Innovations

A fuzzy-based framework for public buildings' construction projects evaluation

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Abstract: *Public building construction project management helps ensure building sustainability, making stakeholders focus on different aspects of managing the projects. Currently, sparse information exists on how to adequately and effectively manage the project because the existing frameworks focus on individual aspects of the managing process, such as costing and personnel management. Hence, this study aims to develop a framework for managing public building construction projects (BCP). It developed a fuzzy balanced scorecard (FBSC) framework for evaluating contractors' performance in public BCPs. Fuzzy analytical hierarchical process (FAHP) to determine the importance of public BCP evaluation criteria. Data were gathered from selected project stakeholders in the six locations in Southwest Nigeria. The results from the framework showed that the second location had the best performance. The overall performance of the developed framework in terms of financial criteria was 99.07%, while the clients' criteria generated 96.59%.Furthermore, the internal process criteria had an overall performance of 93.67%, while the learning and growth criteria had an overall performance of 95.44%. The information demonstrated that it is possible to compare the performance of locations from four perspectives. It highlights locations that could be used as benchmarks for enhancing the performance of public BCPs. The information from this study is important for anyone involved in the building construction business.*

Keywords: 1.*Project management, 2.building construction, 3.balanced scorecard, 4.AHP, 5.fuzzy logic*

1. Introduction

Scholarly works on infrastructure are increasing as the world's population rises. The scholarly works are carried out to ensure best practices in infrastructure management because of the huge investment cost involved during infrastructure construction. Costs for the rework and compensation of a failing infrastructure also provide another reason why researchers are interested in the demand and management of infrastructure. Some scholars are motivated to produce scholarly works in the infrastructure domain because of the need to guide policy-makers on the importance of meeting the United Nations (UN) sustainable development goals, particularly Goal 9 [1], [2]. Policy-makers provide guidelines for project monitoring and evaluation for different construction stages: the preparation and foundation of the structure; completion of rough frame; completion of rough plumbing, electrical heating, ventilation, and air conditioning systems (HVAC); isolation facility, the finish of drywall and interior fittings, as well as the start of Work Breakdown Structure (WBS) created by specialists from the architectural, engineering and building (AEC) sector.

Project monitoring of public buildings is essential in the global development of public building projects [3]. This goal focuses on developing robust infrastructure and the promotion of sustainable industrialisation and innovation[2]. Several scholars believe that attaining the minimum requirements for this goal is directly proportional to a society's standard of living [4]. This assertion is evident in the dichotomy between developed and developing countries. As a result, contemporary research on infrastructure management has reported articles because of the significance of infrastructure monitoring and control [5]. It is a process that begins and ends throughout the project's life cycle [6].

Recently, there have been recurring incidences of building collapse, especially in developing countries; these have made experts in the AEC sector call for a permanent solution to this problem [7], [8]. Scholars have opined that the efficacy of the license-to-work system in most countries must be rigorously assessed to avoid replications in public facilities. The inability to build projects in most developing nations has been associated with derisory planning of the project's execution and inefficient monitoring [9]. In addition, without the proper monitoring and assessment procedure, a properly planned project cannot achieve the intended project conclusion[10]. The participants in the built environment need to adopt a holistic approach since it is hard to monitor and effectively assess a poorly planned project. Hence, project managers must consider, plan and conduct monitoring and assessment of all projects from start to finish [11].

Project monitoring and assessment for building buildings are complex because several factors must be considered and evaluated to guide practitioners. Hence, this study addresses the challenges associated with proper monitoring and assessments of public building projects. Its aims to develop a framework for effectively managing public BCPs to improve the project's profitability. One of its contributions to project management literature is presenting a novel approach to public BCP management. The approach can simultaneously generate practical information that will assist project managers in making solid decisions toward successful projects. Another contribution is that it presents an approach that offers the possibility of conducting internal and external benchmarking of public BCPs. This concept allows stakeholders to problem shoot their performance based on industry standards.

The remaining study's sections are divided into the following groups: Section 2 discusses project production management, while Section 3 provides a framework for assessing contractor performance in public building construction. Section 4 presents the case study used for the framework evaluation; section 5 discusses the applicability of the suggested framework. Section 6 of this study contains the conclusions.

2. Building Production Management (BPM)

BPM is the administration of building production information, tools, supplies, labour, and other resources utilised to actualise a construction project while abiding by building regulations and contractual terms [12]. According to the [13]. It is regarded as the central role or scope of the professional services builders provide to clients in any building project. Hence, it could be referred to as the overall management of on-site building production. Construction planning, building production information analysis, and on-site production process management are all included in the range of services BPM provides. Architectural drawings, electrical and mechanical drawings, specification documents, and structural drawings are all related to building production [14]. The project quality management plan, the construction schedule, and the project health and safety plan are other items that are contained in BPM documents. Construction methodology and early warning system chart information are additional BPM papers essential for enhancing project performance [13]. [15] reported an assessment of BPM awareness and observed low utilisation.

Using project management tools or techniques during the planning and managing construction sites is crucial to BPM. Projects in Controlled Environments (PRINCE/PRINCE2), internal project management methods, cost-benefit analysis (CBA), decision analysis (DA), the build-ability and maintainability analysis, internal decision-making techniques, the programme evaluation and review technique, project sensitivity analysis, the graphical evaluation & review technique, Line of Balance, and the critical path method (CPM) are just a few of the project management tools or techniques that have been discussed in the literature [16]. The CBA, Gantt bar chart and CPM are the construction industry's most often used project management tools and methodologies. According to [16], the critical path method (CPM) is the key project management strategy that impacts managing construction projects. The majority of corporate operations are housed in a structure, sometimes known as a building. Its production draws experts and non-professionals and is deemed finished once the client receives the project [17]. According to [16], it is crucial to concentrate on best construction practices. Most of the time, project managers create a work schedule without consulting actual employees, frequently beginning projects that cannot be finished [18].

