International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 11 | Nov - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

# Integrating Value Engineering and Ishikawa Analysis for Cost Optimization and Sustainable Performance in Construction Projects: A Systematic Review

**Jatan Jigneshkumar Soni[1], Prof. (Dr.) J. R. Pitroda [2], Dr. Reshma L. Patel [3], Dr. Jagruti Shah[4], Prof. Chintan Raichura[5], Dr. K. B. Vaghela[6] , Darshkumar Atinbhai Darji[7]**

[1]Final Year, M.Tech. (Civil) Construction Engineering and Management,
Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar – Gujarat – India.
sonijatan015@gmail.com

[2]Professor, Civil Engineering Department, PG Coordinator Construction Engineering and Management,
Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar – Gujarat – India.
jayesh.pitroda@bvmengineering.ac.in

[3]Head of Civil Engineering Department, PG Coordinator Environmental Engineering,
Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar – Gujarat – India.
rlpatel@bvmengineering.ac.in

[4]Assistant Professor, Structural Engineering Department,
Birla Vishvakarma Mahavidyalaya Engineering College, Vallabh Vidyanagar, Anand, Gujarat, India
jagruti.shah@bvmengineering.ac.in

[5]Research Scholar, Gujarat Technological University, Assistant Professor, Civil Engineering
Darshan University, Rajkot, Gujarat, India
chintan.raichura@darshan.ac.in

[6]Assistant Professor, Applied Mechanics Department, L. E. College - Morbi, Gujarat, India
kbv.applied@gmail.com

[7] Proprietor, Maa Construction & Interiors, Umreth, Anand, Gujarat, India
darshdarji1@gmail.com

**Abstract:** Value Engineering (VE) is an essential, function-oriented management methodology within modern construction management aimed at balancing required project performance with optimum life-cycle expenditure. This systematic review paper examines the structured application of VE principles contemporary research studies in housing, commercial, high-rise, and municipal infrastructure projects. Beyond conventional cost reduction, this paper investigates functional optimization, quality improvement, constructability enhancement, and resource efficiency. The development of a cause-and-effect (Fishbone diagram) model is done to show the relationships between various structural causes of cost overruns in construction, which are classified into five categories: materials, methods, man, machinery/measurement, and management. Additionally, real-life research on VE in the residential sector has been conducted to demonstrate how VE techniques allow releasing savings up to 12.8%, while keeping the building structurally safe, thermally efficient, and functionally usable. In general, the results of the work show that early VE applications during the pre-construction phase, help the owner receive maximum project value and minimum life-cycle costs.

**Keywords:** Construction, Cost Optimization, FAST Diagram, Fishbone Diagram, Housing Construction, Value Engineering, Value Engineering Job Plan

## 1. Introduction

The contemporary construction sector is defined by growing intricacy, economic pressures, material cost instability, and high expectations from clients. Managers involved in the project and engineers must grapple with the problem of ensuring the delivery of well-performing structures within preset budgets and deadlines all the time. The tool that has been successfully utilized to accomplish the above-mentioned dual aims of cost-cutting and performance improvement is VE or value engineering, initially developed by Lawrence D. Miles at General Electric during World War II.

### 1.1 Definition and Core Philosophy of Value Engineering

Value Engineering is defined as a creative, organized, multi-disciplinary approach that analyzes the functions of a project, service, or system to achieve its essential functions at the lowest total life-cycle cost without sacrificing performance, safety, quality, or reliability [1]. Mathematically, Value (V) is expressed as the ratio of Function (F) to Cost (C):

**Value (V) = Function (F) / Cost (C)**

Unlike traditional cost-cutting exercises which often reduce project scope, downgrade material specifications, or compromise structural quality VE enhances value by optimizing function while systematically identifying and removing unnecessary initial and operating costs.

