitate and rejuvenate urban areas. The Ministry of Urban Development, under its leadership, aims to establish one hundred sustainable and environmentally friendly smart cities across the nation.

Water management and energy conservation are critical to the environmental development of a smart city. It looks at innovative and cutting-edge technology used to build self-sufficient and intelligent toilet systems while considering the ecological growth requirements of smart cities. [4] employs an inexpensive IoT motion detection device to improve workplace ease and efficiency.

The research examines how people use the toilet when more than 20 people work there. Because there is only one bathroom on that level, individuals may leave their workplace only to find the occupied restroom. Therefore, propose a technique that uses an infrared sensor to detect toilet occupancy and an Arduino circuit-based approach to notify individuals. People with vision impairments may be utilizing the public bathrooms. Istanbul Technical University developed the loud step system to assist blind individuals in using public restrooms (ITU). Istanbul Technical University has also devised a lightweight glass system with audio assistance for visually impaired people. People who are blind or visually impaired may be able to see the outside world with this proposed prototype. Even better, it can warn the user of the glasses by anticipating external stimuli. [5]

A visual signal could potentially help users save time in public bathrooms, thereby improving user design. Most public bathrooms lack conductors or workers who guide and keep visitors in unoccupied stalls. Many public bathrooms already feature these visual clues. Color-changing locks, colorful digital doors, flags atop cubicles, and automatically opening weighted stall doors are some examples. [6] They recommend using a mobile flush toilet. Finding a suitable restroom during an emergency can be challenging.

Shelters face challenges in maintaining clean bathrooms due to damage to essential infrastructure. The purpose of this project is to design a portable flush toilet with its own drainage, electrical, and water supply. They successfully conducted the field test in flood-damaged regions. Place this mobile toilet near public buildings that serve as emergency shelters during a disaster to enhance access to clean bathrooms.

Furthermore, impoverished nations with limited infrastructure may utilize this toilet design. [7] In this context, the PCMC area conducts a survey as part of the smart city planning process to determine the future demand for public toilets in various parts of the city, considering the current availability of such toilets for the floating population, the projected population growth in the coming years, and the operational life of existing toilet blocks.

The evaluation findings establish that the first stage necessitates the construction of public toilets at 26 sites throughout the city, focusing on maintaining the highest level of sanitation, minimizing water waste, and ensuring 24/7 availability for consumers. As a result, the suggested toilets should have smart characteristics. This novel project concept has resulted in greater livability, economic viability, and sustainability. The project currently envisions 26 toilet blocks.

However, the project may replace other toilet blocks in the city with smart toilets. This study examines the key aspects of Smart Sustainable Public Toilets (SSPT) and identifies and analyzes the crucial variables for their effective completion

1.1. Features of Smart Toilets

- Water conservation: Low-flow fixtures, efficient flushing mechanisms, and other water-saving technology are critical components of smart toilet design. Cities may save money and resources and use less water by doing so.

- Hygiene monitoring: Smart toilets may provide real-time use and cleanliness statistics due to sensor and other technology integration. Cities can use this data to pinpoint areas that require cleanliness attention and implement proactive measures to safeguard public health.

- Real-time data: Smart toilets can provide cities with real-time data on use patterns, water consumption, and cleanliness standards, enabling them to better understand and manage their sanitation infrastructure. This information may enhance cleaning and maintenance schedules.

- Smart toilets may enhance the user experience by providing additional amenities such as hands-free fixtures, comfortable chairs, and appealing lighting. This might encourage more people to use public bathrooms, which would benefit both health and cleanliness.

1.2. Critical Factors Affecting Success of the Smart Sustainable Toilets Project (SSPT)

The literature research and expert debate provide the basis for this discussion. Figure 1 depicts several critical elements that may impact the performance of the SSPT.

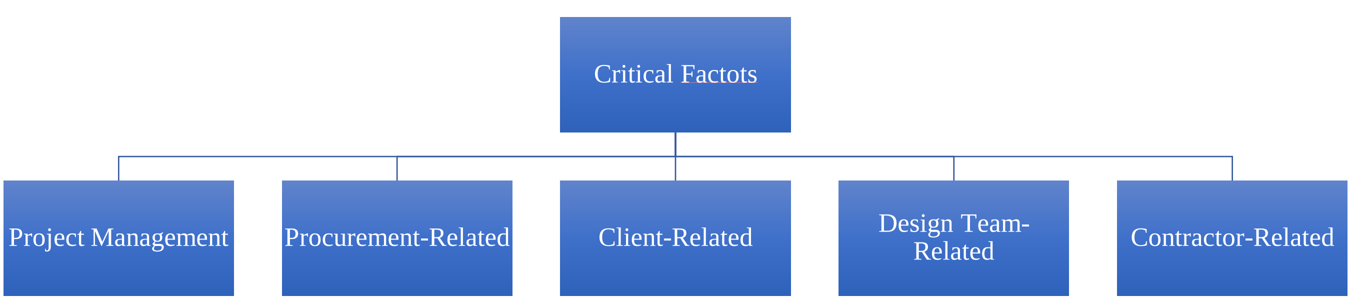

Fig. 1 Critical factors affecting the success of smart sustainable toilets project

1.2.1. Project Management Factors

Managers of construction projects may raise the chance of success by adopting essential project management processes. The following aspects of project management are important to consider.

