CONSTRUCTION PROJECT MANAGEMENT

Assessment of Value Engineering as a Strategic Tool for Cost Optimisation in Construction Project Delivery: A Case Study of a Two-Storey Commercial Complex

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Abstract

Architects and other professionals in the architecture, engineering, and construction industries encounter numerous problems related to on-time and on-budget project delivery. Project failure and delays in developing countries such as Nigeria result from inefficient use and disposal of construction resources and materials, design deficiencies, and inadequate communication and coordination among project team members. This paper presents and evaluates a framework integrating 5D BIM and the Value Engineering Job Plan process to enhance value and reduce costs and time and improve communication and coordination during all phases of a project's life cycle. A mixed-method research design was used to conduct a quantitative survey of built environment professionals in Oyo State, Nigeria (N = 43 out of 50 completed survey questionnaires distributed, an 86.00% response rate), and a quantitative 5D BIM-VE case study of the completed Two-Storey Multipurpose Commercial Complex project (1,770 m^2) on Secretariat-University College Hospital (UCH) Road in Ibadan, Nigeria. Survey methods included mean item rating and relative importance indexes. Orion BIM software data were analyzed at various stages of the VE Job Plan process (including Information, Function Analysis, Creativity, Evaluation, Development, and Proposal) related to the case project. Empirical studies show that individual professionals are generally knowledgeable about VE (mean knowledge index = 3.930, RII = 0.786) but that VE is underutilized by organizations due to a lack of VE skills in the organization (mean institutionalization index = 2.930, RII = 0.586) and other cultural factors inhibiting VE adoption (RII = 0.809). The key factors promoting VE adoption are management support (RII = 0.865) and VE skills (RII = 0.851). Case studies indicate that the major cost components for a project included Sub- and Superstructures (30.00%; ₦56,556,960), Doors, Windows, Wall Cladding, and Cutting Walls (28.00%; ₦52,786,496), and MEP (20.00%; ₦37,704,640). Floor slabs accounted for 49.37% (255.259 m^3) of the total structural concrete volume of 516.998 m^3. Replacing solid slabs and 225 mm sandcrete blocks with waffle or ribbed slabs and 150 mm lightweight blocks and replacing standard glazing with composite glass-aluminium curtain walling raised the weighted criteria score from 85 to 87 points and reduced the project cost from ₦188,523,200 to ₦161,140,300, a savings of ₦26,828,646, or 14.30% of the initial construction cost and up to 15.00% of total lifecycle costs, and saved 15% of the project time without compromising structural integrity or safety.

Keywords: Value engineering (VE); building information modelling (BIM); construction schedule; cost control; VE and BIM integration

1 Introduction

1.1 Background to the study

The construction industry is essential to economic and social progress and capital investment in developed and developing countries. Problems encountered in construction projects in developed and developing countries include high costs and long project schedules, misuse of other resources, communication problems among project participants, and high percentages of unfinished projects (Anyanwu, 2013; Kolo and Ibrahim, 2010). Many construction projects in the public and private sectors in Nigeria remain unfinished for a variety of reasons, including insufficient funding and other financial resources and poor cost-estimating and cost-control practices. Poor value-assessment practices are also widespread (Ewa, 2013; Amade et al., 2015). Cost-control techniques that help owners and other construction professionals achieve a balance between cost, quality, and durability can be valuable to project owners and other construction professionals.

Value engineering is a traditional practice used to reduce costs while maintaining or improving other project objectives. The value engineering practice originated at General Electric Company during World War II when Lawrence D. Miles, Jerry Leftow, and Harry Erlicher were design engineers looking for solutions to labor and material shortages. Value engineering has been refined into a formal process called value analysis or value control (Sharma and Belokar, 2012). Value engineering is defined by SAVE International (2020) and the US Department of Defense (2006) as a disciplined, team approach to examining the functions of systems, facilities, equipment, and services to achieve those functions in the lowest life-cycle cost compatible with required quality, reliability, safety, and other attributes.