According to [18], up to 50% of construction man-hours were unproductive since about 50% of the work started on construction sites could not be completed as anticipated. Building abandonment, building collapse and project success can all be prevented with efficient and effective BPM. The examination of design data kicks off the BPM process. BPM practice is a methodical approach to building products that help the building industry develop its skills and, as a result, deliver and achieve project success. Professionalism is essential to the BPM process since it controls how resources are managed for the client's benefit. When BPM is used successfully and efficiently, the three major phases of the construction process - design, planning, and production - all experience significant tangible benefits.

3. Methodology

This paper offers a framework for assessing the performance of public buildings that combines a fuzzy analytical hierarchy approach and a balanced scorecard. The FAHP approach is utilised in the framework to evaluate the significance of the criteria, and the balanced scorecard (BSC) is used to determine the performance of building projects.

i. FAHP method

FAHP method is used to determine the importance of different criteria, which is the study's first objective for analysing public BCPs. A fuzzy set is a collection of items with a range of membership grades. A membership (characteristic) function, which assigns a grade of membership to each item ranging from zero to one, characterises such a set. A tilde is added above a symbol representing a fuzzy set. Figure 1 depicts a triangular fuzzy number (TFN). On the left and right sides of each TFN are linear representations, resulting from which its membership function can be described as Equation (1).

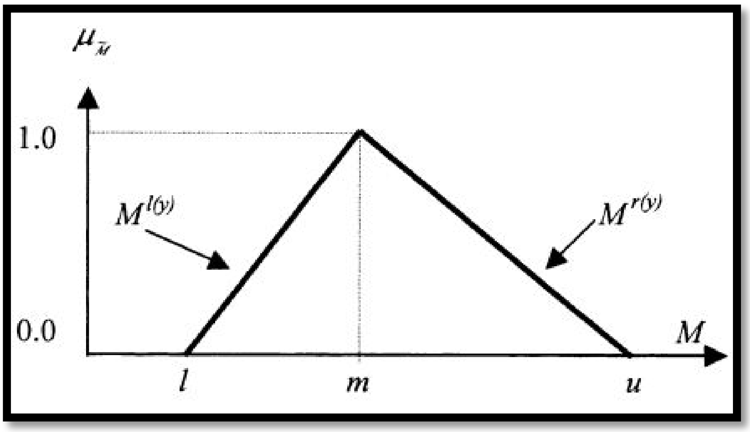

Figure 1: Triangular fuzzy number

Where, l denotes the least possible value that can be achieved to describe a fuzzy situation, m denotes the best value that can be achieved to describe a fuzzy situation, and u denotes the most significant value that can be achieved to describe a fuzzy situation.

$$\mu(x/\tilde{M}) = \begin{cases} 0, & x < l \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u. \end{cases} \quad (1)$$

The left and right representations of each degree of membership can always be used to calculate a fuzzy number (Equation 2).

$$\tilde{M} = \left(M^{l(y)}, M^{r(y)}\right) = (l + (m-l)y, u + (m-u)y), \quad y\epsilon[0,1], \quad (2)$$

where $l(y)$ and $r(y)$ are the left and right-side representations, respectively, of a fuzzy number; in the literature, many ranking techniques for fuzzy numbers have been established. These approaches may produce varied rankings, and most of them are time-consuming in terms of graphic manipulation and complex mathematical calculations.

In a preliminary investigation, the multi-criteria decision technique was most appropriate for dealing with complex decision-making situations. Since Saaty introduced it, it has experienced different applications [19]. It represents a framework with a unidirectional hierarchical AHP relationship. This study selects [19] extent analysis method because the stages are more straightforward than those of the other fuzzy AHP approaches.

Let $X = \{x_1, x_2, \dots, x_n\}$ be an object set, and $U = \{u_1, u_2, \dots, u_m\}$ be a goal set.
Each object is taken, and extent analysis for each objective, gi, is performed, according to [19] extent analysis method. As a result, the following signs are used to obtain m extent analysis results for each object (Equation 3):

$$M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m, \qquad i = 1,2,\dots,n \tag{3}$$

Where all the $M_{g_i}^1 (j = 1,2,\dots,m)$are TFNs.
Chang's extent analysis is broken down into the following steps:
Sep 1: Concerning the *ith* object, the value of fuzzy synthetic extent is defined as Equation (4).

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}. \tag{4}$$

Perform the fuzzy addition operation of m extent analysis values for a given matrix to generate (Equation 5).

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j \sum_{j=1}^{m} u_j\right). \tag{5}$$

Furthermore, to get$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}$, use the fuzzy addition of $M_{g_i}^j (j = 1,2,\dots,m)$ values such that (Equation 6).

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i \sum_{i=1}^{n} u_i\right) \tag{6}$$

Compute the inverse of the vector with Equation (7).

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i},\right). \tag{7}$$

Step 2: the degree of possibility of M1 = $(l_1, m_1, u_1) \geq$ M2 = (l_2, m_2, u_2) is given as Equation (8).

$$V(M_2 \geq M_1) = sup\left[min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \tag{8}$$

Furthermore, it can be stated in the following way (Equation 9):

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise, \end{cases} \tag{9}$$

where d is the ordinate of the highest intersection D,μ_{M_1} and μ_{M_1} cross (Figure 1), both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are required to compare M1 and M2.
Step 3: $M_i = (i = 1,2,\dots,k)$ is the degree possible for a convex fuzzy number to be greater than k convex fuzzy numbers (Equation 10).

$$V(M \geq M_1, M_2, \dots, M_k) = V(M \geq M_1) \tag{10}$$

Such that
$(M \geq M_2)$and $(M \geq M_k) = \min V(M \geq M_i)\ i = 1,2,\dots,k$.

$$d'(A_i) = min\ V(S_i \geq S_k) \tag{11}$$

For $k = 1,2,\dots,n; k \neq i$. Then the weight vector is given as Equation (12)

$$W' = \left(d'(A_1), d'(A_2), \dots, d'(A_n)\right)^T \tag{12}$$

where $A_i (i = 1,2,\dots,n)$ are n elements.

$$W' = \left(d'(A_1)\right)^T \tag{13}$$

where $A_i (i = 1,2, \dots, n)$ are n elements

ii. Balance scorecard

According to [20], strategy formulation includes the selection of (1) a financial strategy; (2) target market and customer segments, as well as a corresponding value proposition; (3) critical internal business processes where excellence must be pursued to ensure the delivery of the value proposition to clients; and finally, (4) individual and organisational capacities that will enable the fulfilment of the customer, financial, and societal needs. Considering [20] advice, the following objectives in the four recognised viewpoints are included in creating the project's plan.