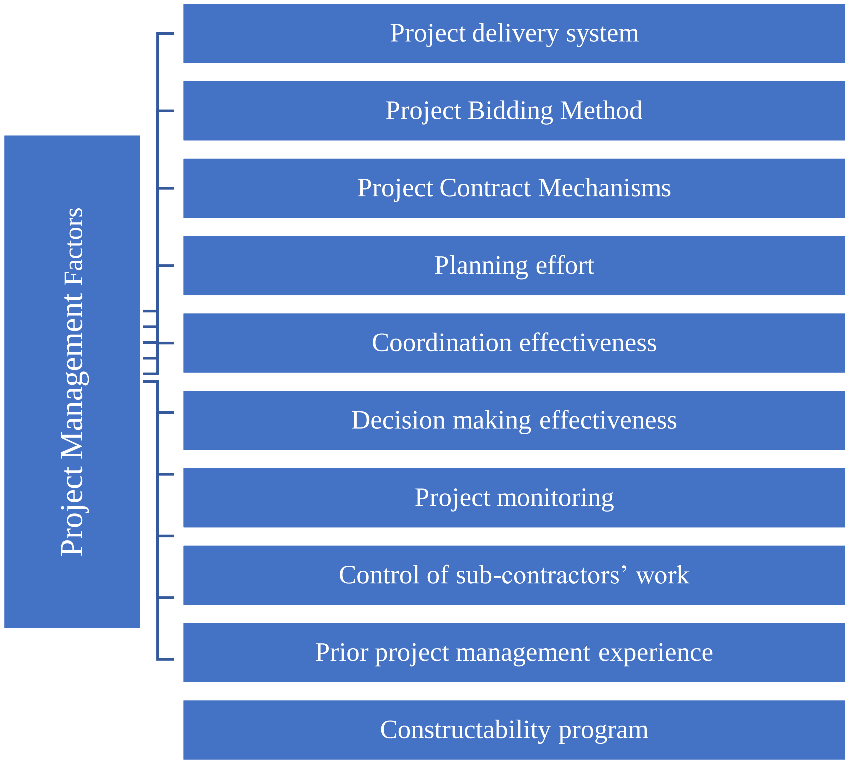

Fig. 2 Project management factors

1.2.2. Procurement-Related Factors

Numerous scholars have underscored the significance of procurement criteria in determining the scope of a contract, as it influences the execution, acquisition, or acquisition of construction activities. As a result, the factor is assessed by two factors: the procurement process used to pick an organization to design and develop a project and the tendering methods used to select project teams, namely key contracting organizations.

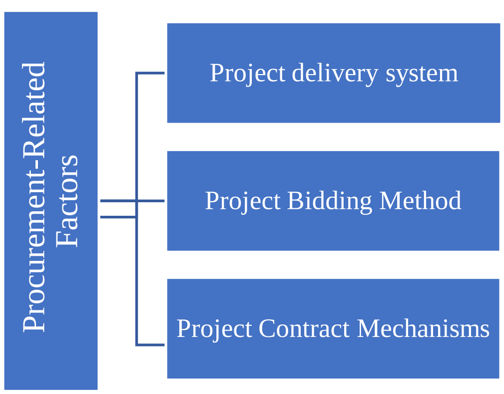

Fig. 3 Procurement-related factors

1.2.3. Client-Related Factors

The literature identified important stakeholders as project managers, clients, contractors, consultants, subcontractors, suppliers, and manufacturers. The following are client-related factors.

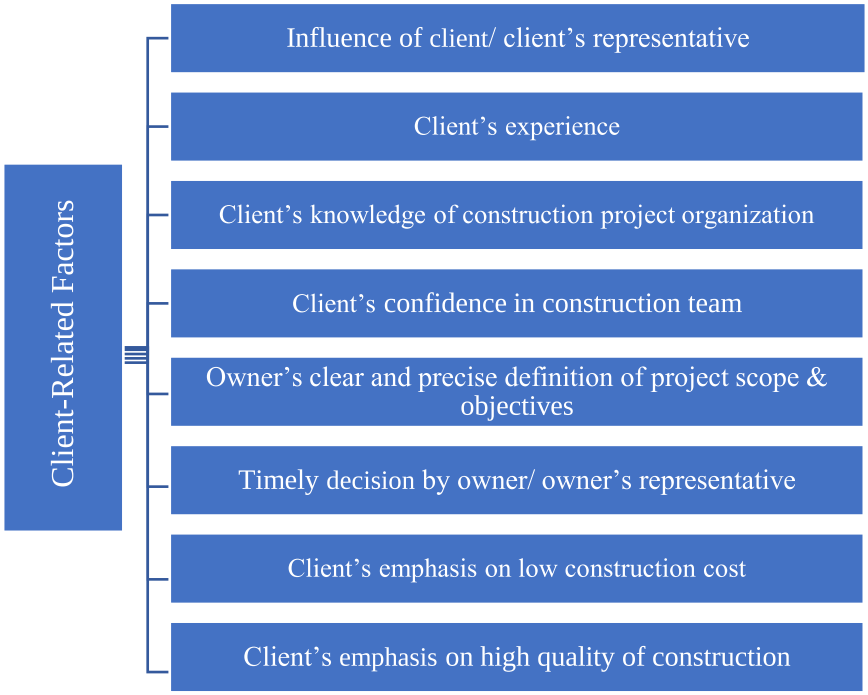

Fig. 4 Client-related factors

1.2.4. Design Team-Related Factors

Designers play an important role since their work spans the whole project life cycle. The following are design team-related variables.