Akinola et al. (2001) found two general categories of cost drivers for building projects: cost drivers for specific building systems and cost drivers for entire building projects. Value engineering methods are particularly valuable because they include peer review of building design options during the design development and schematic design stages of a building project when life-cycle cost savings and other design changes can be made most inexpensively (Khaled and Pandey, 2016; Attard and Rane, 2016). Advances in BIM technology, including 5D BIM tools that integrate 3D and 4D BIM with other cost modeling features, provide other tools and technologies that can aid building project teams with quality takeoff and other 5D modeling tasks (Azhar, 2011; Amoah and Wao, 2023).

1.2 Statement of the problem and research gap

Despite broad consensus in the literature on the benefits of value engineering and Building Information Modeling, DBB procurement in Nigeria encounters obstacles, including cost delays and other issues with relationships among other project parties (Oke and Ogunsemi, 2011; Aduze, 2014). Potential drawbacks to paper-based 2D plan and spreadsheet use in value engineering and other value engineering activities include data shortages and other problems with measurements and other tasks and decision making with multiple parties, as well as price instability (Aya Hasan, 2017; Al-Gahtani, 2022).

In addition to empirical studies in Nigeria on value engineering awareness and constraints among professionals, mainly in Lagos State, and BIM constraints and usage, no functional studies have been conducted (Odeyinka, 2006; Akinola et al., 2022; Baarimah et al., 2021). Few empirical studies in Oyo State include data on value engineering and other subjects and a 5D BIM-VE parametric case study of value engineering application in a commercial building project. A lack of integrated empirical and

technical studies showing cost and time savings has discouraged value engineering workshops by construction and government organizations.

1.3 Aim, objectives and scope of the study

The overall objective of the research is to develop and test a framework for combining Value Engineering and 5D Building Information Modeling techniques to enhance construction project cost and schedule performance and long-term value while preserving project quality and safety. Other objectives of the research include (i) assessing awareness and knowledge of and barriers to and benefits of adopting Value Engineering by built environment professionals in Oyo State; (ii) developing an integrated Value Engineering and 5D Building Information Modeling process that uses parametric takeoff and other design assessment and decision tools; and (iii) implementing and testing the proposed framework through a comparison of structural and elemental costs for a Two-Storey Multipurpose Commercial Complex on Secretariat-University College Hospital (UCH) Road in Ibadan, Oyo State, Nigeria.

1.4 Theoretical framework and literature synthesis

The conceptual architecture of this research rests upon five interlocking theoretical pillars that govern value creation and digital collaboration in construction engineering:

1. **Value Theory:** Value Theory, developed by Lawrence Miles, suggests that a project's value (V) can be calculated by dividing its functional utility (F) by its cost (C). This is expressed as $V = F/C$ (Kelly et al., 2014; SAVE International, 2020). Project value can be increased by increasing functional utility without increasing the overall project cost, decreasing the overall project cost without reducing functional utility or both.
2. **Functional Analysis Theory:** Based on the Pareto principle, which states that around 80% of a building's cost is due to 20% of a building's physical components (Attard and Rane, 2016). Functional Analysis Theory includes two- to three-word functional descriptors for physical components, such as 'transfer load' and 'enclose space'. Use of functional analysis can aid designers in removing unnecessary design elements and identifying material and design alternatives.
3. **Systems Method:** Systems theory describes a building project as consisting of subsystems, such as structural and mechanical and electrical subsystems. Modifying one subsystem, for example, by specifically altering wall and floor designs to make them lighter, can reduce dead loads on columns and footings. Understanding and costing a building project require consideration of the project as a whole, not just its subsystems.
4. **Lifecycle Costing Theory:** Lifecycle Costing Theory provides a framework for making economic assessments, including the costs of operating and maintaining a facility and replacing and disposing of a facility during its life, in addition to the initial investment costs (Jaewook et al., 2020). This theory can help prevent cost-saving decisions that have immediate benefits but higher long-term costs for the facility.
5. **Applications of Decision Theory and 5D BIM:** Applications of Decision Theory and 5D BIM Parametric Theory provide additional options and techniques for making multicriteria decisions, including weighted decision matrices, with input from bidirectional data sharing between 3D and 5D BIM programs, such as Orion and Revit, and other cost estimation software (Lee and Na, 2018; Demirdöğen et al., 2021; Zhang et al., 2022).