This study used the following steps to implement the BSC:

Step 1: Creating a professional performance evaluation panel and identifying the company's vision.

Step 2: Determining the procedures that are used to achieve the company vision.

Step 3: Define BSC perspectives and the metrics dependent on them.

Step 4: For the AHP model, create a hierarchical structure (vision, strategies, BSC perspectives, performance indicators).

Step 5: Determine the local weights of the strategies, BSC viewpoints, and performance measures using pairwise comparison matrices (assume that there is no dependence among the BSC perspectives).

Step 6: Using a fuzzy scale, determine the inner dependence matrix of each BSC perspective about the other BSC perspectives. Multiply this inner dependence matrix by the local weights of the BSC views calculated in Step 5 to get the interdependent weights of the BSC viewpoints.

Step 7: Calculate the global weights of the performance indicators. Global performance indicator weights are obtained by multiplying the local weight of the performance indicator by the interdependence weights of the indicator to which it belongs.

Step 8: Assess the indicators of success.

Step 9: Calculate the corporate performance for a certain period using the global weights produced in Step 7 for the performance indicators and the linguistic values determined in Step 8.

iii. Case study

This study used the literature available to identify the criteria that affect the performance of public BCPs in Nigeria. It adopted a purposive sampling approach to generate data for the framework implementation – via a questionnaire. A total of 20 criteria for public BCPs are based on literature and practitioners' domain knowledge (Table 1).

Table 1. Selected criteria for the evaluation process

Criteria	Sub-criteria	Criteria	Sub-criteria
Financial	Project profitability (F1)	Internal process	Compelling profile (P1)
	Tracking of project costs (F2)		Strong client ties (P2)
Client and developers	High-quality structures (S1)		Top-notch construction (P3)
	Top-notch service to the market (S2)		Project administration effectiveness and efficiency (P4)
	Trust (S3)		Enhance a project's overall efficiency(P5)
	Increase projects (S4)		Effective marketing campaign (P6)
Learning and growth	Encouragement of stakeholders (L1)		Possibility of project abandonment (P7)
	Coherence within the construction industry (L2)		
	High calibre staff (L3)		
	Staff training (L4)		
	Vibrant work environment (L5)		
	Goal-oriented management culture (L6)		
	Staff productivity (L7)		

This study considered contractors' performance in constructing public buildings in the case study. Twenty-four teams of experts (E1, E2, E3 and E4) were consulted to objectively assess the contractors' performance - each team consisted of six members. The selected experts are drawn from six locations in Southwest Nigeria. It used a non-probabilistic sampling approach to generate data – a purposive sampling approach for the framework's implementation. This approach allows the researchers to select experts to participate in the current study (Black, 2019). This study used information collected from experts to implement the proposed framework. They provided information regarding the targeted and actual performance of the criteria in the framework. This study used observations, direct interviews and questionnaires as its research instruments. Observations, direct interviews and questionnaires were used to generate information for the FAHP implementation.

To avoid bias about the criteria importance, this study used the information collected from a multi-national construction company in Lagos, Nigeria, to determine the criteria importance. The selected company has operated in Nigeria for over 40 years as a contractor for public and private building projects. Currently, they have built several public buildings across the selected locations. After several interviews with stakeholders in the company, a questionnaire was filled out to analyse the criteria' importance. The current study considered public BCPs that have been completed in six state locations in Southwest Nigeria.: Ibadan, Ikeja, Abeokuta, Ado-Ekiti, Akure and Osogbo (Figure 2). These locations were selected because developmental activities for public infrastructure often cluster in the state capital. Due to ethical issues, this study used labels to represent the locations because of information confidentiality.

To deal with uncertainty caused by imprecision and vagueness, fuzzy set theory is used to convert linguistic variables to fuzzy triangular numbers (FTN) – see Tables 2 and 3 for more details. This theory allows for applying mathematical operations and programming to the fuzzy domain.

Table 2. Linguistic scales for difficulty and importance

Linguistic variable	Notation	TFN scale	TFN reciprocal scale
Equally significant	1	(1,1,1)	(1,1,1)
Averagely significant	2	(1,2,4)	(1/1,1/2,1/4)
Averagely to strongly significant	3	(1,3,5)	(1,1/3,1/5)
Strongly significant	5	(3,5,7)	(1/3,1/5,1/7)
Very strongly significant	7	(5,7,9)	(1/5,1/7,1/9)
Extremely strongly significant	9	(7,9,11)	(1/7,1/9,1/11)

Table 3. Linguistic values and mean of fuzzy numbers for the evaluation of the location

Linguistic variables	Notation	Fuzzy number mean
Extreme high	EH	0.7, 0.8,0.9
Very high	VH	0.6,0.7,08
High	H	0.5,0.6, 0.7
Moderate	M	0.4,0.5,0.6
Moderately low	ML	0.3,0.4,0.5
Low	L	0.2,0.3, 0.4
Very low	VL	0.1, 0.2,0.3

Figure 2. Map for the case study [1]

4. Discussion of results

4.1 Evaluation of the Criteria Importance

The developed framework implementation commenced with the determination of the important criteria. Using the FAHP method, different comparison matrices were generated. Table 4 presents the results for the financial perspective matrix. The information in this table shows that the relationship between a project's profitability and the cost is strongly significant. Using the information in Table 3, TFN was generated for the criteria (Table 5).