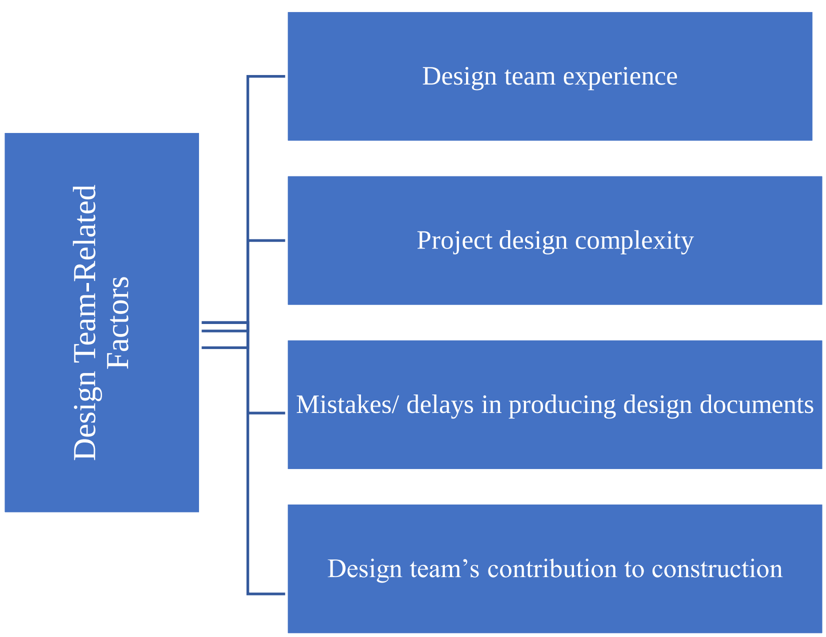

Fig. 5 Design team-related factors

1.2.5. Contractor Related Factors

When a project enters the construction phase, the primary responsibilities of the general contractor and any subcontractors are evident. Contractor-related aspects are given below.

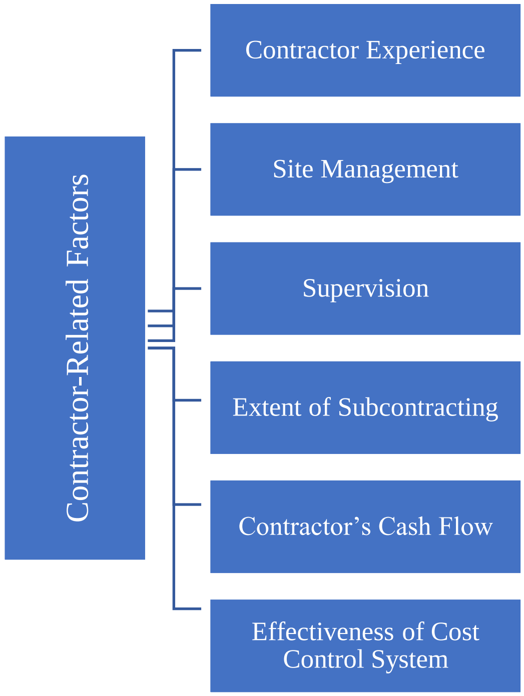

Fig. 6 Contractor-related factors

2. Methodology

To assess the aforementioned parameters, ran an online survey. Developed a detailed and easily accessible survey. Structured the survey questionnaire into five pieces. The first component comprises basic information such as the individual's name, title, firm name, and years of experience. Split the second half of the survey into four sections: A, B, C, and D. Requested that stakeholders score the solution on a five-point scale.

Built into the following components: A deals with project management, B with procurement, C with clients, D with design teams, and E with contractors.

Sent the questionnaire to academic institutions, civil engineering businesses, and government and commercial sector groups. However, only a small number of these entities could not respond, and even fewer provided comprehensive responses. A deleted 17 of the 135 survey questionnaires received because they were incomplete. Each of these responses has its own set of consequences. Used SPSS to carry out statistical analysis and reliability tests. Employed factor analysis to derive the survey's outcomes.

2.1. Reliability Check for Data

In order to guarantee that the sample size was adequate, SPSS was implemented. The number that was discovered using SPSS is illustrated in Table 1. The number may have any value between 0 and 1. The fact that the value of Cronbach's Alpha in this situation is 0.856, which is more than 0.6 and very near to 1, indicates that the sample size of the questionnaire is sufficient for deriving reliable findings.

Table 1. Statistics on reliability

Cronbach's-Alpha	Standardized Items-Cronbach's Alpha	Number of Factors
0.856	0.743	31

2.2. Feasibility of Factor Analysis

Table 2 demonstrates how the Bartlett and Kaiser-Meyer-Olkin (KMO) tests are used to determine if factor analysis is beneficial. Furthermore, Bartlett's sphericity test ensures that questionnaires may be utilized for factor analysis. It was considered a good approach since factor analysis yielded a KMO statistic value 0.743, which was more than 0.5 and near one. Bartlett's Test of Sphericity was used to get the p-value (Sig.) at a 95% significance level. Factor analysis proved to be the most effective method for analyzing the data.

2.3 Internal Consistency of Data

It shows how closely items in each component match, indicating scale reliability. Items that assess the same underlying concept effectively have a higher Cronbach's alpha score, suggesting a better internal consistency.