2 Methodology

2.1 Research design and study area

This study employed a sequential mixed-methods design using a cross-sectional descriptive survey and a quantitative, parametric 5D BIM-VE case study. The study site was Ibadan, the capital of Oyo State in southwestern Nigeria. Ibadan is one of the largest urban centers in West Africa and has thriving commercial and residential real estate industries in which fluctuations in material and labor costs and other design considerations affect project success.

2.2 Empirical survey instrument and statistical analysis

A closed-question survey of 50 built environment professionals working in consulting firms, contractor firms, client organizations, and government and educational institutions in Oyo State was carried out to evaluate their perceptions of the benefits and drawbacks of using value engineering techniques. The survey instrument had seven sections rated on a five-point Likert scale, with scores from 1 to 5, 1 = Strongly Disagree, and 5 = Strongly Agree. Forty-three validated questionnaires were returned out of 50 distributed. The overall response rate was 86.00%.

Survey responses were analyzed using descriptive measures, including frequencies, proportions, Mean Item Scores, and Relative Importance Indexes. The Relative Importance Index was calculated using Equation (1):

$$RII = \frac{\sum W}{A \times N} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1}{5 \times N} \quad (1)$$

where W is the rating assigned by respondents to each statement on a scale of 1 to 5, A is the maximum rating of 5, and n_1 through n_5 represent the number of respondents who assigned each rating, respectively, and N is the number of valid respondents (N = 43). RII values range from 0 to 1 and can be used to rank issues.

2.3 Case study description and 5D BIM data extraction

The empirical case study involved a completed Two-Storey Multipurpose Commercial Building on the Secretariat-University College Hospital (UCH) Road in Ibadan, Oyo State. Data for the case study came from the owner with authorization and included architectural and structural working drawings, BoQs, material lists, and cost data. Analysis and costing software used included Orion BIM and Microsoft Excel to create a 5D BIM baseline model for the case study project.

Table 1 presents the general physical and contractual characteristics of the case study commercial complex.

Table 1. General physical and contractual characteristics of the case study commercial complex.

Project Parameter	Specification / Value
Project Title / Type	Two-Storey Multipurpose Commercial / Office Complex
Geographical Location	Along Secretariat–UCH Road, Ibadan, Oyo State, Nigeria
Number of Floors / Units	Three (3) Floors (Ground + 2 Suspended Floors); 15 Office Units & 1 Multipurpose Hall
Gross Floor Area (GFA)	1,770 m^2
Structural System	Reinforced Concrete Framed Structure (Columns, Beams, and Solid Slabs)

Project Parameter	Specification / Value
Foundation System	Reinforced Concrete Pad Foundations
Walling System	225 mm (9-inch) Sandcrete Hollow Block Walls
Roofing System	Hip Roof with Step-Tile Aluminium Roofing Sheets
Construction Duration	Approximately Six (6) Months (Completed)
Baseline Contract Cost	₦188,523,200 (Initial Estimate: ₦182,000,000)

2.4 Integrated 5D BIM–value engineering job plan procedure

Following SAVE International (2020) standards, the case study evaluation executed the six sequential phases of the Value Engineering Job Plan enhanced by 5D BIM parametric extraction:

Information Phase: Review of structural and other information in the Orion BIM model resulted in estimates of concrete volume (m^3), formwork area (m^2), and high-strength reinforcing steel quantity (kg) and unit costs using the elemental BoQ approach. Elemental cost contributions were determined using Equation (2):

$$\text{Cost contribution}\ (\%) = \frac{\text{Element cost}}{\text{Total project cost}} \times 100 \tag{2}$$

Function Analysis Step: The major systems in the building were analyzed, and primary and secondary functions extracted using verb-noun grammatical techniques to find the high-cost, low-value functions.

Creativity Phase: Multidisciplinary brainstorming generated technically feasible design and material alternatives—specifically waffle/ribbed slab systems, 150 mm lightweight blockwork, and composite glass-aluminium curtain walling—capable of delivering equivalent or superior structural and architectural performance.

Evaluation: Nine alternative solutions were rated based on seven weighted factors: Initial Cost (30%), Functionality (20%), Quality (15%), Durability (15%), Safety (10%), Constructability (5%), and Maintenance (5%). The weighted scores S_j for each alternative j are given by Equation (3):

$$S_j = \sum_{i=1}^{n} w_i r_{ij} \tag{3}$$

where w_i is the weight, expressed as a percentage, of criterion i and r_{ij} is the rating of alternative j on criterion i.

