Innovations

Assessment of Public Building Construction Project Management: A multi-criteria Approach

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Abstract
The built environment deals with several non-financial concerns, which has led academics and professionals to propose solutions that would best benefit all stakeholders. The performance gaps amongst specialists in the industry, however, have only rarely been examined by academics and practitioners when producing solid solutions for the built environment.Therefore, this study suggests a new strategy for managing the construction project of public buildings. The strategy incorporates the balanced scorecard, the Criteria Importance Through Intercriteria Correlation (CRITIC), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The strategy considered the contributions of three construction industry stakeholders: architects, engineers, and constructors. The contributions of these stakeholders were examined from three angles: client, internal process, and development and learning.The proposed applicability was tested using information from six locations in Southwest Nigeria. Information were collected from four experts in the locations. The locations considered are Ibadan (L1), Ikeja (L2), Abeokuta (L3), Ado-Ekiti (L4), Akure (L5) and Osogbo (L6). This investigation showed that L2 had the best performance. On the other hand, L1 had the least performance among the selected lcoations.The study reported that the most important criterion for client's management in the built environment was high-quality structures, while the the least important criterion for client's management was top-notch service to the market. In term of the most and least important criteria for the internal process, it was obsevered that project administration effectiveness and efficiency and strong client ties, resepectively. Furthermore, it was observed the learning and growth in the construction industry showed that the most important criterion was encouragement of stakeholders, while the least important criterion was goal-oriented management culture.

Keywords*:1.Balanced scorecard, 2.CRITIC, 3.fuzzy logic, 4.project management, 5.TOPSIS*

Introduction

Public buildings are essential pieces of infrastructure created to meet various societal demands, including those for business, recreation, and housing(Pamukcu-Albers et al., 2021). Since these requirements varied from community to community, academic works have provided several strategies for maximising the advantages for which a public facility is constructed. Stakeholders' contributions during the conceptualisation of a building are the basis for optimising a public building's benefits. During the conceptualisation of a public building, key parties, including the government, architects, builders, engineers, and clients, are needed. Project managers are in charge of coordinating the contributions of different stakeholders for the good of the public. Therefore, project managers are expected to comprehend, analyse, and harness these stakeholders' motivations in today's dynamic constructed environment for public buildings(Denicol & Davies, 2022).
Modern built environment practices have changed the dynamics of project management for public building construction(Mandeli, 2019). First, investors emphasise the financial consequences from project conception through project commission. Second, due to the wealth of information at clients' disposal, they are demanding top-notch service delivery. Third, engineers and builders are expected to undertake training and retraining due to

the shifting need for public structures. Finally, in order to promote a sustainable built environment, governments frequently update their public building regulations(Hürlimann et al., 2022).
Academics and professionals in the field are constantly proposing models to help stakeholders in the built environment better understand one another(Munaro et al., 2020). Some of the models that have been put forth address the built environment's demand side. The models are created to advise the government on the best strategy needed to offer citizens dependable and affordable housing. The supplyside of the built environment is a subject that scholars are also interested in providing a robust solutions. In more concrete terms, they produce data that clients could utilise to choose facilities that will help them live up to their expectations. Public buildings' requirements include space management, communication management, and security.
Scholarly works on these requirements have attempted to analyse them from different approaches. For instance, it has been considered a multi-criteria problem. This consideration has allowed scholars to present an AHP-based model for dealing with project delays (Lai et al., 2008). Recently, the changing needs of citizens have made scholars evaluate public buildings' modernisation using a multi-criteria approach (Starynina & Ustinovichius, 2020). Multi-criteria approach has been considered a practical approach for dealing with public buildings design and management (Turskis et al., 2009). This approach is essential in analysing the criteria necessary for construction projects (Nilashi et al., 2015). Despite the literature on multi-criteria approaches for construction project management, scholars have sparsely discussed this approach's implications on the aggregation of stakeholders' impacts on public building projects.
This study aims to create a technique for assessing stakeholders' performance regarding financial and non-financial needs. To this end, it analysed information about the built environment stakeholders using balance scorecard,TOPSIS, and Criteria Importance Through Intercriteria Correlation (CRITIC). The information provided will assist policymakers in identifying best practices for this situation. From a requirement-based standpoint, it will also show any potential performance gaps.

