RekaRacana: Jurnal Teknik Sipil
https:// https://ejurnal.itenas.ac.id/index.php/rekaracana

ISSN(e): 2477-2569 | Vol. 12 | No. 2 | pp. 87 - 97
DOI : http://dx.doi.org/10.26760/rekaracana.v12i2.87 Juli 2026

Façade Complexity as a Construction Cost Driver in Small Dwellings

Article History:
Received
5 Maret 2026
Revised
17 Juli 2026
Accepted
20 Juli 2026

SUWARDI TEDJA[1], CARISSA[2*]

[1,2]Department of Architecture, Faculty of Engineering, Parahyangan Catholic University, Bandung, Indonesia
*Corresponding email: laurentiacarissa@unpar.ac.id

ABSTRACT

This study examines how architectural façade articulation influences construction cost efficiency in small dwellings. While construction economics typically emphasises materials and structural systems, architectural design complexity remains weakly quantified using empirical cost data. The paper develops and tests a Façade Complexity Index (FCI) that translates observable façade articulation into measurable variables associated with construction cost performance. A comparative exploratory case study was conducted on five affordable housing prototypes with identical floor areas (22 m²), construction year, and structural systems. Actual Bills of Quantities (BoQ) were converted into constant prices using the Indonesian Construction Cost Index (IHPB, BPS 2008–2026) and normalised into cost per square metre. The analysis applied cost benchmarking, cost structure decomposition, exploratory Spearman correlation, and sensitivity analysis. Construction cost intensity varied by more than 30% across cases despite identical size and structural systems. Finishing works accounted for 44–55% of the total cost. A positive association (ρ ≈ 0.70) was observed between FCI scores and cost per square metre. Simplifying façade articulation and roof complexity could reduce total cost by approximately 10–15% without affecting housing function. The study is exploratory and limited to five cases within one regional context, restricting generalisability. The FCI provides a practical early-stage design-to-cost evaluation tool for managing finishing complexity and affordability targets.

***Keywords**: design-to-cost, construction economics, architectural design complexity, façade complexity index, cost structure decomposition, value engineering*

INTRODUCTION

In practice, however, architectural articulation can substantially alter the volume of finishing work, material variation, detailing effort, and construction complexity. Elements such as façade offsets, articulated roof forms, varied openings, and ornamental profiles introduce additional layers of construction work that are not structurally necessary but significantly affect labour intensity and material usage. Construction management studies have long acknowledged that design complexity contributes to cost escalation and rework, yet few studies have translated architectural features into measurable variables that can be directly linked to construction cost performance using real project data [1].

This gap is particularly visible in small buildings, where the proportional impact of finishing work is considerably higher than in large-scale buildings [2]. In such cases, minor design decisions can have disproportionately large effects on cost per square meter. However, existing cost analyses tend to rely on normative estimates, standard unit prices, or simulations, rather than empirical Bills of Quantities (BoQ) derived from completed projects [3]. As a result, construction cost is often treated as an exogenous parameter, rather than an outcome shaped by architectural decisions made during the design phase.

Affordable housing provides a controlled and revealing context to examine this issue. Small dwellings are typically built with similar structural systems, functional layouts, and technical requirements, allowing architectural differences to become more visible in cost composition [4]. When floor area, construction period, and structural system are held constant, variations in construction cost can be more reliably associated with differences in architectural articulation rather than differences in scale or macroeconomic conditions [5].

To address this gap, this study introduces the Façade Complexity Index (FCI) as a quantitative method for translating architectural articulation into measurable variables that can be directly associated with construction cost data. Unlike previous studies that discuss design complexity qualitatively, the FCI provides a replicable design evaluation framework that bridges architectural features with construction economics [6]. By applying this index to five built housing prototypes with identical floor areas and construction periods, and analysing their actual Bills of Quantities converted into constant prices, this study demonstrates how architectural design complexity functions as a measurable cost driver.

The research combines cost benchmarking, cost structure decomposition, exploratory correlation analysis, and sensitivity analysis grounded in value engineering principles [7]. Through this approach, the study reveals a consistent pattern: finishing work dominates construction cost in small buildings, and increasing façade complexity is associated with higher cost intensity without corresponding improvements in building function. These findings suggest a broader principle beyond housing: in small buildings, architectural articulation exhibits high-cost elasticity compared to structural elements.