Development and Request for Proposal Stage: The top choices by weighted score were fully developed to validate structural adequacy and cost improvements and updated BoQ quantities and savings, using Equations (4) and (5). Life-cycle costs were validated using Equation (6).

$$\text{Cost saving} = C_o - C_v \tag{4}$$

$$\text{Percentage saving}\ (\%) = \frac{C_o - C_v}{C_o} \times 100 \tag{5}$$

$$LCC = C_i + C_{op} + C_m + C_r \tag{6}$$

where cost saving is expressed in naira (₦), C_o is original baseline cost, C_v is the Value Engineering alternative cost, C_i is initial cost, C_{op} is operating cost, C_m is maintenance cost, and C_r is replacement cost.

3 Results and discussion

3.1 Empirical survey findings: respondent profile and VE awareness

Of 50 questionnaires distributed to built environment professionals in Oyo State, 43 completed responses were analyzed (86% response rate). Table 2 describes the background characteristics of respondents, who were high-level built environment professionals: 27.91% civil engineers, 16.28% quantity surveyors, 11.63% structural engineers, 11.63% builders, 9.30% project managers, 9.30% contractors, and 6.98% architects. About three-fourths (74.42%) of respondents have a bachelor's or higher degree, including 27.91% with master's degrees and 4.65% with doctorates; more than 80% (81.40%) have more than five years of built environment experience, including 51.16% with more than ten years of experience; and more than half (53.49%) have completed more than 20 construction projects. Professional organizations to which respondents belong include COREN (32.56%), NSE (27.91%), NIQS (9.30%), and NIOB (6.98%). Respondents rate themselves as highly competent professionals.

Table 2. Demographic and professional profile of survey respondents (N = 43).

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male / Female / Prefer not to say	31 / 11 / 1	72.09% / 25.58% / 2.33%
Age Group	Below 25 / 25–34 / 35–44 / 45–54 / ≥ 55 yrs	5 / 17 / 13 / 6 / 2	11.63% / 39.53% / 30.23% / 13.95% / 4.65%
Profession	Civil Engineer	12	27.91%
	Quantity Surveyor	7	16.28%
	Structural Engineer / Builder (each)	5 / 5	11.63% / 11.63%
	Project Manager / Contractor (each)	4 / 4	9.30% / 9.30%
	Architect / Estate Surveyor / Others	3 / 1 / 2	6.98% / 2.33% / 4.65%
Highest Qualification	B.Sc./B.Eng./B.Tech / Master's / HND / PGD / PhD	18 / 12 / 7 / 4 / 2	41.86% / 27.91% / 16.28% / 9.30% / 4.65%
Professional Body	COREN / NSE / NIQS / NIOB / NIA / Others	14 / 12 / 4 / 3 / 2 / 8	32.56% / 27.91% / 9.30% / 6.98% / 4.65% / 18.60%
Working Experience	< 5 yrs / 5–10 yrs / 11–15 yrs / 16–20 yrs / > 20 yrs	8 / 13 / 10 / 7 / 5	18.60% / 30.23% / 23.26% / 16.28% / 11.63%
Organisation Type	Contractor / Public Sector / Consultant / Client / Others	12 / 11 / 10 / 5 / 5	27.91% / 25.58% / 23.26% / 11.63% / 11.63%
Projects Executed	< 10 / 10–20 / 21–50 / > 50 projects	9 / 11 / 15 / 8	20.93% / 25.58% / 34.88% / 18.60%

Table 3 shows practitioners' and organizations' awareness and adoption of Value Engineering. Survey results suggest the greatest awareness among practitioners about the concept of Value Engineering (Mean = 3.930, RII = 0.786) and about client encouragement to use Value Engineering (Mean = 3.767,

RII = 0.753) in projects. Other indicators of organizational adoption of Value Engineering (Mean = 3.233, RII = 0.647) and availability of skilled staff at the organization level (Mean = 2.930, RII = 0.586) ranked sixth and last, respectively. Overall, institutionalization of Value Engineering appears to lag behind awareness.

Table 3. Level of awareness and adoption of value engineering practices (N = 43).