### 1.2 The Standard 6-Phase VE Job Plan

The International Society of American Value Engineers (SAVE) states that standard VE implementation is based on the structured 6-Phase Job Plan [2]:

1. Information Phase: Gather complete project history, drawings, specifications, BOQ, and cost models.
2. Function Analysis Phase: Determine all project functions in pairs of active verbs and measurable nouns (for example, 'support the load', 'enclose the area', 'distribute water') and create corresponding FAST diagrams.
3. Creative Phase: Organize multidisciplinary brainstorming workshops to create different alternative ways to achieve key functions.
4. Evaluation Phase: Evaluate alternatives generated in the brainstorming process according to the way of realizing the initial cost, constructability, risks, and structural integrity.
5. Development Phase: Bring alternatives in the rank according to the developing of the proposal in the form of formal Value Engineering proposals, including technical drawings, structural settings, and LCC analysis.
6. Presentation and implementation Phase: Communicate developed ideas to key stakeholders, owners, and design teams for their approval.

### 1.3 Benefits, Challenges, and Industry Context

The advantages of VE in construction comprise considerable direct financial savings (around 5%-15%), shorter project execution schedules, better constructability, lower operation and maintenance costs, and increased sustainability. However, its implementation is hindered by various obstacles such as the refusal of architects to alter designs, deficiencies in VE expertise of project teams, strict pre-construction schedules, and inflexible municipal procurement procedures.

## 2. Systematic Review of Previous Research Studies

In order to build a strong empirical base, previously published peer-reviewed articles and industry report focusing on Value Engineering in construction were methodologically selected, analyzed, and synthesized. As illustrated in Table 1, major research objectives, research methodologies, areas of focus of which were analyzed, as well as main outcomes of these studies are reported.

**Table 1: Systematic Summary of Previous Value Engineering Research Papers**

| Focus Area & Methodology | Key Findings & Impact | References |
|---|---|---|
| Six-story hospital facade; LCCA & FAST analysis | Optimized facade structural framing and glass panel selection, achieving 8.4% direct cost reduction and lower operational cooling load. | [3] |
| General building cost management & SAVE Job Plan | Demonstrated that applying VE during early schematic design saves 10-15% of project budget without affecting quality or safety. | [4] |
| Systematic review of VE implementation barriers | Identified key implementation barriers, noting that 70% of cost savings potential occurs before design freeze. | [5][6] |
| Green building materials, carbon footprint & LCCA | Combined Life Cycle Assessment (LCA) with VE, demonstrating 14% carbon emission reduction alongside operational cost savings. | [7] |
| Structural and architectural cost-function substitution | Replaced solid slab with ribbed slab in non-critical spans, saving 9.2% concrete volume and structural steel. | [8] |
| Public-Private Partnership infrastructure & roadworks | Optimized pavement thickness and drainage layer design, reducing capital expenditure by 11.5% across 45 km road corridor. | [9] |
| Literature synthesis of VE tools and FAST diagrams | Emphasized that functional analysis (FAST) is the key differentiator separating VE from crude cost cutting. | [10][11] |
| Bregana-Zagreb Motorway; Bridge & tunnel optimization | Achieved $43M cost savings and 12-month schedule compression via climbing formwork elevation and bridge re-profiling. | [12] |
| Statistical survey of project managers & clients | Ranked multi-disciplinary team expertise and owner commitment as the top two critical success factors for VE efficacy. | [13] |
| BIM-driven Quantity Takeoff (QTO) & VE integration | Integrated 5D BIM with VE job plan, enabling automated scenario modeling and saving 40% time during evaluation phase. | [14] |
| FAST diagram logic in green residential construction | Utilized FAST diagrams to eliminate secondary non-value-adding architectural elements, cutting costs by 7.6%. | [15] |
| Precast vs. cast-in-situ concrete comparative study | Proved that precast modular elements reduce construction duration by 25% and overall structural cost by 8.8%. | [16] |
| Client-architect coordination & execution case studies | Highlighted institutional procurement constraints in developing nations as the primary bottleneck to VE adoption. | [17] |
| Quantitative process simulation & functional evaluation | Combined simulation modeling with VE to streamline hospital MEP layouts, lowering maintenance failure rates by 18%. | [18] |
| Synergy between Lean Construction & Value Engineering | Formulated the LiVE model, combining Lean waste elimination with VE function analysis to boost client value delivery. | [19] |
| Building footprint & layout analysis in mass housing | Demonstrated that initial layout decisions drive 65% of overall construction cost, outstripping later material changes. | [20][21] |
| Infrastructure & structural framework analysis | Evaluated structural optimization techniques across multi-story buildings, achieving 10.5% savings in rebar tonnage. | [2][22] |
| Mass housing project; Material & BOQ optimization | Applied 6-phase VE plan in Gujarat housing scheme, saving INR 3.85 Lakhs per block via AAC block and lightweight plaster adoption. | [23] [24] |