Table 6 presents the results for the client perspective matrix. From this table, it could be deduced that there is an inverse relationship between the criteria' importance. For example, the relationship between high-quality structures and trust is inversely proportional. It was also observed that the relationship between top-notch service to the market and the increased project is inversely proportional. Further analysis of the information in Table 6 showed a strong relationship between high-quality structures and top-notch service to the market. The exact relationship also exists between top-notch service to the market and trust. The results in Table 6 were used to generate a fuzzy-based comparison matrix for the clients' perspectives (Table 7).

Table 4. Financial perspective matrix

Criterion	F1	F2
F1	1	5
F2	1/5	1

Table 5. Comparison matrix for the financial perspective using TFN

Criterion	F1	F2
F1	(1.00,1.00,1.00)	(3.00,5.00,7.00)
F2	(0.33,0.20,0.14)	(1.00,1.00,1.00)

Table 6. Clients' perspective matrix

	S1	S2	S3	S4
S1	1	7	1/2	5
S2	1/7	1	7	1/2
S3	2	1/7	1	3
S4	1/5	2	1/3	1

Table 7. Comparison matrix for the client's perspective using TFN

Criterion	S1	S2	S3	S4
S1	(1.00,1.00,1.00)	(5.00,7.00,9.00)	(1.00,0.50,0.25)	(3.00,5.00,7.000)
S2	(0.20,0.14,0.11)	(1.00,1.00,1.00)	(5.00,7.00,9.00)	(1.00,0.5,0.25)
S3	(1.00,2.00,4.00)	(0.20,0.14,0.11)	(1.00,1.00,1.00)	(1.00,3.00,5.00)
S4	(0.33,0.20,0.14)	(1.00, 2.00,4.00)	1.00,0.30,0.20)	(1.00,1.00,1.00)

Table 8 presents the relationship between the different internal process criteria. From this table, it could be deduced that seven inverse relationships exist among the internal process criteria. Out of this number, four of the inverse relationship was for P1. This criterion had inverse relationships with strong client ties, top-notch construction, enhanced overall project efficiency and effective marketing campaign. The other inverse relationships exist among strong client ties, top-notch construction and project administration effectiveness and efficiency for effective marketing campaigns. From Table 8, this study observed that five relationships had an extremely significant value. For instance, the P3 relationship with P4 and P7 was highly significant. P4 also had an exceptionally strongly significant with P5 and P7. Lastly, an extremely strongly significant exists between P5 and P6. The other relationship is shown to have values that were at least averagely to strongly significant. Based on Table 8, this study generated TFN values for the internal process criteria's relationships (Table 9).

Table 10 presents the learning and growth criteria relationships. From these relationships, it could be deduced that L2 and L3 had inverse relationships with the other criteria, except L1. This study observed that averagely significant values occurred more than other values in this table among the inverse relationship. Using these relationships, this study generated the TFN values for the learning and growth criteria (Table 11).

Table 8. Internal process perspective matrix

Criterion	P1	P2	P3	P4	P5	P6	P7
P1	1	1/7	1/2	7	1/9	1/2	7
P2	7	1	7	5	5	1/7	7
P3	9	1/7	1	9	7	1/5	9
P4	1/7	1/5	1/9	1	9	1/5	9
P5	9	1/5	1/7	1/9	1	9	3
P6	2	7	5	5	1/9	1	1/5
P7	1/7	1/7	1/9	1/9	1/3	5	1

Table 9. Comparison matrix for the internal process perspective using TFN

Criterion	L1	L2	L3	L4	L5	L6	L7
L1	(1.00,1.00,1.00)	(0.20,0.14,0.11)	(1.00,0.50,0.25)	(5.00,7.00,9.00)	(0.14,0.11,0.09)	(1.00,0.50,0.25)	(5.00,7.00,9.00)
L2	(5.00,7.00,9.00)	(1.00,1.00,1.00)	(5.00,7.00,9.00)	(3.00,5.00,7.00	(3.00,5.00,7.00)	(0.20,0.14,0.11)	(5.00,7.00,9.00)
L3	(7.00,9.00,11.00)	(0.20,0.14,0.11)	(1.00,1.00,1.00)	(7.00,9.00,11.00)	(5.00,7.00,9.00)	(0.33,0.20,0.14)	(7.00,9.00,11.00)
L4	(0.20,0.14,0.11)	(0.33,0.20,0.14)	(0.14,0.11,0.09)	(1.00,1.00,1.00)	(7.00,9.00,11.00)	(0.33,0.20,0.14)	(7.00,9.00,11.00)
L5	(7.00,9.00,11.00)	(0.33,0.20,0.14)	(0.20,0.14,0.11)	(0.14,0.11,0.09)	(1.00,1.00,1.00)	(7.00,9.00,11.00)	(1.00,3.00,5.00)

L6	(1.00,2.00,4.00)	(5.00,7.00,9.00)	(3.00,5.00,7.00)	(3.00,5.00,7.00)	(0.14,0.11,0.09)	(1.00,1.00,1.00)	(0.33,0.20,0.14)
L7	(0.20,0.14,0.11)	(0.20,0.14,0.11)	(0.14,0.11,0.09)	(0.14,0.11,0.09)	(1.00,0.33,0.20)	(3.00,5.00,7.00)	(1.00,1.00,1.00)

Table 10. Comparison matrix for the training and growth perspective

Criterion	L1	L2	L3	L4	L5	L6	L7
L1	1	9	2	1/7	2	3	7
L2	1/9	1	1/9	1/7	1/2	1/3	1/5
L3	1/2	9	1	1/2	1/2	1/7	1/2
L4	7	7	2	1	1/2	1/2	5
L5	1/2	2	2	2	1	5	1/7
L6	1/3	3	7	2	1/5	1	1/5
L7	1/7	5	2	1/5	7	5	1