2. Methodology

This section contains four sub-sections. First, fuzzy balanced scorecard is presented; second, TOPSIS method is discussed; third, CRITIC method is discussed; and fourth, a study for the proposed model evaluation is presented.

i. Balanced scorecard

BSC is an established approach that has led to system improvement because it can synergise system objectives with its critical processes. BSC examines the financial and non-financial objectives of the system to measure its business success (Tan, Zhang, &Khodaverdi, 2017). The current study used an FBSC to investigate the developers' performance. The study selected a balanced scorecard as an investigative tool for evaluating the performance of the Nigerian construction industry because it provides a basis for understanding the root cause of performance gaps in a system. The four perspectives that underpin this approach are:

- Financial: This perspective focuses on the need for a system to succeed financially. Hence, emphasis is on how the system appears to its stakeholders.
- Client: This perspective uses a system's vision to improve its performance. Hence, the issue of how it appears to clients is considered under this perspective.
- Internal processes: This perspective centers on what is necessary to simultaneously meet stakeholders' and clients' expectations. Technically, it deals with the issue of what a system needs to excel.
- Learning and growth: This perspective focuses on the issue of activities that a system must consider to achieve its vision.

These perspectives allow the study to draw a location strategy map to explain an organisation's appearance. In building the Nigerian construction industry map, this study shows how the perspectives'objectives support one another. According to Kaplan and Norton (1992), 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 Kaplan and Norton's (1992) advice, the following objectives in the four recognised viewpoints are included in creating the project's plan.

Using the information presented in Table 1, this study redefined the steps in to suit its second, third and fourth objectives as follows:

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 CRITIC framework, 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.

The FBSC framework addresses the fourth objective in the current study. The strategic objectives in this strategy are concentrated on the essential internal business processes that have the most impact on providing the value proposition to target consumers and meeting financial obligations. Hence, the financial goal is to control project costs. For this framework, three client criteria are considered:

- High-quality structures (S1)
- Top-notch service to the market (S2)
- Trust (S3)

This framework considered four business processes as essential to the contribution of engineers and architects in public BCPs. The criteria are:

- Compelling profile (P1)
- Strong client ties (P2)
- Top-notch construction (P3)
- Project administration effectiveness and efficiency (P4)

This framework considers five strategic criteria for the engineers' and architects' performance evaluation based on the criteria in Table 3.1. The criteria are

- Encouragement of stakeholders (L1)
- High calibre staff (L3)
- Staff training (L4)
- Vibrant work environment (L5)
- Goal-oriented management culture (L6)

iii. TOPSIS method

TOPSIS method has been recognised as the leading MCDM tool in decision science. Its popularity is based on it ability to seamlessly combine the ideal and non-ideal solutions for criteria to determine the suitability of alternatives as solution for a decision making problem. This method uses attribute information, offers a cardinal ranking of options, and does not require individual attribute preferences(Tzeng & Huang, 2011). The attribute values must be numerical, monotonically growing or decreasing, and have comparable units in order to use this strategy.

Technically, this method uses information that are presented in a decision matrix to anlysealternatives’s suitability for a problem. A decision matrix comprises of a set of alternatives and criteria ratings (Equation 1). The method uses this matrix as the foundation for generating information that leads to the determination of the alternatives closeness coefficients. The coefficients serves as the basis for ranking the alternatives suitability for a MCDM problem.

$$D_{mn} = \begin{matrix} A_1 \\ \vdots \\ A_2 \end{matrix} \begin{vmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mn} \end{vmatrix} \quad (1)$$

Based on the matrix, a normalised decision matrix is created using appropriate mathematical expressions. Equation (2) is used as the mathematical expression for normalising the current decision-making problem. The choice of this expression is to limit the computational time associated with defining a criterion as either benefit or cost-oriented criterion. The normalized decision matrix for an MCDM problem is shown in Equation (3).

$$n_{ij} = \sqrt{\frac{x_{ij}}{\sum_{j=1}^{n}\left(x_{ij}\right)^2}} \quad (2)$$

$$\bar{D}_{mn} = \begin{matrix} A_1 \\ \vdots \\ A_2 \end{matrix} \begin{vmatrix} n_{11} & \cdots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{m1} & \dots & n_{mn} \end{vmatrix} \quad (3)$$

From the normalised decision matrix, Equation (4) is used to construct a weighted normalised decision matrix. The information in this matrix is used to determine the criteria ideal and non-ideal solutions. For instance, Equation (5) is used to determine the ideal distance for criteria based on the information in the matrix. This equation gives consideration to criteria whose maximum values are desired, Likewise, it considers criteria whose minimum values are desired.

$$\bar{v}_{mn} = \begin{matrix} A_1 \\ \vdots \\ A_2 \end{matrix} \begin{vmatrix} w_1 n_{11} & \cdots & w_n n_{1n} \\ \vdots & \ddots & \vdots \\ w_1 n_{m1} & \dots & w_n n_{mn} \end{vmatrix} \quad (4)$$

$$x_j^+ = \max_j\left(w_j n_{ij}\right) \Big| j \in B; \min_j\left(w_j n_{ij}\right) | j \in C \quad (5)$$