**3. Cause & Effect (Fishbone Diagram) Analysis for Cost Overruns & VE Interventions**

The Ishikawa diagram provides evidence for the connection between the causes of overruns in construction projects and available options through Value Engineering (VE). An important point in regards to construction management is the fact that project cost escalation is not usually caused by an individual issue, usually people experience problems with

finances as a result of multiple causes such as labour restrictions, poor construction techniques, materials issues, performance of equipment, problems related to finance, scheduling issues, and conditions from the outside.

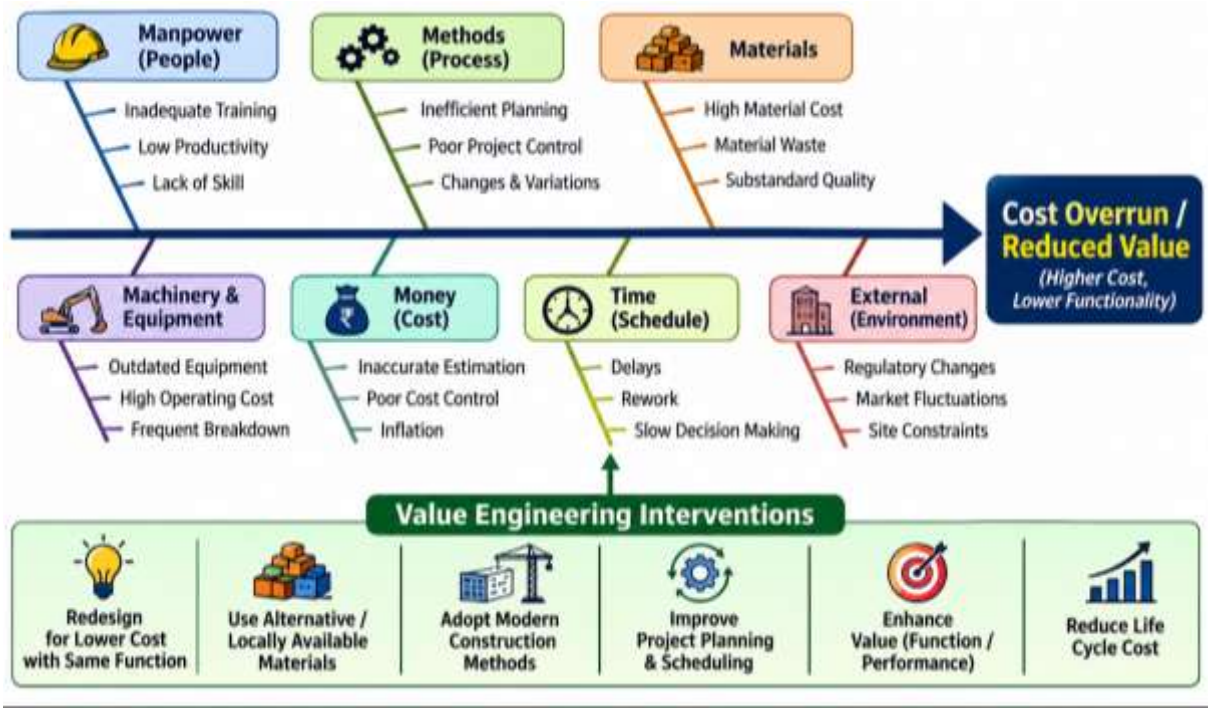



**Figure 1: Ishikawa (Fishbone) Diagram for Value Engineering Interventions**

The illustration elaborates on 7 principal categories affecting project performance. Each one of them stands for a particular dimension of construction management, though they all affect each other. For instance, insufficient qualification of the workforce can lead to poor quality of construction, thus resulting in more materials used and more rework. Likewise, inefficient construction planning can provoke equipment idling and delays in procurement with its corresponding costs.