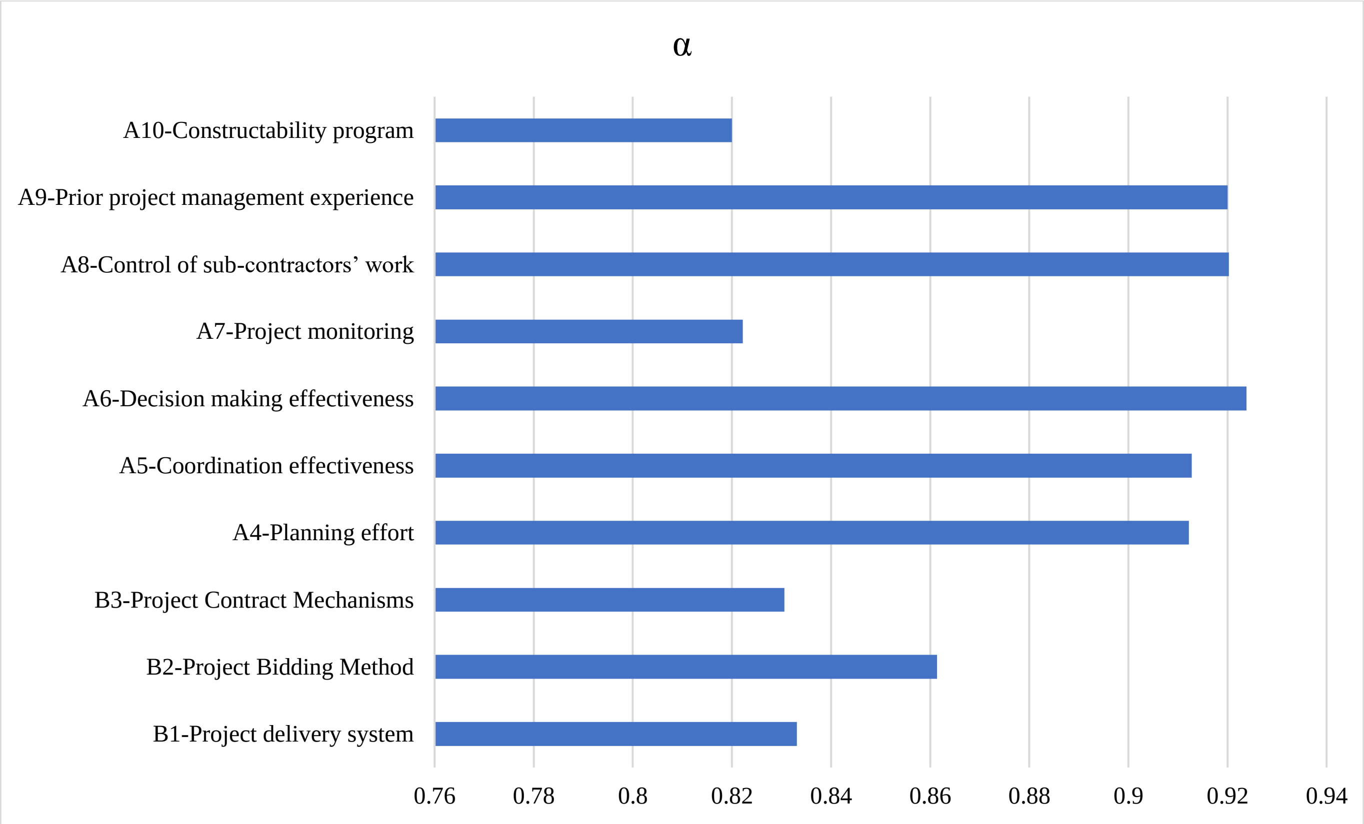

Fig. 7 Cronbach's alpha for the identified factors of project management factors

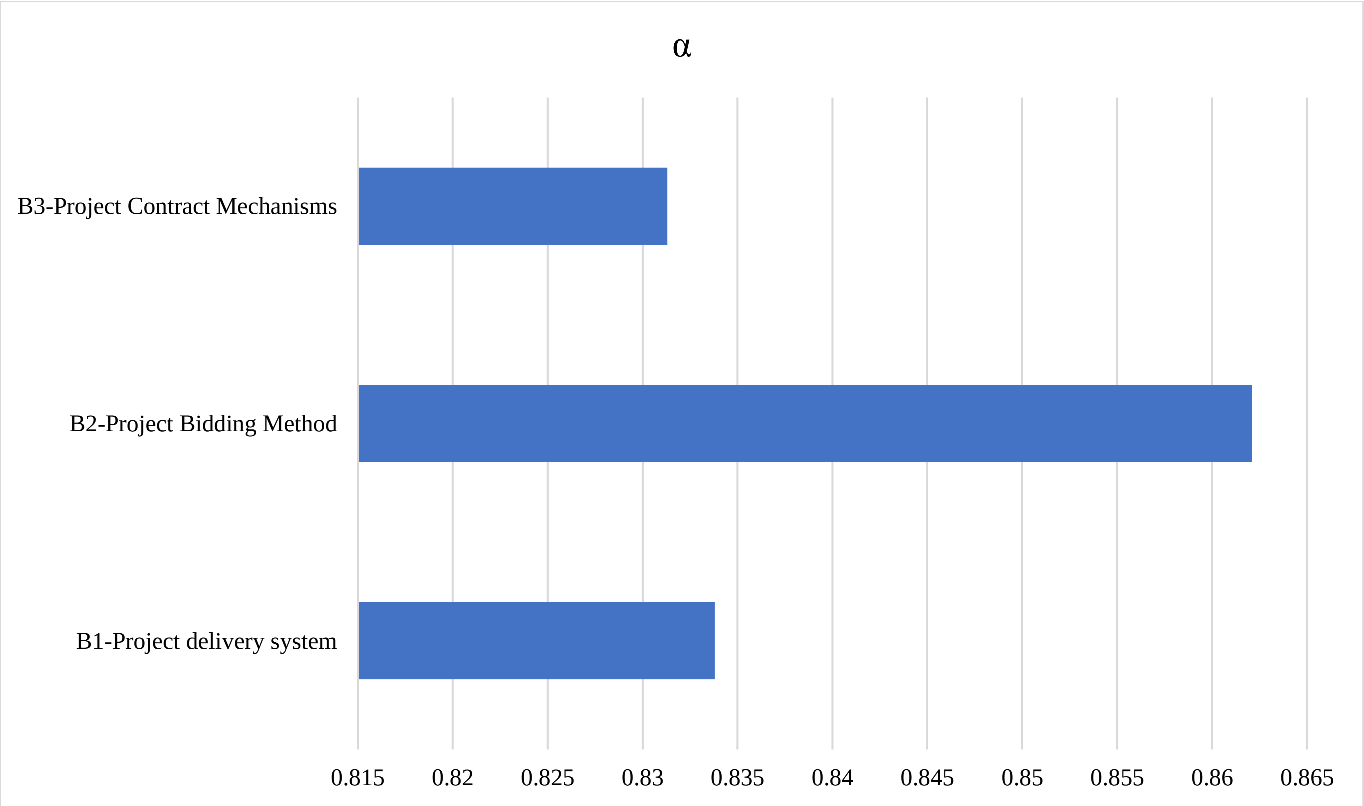

Fig. 8 Cronbach's alpha for the identified factors of procurement-related factors