Equation (6) gives the expression for the non-ideal solutions regrading the criteria whose maximum and minimum values are desired. The equation implementation is based on the information contained a weighted normalised matrix.

$$x_j^- = \min_j\left(w_j n_{ij}\right) \Big| j \in B; \max_j\left(w_j n_{ij}\right) | j \in C \quad (6)$$

$$v_{ij} = w_j n_{ij} \quad (7)$$

Equation (8) gives the matrix for the ideal and non-ideal solutions. The linear relationship between this matrix and the weighted normalised matrix is used to determine the alternatives ideal and non-ideal solutions(M. O. Babatundea & D. E. Ighravweb, 2019). Equation (9) gives the expression for an alternative's ideal solution, while Equation (10) gives the expression for an alternative's non-ideal solution.

$$S = \begin{vmatrix} x_1^+ & x_1^- \\ \vdots & \vdots \\ x_n^+ & x_n^- \end{vmatrix} \quad (8)$$

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - x_j^+\right)^2} \quad (9)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - x_j^-\right)^2} \quad (10)$$

The alternatives' closeness coefficients is expressed as a function of these distances (Equation 11). Based on these expression, the most suitable alternative is the alternative with the largest coefficient. The alternative with the lowest coefficient is considered as the least suitable alternative.

$$S_i = \frac{S_i^-}{S_i^+ - S_i^-} \quad (11)$$

iii. CRITIC method

Diakoulaki et al. (1995)introduced this method as a tool for simplying MCDM analysis. It has the unique property of using the value of alternatives rating to determine the criteria importance. Hence, it reduces the data requirement for a MCDM problem(Ighravwe & Babatunde, 2018). To determine criteria importance, it evaluates criteria standard deviation and correlation coefficients; the values used for this analysis could be

obtained from a weighted normalised decision matrix (Equation 4).
The correlation coefficient is used to evaluation the conflict which a criterion creates by including it into a decision-making problem. Equation (12) is used to measure this conflict in a MCDM problem.

$$C_j = \sum_{k=1}^{m} (1 - r_{jk}) \quad (12)$$

$$r_{jk} = \frac{\sum_{i=1}^{m} (n_{ij} - \bar{n}_j)(n_{ik} - \bar{n}_k)}{\sqrt{\sum_{i=1}^{m} (n_{ij} - \bar{n}_j)^2 (n_{ik} - \bar{n}_k)^2}} \quad (13)$$

The quantity of information which a criterion contains when analysing a MCDM depends on the conflict values and a criterion standard deviation (Equation 14).

$$q_j = \sigma_j c_j \quad (14)$$

$$\sigma_j = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (n_{ij} - \bar{n}_j)^2} \quad (15)$$

Based on the criteria information quantity values, Equation (16) is used to determine the criteria objective weights (Slebi-Acevedo et al., 2019).

$$w_j = \frac{q_j}{\sum_j^n q_j} \quad (16)$$

3. Case study

This study used the literature available to identify the criteria that affect the performance of public BCPs in Nigeria. A total of 20 criteria for public BCPs are based on literature and practitioners' domain knowledge. It adopted a purposive sampling approach to generate data for the framework implementation – via a questionnaire. This approach is a non-probabilistic sampling technique that considers people with domain knowledge about an investigative study. The study's population of interest is experts in the built environment in Southwest Nigeria. The selected experts are drawn from six locations in Southwest Nigeria. Table 3.1 presents the experts' attributes.

The study 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). The study adopted the primary data collection method as its data source. Due to the lack of previous reports on the criteria, this method is considered and used to generate relevant information for the framework implementation. The study used information collected from 72 experts to implement the designed FBSC framework. Table 3.2 presents the distribution of the experts for the different FBSC frameworks. They provided information regarding the targeted and actual performance for the criteria in the FBSC models.

The study used observations, direct interviews and questionnaires were used as its research instruments. Observations, direct interviews and questionnaires were used to generate information for the CRICTIC implementation. On the other hand, the study used questionnaires to generate information for the FBSC framework implementation.

To avoid bias about the criteria importance, the 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.

Measurement tools like scales and questionnaires were used as research instruments. These tools were created to collect information from research participants. The primary research tool was a structured questionnaire, along with organisational data. A team of experts created and approved the questionnaire self-administered by the relevant project stakeholders in the study's chosen population.