The main result, defined by us as Cost Overrun / Decrease in Value, encompasses all consequences generated by the abovementioned inefficiencies in management and operation.

The parameter that adds the value to the model is the link between problem recognition and problem-solving methods. The upper part and the lower part of the fishbone diagram explain the reasons for the problems, while the applications of the principles of Value Engineering show possible ways to eliminate them.

### 3.1 Detailed examination of the cause-and-effect relationship

**1. Manpower (People)**

The importance of human resources in delivering construction projects is immense. Indeed, the effectiveness of construction processes is highly dependent on the technical competence, work experience and ability of the individuals involved in the project.

The provided diagram indicates three key issues: insufficient training, low level of productivity, and absence of expertise. These problems can have a serious impact on the accuracy of the construction process and the probability of imperfect and defective work. This is due to the fact that untrained workers will need to receive instructions and supervision again, and lack of professionals will stop certain processes which require qualified professionals.

It should also be mentioned that productivity of employees is not only the number of employees involved in the construction project. The quality of work done, time spent for doing this work, resources available for carrying out construction processes, and coordination of the work carried out are of great importance as well.

Value Engineering opportunities:

- Introduce competency-based training programmes.
- Improve workforce allocation and productivity monitoring.
- Develop standard operating procedures for repetitive activities.
- Reduce errors through improved supervision.

- Promote skill development and multiskilling.

**2. Methods (Construction Process)**

The way a construction project carries out different processes is determined by construction techniques used. Failure to plan appropriately, ineffective control of project progresses and constant changes in building requirements might disrupt the planned order of stages.

Methods that appeared to be cost-effective during preparation and planning stage might become inefficient due to specific conditions on site, availability of workers and machines and movement of materials.

The rise of modern building technologies makes it possible to rethink traditional approaches. Building methods like prefabrication, modular construction, lean construction and building information modeling can be useful in terms of better coordination and removing unnecessary actions.

Value Engineering opportunities:

- Review alternative construction methods.
- Apply constructability analysis during the design stage.
- Introduce lean construction practices.
- Improve coordination through BIM.
- Reduce unnecessary construction activities and rework.

**3. Materials**

The selection of materials represents a key factor affecting the costs of a construction project and subsequent performance of the resulting structure. The schematic traces three major concerns regarding the costs of materials: high expenses, unnecessary losses, and poor quality.

Material issues may occur throughout any phase of construction from design to installation. Wrong calculations may lead to overbuying materials and wrong storage methods may damage materials or make them unusable.

Using the price of materials as the sole criterion is another problem regarding materials. A low-cost material may prove to be much more expensive to maintain in future.

Thus, Value Engineering in respect to materials should address the technological and other specifications of materials as well as their availability, durability, ecological impact, and full lifecycle costs.

Value Engineering opportunities:

- Identify locally available alternative materials.
- Evaluate recycled and sustainable construction materials.
- Optimise material quantities and specifications.
- Introduce systematic material inventory management.
- Compare alternatives using life-cycle costing.
- Reduce construction waste through better planning.

**4. Machinery and Equipment**

The role played by construction machinery is crucial for better productivity and lowering time for labour-intensive activities; however, its effectiveness under economic terms is connected to the choice of equipment, its use, maintenance, and suitability.

The use of obsolete machinery may lead to an increased fuel consumption as well as costly repairs. Likewise, incorrect equipment selection may result in lower productivity when equipment is unsuitable for site conditions or operational demands.

Thus, costs related to equipment may be considered only for the entire duration of its use, but not only when acquiring or renting it.

Value Engineering opportunities:

- Assessing equipment through comparative analysis of expenditures on machinery ownership vs. operating costs.
- Improving equipment performance.
- Implementing maintenance policies.
- Looking for equipment rental options.

- Utilising modern mechanisation and automation options.
- Monitoring fuel costs.

**5. Money (Financial Management)**

Financial management gives the economic basis for conducting construction projects. Inaccurate cost estimates, inefficient cost management, and inflation can result in significant deviations between planned and actual costs.

Initial cost estimates become untrustworthy when market conditions change or when a project undergoes design changes, additional quantities, or unforeseen resource needs.