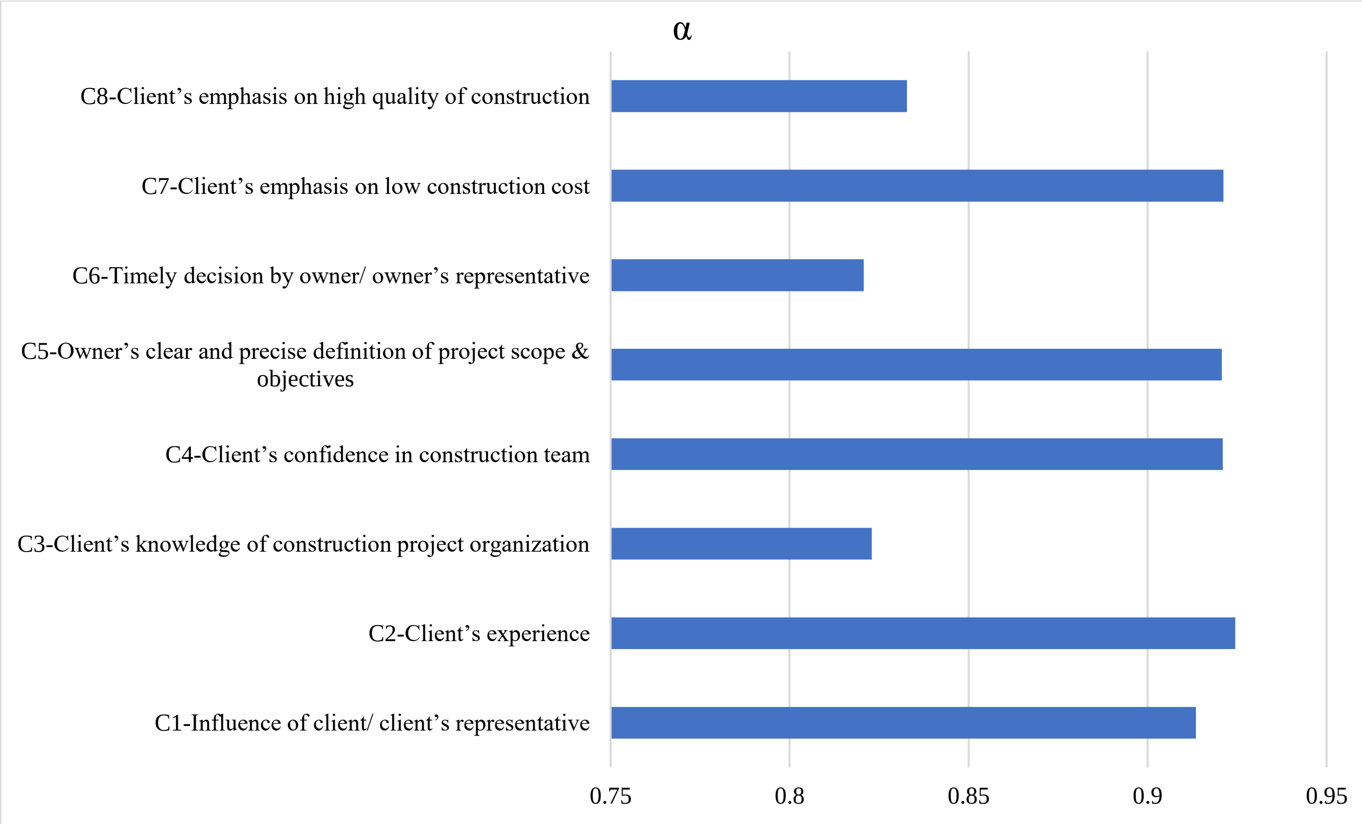

Fig. 9 Cronbach's alpha for the identified factors of client-related factors

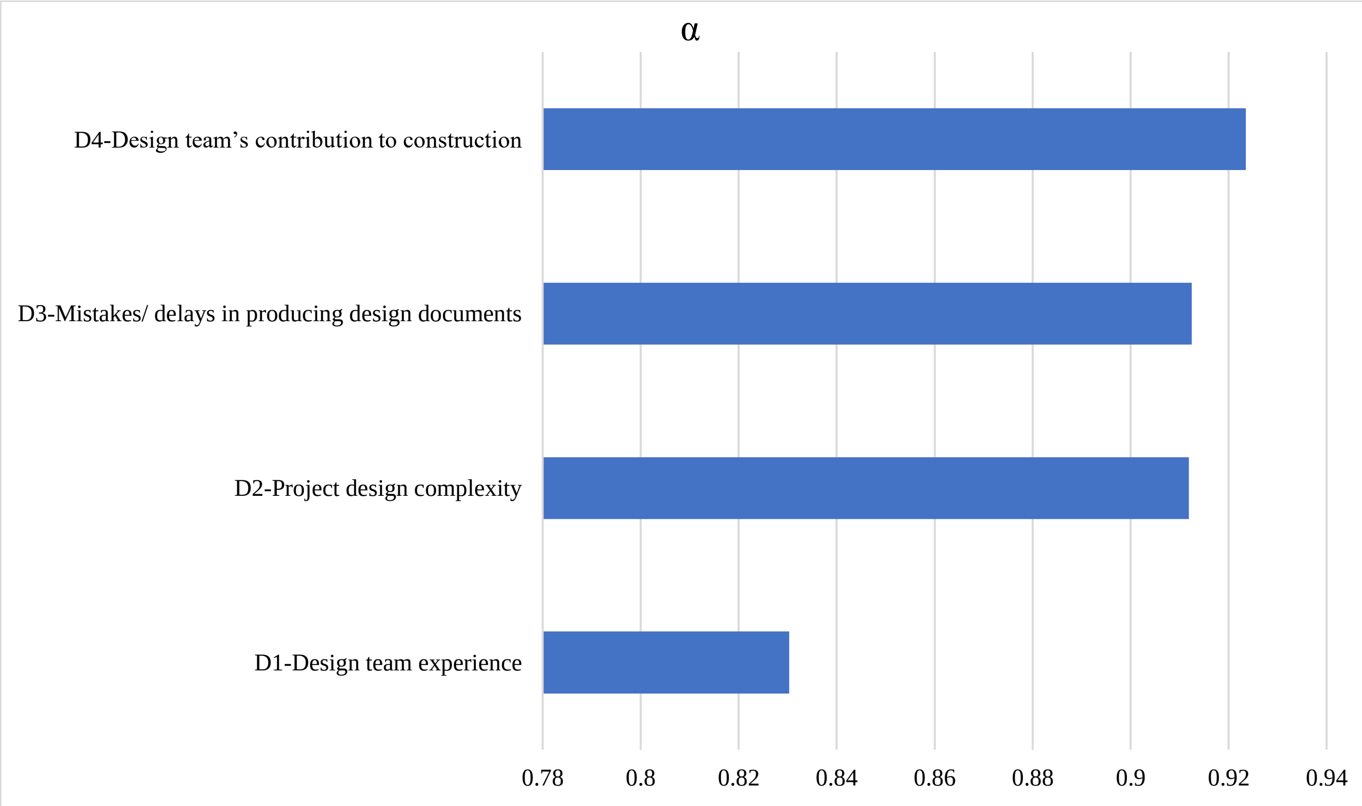

Fig. 10 Cronbach's alpha for the identified factors of design team-related factors