Statement	SA	A	N	D	SD	Mean	RII	Rank
I am familiar with Value Engineering principles.	14	18	6	4	1	3.930	0.786	1
Clients encourage the use of VE.	12	17	8	4	2	3.767	0.753	2
VE forms part of project planning.	10	16	9	6	2	3.605	0.721	3
VE studies are conducted before major design decisions.	9	16	8	7	3	3.488	0.698	4
Value Engineering is introduced during conceptual design.	8	15	9	8	3	3.395	0.679	5
Value Engineering is regularly applied in my organisation.	7	13	10	9	4	3.233	0.647	6
My organisation has trained VE personnel.	5	10	11	11	6	2.930	0.586	7

Note: SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; RII = relative importance index.

3.2 Implementation drivers, cost optimisation contributions and barriers

Assessment of eight main VE implementation factors (Table 4) shows that internal organizational factors are more significant than external factors. Senior management support was the most significant factor (Mean = 4.326, RII = 0.865), followed by employee skills (Mean = 4.256, RII = 0.851), relationships with other stakeholders (Mean = 4.233, RII = 0.847), and availability of full project information (Mean = 4.209, RII = 0.842). The findings are similar to those of Khaled and Pandey (2016) and indicate benefits of using 5D BIM technology to share information and promote VE.

Table 4. Factors influencing value engineering implementation (N = 43).

Implementation Factor	SA	A	N	D	SD	Mean	RII	Rank
Management commitment influences VE implementation.	22	15	4	2	0	4.326	0.865	1
Professional competence affects implementation.	20	16	5	2	0	4.256	0.851	2
Stakeholder collaboration enhances VE.	19	17	5	2	0	4.233	0.847	3
Availability of project information supports VE.	18	18	5	2	0	4.209	0.842	4
Client awareness influences VE adoption.	17	18	5	2	1	4.116	0.823	5
Adequate project time encourages VE.	13	18	8	3	1	3.907	0.781	6
Government policy promotes VE.	11	17	9	4	2	3.721	0.744	7
Project size influences VE adoption.	10	16	10	5	2	3.628	0.726	8

Note: SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; RII = relative importance index.

Regarding direct and indirect benefits (Tables 5 and 6), project professionals identified the highest levels of direct benefits as cost avoidance (Mean = 4.233, RII = 0.847), improved project cost performance (Mean = 4.209, RII = 0.842), and reduced waste and improved resource productivity (Mean = 4.186, RII = 0.837). Other major indirect benefits reported by respondents include improved

decision-making (Mean = 4.116, RII = 0.823), improved constructability (Mean = 4.070, RII = 0.814), improved lifecycle value (Mean = 4.047, RII = 0.809), and improved client satisfaction (Mean = 4.023, RII = 0.805).

Table 5. Contribution of value engineering to construction cost optimisation (N = 43).

Cost Optimisation Contribution	SA	A	N	D	SD	Mean	RII	Rank
VE reduces unnecessary construction costs.	19	17	5	2	0	4.233	0.847	1
VE improves overall project cost performance.	18	18	5	2	0	4.209	0.842	2
VE minimizes material waste.	18	17	6	2	0	4.186	0.837	3
VE enhances resource utilisation.	17	19	5	2	0	4.186	0.837	3
VE improves budget performance.	15	18	7	2	1	4.023	0.805	5
VE improves labour productivity.	12	18	9	3	1	3.860	0.772	6
VE reduces project variations.	10	17	10	4	2	3.674	0.735	7
VE reduces project delays.	9	16	11	5	2	3.581	0.716	8

Note: SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; RII = relative importance index.

Table 6. Overall qualitative and lifecycle benefits of value engineering (N = 43).

Benefit Statement	SA	A	N	D	SD	Mean	RII	Rank
VE improves decision-making.	17	18	5	2	1	4.116	0.823	1
VE improves constructability.	16	18	6	2	1	4.070	0.814	2
VE improves lifecycle value.	16	17	7	2	1	4.047	0.809	3
VE improves client satisfaction.	15	18	7	2	1	4.023	0.805	4
VE improves project quality.	14	18	8	2	1	3.977	0.795	5
VE enhances sustainability.	14	17	8	3	1	3.930	0.786	6
VE enhances communication.	13	18	8	3	1	3.907	0.781	7
VE reduces project risks.	12	18	8	4	1	3.837	0.767	8

Note: SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; RII = relative importance index.