Effective value engineering requires a careful analysis of financial effects associated with several alternatives. One option must not be chosen only because of the fact that it lowers the initial cost. The effect on operation, maintenance, durability, and replacement costs must also be taken into account.

Value Engineering opportunities:

- Improve cost estimation and budgeting.
- Introduce regular cost variance analysis.
- Conduct Life Cycle Cost Analysis (LCCA).
- Strengthen financial risk management.
- Evaluate alternative procurement strategies.
- Improve financial monitoring throughout project execution.

**6. Time (Project Schedule)**

Time and cost are vital components of construction project management. Any delay in construction will cause labour costs, equipment hires costs, site overhead costs, and other indirect costs to rise.

The diagram shows that delay, rework, and decision-making problems are the essential scheduling issues. Such issues may arise due to such reasons as incomplete drawings, poor coordination, approval delays, poor resource planning, and changes in project scope.

A successful Value Engineering strategy should evaluate the possibility of using various alternatives in technology, scheduling, and construction sequence to shorten the project time, while maintaining the level of quality and functions required.

Value Engineering opportunities:

- Apply Critical Path Method (CPM).
- Improve resource allocation and levelling.
- Integrate 4D BIM with project scheduling.
- Reduce rework through early design coordination.
- Improve decision-making and approval procedures.
- Monitor construction progress against planned targets.

**7. External Environment**

Construction projects are affected by a variety of external conditions that cannot be controlled by the project team. Changes in regulations, market fluctuations, and difficulties experienced at the site can change the availability and cost of materials needed for construction.

For instance, when the prices for materials change, procurement plans may need to be adjusted or modified in accordance with the new prices. In case of unexpected conditions at the site, construction methods that were planned are also affected.

It is therefore important to take uncertainties into consideration from the onset of project development in order to be able to create project alternatives that reduce the consequences of external risks.

Value Engineering opportunities:

- Conduct early regulatory and statutory assessments.
- Evaluate alternative procurement arrangements.
- Incorporate site-specific design considerations.
- Assess market and material price uncertainties.
- Adopt climate-responsive construction planning.

- Develop flexible project execution strategies.

### 3.2 Critical relationship between root causes and Value Engineering interventions

An important aspect of the diagram is that every identified problem can be translated into an opportunity for improvement. However, the proposed intervention should be selected only after understanding the actual reason behind the problem.

The following table 2 provides a more detailed analytical interpretation suitable for inclusion in a review paper.

**Table 2: Critical relationship between root causes and Value Engineering interventions**

| Ishikawa category | Root cause | Possible consequence | VE intervention |
|---|---|---|---|
| Manpower | Inadequate training | Low productivity and rework | Skill development |
| Manpower | Labour shortage | Activity delays | Workforce optimisation |
| Methods | Inefficient planning | Resource wastage | Lean construction |
| Methods | Poor project control | Cost and schedule deviations | Digital project monitoring |
| Materials | High material cost | Budget escalation | Alternative materials |
| Materials | Material wastage | Increased consumption | Quantity optimisation |
| Machinery | Outdated equipment | Low operational efficiency | Modern equipment |
| Machinery | Frequent breakdown | Work interruption | Preventive maintenance |
| Money | Inaccurate estimation | Budget deviations | Cost forecasting |
| Money | Inflation | Increased procurement expenditure | Procurement optimisation |
| Time | Delays | Higher indirect costs | Schedule optimisation |
| Time | Rework | Additional labour and material costs | Quality and design coordination |
| Environment | Regulatory changes | Additional compliance costs | Early regulatory assessment |
| Environment | Site constraints | Construction difficulties | Alternative construction planning |

## 4. Empirical Case Study Analysis: Application of VE in Housing Projects

In order to demonstrate how the Value Engineering approach can be put into practice and its financial consequences, the article examines an extensive empirical investigation. This investigation is related to the development of a real estate project (the construction of residential buildings) in Ahmedabad, Gujarat, India [25].