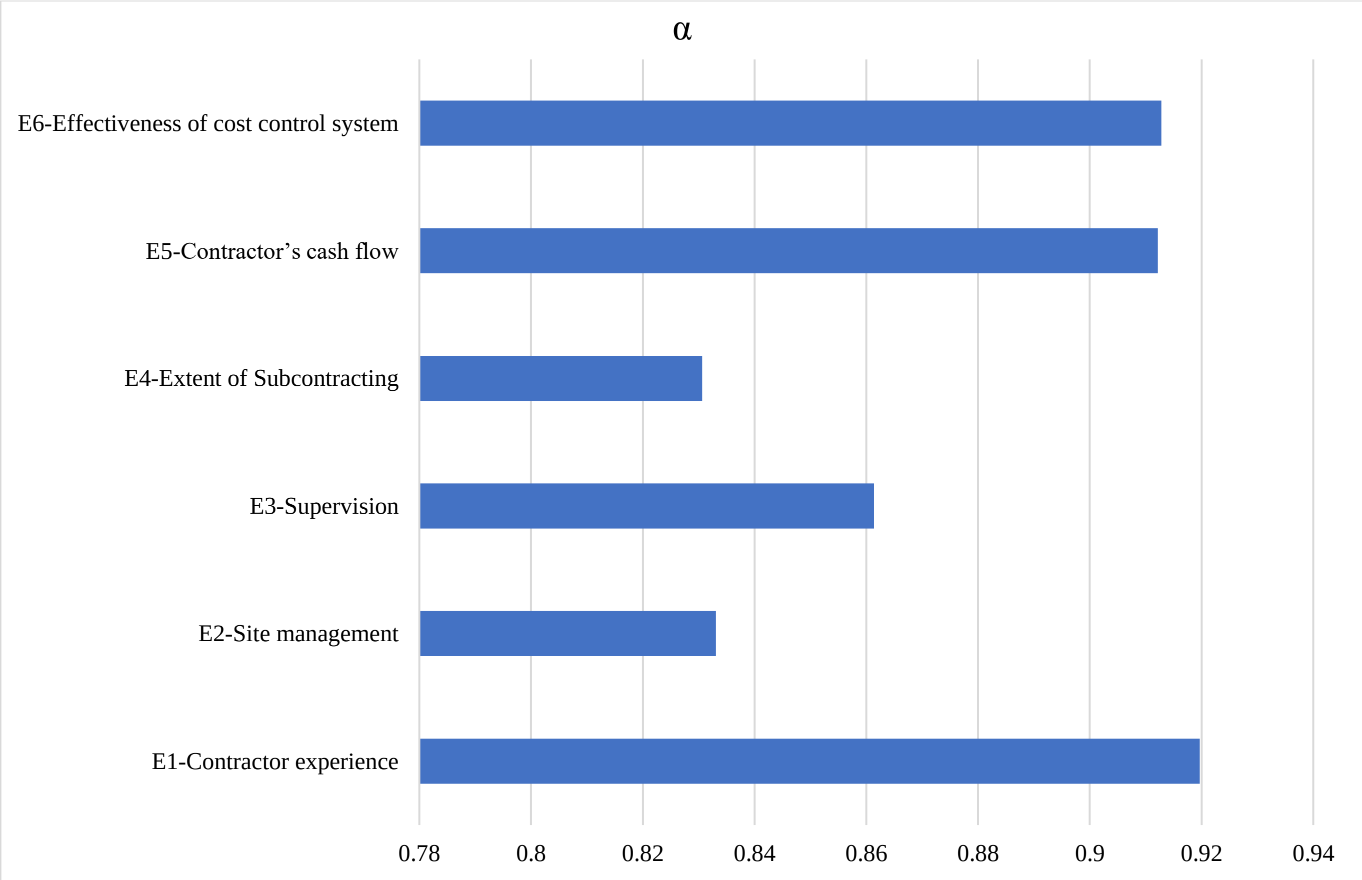

Fig. 11 Cronbach's alpha for the identified factors of contractor-related factors

Next, the study's internal consistency is assessed using the correctness or fineness criteria, following the reliability analysis. More than 0.80 was the Cronbach's alpha. Given that it exceeds the commonly accepted threshold of 0.7, it may be inferred that the data was internally consistent.

2.4. Identification of the Major Influencing Factors

The Rotated Factor Matrix displayed rotated factor loadings, which are correlations between variables and factors. The element segment displays the transformed variables, separated from the entire component. These fundamental characteristics were selected as the final factor after reducing the data. Gave each set of factors a name that matched the factor grouping, reflecting both the grouped factor and its individual components. This research applies the Varimax Orthogonal Rotation Factor Rotation technique. Figure 7 depicts the identified primary influencing elements for successfully completing the SSPT. 14 of the 31 variables were recognized as important impacting factors.

2.5. Model Fit and Quality Indices

The APC averages 0.928. The average route rating of 0.90 suggests a favorable match. Some contend that R2 equals 0.941. R2 is a statistical indicator that always varies between 0 and 100%. Therefore, a model that disregards the volatility of the response variable around its mean would be unable to provide any meaningful explanation. The regression model, in conjunction with the dependent variables, has the potential to predict the response variables. A model fits 100% of the data if it can explain all variations around the response variable's mean. Greater R2 values often indicate a better fit between the regression model and your data. A GoF of 0.137 denotes an outstanding match. The goodness-of-fit (GOF) score reflects how well the model describes the trial data. The GOF ratings range from 0 to 1, indicating the strategy's global approval. Giant equals 0.36, medium 0.25, and small 0.10. Models that fit are functional.

2.6. Relative Importance Index

Statistical Package for the Social Sciences (SPSS) was used to facilitate the review, and the Relative Importance Index (RII) was used to identify the most essential components.

$$RII = \Sigma W / (A*N) \ (0 \leq RII \leq 1).$$

An integer between 1 and 5 was assigned to the variable "weight," with 1 representing "strongly disagree" and 5 "strongly agree." The poll had a maximum value of 5, and N persons filled it out.