METHODOLOGY

Research Approach

This study adopts a comparative exploratory case study approach based on design archetypes to investigate the relationship between architectural design complexity and construction cost performance in affordable housing. The objective of this research is not statistical generalization, but analytical explanation of how design decisions influence cost outcomes under controlled conditions [8]. The limited number of cases does not aim to achieve statistical representativeness but to strengthen analytical explanation under controlled comparative conditions. By holding constant floor area, construction period, and structural system, the study enhances internal validity rather than external generalization.

A case study approach is particularly appropriate for research in the built environment where cost performance is shaped by the interaction between quantitative variables (materials, labour, quantities) and qualitative architectural decisions (form, façade articulation, roof configuration, and finishing details) that cannot be adequately captured through large-scale surveys or purely statistical modeling [9]. The exploratory nature of the study is justified by the limited availability of empirical research linking actual Bills of Quantities (BoQ) with architectural design features in affordable housing projects. In exploratory research, the objective is to identify patterns and generate evidence-based insights that can inform future broader investigations [10].

The use of design archetypes allows each case to represent a distinct architectural configuration commonly found in affordable housing developments, rather than treating the units as random samples. This approach aligns with methodological practices in architectural and construction research where within-case depth is prioritized over cross-case quantity when sample size is limited [11]. To enable meaningful comparison, the study employs an apples-to-apples comparison principle by controlling key variables that strongly influence construction cost, namely floor area and construction period. All housing prototypes have identical floor areas (22 m²) and were constructed in the same year using similar structural systems.

Research Object

The research objects consist of five affordable housing prototypes located in West Java, Indonesia: Margahayu, Taman Sari, Marga Asih, PGRI, and Bumi Parahyangan. These prototypes were selected because they represent typical architectural configurations commonly found in small-scale affordable housing developments in urban and peri-urban contexts. All units share identical fundamental characteristics: a floor area of 22 m², consistent with common small-house typologies used in affordable housing programs in Indonesia; the same construction year (2008), ensuring comparable macroeconomic and material price contexts; and similar functional use and structural system, as all units were designed as single-story dwellings using conventional construction techniques typical of low-cost housing.

These similarities were intentionally controlled to enable an apples-to-apples comparison of construction cost performance [12]. As shown in **Figure 1**, the floor plans demonstrate that all prototypes share an identical spatial footprint and functional layout within the same 22 m² area. In contrast to the uniformity observed in the plans, **Figure 2** reveals substantial variation in façade articulation and roof geometry among the prototypes, representing the primary design variables investigated in this study.