### 4.1 Project Background and Existing Scope

The project of the case study aims at multi-block residential housing development including G+4 level apartments fulfilling the low income and middle-income category urban housing requirements. The specifications matching the framework are that the design implies the traditional building methods of construction: framework of reinforced concrete (RCC), using outer walls made of burnt clay bricks of 230 mm in thickness and inner interior partitions of 115 mm formed of bricks, cement-sand plastering and conventional granite/marble type flooring [25].

### 4.2 Execution of the 6-Phase VE Job Plan

The research staff implemented the standardized six-step VE Job Plan as follows on the costly components of the Bill of Quantities (BOQ) for the project:

1. Information and Function Analysis Phase: The analysis of the BOQ showed that more than 68% of the total cost of the structure belongs to Masonry walling, structural concrete, reinforcement steel, and internal and external wall finishes. The FAST diagrams were utilized to identify basic functions ('Enclose space' 'Support load' 'Resist heat') and secondary functions ('Provide aesthetics', 'Separate rooms').
2. Creative and Evaluation Phase: The brainstorming process produced various combinations of materials that were later evaluated according to weighted scoring criteria (strength of materials, thermal insulation, availability, time of execution, and cost).
3. Development and Proposal Phase: In total, three main Value Engineering Proposals (VEPs) were created.
   - Proposal A (Masonry Work): Replace traditional burnt clay bricks with Lightweight Autoclaved Aerated Concrete (AAC) Blocks.
   - Proposal B (Plastering Work): Replace conventional 20 mm 2-coat cement-sand plaster with Single-Coat Gypsum Plaster internally and Polymer-modified Mortar externally.
   - Proposal C (Partition & Flooring): Adopt pre-cast ferrocement wall panels for non-structural partitions and vitrified tiles for flooring.

### 4.3 Cost Optimization & Comparison Results

The following table 3 provides a comparative cost analysis of case study components for inclusion in a review paper.

**Table 3: Comparative Cost Analysis of Case Study Components** [25]

| **Building Component** | **Original Specification (Baseline)** | **VE Alternative Proposed** | **Cost Difference per Unit** | **% Cost Reduction** |
|---|---|---|---|---|
| External & Internal Masonry | Burnt Clay Brick Masonry (230mm / 115mm) | AAC Block Masonry (200mm / 100mm) | Savings of ₹450 / $m^3$ | 18.5% Savings |
| Internal Wall Finishing | 20mm 2-Coat Cement-Sand Plaster | 12mm Single-Coat Gypsum Plaster | Savings of ₹110 / $m^2$ | 22.0% Savings |
| Non-structural Partitions | 115mm Brick Partition Wall | 50mm Pre-cast Ferrocement Panel | Savings of ₹280 / $m^2$ | 31.2% Savings |
| Superstructure Structural Steel | Fe-415 Standard TMT Bars | Fe-500D High Ductility TMT Bars | Savings of ₹3,200 / Ton | 6.5% Savings |
| **Total Project Impact (Per Block)** | **Original BOQ Cost: ₹30,15,000** | **Revised VE BOQ Cost: ₹26,30,000** | **Net Savings: ₹3,85,000** | **12.8% Overall Cost Reduction** |

### 4.4 Technical & Operational Benefits of Case Study Results [25]

In addition to achieving a **12.8% overall project cost reduction** (saving INR 3,85,000 per residential block), study demonstrated significant structural and lifecycle advantages:

1. Reduction of Structural Weight: AAC block technology has made it possible to decrease the structural dead load by around 35%. As a result, it is possible to minimize the size of the columns and the overall volume of the concrete used in the foundations.
2. Thermal Insulation and Energy Efficiency: The thermal conductivity of AAC blocks is 0.16-0.18 W/mK, while that of red bricks is 0.81 W/mK. Such a difference contributes to a 15-20% reduction in the energy costs needed to cool and heat the building.
3. Speed of Construction: Given the size of AAC blocks in comparison to red bricks (3-4 times larger), the speed of building the walls increases, and it reduces the need for masonry workforce by 40%.

