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Value Engineering Approaches in Low-Budget Residential Construction

Gocha Kalandadze

Independent Researcher
Tbilisi, Georgia
gkalandadze770@gmail.com

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***Abstract*— *This study reconsiders value engineering in the context of low-budget residential construction, where limited resources intensify the need to achieve an optimal balance between cost and functional performance. The findings demonstrate that the primary drivers of cost deviations arise not from individual design decisions but from the initial definition of the project's spatial structure, which determines the distribution of functions and the subsequent behavior of costs. The study examines the interrelationship between architectural configuration, material selection, and construction process organization within a unified framework of cost formation. It is argued that the conventional approach, which focuses on cost adjustments after the completion of the design phase, restricts the potential of value engineering and fails to deliver sustainable long-term benefits. The principal outcome of the research is an original model in which cost management is achieved through the early development of the project's functional structure while accounting for the building's life cycle. The proposed approach extends the practical application of value engineering and may be employed in the development of affordable housing projects under conditions of significant cost pressure.*

Keywords*— *value engineering, affordable housing, building design, building structure, life cycle, construction cost, functional efficiency.

I. INTRODUCTION

Affordable housing continues to face a persistent supply deficit. Demand is increasing alongside population growth and urbanization, while the pace of housing delivery remains insufficient to meet this demand. Even where government support programs are available, a substantial proportion of households remain excluded from the formal housing market, and the gap between housing prices and household incomes continues to widen [2]. At the same time, construction costs are subject to growing pressure. Material prices, transportation expenses, and labor costs continue to increase. Conventional design solutions are losing their former economic efficiency, and even standardized projects no longer generate the expected cost savings.

Attempts to reduce costs through direct cost-cutting produce only short-term benefits and are quickly reflected in the performance of buildings. Service life is reduced, operating costs increase, and the quality of the built environment deteriorates. Under these conditions, cost management requires a different perspective in which functional performance and its relationship with cost become the central focus [5]. Existing research on value engineering primarily emphasizes materials and construction technologies, whereas planning decisions and building structure, which establish the fundamental cost framework of a project, receive considerably less attention. In practice, value engineering is frequently introduced only after the principal project parameters have already been determined, when opportunities for meaningful design modifications have become limited.

The aim of this study is to develop and theoretically substantiate a value engineering model for low-budget residential construction that integrates design decisions, material selection, and construction process organization with the overall cost and value of housing. The objectives of the study are as follows:

– to analyze existing approaches to value engineering in construction;

– to identify the quantitative effects of its application;

– to determine the levels at which cost is formed in residential projects;

– to systematize solutions that affect functionality and costs.

The research hypothesis is that the principal determinants of the cost of affordable housing are established at the stage when its spatial structure is defined. Building density, layout, and configuration exert a greater influence on future costs than the subsequent selection of construction materials. Addressing these parameters during the early design stage reduces costs by redistributing functions within the project while preserving the building's essential performance characteristics.

The scientific novelty of the study lies in shifting the analytical focus from cost estimates and material-related decisions to the architectural level, where the project's baseline cost is established. In most previous studies, value engineering is treated primarily as a tool for identifying less expensive design alternatives while assuming the building structure to be fixed. In contrast, the present study considers cost as a consequence of planning logic, reflected in building density, spatial allocation, and the organization of space. This perspective makes it possible to identify the origins of project costs at the stage of conceptual design, which has only rarely been examined as an independent subject of analysis.

II. MATERIALS AND METHODS

The study was conducted as an analytical review of the scientific literature followed by the development of a conceptual model. The review focused on publications addressing value engineering, construction cost optimization, design decision-making in residential construction, building life-cycle assessment, and the evaluation of architectural efficiency. Particular attention was given to studies examining construction costs in relation to spatial planning, development density, structural design solutions, and the organization of construction processes.

The literature search was performed using the Google Scholar, ScienceDirect, SpringerLink, and MDPI databases. The search strategy included combinations of the following keywords: value engineering in construction, affordable housing, cost optimization in residential construction, building life cycle, planning efficiency, development density, structural solutions for low-budget construction, and housing construction costs. Boolean operators AND and OR were applied to refine the search results. The review included publications published between 2022 and 2025 that reflect both recent developments in value engineering methodology and contemporary approaches to cost reduction in residential construction. Studies unrelated to construction costs, architectural design, or construction processes were excluded from the analysis.

At the initial stage, 42 publications addressing construction costs and value engineering were identified. The selection was subsequently narrowed to studies reporting quantitative evidence on cost reduction, schedule improvements, or the influence of project stages on project performance. Finally, only studies linking construction costs with architectural parameters—such as development density, floor area distribution, and building typology—were retained. The final dataset consisted of 12 publications.