On the other hand, Table 7 shows major barriers to VE application in Oyo State. The most important barrier is a lack of VE professionals (Mean = 4.116, RII = 0.823). Other barriers include cultural resistance to change and lack of support from top management (Mean = 4.047, RII = 0.809) and a lack of knowledge of technical VE issues (Mean = 3.977, RII = 0.795). Table 8 lists major strategies for overcoming barriers to VE in Oyo State. Strategies include training more VE professionals (Mean = 4.349, RII = 0.870), incorporating VE into project planning (Mean = 4.279, RII = 0.856), engaging stakeholders early in the project planning process (Mean = 4.209, RII = 0.842), and improving university VE training courses (Mean = 4.186, RII = 0.837).

Table 7. Challenges and barriers hindering value engineering practice (N = 43).

Barrier / Challenge	SA	A	N	D	SD	Mean	RII	Rank
Lack of trained professionals hinders VE.	18	16	6	2	1	4.116	0.823	1

Barrier / Challenge	SA	A	N	D	SD	Mean	RII	Rank
Resistance to change affects VE.	17	16	6	3	1	4.047	0.809	2
Insufficient management support hinders VE.	16	17	7	2	1	4.047	0.809	2
Lack of awareness limits VE.	15	17	7	3	1	3.977	0.795	4
Limited project time discourages VE.	14	17	8	3	1	3.930	0.786	5
Poor stakeholder collaboration limits VE.	13	17	8	4	1	3.860	0.772	6
Clients are reluctant to adopt VE.	11	16	10	4	2	3.698	0.740	7
Government policy is inadequate.	10	15	11	5	2	3.605	0.721	8

Note: SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; RII = relative importance index.

Table 8. Actionable strategies for enhancing value engineering practice (N = 43).

Improvement Strategy	SA	A	N	D	SD	Mean	RII	Rank
Increase professional training.	23	15	3	1	1	4.349	0.870	1
Encourage VE during project planning.	21	16	4	1	1	4.279	0.856	2
Encourage early stakeholder involvement.	20	16	4	2	1	4.209	0.842	3
Strengthen VE education in universities.	19	17	4	2	1	4.186	0.837	4
Develop national VE guidelines.	18	17	5	2	1	4.140	0.828	5
Increase awareness campaigns.	17	18	5	2	1	4.116	0.823	6
Establish dedicated VE teams.	17	17	6	2	1	4.093	0.819	7
Make VE workshops mandatory for major projects.	16	17	6	3	1	4.023	0.805	8

Note: SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; RII = relative importance index.

3.3 Case study information and functional analysis phases (5D BIM extraction)

Parametric analysis of the Orion 5D BIM model for the Two-Storey Multipurpose Commercial Complex yielded information on structural building material quantities and costs (Tables 9 and 10). The total concrete volume in the project was 516.998 cubic meters, and the total timber formwork area was 3,884.795 square meters. Other materials used in the project included 26,129.7 kilograms of high-yield reinforcement steel. The total concrete volume for solid reinforced concrete slabs was 255.259 cubic meters, or 49.37% of the total concrete volume for the project. The total concrete volume for reinforced concrete beams was 160.513 cubic meters, or 31.05% of the total concrete volume for the project, and the total steel used for reinforced concrete beams was 17,013.1 kilograms, or 65.11% of the total steel used for the project.

Table 9. Parametric structural quantities extracted from the 5D BIM model.

S/N	Structural Component	Concrete Volume (m^3)	Share of Concrete (%)	Formwork Area (m^2)	Reinforcement Steel (kg)
1	Columns	37.790	7.31%	570.230	3,224.9
2	Beams	160.513	31.05%	1,483.241	17,013.1
3	Slabs	255.259	49.37%	1,701.725	5,328.7
4	Pad Foundations	63.436	12.27%	129.600	563.0

S/N	Structural Component	Concrete Volume (m^3)	Share of Concrete (%)	Formwork Area (m^2)	Reinforcement Steel (kg)
TOTAL	All Principal Elements	516.998	100.00%	3,884.795	26,129.7

According to the 80/20 rule (Attard and Rane, 2016), as summarized in Table 10, 78.00% of the ₦188,523,200 total cost of the project is related to three work packages: Sub and Super Structures, 30.00% (₦56,556,960); Doors, Windows, Wall Cladding and Cutting Walls, 28.00% (₦52,786,496); and MEP Services, 20.00% (₦37,704,640). Functional analysis, as presented in Table 11, uncovered inefficiencies in dead load and cost for solid slabs, 225 mm sandcrete partitions, and heavy glazed curtain walls.