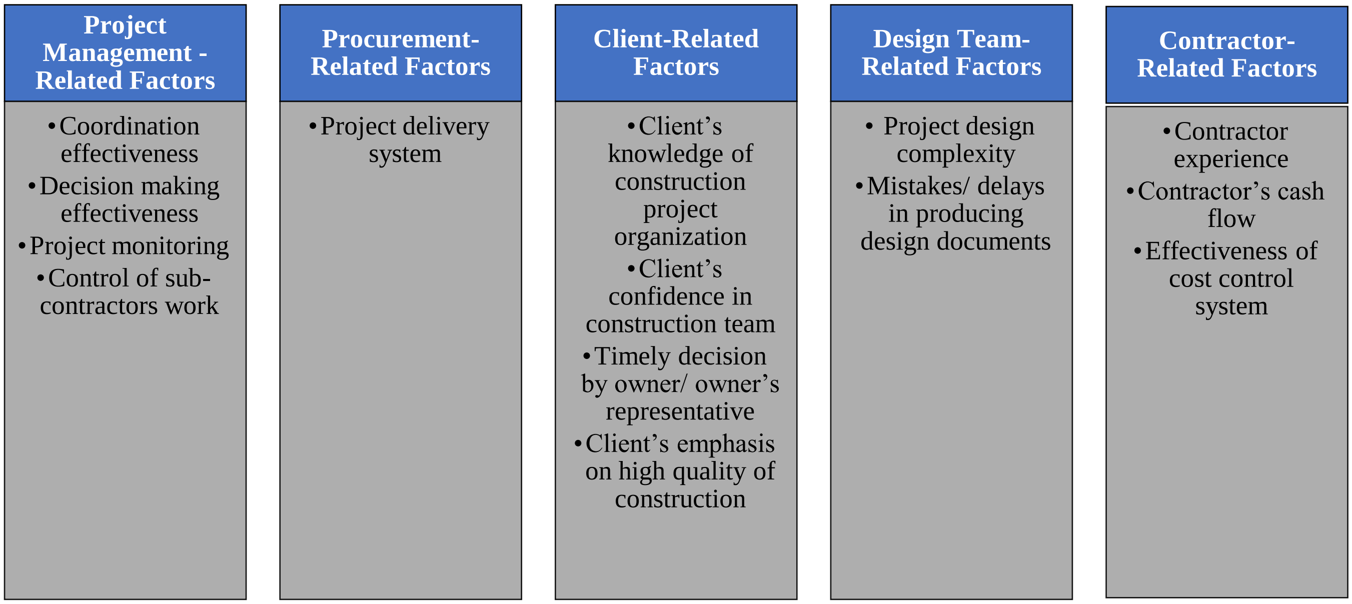

Fig. 12 Major influence factors for successful completion of SSPT

Table 2. Relative importance index for causes

Sr. no.	Variables	RII	Rank
1	Coordination effectiveness	0.906	1
2	Decision-making effectiveness	0.903	2
3	Project delivery system	0.896	3
4	Client's knowledge of construction project organization	0.896	4
5	Client's confidence in the construction team	0.893	5
6	Contractor experience	0.893	6
7	Contractor's cash flow	0.89	7
8	Project monitoring	0.872	8
9	Control of sub-contractors' work	0.866	9
10	Timely decision by owner/ owner's representative	0.862	10
11	Project design complexity	0.862	11
12	Effectiveness of cost control system	0.859	12
13	Client's emphasis on high-quality construction	0.856	13
14	Mistakes/ delays in producing design documents	0.856	14

3. Case Studies of Smart Toilet Implementations

Various metropolitan settings across the globe have successfully tested smart toilet implementations, demonstrating their potential to improve public health and resource management. For example, Tokyo's "Washlet" initiative combines modern bidet technology with real-time health data collection, allowing for early identification of diseases such as diabetes via urine analysis. In Singapore, smart public bathrooms use IoT sensors to track use trends and improve cleaning schedules, lowering maintenance expenses by 30%. Similarly, India's "e-Toilet" effort combines solar-powered devices with remote monitoring systems to offer cost-effective and environmentally friendly sanitation solutions in rural regions. These case studies demonstrate the several advantages of smart toilets, including enhanced cleanliness, sustainable water usage, and increased accessibility in both urban and underprivileged regions.

3.1. User-Centric Design Approaches in Smart Toilets

Including user experience in designing and functioning smart toilets is critical for improving usability, acceptability, and public health results. The user-centric design focuses on understanding varied users' requirements, interests, and behaviors in order to produce solutions that are simple, accessible, and inclusive. Automated cleaning, tailored settings, voice help, and touchless controls are examples of features that cater to hygiene and comfort of use, especially for the elderly or differently abled. Furthermore, privacy concerns and cultural sensitivity are important in determining the user interface and form factor. Smart toilets may bridge the gap between cutting-edge technology and daily comfort by emphasizing user input and iterative testing, enabling wider adoption while contributing to better sanitation and health inequities.

3.2. Cost-Benefit Analysis of Smart Toilets

Examining the economic viability of smart toilets demonstrates both short-term and long-term advantages over standard sanitation methods. While smart toilets have higher upfront installation costs due to advanced technologies such as IoT sensors, automated cleaning systems, and water-saving features, the long-term savings from reduced water consumption, optimized maintenance schedules, and reduced downtime frequently outweigh these initial investments. For example, IoT-enabled monitoring decreases the frequency of unneeded cleaning, saving labor and resource expenses, while real-time notifications for defects save costly repairs. Furthermore, greater user happiness and cleanliness lead to larger social advantages, such as improved public health and productivity. By weighing these savings against the initial expenses, decision-makers may make data-driven decisions to justify the change to a more sustainable infrastructure.