## 5. Conclusion & Recommendations

Value Engineering (VE) is a basic management approach, closing the gap between financial economy and operations in the construction industry. Through an analysis of contemporary research papers and empirical data from housing case studies, this review paper provides several important findings:

1. Proactive Life-Cycle Approach: VE methodology hits the highest impact when applied in pre-construction design phases - during the stages of concept development and schematic design, as flexibility in decision-making is high and cost of design change is low.
2. Function over Cost-Cutting: VE methodology differs from traditional cost-saving approach in that instead of cuts, VE focuses on improving or at least saving core functions of the structure, applying tools like FAST diagrams and Fishbone analysis.
3. Empirical Feasibility: Results of case studies show that the use of lightweight materials instead of cumbersome traditional materials (AAC blocks, ferrocement panels and optimized plastering) results in the savings of 10% - 15% of the net capital while increasing the performance of the structures in terms of thermal efficiency.
4. Technology Integration: From a practical perspective, the future of VE requires digitization of processes such as the 5D BIM and automated LCCA instruments.

## Acknowledgement

The researchers express their heartfelt gratitude to Prof. (Dr.) Vinay Patel, Principal, Birla Vishvakarma Mahavidyalaya Engineering College (BVM), and Prof. (Dr.) Reshma L. Patel, Head and Professor, Civil Engineering Department, Birla Vishvakarma Mahavidyalaya Engineering College (BVM), Vallabh Vidyanagar, Gujarat, India, for enabling this research.

## References

[1] N. B. Yadav, R. Kacha, N. D. Sharma, and H. A. Rathod, "A Review on Value Engineering Techniques in Indian Context," *Int. J. Civil, Struct. Environ. Infrastruct. Eng. Res. Dev.*, vol. 3, no. 5, pp. 1–8, 2013, [Online]. Available: http://www.tjprc.org/view_archives.php?year=2013&id=11&jtype=2&page=4

[2] M. M. Chaudhari and J. R. Pitroda, "Adoption of Value Engineering in the Affordable Housing Initiative-A Review," *Int. Res. J. Eng. Technol.*, vol. 09, no. 03, pp. 1948–1955, 2022, [Online]. Available: www.irjet.net

[3] T. Aung, Sui Reng Liana, Arkar Htet, and Amiya Bhaumik, "The Application of Value Engineering Analysis in Façade Construction: A Case Study of Six Storey Building Facade," *J. Innov. Bus. Ind.*, vol. 02, no. 01, pp. 39–44, 2024, doi: 10.61552/JIBI.2024.01.005.

[4] A. Pandit, "The Impact Of Value Engineering On Pre-Construction Cost Control: Striking The Balance Between Quality And Budget," *Int. Sci. J. Eng. Manag.*, vol. 02, no. 11, pp. 1–6, 2023, doi: 10.55041/isjem01299.

[5] A. S. Patel, J. J. Bhavsar, and J. Pitroda, "A Cost Effective Assessment of Aganwadi Building through Value Engineering Methodology," *Int. J. Adv. Eng. Res. Dev. (IJAERD), e-ISSN 2348 - 4470, print-ISSN2348-6406*, vol. 1, no. 05, pp. 1–14, 2014, doi: 10.21090/ijaerd.010562.

[6] K. A. A. Ahmed and R. K. Pandey, "Concept of Value Engineering in Construction Industry," *Int. J. Sci. Res.*, vol. 5, no. 4, pp. 1231–1237, 2016.

[7] E. M. H. Ismaeil, "Sustainability-Based Value Engineering Management as an Integrated Approach to Construction Projects," *Buildings-MDPI*, vol. 14, no. 903, pp. 1–23, 2024.

[8] M. Ravish and K. Vinoth, "A study on application of Value Engineering in residential building projects," *Shanlax Int. J. Arts, Sci. Humanit. ISSN 2321 – 788X*, vol. 4, no. 1, pp. 1–10, 2016.

[9] A. M. Selim, O. A. R. Meetkees, and M. R. Hagag, "Value engineering (VE) application in infrastructure projects by public-private partnerships (PPPs)," *Int. J. Appl. Eng. Res.*, vol. 12, no. 20, pp. 10367–10375, 2017.

[10] P. Arumsari and R. Tanachi, "Value engineering application in a high rise building (a case study in Bali)," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 195, no. 1, pp. 1–10, 2018, doi: 10.1088/1755-1315/195/1/012015.