The research methodology combined literature analysis, comparison of cost-related factors, interpretation of quantitative findings, and the development of a conceptual model. A limitation of the study is that the analysis is based on generalized evidence rather than project-specific empirical data. Nevertheless, the selected publications provide sufficient evidence to identify consistent relationships among architectural design, material selection, and the organization of construction activities.

III. RESULTS

The comparison of value engineering implementation scenarios was performed by evaluating two variables: the timing of intervention and the level at which design modifications were introduced. For each scenario, changes in project cost and schedule were recorded and subsequently compared across the groups [13]. The distinction between the scenarios is evident and does not require additional assumptions. Projects in which value engineering is applied during the design formation stage exhibit one range of outcomes, whereas projects where intervention occurs only after the completion of design demonstrate a distinctly different range. No overlap is observed between these groups. The dividing boundary corresponds to the stage at which the project structure becomes fixed and no longer allows modifications at the functional level [9]. Table 1 presents the analyzed scenarios, differentiated by the depth of intervention and the nature of the design changes.

Table 1 – Quantified Effects of Value Engineering in Construction Projects (Compiled by the author based on Source: [1])

VE Application Scenario	Cost Savings	Time Reduction	Source of Effect
Early project stage	10–25%	Before construction	Early design decision-making
Project preparation and revision	6%	17%	Integrated project optimization
Project preparation and revision	$43 million	12 months	Combined VE implementation
Material substitution	8%	No functional loss	Alternative material selection
Industry practice	6–10%	2–3 weeks (VE duration)	Typical VE implementation

A comparison of the presented data reveals two fundamentally different modes of value engineering implementation. In the first, the underlying project logic is reconsidered, including the distribution of functions and the relationships among building components. In the second, the project structure remains unchanged, and intervention is limited to the replacement of individual components. The distinction between these approaches is qualitative rather than incremental. Functional modifications redistribute costs throughout the entire project, whereas component substitution affects only isolated parts of the system.

A direct comparison further demonstrates that once the project structure has been fixed, the opportunity for fundamental design changes is effectively lost. From this point onward, value engineering can no longer influence the baseline project cost and instead becomes a tool for incremental cost adjustment. The expected level of cost reduction is therefore unattainable because functional relationships have already been established and embedded within the project.

An assessment based on project duration leads to the same conclusion. Changes in construction sequencing and process organization affect the overall project schedule, whereas modifications to individual operations influence only localized activities without altering the performance of the system as a whole [4]. The distinction between the implementation scenarios therefore remains consistent.

The effect becomes even more pronounced in low-budget residential construction. Limited financial resources leave little capacity to absorb inefficient design decisions. Consequently, any error introduced during the formation of the project's structural framework is directly reflected in total construction cost. When value engineering is applied at a later stage, the only remaining option is to redistribute costs within an already established configuration rather than modify the configuration itself. This defines the practical limit of value engineering effectiveness and shifts its role from optimization to cost maintenance [8].

The next stage of the analysis focuses on identifying the parameters that determine the baseline project cost. The comparison was conducted across building typologies differing in development density and floor area distribution. These parameters were selected because they establish the project's structural framework before decisions regarding materials and construction technologies are made. In the affordable housing sector, their influence is particularly significant because limited financial margins provide little opportunity to offset design deficiencies during later project stages [14]. Table 2 presents three building configurations distinguished by development density and floor area distribution.

Table 2 – Impact of Architectural Typology on Cost and Efficiency in Low-Budget Housing (Compiled by the author based on Source: [3])

Architectural Solution	Plinth–Carpet Ratio	Units per Floor	Optimization Outcome
Typology A22	1.31	8	Lowest cost and lowest embodied energy
Typology A13	1.30	4	Low values, but not optimal
Typology A11	1.51	2	Highest cost and embodied energy

A comparison of the extreme building configurations demonstrates that structural modifications shift project costs independently of material selection. Development density and floor area distribution operate as an interdependent set of parameters. Altering one parameter without adjusting the other does not produce a stable outcome; rather, the overall configuration is determined by their combined effect.

The intermediate configuration further reinforces this distinction. Even when one parameter remains at a similar level, variation in the other results in a measurable change in project cost. No compensatory effect is observed. Consequently, attempts to explain cost behavior through individual characteristics alone prove inadequate [12]. Construction cost is determined primarily at the structural level rather than by isolated project elements.

The relationship between these parameters and construction cost is mediated by the distribution of functions within the building. Development density influences structural and infrastructure demands, whereas floor area distribution determines the proportion of auxiliary and non-revenue-generating spaces. Changes in the overall configuration alter the balance among these components and are directly reflected in project costs [7].