Table 11. Comparison matrix for the training and growth perspective using TFN

Criterion	P1	P2	P3	P4	P5	P6	P7
P1	(1.00,1.00,1.00)	(7.00,9.00,11.00)	(1.00,2.00,4.00)	(0.20,0.14,0.11)	(1.00,2.00,4.00)	(1.00,3.00,5.00)	(5.00,7.00,9.00)
P2	(0.14,0.11,0.09)	(1.00,1.00,1.00)	(0.14,0.11,0.09)	(0.20,0.14,0.11)	(1.00,0.50,0.25)	(1.00,0.33,0.20)	(0.33,0.20,0.14)
P3	(1.00,0.50,0.25)	(7.00,9.00,11.00)	(1.00,1.00,1.00)	(1.00,0.50,0.25	(1.00,0.50,0.25)	(0.20,0.14,0.11)	(1.00,0.50,0.25)
P4	(5.00,7.00,9.00)	(5.00,7.00,9.00)	(1.00,2.00,4.00)	(1.00,1.00,1.00)	(1.00,0.50,0.25)	(1.00,0.50,0.25	(3.00,5.00,7.00)
P5	(1.00,0.50,0.25)	(1.00,2.00,4.00)	(1.00,2.00,4.00)	(1.00,2.00,4.00)	(1.00,1.00,1.00)	(0.33,0.20,0.14)	(0.20,0.14,0.11)
P6	(1.00,0.33,0.20)	(1.00,0.33,0.20)	(5.00,7.00,9.00)	(1.00,1.00,1.00)	(0.33,0.20,0.14)	(1.00,1.00,1.00)	(0.33,0.20,0.14)
P7	(0.20,0.14,0.11)	(3.00,5.00,7.00)	(1.00,2.00,4.00)	(0.33,0.20,0.14)	(5.00,7.00,9.00)	(3.00,5.00,7.00)	(1.00,1.00,1.00)

Table 12 presents the local weights generated for the criteria based on the information in tables 5,7, 9 and 11. The following information is generated about the criteria importance:

- This study observed that project P1 is more important than P2.
- The clients' criteria results showed that S1 and S2 are the most and least critical criteria for evaluating public BCP evaluation.
- The internal process results showed that P2 and P7 are the essential criteria for evaluating public BCP evaluation.
- The learning and growth results showed that L4 and L2 are the essential criteria for public BCP evaluation.

The local weights in Table 12 were aggregated to determine the influence of the criteria on public BCPs. From the information obtained, the following deductions are made:

- F1 is considered the essential criterion for public BCP evaluation.
- L2 is considered the least essential criterion for public BCP evaluation.

Table 12. Fuzzy and crisp importance for the criteria

Criterion	Fuzzy weight			Local weight	Global weight
F1	1.4422	2.2361	2.6458	0.8200	0.2050
F2	0.6934	0.4472	0.3780	0.1800	0.0450
S1	1.9680	2.0453	1.9921	0.4546	0.1136
S2	1.0000	0.8409	0.7071	0.1899	0.0475
S3	0.6687	0.9622	1.2209	0.2149	0.0537
S4	0.7598	0.6043	0.5814	0.1407	0.0352
P1	1.2585	1.0832	0.9211	0.1126	0.0281
P2	2.1678	2.7616	3.2666	0.2849	0.0712
P3	1.9680	2.0375	2.1163	0.2115	0.0529
P4	0.7666	0.6545	0.5902	0.0687	0.0172
P5	1.1843	1.3189	1.3815	0.1356	0.0339
P6	1.1150	1.3405	1.5642	0.1390	0.0348
P7	0.5594	0.4507	0.3976	0.0477	0.0119
L1	1.3205	1.9520	2.6341	0.2213	0.0553
L2	0.4902	0.3625	0.3033	0.0422	0.0106
L3	1.0492	0.8503	0.6925	0.0967	0.0242
L4	1.8530	2.1944	2.4738	0.2465	0.0616
L5	0.9296	1.1618	1.4336	0.1319	0.0330
L6	0.9195	0.9205	0.9569	0.1046	0.0261
L7	1.1699	1.3895	1.6097	0.1568	0.0392

4.2 FBSC results

Table 13 presents the experts' responses to the public BCP evaluations for Location 1. This information and those of the other locations were converted to FTN values.

Table 13. Location 1 linguistic target and actual values for FBSC

Criterion	Target performance					Actual performance			
	DM1	DM2	DM3	DM4		DM1	DM2	DM3	DM4
F1	M	H	VL	M		M	H	VH	L
F2	VL	M	H	VL		H	ML	M	ML
S1	H	ML	H	L		VH	H	L	L
S2	VL	H	EH	EH		L	L	L	VL
S3	VH	VH	VH	ML		ML	VH	VL	VL
S4	M	ML	H	M		H	VL	L	ML
P1	VL	EH	L	M		H	ML	VH	L
P2	VL	L	ML	ML		VL	ML	ML	VL
P3	VL	ML	H	VL		VL	VL	ML	VH
P4	ML	L	L	L		ML	L	H	H
P5	H	VL	M	ML		H	VL	H	M
P6	VH	VL	ML	L		VL	VH	VL	VL
P7	VH	VH	ML	VL		L	M	VL	M
L1	VL	VH	M	L		VL	H	ML	VH
L2	EH	H	EH	ML		M	M	VH	VH
L3	M	ML	ML	EH		VL	VL	ML	L
L4	ML	VH	H	ML		VL	VL	VL	VL
L5	VH	ML	M	M		H	L	ML	VH
L6	VL	VH	VL	ML		VL	VH	M	L
L7	EH	L	L	VL		VH	VL	H	L

i. Financial criteria

Table 14 shows the crisp values for the location's performance. From this table, it was only Location 5 that attained the most targeted values for the financial criteria. On the contrary, it was observed that Location 1 could not attain any targeted financial values for the criteria. The results in this table showed that four locations generated more than their targeted values under the project's profitability (locations 2, 3, 5 and 6). Among these locations, Location 2 had the most surplus values under the project's profitability. On the other hand, this study observed that only two locations (locations 4 and 5) generated results above the targeted values under project costs (Table 14). These results showed that Location 4 performed better than Location 5 for this criterion.