[11] W. T. Chen, H. C. Merrett, H. L. Chen, M. Edward, and Y. Danny, "Value engineering in construction : a systematic review of applications and research trends," *Eng. Constr. Archit. Manag.*, vol. 32, no. 13, pp. 477–

500, 2026, doi: 10.1108/ECAM-07-2025-1086.

[12] Senay Atabay and Niyazi Galipogullari, "Application of Value Engineering in Construction Projects," *J. Traffic Transp. Eng.*, vol. 1, no. 12, pp. 39–48, 2013, doi: 10.17265/2328-2142/2013.12.005.

[13] S. Goel, "Challenges and Critical Factors in the Implementation of Value Engineering in Construction Management : A Literature Review, Survey Analysis, and Case Study Comparison," *J. Civ. Constr. Eng.*, vol. 11, no. 2, pp. 1–21, 2025.

[14] A. H. Taher and E. E. Elbeltagi, "Integrating building information modeling with value engineering to facilitate the selection of building design alternatives considering sustainability," *Int. J. Constr. Manag. Taylor Fr. Gr.*, pp. 1–16, 2021, doi: 10.1080/15623599.2021.2021465.

[15] R. Janani, P. R. K. Chakravarthy, and Dr. R. Rathan Raj, "A Study on Value Engineering & Green Building in Residential Construction," *Int. J. Civ. Eng. Technol.*, vol. 9, no. 1, pp. 900–907, 2018.

[16] K. Miladi and O. A. Yamini, "The Methodology of Using Value Engineering in Construction Projects Management," *Civ. Eng. J.*, vol. 2, no. 6, pp. 262–269, 2016.

[17] W. T. Chen, H. C. Merrett, S. Liu, N. Fauzia, and F. N. Liem, "A Decade of Value Engineering in Construction Projects," *Adv. Civ. Eng. Hindawi*, vol. 1, no. 1, pp. 1–13, 2022, doi: 10.1155/2022/2324277.

[18] X. Zhang, X. Mao, and S. M. Abourizk, "Automation in Construction Developing a knowledge management system for improved value engineering practices in the construction industry," *Autom. Constr.*, vol. 18, no. 6, pp. 777–789, 2009, doi: 10.1016/j.autcon.2009.03.004.

[19] E. M. A. C. Ekanayake and Y. G. Sandanayake, "LiVE approach : Lean integrated Value Engineering for construction industry," *Built Environ. Proj. Asset Manag.*, vol. 7, no. 5, pp. 518–533, 2017, doi: 10.1108/BEPAM-11-2016-0071.

[20] A. S. Patel, J. Pitroda, and J. J. Bhavsar, "Cost Effective Assessment of Construction Projects By Value Engineering Concepts," *J. Int. Acad. Res. Multidiscip. ISSN 2320 -5083*, vol. 1, no. 9, pp. 364–369, 2013.

[21] G. Kalandadze, "Value Engineering Approaches in Low-Budget Residential Construction," *Int. J. Adv. Eng. Manag. Sci.*, vol. 12, no. 4, pp. 96–102, 2026.

[22] C. Mehta, S. Parth, Mehta, and J. R. Pitroda, "Value Engineering as an Effective Tool for Construction Projects: A Review," *Stud. Indian Place Names, ISSN 2394-3114*, vol. 40, no. 60, pp. 1927–1936, 2020.

[23] B. Ramani and J. Pitroda, "A Critical Literature Review on Application of Value Engineering in Building Construction Project," *Int. J. Creat. Res. Thoughts (IJCRT), ISSN 2320-2882*, vol. 5, no. 4, pp. 1461–1464, 2017.

[24] P. Sharma and R. Srikonda, "Application of Value Engineering in Affordable Housing in India," *Int. J. Eng. Technol. Manag. Res.*, vol. 8, no. 2, pp. 29–40, 2021, doi: 10.29121/ijetmr.v8.i2.2021.865.

[25] B. Ramani and J. Pitroda, "A Study on Application of Value Engineering in Housing Project," *Int. J. Tech. Innov. Mod. Eng. Sci. ( IJTIMES ), e-ISSN 2455-2585*, vol. 4, no. 5, pp. 289–296, 2018.