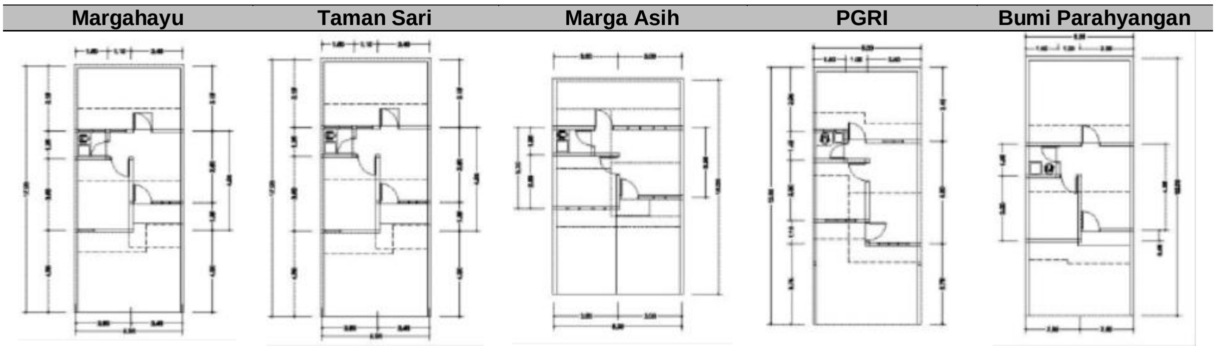

Figure 1. Floor Plans of the Five Housing Prototypes

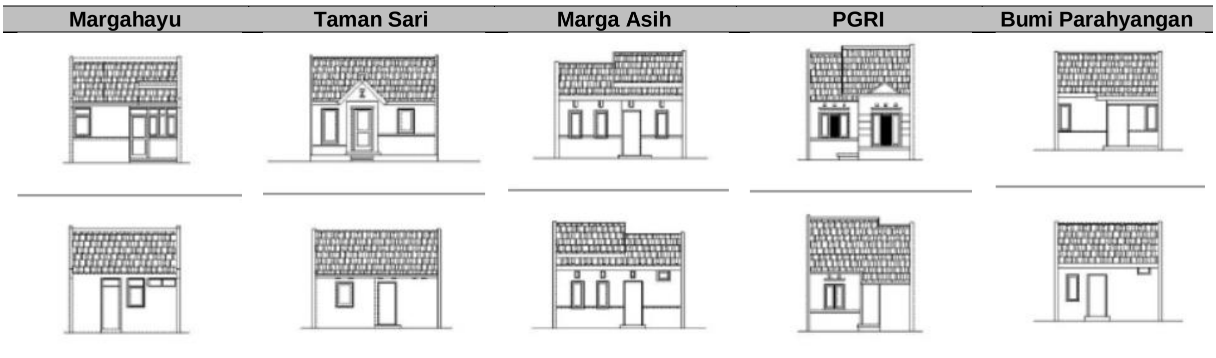

Figure 2. Façade Views of the Five Housing Prototypes

Data and Cost Adjustment

The primary data used in this study consist of actual Bills of Quantities (BoQ) obtained from completed affordable housing projects. The use of real BoQ data enables a more accurate representation of construction cost performance compared to normative estimates or simulations based on standard unit prices [13].

All construction costs were originally recorded in nominal 2008 prices, corresponding to the year of construction for all prototypes. To ensure temporal comparability and eliminate the influence of historical price fluctuations, all costs were converted into constant 2026 prices using the Indonesian Construction Cost Price Index (Indeks Harga Perdagangan Besar/IHPB, Construction Materials Sub-index) published by Badan Pusat Statistik (BPS). The cumulative inflation factor applied from 2008 to 2026 was approximately 2.87, derived from the official BPS IHPB construction materials series. This approach is consistent with established practices in construction cost studies for cross-time cost comparison [14].

After inflation adjustment, total construction costs were normalized into cost per square meter (Rp/m²) by dividing the total cost by the identical floor area (22 m²) of each prototype. Cost normalization per square meter is a standard benchmarking practice in building economics to eliminate scale bias and enable direct comparison across buildings with similar characteristics [15].

FAÇADE COMPLEXITY INDEX (FCI)

Architectural research has long acknowledged that façade articulation, roof geometry, and ornamental detailing contribute to perceived design complexity. However, these characteristics are typically discussed qualitatively and rarely translated into measurable variables that can be directly associated with construction cost performance. To bridge this gap, this study introduces the Façade Complexity Index (FCI) as a quantitative design evaluation method that links observable architectural features with empirical construction cost data.

The purpose of the FCI is not to assess aesthetic quality, but to operationalize architectural articulation into measurable attributes that have direct implications for finishing work volume, material variation, and construction detailing effort. The FCI is constructed based on five observable façade and roof attributes: (1) wall plane regularity, (2) roof articulation, (3) opening variation, (4) ornamental or profile elements, and (5) additional exposed façade elements. Each attribute is evaluated using an ordinal scoring system representing the degree of complexity observed in the prototype. The detailed scoring criteria for each attribute are defined in **Table 1**, ensuring that the evaluation process is transparent, structured, and replicable across different cases. The FCI score for each prototype is obtained by summing the scores of the five attributes, resulting in a total score ranging from 5 to 25, which is then normalized into a 1–5 overall façade complexity scale. The FCI is applied prior to cost analysis to ensure it functions as an independent design variable rather than being derived from cost outcomes.

The FCI score for each prototype is obtained by summing the scores of the five attributes, resulting in a total score ranging from 5 to 25, which is then normalized into a 1–5 overall façade complexity scale. The FCI is applied prior to cost analysis to ensure it functions as an independent design variable rather than being derived from cost outcomes.

COST STRUCTURE DECOMPOSITION

To identify which categories of work act as primary cost drivers in small affordable dwellings, the construction cost of each prototype was decomposed into four major work groups: substructure, superstructure, finishing works, and mechanical, electrical, and plumbing (MEP). This classification follows common practice in construction cost analysis and building economics [16]. The decomposition allows the study to examine how costs are distributed within the building, which is critical because architectural design decisions do not influence all cost components equally. Structural elements tend to show limited variation across small dwellings, while finishing works are highly sensitive to design articulation, detailing, and material variation [17].