Table 14. Financial criteria results

Location	Criterion	Target performance	Actual performance	Score (%)	Remark
	F1	0.4500	0.3750	83.33	Under target
1	F2	0.6667	0.5500	82.50	Under target
	F1	0.3000	0.4000	133.33	Exceed target
2	F2	0.4958	0.3750	75.63	Under target
	F1	0.3250	0.4000	123.08	Exceed target
3	F2	0.4500	0.3250	72.22	Under target
	F1	0.5250	0.3000	57.14	Under target
4	F2	0.3250	0.5750	176.92	Exceed target
	F1	0.5000	0.5208	104.17	Exceed target
5	F2	0.4750	0.5750	121.05	Exceed target
	F1	0.4250	0.5500	129.41	Exceed target
6	F2	0.5750	0.4250	73.91	Under target

ii. Clients' criteria

Using the information in Table 13, this study generated the results for client's requirements for the locations (Table 15). The results obtained showed that Location 2 had the worst performance because it could not generate actual values that were the same for the three criteria. On the other hand, Location 4 had the best performance because it generated actual values that were more than 100% for all criteria.

From a location-wise perspective, this study observed the following issues about the locations with the worst performance:

- Location 5 generated had the worst result regarding high-quality structures.
- Location 6 generated had the worst result regarding top-notch service.
- Location 1 generated had the worst result regarding the relationship of trust with clients and increased projects.

The following information was obtained about the best performance from a location-wise standpoint:

- Location 3 generated had the best results regarding high-quality structures.
- Location 4 generated had the best results regarding service to the market and relationship of trust with clients.
- Location 5 generated had the best results regarding increased projects.

From the preceding discussion, the following highlights were deduced the location's overall performance:

- Location 2 had the worst performance regarding the client's requirements.
- Location 3 had the best performance regarding the client's requirements.

Table 15. Clients' criteria results

Location	Criterion	Target performance	Actual performance	Score (%)	Remark	Location	Criterion	Target performance	Actual performance	Score (%)	Remark
	S1	0.4000	0.4500	112.50	Exceed target		S1	0.5417	0.6000	110.77	Exceed target
	S2	0.5208	0.5750	110.40	Exceed target		S2	0.4000	0.4500	112.50	Exceed target
1	S3	0.5708	0.4750	83.21	Under target	4	S3	0.4000	0.6000	150.00	Exceed target
	S4	0.4708	0.3500	74.34	Under target		S4	0.4458	0.4750	106.54	Exceed target
	S1	0.5000	0.3750	75.00	Under target		S1	0.6708	0.4000	59.63	Under target
	S2	0.5250	0.5250	100.00	Exact		S2	0.5250	0.5000	95.24	Under target
2	S3	0.4000	0.3250	81.25	Under target	5	S3	0.4708	0.5458	115.93	Exceed target
	S4	0.5458	0.4500	82.44	Under target		S4	0.4250	0.6167	145.10	Exceed target
	S1	0.3750	0.4250	113.33	Exceed target		S1	0.5250	0.5250	100.00	Exceed target
3	S2	0.5750	0.5500	95.65	Under target	6	S2	0.4750	0.2750	57.89	Under target
	S3	0.4458	0.5250	117.76	Exceed target		S3	0.4000	0.4500	112.50	Exceed target
	S4	0.4500	0.4000	88.89	Under target		S4	0.6000	0.6000	100.00	Exact

Table 16. Internal processes results

Location	Criterion	Target performance	Actual performance	Score (%)	Remark	Location		Criterion	Target performance	Actual performance	Score (%)	Remark
	P1	0.4750	0.3500	73.68	Under target			P1	0.2750	0.5500	200.00	Exceed target
	P2	0.4917	0.2500	50.85	Under target			P2	0.6000	0.6250	104.17	Exceed target
	P3	0.4500	0.4000	88.89	Under target			P3	0.6417	0.4750	74.03	Under target
1	P4	0.4208	0.3500	83.17	Under target	4		P4	0.3708	0.5250	141.57	Exceed target
	P5	0.5458	0.4500	82.44	Under target			P5	0.5000	0.4500	90.00	Under target
	P6	0.4250	0.3500	82.35	Under target			P6	0.4500	0.6250	138.89	Exceed target
	P7	0.5000	0.4000	80.00	Under target			P7	0.2750	0.4250	154.55	Exceed target
	P1	0.7417	0.5000	67.42	Under target			P1	0.6208	0.4250	68.46	Under target
	P2	0.4250	0.5750	135.29	Exceed target			P2	0.5250	0.3250	61.90	Under target
	P3	0.4500	0.5000	111.11	Exceed target			P3	0.5958	0.4750	79.72	Under target
2	P4	0.4750	0.4500	94.74	Under target	5		P4	0.3500	0.5417	154.76	Exceed target
	P5	0.3750	0.5750	153.33	Exceed target			P5	0.6208	0.3750	60.40	Under target
	P6	0.3500	0.5250	150.00	Exceed target			P6	0.5458	0.5208	95.42	Under target
	P7	0.5208	0.3500	67.20	Under target			P7	0.6417	0.6167	96.10	Under target
	P1	0.2250	0.2750	122.22	Exceed target			P1	0.3500	0.5500	157.14	Exceed target
	P2	0.4500	0.4250	94.44	Under target			P2	0.5208	0.4250	81.60	Under target
	P3	0.4000	0.4750	118.75	Exceed target			P3	0.4000	0.5750	143.75	Exceed target
3	P4	0.5917	0.4250	71.83	Under target	6		P4	0.4958	0.4250	85.71	Under target
	P5	0.5667	0.5250	92.65	Under target			P5	0.7167	0.5000	69.77	Under target
	P6	0.6958	0.3500	50.30	Under target			P6	0.6708	0.3000	44.72	Under target
	P7	0.5208	0.4250	81.60	Under target			P7	0.4250	0.5000	117.65	Exceed target

iii. Internal process criteria

Based on the information presented in Table 13, this study generated crisp values for the locations' performance. Table 16 presents the results that were generated about the locations' internal processes. From the information in this table, no location generated the exact target values for the criteria. However, it was observed that some locations generate more targeted values for criteria, except Location 1. The following highlights are made about the criteria's worst performance for the criteria:

- Location 2 has the worst performance regarding compelling profile, the establishment of solid client ties and project abandonment.
- Location 4 had the worst performance regarding top-notch construction.
- Location 3 had the worst performance regarding effective project management.
- Location 6 had the worst performance regarding the project's overall efficiency and the boosting of the effectiveness of a marketing campaign.

Following facts emerged about the best criteria performance among the selected locations used in the current study:

- Location 4 had the best performance regarding compelling profile. This location was able to double its expected targeted values for this criterion.
- Location 2 had the best performance regarding establishing solid client ties. This location exceeded its targeted value by about 35.29%.
- Location 6 had the best performance regarding top-notch construction. This location was selected best because it exceeded its target by about 43.75%.
- Location 4 had the best performance regarding effective project management. This study observed an improvement of about 41.57% regarding the targeted values for this location.

iv. Learning and growth results

Table 17 presents the learning and growth results of the case study. From this information, all the locations had at least one performance that exceeded its targeted values. However, none of the locations generated more than the targeted values for all the learning and growth criteria. The following were observed regarding the location's worst performance:

- Location 4 had the worst performance regarding encouraging developers and community members to share their knowledge.
- Location 1 had the worst performance regarding encouraging coherence within the construction industry. It was also observed that this location had the worst results when the issue of ascertaining that the construction staff is of the highest calibre was considered.
- Location 5 had the worst performance regarding ensuring enough infrastructure and resources for staff training.
- Location 3 had the worst performance regarding promoting a vibrant work environment.
- Location 1 had the worst performance regarding promoting monitoring, assessment, and goal-oriented management culture.
- Location 6 had the worst performance regarding the developer's productivity.

The following were observed regarding improved performance:

- Location 2 has the highest percentage increment regarding encouraging developers and community members to share their knowledge.
- Location 2 had the highest increment regarding coherence within the construction industry. This increment amounts to about 57.14%.
- The evaluation of the locations regarding construction staff is of the highest calibre and showed that Location 3 exceeded the stakeholders' targeted values compared with the other locations. The extra performance improvement amounted to about 18.18%.
- The results on infrastructure and resources for staff training showed that the maximum improvement for this parameter among the location was 26.05% (Location 2).

- The performance of Location 3 for promoting a monitoring, assessment, and goal-oriented management culture in BCPs was better than that of the other locations. It improved by about 46.67% based on the stakeholders' targeted values.
- The evaluation of the locations regarding increasing the developer's productivity in BCPs showed that Location 1 could generate a performance improvement of about 15.38%. When this value was compared with other locations, this study observed that it was the maximum improvement that could be obtained for this parameter.

v. Aggregated performance

The ranking of the locations concerning the perspectives is shown in Figure 3. From a financial perspective, Location 2 performed the best, while Location 4 performed the worst. Figure 3 demonstrated that Location 2 performed best while Location 3 performed worse from the client's perspective. Regarding the internal process perspective, Locations 2 and 1 performed the best and worst, respectively. Additionally, Location 2 outperformed the other locations in learning and growth, whereas Location 3 performed worst.

Table 17. Learning and growth for framework

Location	Criterion	Target performance	Actual performance	Score (%)	Remark	Location	Criterion	Target performance	Actual performance	Score (%)	Remark
1	L1	0.3958	0.5000	126.32	Exceed target	4	L1	0.6500	0.4250	65.38	Under target
	L2	0.7625	0.4000	52.46	Under target		L2	0.4208	0.4250	100.99	Exceed target
	L3	0.6625	0.4000	60.38	Under target		L3	0.5000	0.4250	85.00	Under target
	L4	0.4458	0.5500	123.36	Exceed target		L4	0.4250	0.4250	100.00	Exact
	L5	0.5667	0.4750	83.82	Under target		L5	0.4000	0.4500	112.50	Exceed target
	L6	0.4000	0.3000	75.00	Under target		L6	0.4750	0.4250	89.47	Under target
	L7	0.3250	0.3750	115.38	Exceed target		L7	0.6000	0.6000	100.00	Exact
2	L1	0.5708	0.6750	118.25	Exceed target	5	L1	0.3500	0.5000	142.86	Exceed target
	L2	0.3500	0.5500	157.14	Exceed target		L2	0.4708	0.5000	106.19	Exceed target
	L3	0.6458	0.4000	61.94	Under target		L3	0.4000	0.5458	136.46	Exceed target
	L4	0.4958	0.6250	126.05	Exceed target		L4	0.5250	0.4000	76.19	Under target
	L5	0.5917	0.4250	71.83	Exceed target		L5	0.6417	0.4208	65.58	Under target
	L6	0.4250	0.5000	117.65	Exceed target		L6	0.5458	0.6208	113.74	Exceed target
	L7	0.4750	0.5750	121.05	Exceed target		L7	0.5000	0.4000	80.00	Under target
3	L1	0.4750	0.4500	94.74	Under target	6	L1	0.5958	0.4750	79.72	Under target
	L2	0.5708	0.5250	91.97	Under target		L2	0.5208	0.4500	86.40	Under target
	L3	0.2750	0.3250	118.18	Exceed target		L3	0.5708	0.5500	96.35	Under target
	L4	0.5000	0.4250	85.00	Under target		L4	0.4958	0.4000	80.67	Under target
	L5	0.6208	0.3000	48.32	Under target		L5	0.3000	0.5000	166.67	Exceed target
	L6	0.3750	0.5500	146.67	Exceed target		L6	0.4250	0.4000	94.12	Under target
	L7	0.5500	0.4250	77.27	Exceed target		L7	0.5708	0.4250	74.45	Under target