The current study considered public BCPs that have been completed in six state capitals in Southwest Nigeria. The locations considered are Ibadan (L1), Ikeja (L2), Abeokuta (L3), Ado-Ekiti (L4), Akure (L5) and Osogbo (L6). Figure 1 presents the locations' map. These locations were selected because developmental activities for public infrastructure often cluster in the state capital. Due to ethical issues, the study used labels to represent the locations because of information confidentiality. Furthermore, most people who can provide information about public BCPs have their offices in their respective state capital.

Figure 1. Map for the case study (Simwa, 2017)

Information collected was processed, analysed and evaluated. To deal with uncertainty caused by imprecision and vagueness, Zadeh (1965) proposed the fuzzy set theory. The capacity of fuzzy set theory to describe ambiguous data is a significant addition. In addition, the theory allows for applying mathematical operations and programming to the fuzzy domain. This method was implemented based on the information presented in Table 1.

Table 1: Linguistic values and mean of fuzzy numbers

Linguistic variables	Notation	Fuzzy number mean
Extremely 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

4. Results and Discussion

This sections contains information about results obtained about the CRITIC, FBSC and TOPSIS methods.

4.1 Criteria Importance

4.2 FBSC performance

The linguistic values for Location 1 are in Table 4.16 presents. The linguistic values for the other locations are presented in Table 3**Ошибка! Источник ссылки не найден.**. These values were converted to crisp values and used to discuss the location's performance under builders' considerations.

i. FBSC result for the financial criteria

present the FBSC framework's results for the selected locations. These results showed that four locations underperformed based on the potential to keep track of project costs (Location 2, Location 4, Location 5 and Location 6). The average under-performance for these four locations is 57.39%. Among these locations, which have underperformed, Location 6 had the worst performance because its deviation from the expected targeted value was 43.24%. On the other hand, Location 2 had a minor negative deviation from its targeted values (10%). The study observed that two location results exceeded their targeted values (locations 1 and 3). The average performance improvement for locations 1 and 3 is 6.67%. For Location 1, this study observed a performance improvement of about 0.84% (Table 4). On the other hand, there was a performance improvement of about 12.50% for Location 3. Since Location 3 performed better than the other locations, stakeholders in the other locations could use it to benchmark the performance of their locations. According to this analysis, the average performance for the financial criteria was 88.09%. This performance could be attributable to the findings from four places: Locations 2, 4, 5, and 6. However, locations 5 and 6 contributed more to the poor performance than locations 2 and 4.

Table 1: Location 1 linguistic target and actual values for FBSC

	Targeted performance				Actual performance			
Criterion	DM1	DM2	DM3	DM4	DM1	DM2	DM3	DM4
F2	EH	L	ML	M	L	VH	VH	L
S1	H	ML	VL	VL	VH	L	ML	VH
S2	VH	H	VL	M	H	M	ML	M
S3	VL	L	VH	M	VH	VL	M	M
P1	VH	L	EH	EH	M	M	H	H
P2	VH	VH	L	H	VH	ML	H	ML
P3	ML	EH	L	VH	VH	M	ML	ML
P4	H	VH	EH	EH	L	L	VL	ML
L1	L	M	M	H	L	VL	ML	ML
L3	VH	VL	M	ML	ML	VL	L	ML
L4	ML	VL	ML	H	VH	VH	M	L
L5	H	H	ML	L	VH	ML	H	VL
L6	M	EH	L	VH	VL	ML	ML	H

Table 2: Aggregated fuzzy scores for FBSC criteria for Location 1

Criterion	Target performance			Actual performance		
	a_1	a_2	a_3	a_1	a_2	a_3
F2	0.40	0.50	0.58	0.40	0.50	0.60
S1	0.25	0.35	0.45	0.43	0.53	0.63
S2	0.40	0.50	0.60	0.40	0.50	0.60
S3	0.33	0.43	0.53	0.38	0.48	0.58
P1	0.55	0.65	0.70	0.45	0.55	0.65
P2	0.48	0.58	0.68	0.43	0.53	0.63
P3	0.45	0.55	0.63	0.40	0.50	0.60
P4	0.63	0.73	0.78	0.20	0.30	0.40
L1	0.38	0.48	0.58	0.23	0.33	0.43
L3	0.35	0.45	0.55	0.23	0.33	0.43

L4	0.30	0.40	0.50	0.45	0.55	0.65
L5	0.38	0.48	0.58	0.38	0.48	0.58
L6	0.48	0.58	0.65	0.30	0.40	0.50

Table 3: FBSC result for financial requirement

Location	Target performance	Actual performance	Score (%)	Remarks
Location 1	0.4958	0.5000	100.84	Exceed target
Location 2	0.5000	0.4500	90.00	Under target
Location 3	0.4000	0.4500	112.50	Exceed target
Location 4	0.5958	0.4750	79.72	Under target
Location 5	0.5958	0.3500	58.74	Under target
Location 6	0.6167	0.3500	56.76	Under target

ii. FBSC result for the clients' criteria

Table 6 presents the performance of the locations based on the analysed data for the clients' information. Only one location achieved the targeted values for the different parameters (Location 1) from this table. On the contract, two locations could not achieve the targeted values for the different parameters (locations 4 and 6). More information about the locations' overview is presented in Table 6.From the score presented, the following information was extracted about the criteria performance:

- The results showed that the best performance was recorded for the propensity to construct high-quality buildings, especially in Location 1. This improvement indicated a possibility of exceeding targeted values for this criterion by about 50%.
- The locations are considered to lack the capacity to provide top-notch service to their market. This problem is predominant in the markets that are situated in Location 3. Further analysis of this location's performance showed that the target value's negative deviation was about 37.50% for the criterion.

The locations' overall performance showed that Location 2 had the best performance improvement regarding the selected criteria for the client-balanced scorecard (73.96%). The performance improvement for the other locations is 61.76% for Location 1 and Location 3 for 14.00%. On the contrary, this study observed that Location 5 had the minimum overall negative deviation from their criteria targeted value (-17.39%). The minimum overall negative deviation from their criteria targeted value for the other locations is 24.72% for Location 4 and 28.50% for Location 6.

Table 4: FBSC result for client performance

Location	Criterion	Target performance	Actual Performance	Score (%)	Remark
1	S1	0.3500	0.5250	150.00	Exceed target
	S2	0.5000	0.5000	100.00	Exceed target
	S3	0.4250	0.4750	111.76	Exceed target
2	S1	0.4208	0.5750	136.63	Exceed target
	S2	0.4000	0.6250	156.25	Exceed target
	S3	0.6167	0.5000	81.08	Under target
3	S1	0.3708	0.5000	134.83	Exceed target
	S2	0.6000	0.3750	62.50	Under target
	S3	0.4500	0.5250	116.67	Exceed target

4	S1	0.5250	0.4500	85.71	Under target
	S2	0.5500	0.5250	95.45	Under target
	S3	0.4250	0.4000	94.12	Under target
5	S1	0.4750	0.5500	115.79	Exceed target
	S2	0.5167	0.4500	87.10	Under target
	S3	0.5958	0.4750	79.72	Under target
6	S1	0.5500	0.4500	81.82	Under target
	S2	0.4500	0.4250	94.44	Under target
	S3	0.5250	0.5000	95.24	Under target

Figure 4.6 presents the client's criteria average results for FBSC. The results showed that the performance for S1 was better than for S2 and S3. On the other hand, S2 performance was better than that of S3.

iii. FBSC result for internal process criteria

Table 7present the locations' internal processes results based on the domain experts' information. These results showed that the locations could not concurrently generate performance that exceeded the targeted values for the four criteria. This study observed that two locations could not exceed the targeted values for any criteria (locations 1 and 4). Further investigations of these locations showed that Location 1 had a deficit of about 89.53% when its overall performance was evaluated. On the other hand, this study observed that the Location 4 performance deficit was less than Location 1 - 84.60% was obtained as Location 4 performance deficit.

The other locations' overall performance summary showed that only Location 2 had a performance surplus - 28.20%. Hence, the following highlights present information about the other locations' performance deficits:

- For Location 3, a performance deficit of about 21.77% was observed. This issue was caused by the poor performances that were recorded for P3 and P4. Hence, the stakeholders in this location need to devise strategies to improve performance regarding these criteria.
- The evaluation of Location 5 results showed that stakeholders must improve their internal processes, especially in P3 and P4. Such improvement will help reduce the location's performance deficit -4.55%.
- The performance deficit that was recorded for Location 6 is about 62.39%. This deficit is due to the poor performance that was observed in P2 and P4 (Table 7). Hence, the stakeholders in these locations need to consult other locations' stakeholders, especially those in Location 2

Generally, the results showed that the result for P4 in all the locations was below their target values. A similar observation was obtained for P3, except for Location 6. For the other criteria, this study observed that the results for P1 generated a maximum performance improvement of about 38.89% - based on the results presented for Location 2. Table 7 showed a performance improvement of 15.97% for P2 – see Location 5 for more details. The average values for the FBSC internal process criteria are displayed in Figure 4.7. One could infer from this figure that P1 produced a better result than the other criteria. Additionally, it was shown that P2 performed better than P3 and P4.