Table 10. Baseline elemental cost analysis and value engineering priority matrix.

S/N	Building Element	Original Cost (₦)	Cost Share (%)	VE Priority
1	Sub and Super Structures	56,556,960	30.00%	High
2	Doors, Windows, Wall Cladding and Cutting Walls	52,786,496	28.00%	Medium / High
3	MEP Installations	37,704,640	20.00%	High
4	Professional Fees / Statutory Permits	18,852,320	10.00%	High
5	Roof Construction	9,426,160	5.00%	Medium
6	External Works and Landscaping	9,426,160	5.00%	Medium
7	Preliminaries	3,770,464	2.00%	Low
TOTAL	Total Baseline Project Cost	188,523,200	100.00%	—

Table 11. Verb–noun functional analysis of key building elements.

Building Element	Existing Solution	Primary Function	Secondary Function
Foundation	Reinforced concrete pad foundation	Transfer load	Support building / distribute soil pressure
Slabs & Beams	Solid RC slab (1:2:4) & RC beams	Support floor loads	Provide usable floor surface & span spaces
Columns	Reinforced concrete columns	Transfer vertical loads	Provide lateral & vertical stability
External / Internal Walls	225 mm (9") sandcrete block wall	Enclose space	Provide security, acoustic & thermal separation
Windows / Curtain Wall	Full glazed aluminium curtain walls	Admit light / ventilate	Provide external aesthetics & security
Roof System	Step-tile aluminium on roof frame	Protect building	Provide weather & thermal protection

3.4 Creativity, multi-criteria evaluation and cost optimisation outcomes

During the Creativity and Evaluation phases, three main technical modifications were made (Table 12): (i) Replacement of solid concrete slab with ribbed or waffle slab; rationalization of spacing between reinforcing bars to eliminate non-structural concrete in tensile zones of slab; (ii) Replacement of 225 mm sandcrete block wall with 150 mm lightweight block walls in non-load-

bearing walls to reduce dead load on beams and columns and pad footings; and (iii) Use of both glass and composite aluminum panels in building facades.

Table 12. Summary of existing baseline solutions and proposed value engineering alternatives.

S/N	Component	Existing Baseline Solution	Proposed VE Alternative	Primary Quantities Optimised
1	Floor Slabs & Frame	Solid RC slab (1:2:4 mix), high-yield steel (Y20–Y10), marine board formwork	Ribbed / Waffle slab system with rationalised member sizing	Concrete volume, reinforcement steel, dead load
2	Partition & Infill Walls	225 mm (9-inch) sandcrete hollow blockwork	150 mm lightweight concrete / masonry blocks	Blockwork cost, mortar, frame dead load
3	Curtain Walls & Facade	Full heavy glazed external walling	Composite glass combined with aluminium panelling	Cladding cost, thermal load, installation time

Using the weighted decision matrix approach (Equation 3; Table 13), the Value Engineering alternative scored 87 out of a possible 100 points, while the present design scored 85 out of 100. The Value Engineering alternative scored better than the present design in Initial Cost (27 vs. 25), Quality (15 vs. 13), and Safety (8 vs. 7). The Value Engineering and present designs were equal in functional performance (18 vs. 18).

Table 13. Multi-criteria weighted decision matrix comparing existing and VE alternatives.

Evaluation Criterion	Assigned Weight (%)	Existing Design Score	Proposed VE Alternative Score
Initial Cost	30	25	27
Functionality	20	18	18
Quality	15	13	15
Durability	15	14	13
Safety	10	7	8
Constructability	5	4	3
Maintenance	5	4	3
TOTAL WEIGHTED SCORE	100	85	87

Table 14 compares the elemental costs of pre- and post-5D BIM-VE solutions. Benefits from optimized solutions included reduced costs of ₦26,828,646, a 14.3% decrease, for construction costs and 15.0% total project cost savings, including indirect costs avoided through reduced preconstruction and construction durations, for a total project cost of ₦161,140,300 compared with ₦188,523,200. Major cost savings from optimized solutions included substructure and superstructure costs (₦8,214,900 saved), door, window, and wall cladding and cutting-wall costs (₦7,667,240 saved), and MEP system costs (₦5,476,600 saved). Other advantages of using 5D BIM included a 15.0% reduction in construction time, from 6.0 to 5.1 months, and reduced life-cycle cooling and maintenance costs.