3.3. Future Trends in Smart City Infrastructure: Smart Toilets

The emergence of smart toilets has the potential to impact the future of urban sustainability and public health. Emerging technologies such as AI-powered analytics, improved biosensors, and seamless interaction with smart city networks may provide predictive maintenance, health monitoring, and effective resource management. For example, future smart toilets might examine biomarkers for early illness diagnosis and exchange anonymized data with healthcare practitioners, thus contributing to proactive public health efforts. Advances in water-recycling technology and solar-powered units may increase their environmental effect, harmonizing with cities' green infrastructure aspirations. Furthermore, the use of augmented reality (AR) interfaces may give users individualized counseling or health insights, increasing accessibility and acceptance. These technologies have the potential to solve the combined challenges of increasing urban populations and constrained resources, resulting in smarter, healthier, and more resilient cities.

4. Conclusion

The article discusses the problem of poor maintenance and cleanliness in public restrooms, especially in the context of constructing smart cities. Although public restrooms are provided, their unsatisfactory condition often discourages people from utilizing them. The research proposes incorporating intelligent elements into public restrooms to boost sustainability, promote public health, and enhance the user experience. Smart toilets have automated flushing, remote monitoring, and real-time occupancy status indications. These features are intended to ensure public restrooms' functional and sanitary operation. Furthermore, water saving, hygiene supervision, and user experience improvements are important factors in the design of smart toilets. The study finds several critical factors that aid in successfully implementing smart toilet projects, including project management, procurement, clients, design teams, and contractors. Overall, found 31 variables. A questionnaire-based survey was performed. The reliability test findings showed that the questionnaire had a sufficient sample size (Cronbach's Alpha = 0.856). The viability of the factor analysis data was assessed using the Bartlett and Kaiser-Meyer-Olkin (KMO) tests. The values of 0.743 and 95% suggested that the submitted data set was appropriate for factor analysis. Cronbach's alpha was used to measure dependability. Cronbach's alpha was over 0.8, showing internal consistency. Utilized the Rotated Factor Matrix to identify the main impacting elements. Detected 14 factors out of a total of 31. The selected criteria were ranked according to their relevance. The ranking shows that coordination effectiveness is the most important attribute, followed by decision-making effectiveness.

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