Comparison with the previous stage of the analysis reveals an important limitation. Even when value engineering is introduced early in the project, its effectiveness depends on the initial building configuration. An inefficient structural framework continues to impose unnecessary budgetary constraints and limits the scope of subsequent improvements. Modifications at the component level are insufficient to eliminate this underlying structural burden.

Once the building configuration has been fixed, the range of possible modifications becomes substantially narrower. Individual design decisions may still be adjusted, but functional redistribution is no longer feasible. The upper limit of optimization is therefore established during the design stage and remains unchanged throughout the remainder of the project. Evidence from life-cycle assessments confirms the persistence of this effect. Building configuration continues to influence costs after construction has been completed, thereby preserving the differences between alternative design solutions [11]. Attempts to compensate for an inefficient structural framework through material substitution do not eliminate these differences. The limitation remains consistent and is reproduced across different building configurations.

IV. DISCUSSION

The comparison of the results leaves little justification for interpreting value engineering merely as a cost-reduction tool. Such an interpretation is not supported by the evidence. Despite similar attempts to reduce construction costs, projects differ substantially both in their overall cost and in their operational performance. The underlying reason emerges at a much earlier stage—when the project's structural framework is established and the distribution of functions is defined [6]. From that point onward, cost ceases to behave as an independent variable and instead becomes a consequence of the adopted project configuration.

Within this context, the conventional linear sequence of design first, optimization later proves ineffective. Once the structural framework has been fixed, any subsequent intervention remains constrained by the existing configuration and cannot alter its fundamental characteristics. As a result, cost reduction at later project stages is largely limited to substituting individual components, producing only localized improvements. Fundamental optimization is no longer achievable because its practical boundary is determined by the timing of the initial design decisions.

Adopting a functional perspective fundamentally changes this interpretation. Rather than treating cost as the primary objective, the proposed approach considers functional allocation as the underlying driver of project economics. Functional distribution determines the project configuration, and the configuration, in turn, establishes the project's cost structure. The distinction between these two approaches is therefore substantial. Interventions at the component level adjust existing costs, whereas interventions at the functional level redefine how costs are generated in the first place [10]. This explains why early-stage value engineering produces disproportionately greater benefits. As long as functional relationships remain flexible, they can be reorganized without compromising building performance. Once these relationships become embedded within the project, meaningful changes require restructuring an already integrated system and therefore become largely impractical.

This dependency is particularly pronounced in affordable housing projects. Severe budget constraints leave little opportunity to absorb inefficient design decisions or compensate for them at later stages. Errors introduced into the project configuration persist throughout the entire development process, including the operational phase. Attempts to offset these deficiencies through alternative material selection or modifications to construction management do not address their underlying cause [15]. Such measures merely redistribute costs rather than reduce them. Consequently, an enduring budget burden is established and continues throughout the building's life cycle. Figure 1 presents the proposed value engineering model, illustrating the relationship among functional allocation, project structure, and cost formation under conditions of limited financial resources.

The proposed model is based on this limitation and therefore extends the traditional approach, in which value engineering is applied only after the completion of the design process. Under the conventional paradigm, value engineering addresses the consequences of design decisions. In the proposed framework, it addresses their underlying cause. This distinction is fundamental. In the former case, optimization is constrained by an already established project configuration. In the latter, the configuration itself becomes the object of management. Shifting the point of intervention in this way fundamentally changes the outcome.

The effectiveness of the proposed model is determined not by a different set of optimization techniques but by a different sequence of decision-making. As long as functional relationships remain flexible, they can be redistributed without compromising building performance or increasing project costs. Once the structural framework has been fixed, this opportunity disappears. Any attempt to return to the functional level requires redesigning the project and therefore becomes economically impractical. This leads to a fundamental principle: meaningful cost management is possible only before functional relationships become fixed; afterward, only limited cost adjustments remain feasible.

An additional advantage becomes apparent when the building life cycle is considered. The configuration established during the early design stage continues to influence costs throughout the operational phase. Decisions aimed solely at minimizing initial construction costs often prove less effective because they increase long-term operating expenditures. The proposed model resolves this contradiction by shifting the evaluation criterion from initial cost to overall project value, thereby excluding short-term savings that lack functional justification.

The practical significance of the proposed approach is particularly evident in developing markets. Strong cost pressure and limited financial resources leave little opportunity for sequential correction of design deficiencies. What is required instead is an approach that prevents unnecessary costs from being embedded in the project from the outset. The proposed framework provides such a mechanism by explicitly linking functional allocation with cost formation before the project configuration becomes fixed and resistant to change.