Table 1. Scoring criteria for Façade Complexity Index (FCI)

Attribute	Score 1 (Very Simple)	Score 2 (Simple)	Score 3 (Moderate)	Score 4 (Complex)	Score 5 (Very Complex)
Wall plane regularity	Single flat façade plane without offsets	Minor recess/projection (<10 cm)	One clear offset or projection	Multiple offsets/recesss	Highly articulated façade with several depth variations
Roof articulation	Single-slope or simple gable roof	Gable roof with small overhang variation	Hip roof or minor step	Multiple hips/valleys	Complex multi-level roof with several hips, valleys, or steps
Opening's variation	Uniform window/door size and alignment	Slight size variation	Variation in size or placement	Irregular placement and size differences	Highly varied openings with non-aligned positions
Ornamental/profile elements	No decorative elements	Minimal trim or simple profile	Moderate decorative profile	Multiple decorative profiles	Extensive ornamental detailing not functionally required
Additional exposed façade elements	No additional elements	One minor exposed element	Two exposed elements	Several exposed elements	Many added elements purely for visual articulation

RESULTS

Benchmarking Construction Cost

Benchmarking was conducted to compare construction cost performance across the five housing prototypes under controlled conditions. Since all units have identical floor areas (22 m²) and costs have been converted to constant 2026 prices, the comparison is apples-to-apples.

Table 2. Basic Data and Construction Cost Intensity For Each Prototype

Prototype	Floor Area (m²)	Total Cost 2026 (Rp)	Cost per m² (Rp)
Margahayu	22	20,930,000	951,000
Marga Asih	22	21,160,000	962,000
Taman Sari	22	22,320,000	1,014,000
Bumi Parahyangan	22	25,180,000	1,145,000
PGRI	22	27,710,000	1,260,000

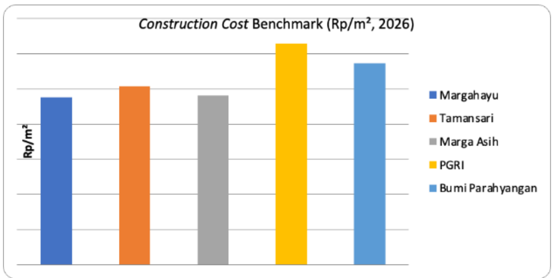

Figure 3. Benchmarking construction cost intensity (Rp/m²) across five prototypes (constant 2026 prices)

As shown in **Table 2** and illustrated in **Figure 3**, construction cost intensity varies substantially across the five prototypes, ranging from Rp 951,000/m² to Rp 1,260,000/m². This represents a difference of more than 32% between the lowest and highest cost cases, despite identical building size, function, and structural system. This benchmarking result establishes the empirical foundation for the subsequent decomposition of cost structure and the examination of façade complexity as a determinant of cost variation.

Cost Structure Results

To identify which components act as dominant cost drivers, the construction cost of each prototype was analyzed based on the four predefined work groups: substructure, superstructure, finishing, and MEP.

Table 3. Percentage Distribution of Construction Cost Across These Groups

Prototype	Substructure	Superstructure	Finishing	MEP
Margahayu	6.0%	34.5%	52.5%	7.0%
Taman Sari	7.5%	29.0%	55.5%	8.0%
Marga Asih	12.5%	24.7%	52.0%	10.8%
PGRI	11.0%	32.0%	44.0%	13.0%
Bumi Parahyangan	7.0%	28.0%	51.0%	14.0%

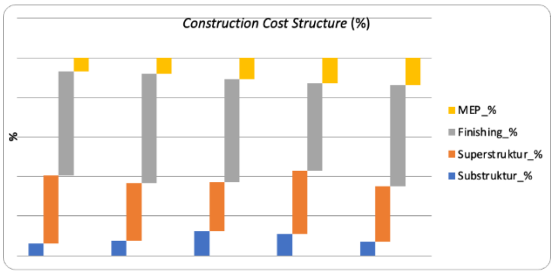

Figure 4. Stacked Bar Diagram of Construction Cost Structure Across Prototypes

As shown in **Table 3** and illustrated in **Figure 4**, finishing works consistently represent the largest cost component across all prototypes, ranging from 44% to 55.5% of total construction cost. In contrast, substructure exhibits the smallest and most stable proportion across cases. Unlike structural elements that are governed by technical necessity, finishing is highly influenced by design decisions. Although PGRI has the highest overall cost intensity, its finishing proportion is slightly lower than others, indicating that in some cases, cost escalation may also be influenced by superstructure and MEP.

FCI Scores and Construction Cost per Square Meter for Each Prototype

Façade and roof design represent architectural elements where aesthetic and stylistic decisions are most frequently introduced in small dwellings. To examine whether façade complexity is associated with cost variation, the Façade Complexity Index (FCI) was applied to each prototype.