Table 14. Elemental cost comparison between existing design and value engineering solution.

S/N	Building element	Existing cost C_o (₦)	VE cost C_v (₦)	Cost saving (₦)	Saving (%)
1	Doors, Windows, Wall Cladding and Cutting Walls	52,786,496	45,119,256	7,667,240	14.52%
2	Preliminary	3,770,464	3,222,804	547,660	14.52%
3	Professional Fees / Permit	18,852,320	16,114,020	2,184,000	11.58%
4	Sub and Super Structures	56,556,960	48,342,060	8,214,900	14.52%
5	Roof Construction	9,426,160	8,057,010	1,369,096	14.52%
6	MEP Installations	37,704,640	32,228,040	5,476,600	14.52%
7	External Works and Landscaping	9,426,160	8,057,010	1,369,150	14.52%
TOTAL	Total Project Cost (Net Elemental Savings)	188,523,200	161,140,300	26,828,646	14.30%

4 Conclusion

4.1 Summary of conclusions

This paper discusses the application of value engineering and five-dimensional building information modeling to solve problems of cost and time overruns and other challenges in the construction industry in Nigeria. Data for the study were obtained through primary research involving 43 built environment professionals in Oyo State and other data gathered through a case study involving parametric modeling of a 5D BIM-VE model for the Two-Storey Multipurpose Commercial Complex in Ibadan. Important conclusions from the study include the following:

1. **Awareness-Implementation Gap:** Construction professionals in Oyo State have knowledge of value engineering (RII = 0.786) but low implementation levels (RII = 0.647), mainly due to insufficient value engineering practitioners in their organizations (RII = 0.823) and other factors, such as resistance to change (RII = 0.809) and lack of management support (RII = 0.809).
2. **Advantages of Integrating 5D BIM and VE Job Planning:** Using parametric 5D BIM software tools like Orion BIM, combined with VE Job Planning from SAVE International, eliminates or reduces other steps in the project process, including quantity surveys, enables early design evaluation of structural dead loads and costs, and improves communication among project stakeholders.
3. **Cost and Time Savings:** Structural slabs, used in 49.37% of concrete construction, and structural beams, used in 31.05% of concrete construction and 65.11% of steel construction, are major cost elements in commercial construction projects. Using waffle or ribbed concrete slabs and 150 mm lightweight blocks and glass-and-aluminum curtain walls instead of 225 mm sandcrete walls and heavy glazing saved a project ₦26,828,646, or 14.30% of total costs and up to 15% over the life of the project, and shortened the project schedule by 15% without affecting structural integrity, safety, or functionality.
4. **Greater Total Value Throughout the Building's Life:** A weighted decision model analysis shows that the 5D BIM-VE design has a higher total value score than the conventional design (87 compared with 85). Systematic Value Engineering not only lowers initial costs but also increases building value and quality over the building's life.

4.2 Recommendations and areas for further research

Measures to introduce 5D BIM-VE practices into the construction industry include: (i) public and private clients requiring 5D BIM-VE training for designers during the conceptual and preliminary design phases of project development, prior to preparing bid documents; (ii) public authorities (COREN, NSE, NIQS, NIOB, and NIA) requiring mandatory Continuing Professional Development (CPD) certifications in Value Methodology and 5D BIM-VE cost modeling; (iii) universities requiring 5D BIM-VE training for students in Civil Engineering, Quantity Surveying, Building, and Architectural degree programs; and (iv) public agencies encouraging or requiring the use of public policies and incentives to promote VE in public works projects. Areas for future research include post-occupancy Lifecycle Cost Analysis (LCCA) of BIM-VE projects, extending the use of these techniques to highways and bridges, and exploring ways to use artificial intelligence and other technologies to support multicriteria decision making in BIM projects.

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