Table 5: Internal process results for the FBSC

Location	Criterion	Target performance	Actual Performance	Score (%)	Remark
1	P1	0.6417	0.5500	85.71	Under target
	P2	0.5750	0.5250	91.30	Under target
	P3	0.5458	0.5000	91.60	Under target
	P4	0.7167	0.3000	41.86	Under target

2	P1	0.4500	0.6250	138.89	Exceed target
	P2	0.3750	0.4000	106.67	Exceed target
	P3	0.4208	0.4000	95.05	Under target
	P4	0.5708	0.5000	87.59	Under target
3	P1	0.6167	0.7000	113.51	Exceed target
	P2	0.5500	0.4500	81.82	Under target
	P3	0.5208	0.4500	86.40	Under target
	P4	0.5958	0.5750	96.50	Under target
4	P1	0.5708	0.4750	83.21	Under target
	P2	0.6167	0.4250	68.92	Under target
	P3	0.3708	0.2750	74.16	Under target
	P4	0.4208	0.3750	89.11	Under target
5	P1	0.3958	0.4750	120.00	Exceed target
	P2	0.4958	0.5750	115.97	Exceed target
	P3	0.6208	0.4000	64.43	Under target
	P4	0.4208	0.4000	95.05	Under target
6	P1	0.4208	0.4500	106.93	Exceed target
	P2	0.6000	0.3750	62.50	Under target
	P3	0.4500	0.4500	100.00	Exact
	P4	0.5500	0.3750	68.18	Under target

iv. FBSC result for the learning and growth criteria

From the above discussion, it could be deduced that Location 1 had the worst performance regarding the internal process of the building construction industry in Southwest Nigeria. The results that were discussed showed that Location 2 had the best performance in the internal process of building construction industry in Southwest Nigeria.

Table 8present the locations' learning and growth criteria results. From the information, it could be deduced that only Location 2 could not produce a performance that exceeded the targeted values for the criteria. This location performed poorly, especially under L3 –a deficit of 15.79% from the targeted value for this criterion. L5 generated the best results for this location and deviated from its targeted value by 5.26%. However, the overall performance for this location was more than the targeted performance by about 47.92%. Table 8 showed that the other locations generated overall performance exceeding their targeted values. However, Location 3 generated the best result regarding exceeding the specified values (223.46%). This performance could be attributed to the location's capacity of generated more than the targeted values for the learning and growth criteria, except for L5 – which had a negative deviation of about 25.55%.

Location 6 generated the next performance close to that of Location 3. In Location 6, this study observed an overall improvement regarding the criteria contained in the FBSC framework (148.41%). This improvement has a result of the performance obtained from Location 4. For other criteria, this location performed poorly; for instance, a 27.78% deviation was obtained as the performance gap for Location 1. The results for the other criteria were above 90%. Table 8**Ошибка! Источник ссылки не найден.** showed that Location 4 overall performance was above 100% because of the contributions from three criteria – L1, L4 and L5. In the specific term, the overall performance was 113.58%, which could not exceed this value due to the poor performance obtained from locations 3 and 6. The remaining two locations' overall performance is less than 100%. It was observed that locations 1 and 5 had an overall performance improvement of 48.21 and 59.22%, respectively. Location 1 could not generate more than 50% overall performance improvement because of the results obtained for L1, L3 and L6.

The learning and growth criteria for the FBSC framework are shown in Figure 4.8. According to the results, only three criteria (L1, L4 and L5) performed above 100%. L4 performed the best among these criteria, whereas L1 outperformed L5 in performance. This figure indicated that among the learning and growth criteria, L6 had the weakest performance.Figure 4.8 demonstrates that the builders successfully produced L4 performance superior to the other learning and growth criteria. On the other hand, L6's result was the lowest among the learning and growth criteria. The other criteria are ranked L5 as second, L3 as third, and L1 as fourth. Figure 4.9 showed that the builders performed better from the client's perspective than from any other standpoint. In comparison to the other two perspectives, their performance from a financial perspective is worse.