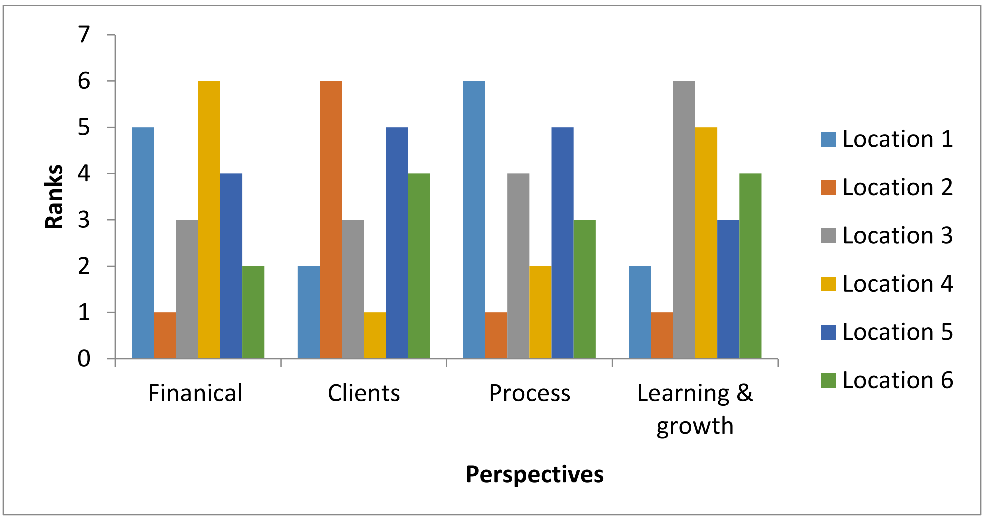

Figure 3. Ranking of the locations' aggregated values

Figure 4 presents the perspectives aggregated values. The data demonstrated that the financial perspective led to a superior case study performance than the other views. However, the learning and growth approach had the worst outcome.

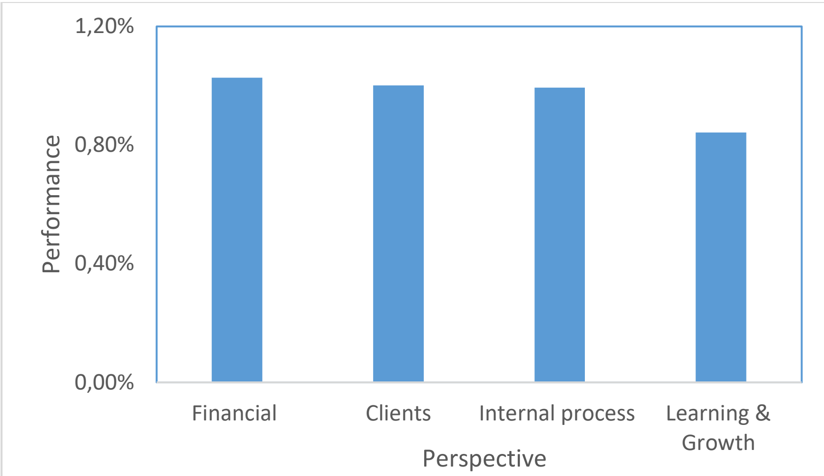

Figure 4. Aggregated values for the perspective

As presented in Table 18, 95% confidence interval was used to evaluate the statistical difference among the selected location. The null hypothesis for test is that there is no significant difference among the contractors performance in the management of public BCP in Southwest Nigeria. The aggregated values for the locations regarding the perspectives were used as the input parameters for ANOVA implementation. The study observed that the calculated calculated F-value (0.56333) was less than the F-critical value (2.7729); hence, the null hypothesis is accepted.

Table 18. ANOVA results for the locations performance.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00612792	5	0.00122558	0.56333	0.72683	2.77285
Within Groups	0.03916096	18	0.00217561			
Total	0.04528888	23				

5. Concluding remarks

This study provided a methodology for assessing BCPs based on data from theoretical and empirical evaluations. The reviews revealed a dearth of knowledge regarding creating a framework that may produce useful data for many industry players. This study filled this information gap by presenting a fuzzy-based balanced scorecard that identifies variability between a location's actual and targeted performance. Evaluating the various criteria that affect the success of a BCP, this study used a fuzzy-based analytical hierarchical process (FAHP) to determine the criteria's importance.

The FAHP results observed that project profitability was the essential criterion for analysing the financial implication of managing BCPs in Southwest Nigeria. It was observed that the issue of the project cost was the least essential criterion when it was compared with the profitability of projects. The FAHP results showed that high-quality structure was the essential criterion for the performance analysis of contractors. Furthermore, this study observed that increasing projects in the number of completed was the least essential criterion for the same analysis. During the internal process criteria evaluation, the study observed that coherence within the construction industry and developers' productivity were the least essential criteria for implementing the framework.

The ranking of the locations concerning the perspectives showed that. From financial, internal process, and learning and growth perspectives, Location 2 performed the best. Location 4 performed best under the client's perspective. Location 4 performed the worst under financial, while Locations 2 and 1 performed worse from the perspectives of the client and internal process, respectively, whereas Location 3 outperformed was the worst under the learning and growth perspective.

This study recommends the following matters regarding the developed model's extension. A fuzzy cognitive map should be developed to study the impact of the different components on stakeholders' performance in project management and control. The map will help to improve project monitoring and control. An intelligent system could be designed to give real-time information for assessing stakeholders' contributions to a project's success. The system will assist project managers in offering solid project solutions.

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