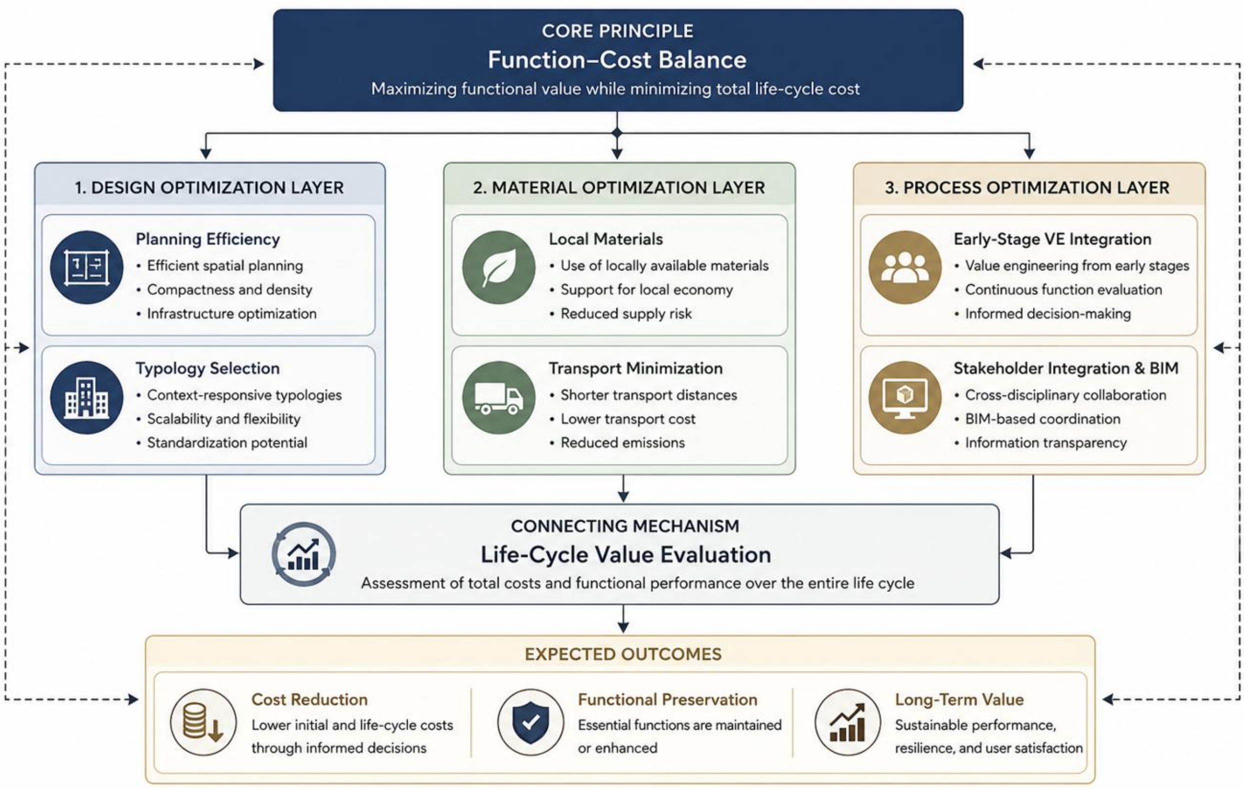

Fig.1 – Integrated Value Engineering Model for Low-Budget Residential Construction (Author's Own Development)

As a result, value engineering is no longer treated merely as an optimization technique but as a fundamental design principle. Cost management is not introduced after project development; it is embedded within the design process itself. This conceptual shift replaces the conventional practice of optimizing already completed design solutions and establishes a different framework for the development of affordable housing projects.

V. CONCLUSION

The findings of this study demonstrate that the effectiveness of value engineering depends primarily on the timing and level at which project decisions are made. The greatest influence on construction cost is established during the stage at which the project's spatial structure is defined, because this is where functional allocation and the overall project configuration become fixed. Once this stage has been completed, opportunities for cost reduction become substantially constrained and are limited to localized adjustments.

The identified relationship shifts the focus of cost management from project implementation to the design stage. Within this framework, value engineering should be regarded not merely as an optimization tool but as a design principle in which project cost is determined through functional allocation and its spatial organization.

The proposed model reflects this conceptual framework by enabling cost management before the project structure becomes fixed. As a result, construction costs can be reduced without compromising functional performance while simultaneously accounting for the long-term value of the building throughout its life cycle.

The research hypothesis is supported. The cost of affordable housing is determined predominantly by the parameters of its spatial structure. Addressing these parameters during the early design stage produces substantially greater benefits than subsequent modifications to construction materials or project execution processes.

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