Table 6: Learning and growth results for the FBSC framework

Location	Criterion	Target performance	Actual Performance	Score (%)	Remark	Location	Criterion	Target performance	Actual Performance	Score (%)	Remark
1	L1	0.4750	0.3250	68.42	Under target	4	L1	0.5458	0.5500	100.76	Exceed target
	L3	0.4500	0.3250	72.22	Under target		L3	0.5917	0.5000	84.51	Under target
	L4	0.4000	0.5500	137.50	Exceed target		L4	0.5000	0.6000	120.00	Exceed target
	L5	0.4750	0.4750	100.00	Exact		L5	0.4250	0.6000	141.18	Exceed target
	L6	0.5708	0.4000	70.07	Under target		L6	0.5958	0.4000	67.13	Under target
2	L1	0.5208	0.4750	91.20	Under target	5	L1	0.3500	0.5250	150.00	Exceed target
	L3	0.4750	0.4000	84.21	Under target		L3	0.7125	0.2750	38.60	Under target
	L4	0.4000	0.3500	87.50	Under target		L4	0.4708	0.3750	79.65	Under target
	L5	0.4750	0.4500	94.74	Under target		L5	0.4750	0.5000	105.26	Exceed target
	L6	0.4708	0.4250	90.27	Under target		L6	0.4958	0.4250	85.71	Under target
3	L1	0.3750	0.5750	153.33	Exceed target	6	L1	0.4500	0.3250	72.22	Under target
	L3	0.2500	0.4000	160.00	Exceed target		L3	0.5500	0.5250	95.45	Under target
	L4	0.4250	0.5250	123.53	Exceed target		L4	0.2500	0.4750	190.00	Exceed target
	L5	0.5708	0.4250	74.45	Under target		L5	0.4750	0.4500	94.74	Under target
	L6	0.4458	0.5000	112.15	Exceed target		L6	0.5208	0.5000	96.00	Under target

4.3 TOPSIS results

Based on the FBSC outputs, TOPSIS is used to aggregated the locations' performance to indentify the best and least performaing locations. Table 9 presents the decision matrix used for the performance aggregation using the TOPSIS method. Using Equation (), the normalised values for the criteria were generated.

Table 7: Decision matrix for the performance evaluation problem

Criterion	L1	L2	L3	L4	L5	L6
C1	0.500	0.450	0.450	0.475	0.350	0.350
C2	0.350	0.421	0.371	0.525	0.475	0.550
C3	0.500	0.400	0.600	0.550	0.517	0.450
C4	0.425	0.617	0.450	0.425	0.596	0.525
C5	0.642	0.450	0.617	0.571	0.396	0.421
C6	0.575	0.375	0.550	0.617	0.496	0.600
C7	0.546	0.421	0.521	0.371	0.621	0.450
C8	0.717	0.571	0.596	0.421	0.421	0.550
C9	0.325	0.475	0.575	0.550	0.525	0.325
C10	0.325	0.400	0.400	0.500	0.275	0.525
C11	0.550	0.350	0.525	0.600	0.375	0.475
C12	0.475	0.450	0.425	0.600	0.500	0.450
C13	0.400	0.425	0.500	0.400	0.425	0.500

From Figure 2, it was observed that the most important criterion for client's management in the built environment was high-quality structures. It was also observed the the least important criterion for client's management was top-notch service to the market. In term of the most and least important criteria for the internal process within the construction industry was project administration effectiveness and efficiency and strong client ties, resepectively. The results about the learning and growth in the construction industry showed that the most important criterion was encouragement of stakeholders. On the other hand, it was observed that the least important criterion was goal-oriented management culture.

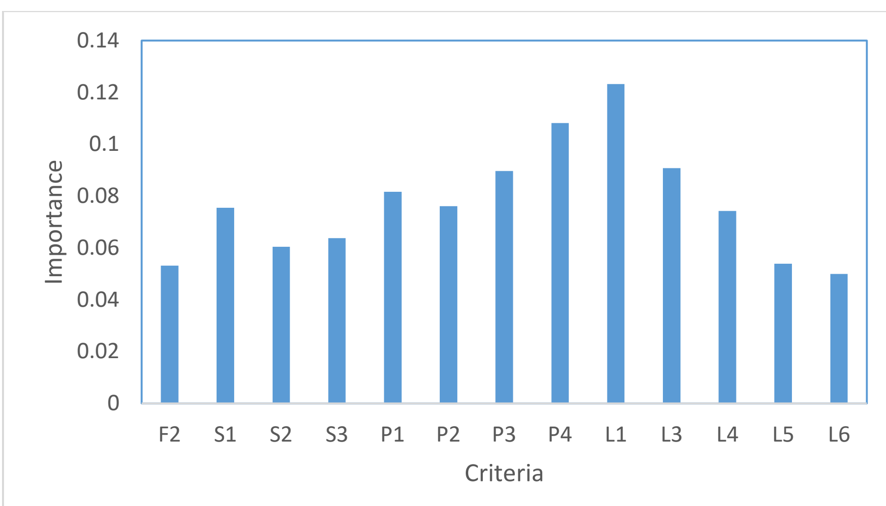

Figure 2: CRITIC method outputs

Table 10 represents the weighted normalised decision matrix for the current decision-making problem. The matrix was generated using the criteria's importance and the normalised values for the locations' performance. Using the information in Table Table 10, the criteria's ideal and non-ideal values were selected from the weighted normalised decision matrix. The selection of the criteria's ideal solutions was based on Equation (11). Similarly, this study used Equation (2) to select the criteria's non-ideal solutions.

Table 8: Weighted normalized decision matrix for the performance evaluation problem

Criterion	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**
C1	0.025	0.023	0.023	0.024	0.018	0.018
C2	0.024	0.029	0.025	0.036	0.032	0.037
C3	0.024	0.019	0.029	0.027	0.025	0.022
C4	0.022	0.031	0.023	0.022	0.030	0.027
C5	0.041	0.029	0.039	0.036	0.025	0.027
C6	0.033	0.022	0.032	0.035	0.028	0.034
C7	0.040	0.031	0.038	0.027	0.046	0.033
C8	0.057	0.045	0.047	0.033	0.033	0.044
C9	0.035	0.050	0.061	0.058	0.056	0.035
C10	0.029	0.036	0.036	0.045	0.025	0.047
C11	0.034	0.022	0.033	0.037	0.023	0.030
C12	0.021	0.020	0.019	0.027	0.023	0.020
C13	0.018	0.019	0.023	0.018	0.019	0.023

Next, this study generated the loctions' ideal and non-ideal solutions; these solution are requirements for the locations' closeness coefficients determination. Equation (3) was used to generate the locations' ideal solution. On the other hand, Equation (4) was used to generate the locations' non-ideal solutions. Equation (5) was used to aggregate the location's ideal and noon-ideal solutions. Table 11 presents the results that were obtained.

Table 9: TOPSIS summary for the problem

	L1	**L2**	**L3**	**L4**	**L5**	**L6**
Ideal solution	0.0014	0.0007	0.0017	0.0018	0.0010	0.0011
Noo-ideal solution	0.0028	0.0128	0.0174	0.0172	0.0137	0.0141
Coeeficient	0.6724	0.9486	0.9109	0.9036	0.9299	0.9272

Figure 3 presents the TOPSIS method's results for the current decision-making problem. This figure indicates that Location 2 had the best performance. On the other hand, L1 had the least performance among the selected lcoations. The ranking order, in a decendeing order, for the other locations are: Location 5, Location 6, Location 3 and location 4.

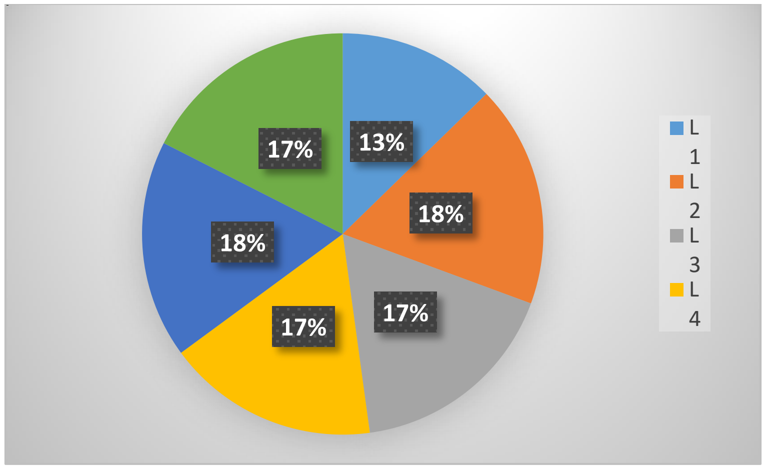

Figure 3: TOPSIS results for the locations

5. Conclusions

This paper contains the application of a fuzzy BSC and TOPSIS for the analysis of architects and engineers performance evaluation in different locations. The performance evaluation is based on these stakeholders contributions towards a sustainable project construction for public buildings. Hence, discussion on the stakeholders performance were presented based on the comparative analysis of outputs from a FBSC framework. TOPSIS is used to analyse the FBSC outputs based on six locations performance. First, information about selected criteria was presented. Second, performance gaps for the selected locations were evaluated. Last but not the least, TOPSIS method was used to rank the locations performance. Six experts in the locations were consulted to provide information about the architects and engineers performance regarding the selected criteria.

It was observed that the most important criterion for client's management in the built environment was high-quality structures. In term of the most important criteria for the internal process within the construction industry was project administration effectiveness and efficiency. The results about the learning and growth in the construction industry showed that the most important criterion was encouragement of stakeholders. The TOPSIS results showed that the location with the best performance among architects and engineers was Location 2. It was also observed that the location with the least performance among these stakeholders was Location 1. Having established the applicability of a combined TOPSIS and FBSC method, it couls be suggested that other MCDM could be used to substitute the TOPSIS in the proposed framework. This suggestion will allow for comparison of results between the substituted MCDM and the TOPSIS method. Furthermore, environmental and policy requirements ccould be included in the proposed framework. This inclusion will improve the proposed framework rubustness.

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