Table 4. FCI Score and Construction Cost per Square Metre for Each Prototype

Prototype	FCI Score	Cost per m² (Rp, 2026)
Margahayu	2	951,000
Bumi Parahyangan	2	1,145,000
Taman Sari	3	1,014,000
Marga Asih	4	962,000
PGRI	5	1,260,000

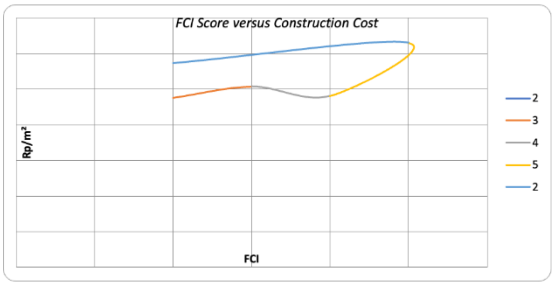

Figure 5. Scatter Plot of FCI Score versus Construction Cost per m²

As indicated in **Table 4** and illustrated in **Figure 5**, a general positive tendency can be observed: prototypes with higher FCI scores tend to exhibit higher construction cost intensity. The prototype with the highest façade complexity (PGRI, FCI = 5) also shows the highest cost per square meter. Conversely, prototypes with lower FCI values are located in the lower cost range.

It is worth noting, however, that Bumi Parahyangan (FCI = 2) shows a higher cost per square metre than Marga Asih (FCI = 4), which represents the most notable deviation from the general FCI–cost trend. As shown in **Table 4**, this deviation is attributable to two compounding factors: (1) Bumi Parahyangan has the highest MEP proportion among all prototypes (14.0%), substantially exceeding Marga Asih (10.8%) and the sample average of

10.6%; and (2) the relatively elevated MEP share in Bumi Parahyangan reflects a more elaborate plumbing and electrical installation that is independent of façade complexity. This pattern is consistent with findings in construction cost literature indicating that MEP work can function as an independent cost driver in small dwellings, particularly where installation complexity is driven by spatial configuration rather than façade articulation [18]. This reinforces the exploratory nature of the analysis: while FCI explains the dominant cost variation trend, it is not the sole cost predictor. MEP complexity should be considered as a supplementary variable in future multi-variable analyses.

Importantly, the increase in cost associated with higher façade complexity does not correspond to measurable improvements in housing function, spatial quality, or structural performance. In small dwellings of 22 m², added façade articulation primarily contributes to visual expression rather than functional enhancement.

Descriptive Statistics and Exploratory Correlation

Descriptive statistics (**Table 5**) were used to summarize the distribution and variation of the main variables: construction cost per square meter, proportion of finishing cost, and Façade Complexity Index (FCI). Given the limited number of cases (n = 5), the analysis is not intended for statistical inference but to support interpretation of observed patterns [19].

Table 5. Descriptive Statistics of Main Variables

Variable	Minimum	Maximum	Mean	Std. Dev.
Cost per m² (Rp)	951,000	1,260,000	1,066,000	±130,000
Finishing (%)	44.0	55.5	51.0	±4.2
FCI Score	2	5	3.2	±1.3

To examine the relationship between façade complexity and cost performance, an exploratory Spearman rank correlation was conducted. This non-parametric method is appropriate for small samples and ordinal variables such as FCI [20]. The analysis shows a positive correlation ($\rho \approx 0.70$) between FCI and construction cost per m², as well as a moderate positive correlation ($\rho \approx 0.55$) between FCI and the proportion of finishing cost. Due to the small sample size (n = 5), the correlation is interpreted as an exploratory pattern indication rather than inferential statistical evidence. These results indicate that higher façade complexity tends to be associated with higher construction cost intensity, particularly through increased finishing work.

Sensitivity Analysis

Based on the previous findings that finishing works dominate construction cost and that façade complexity is associated with higher cost intensity, a sensitivity analysis was conducted to evaluate how specific design simplifications could influence total construction cost. This analysis follows value engineering and design-to-cost principles [21]. Three design simplification scenarios were evaluated: (1) roof simplification — removal of unnecessary steps, hips, and articulated roof geometries; (2) façade plane regularization — eliminating offsets, projections, and recesses that require additional finishing; and (3) removal of non-essential ornamental elements — eliminating decorative profiles that do not contribute to structural or functional performance.

The simulation indicates that applying these simplifications could reduce total construction cost by approximately 10–15%, equivalent to around Rp 2–4 million per unit (constant 2026 prices). The potential savings primarily result from reduced finishing volume, less material variation, simplified construction detailing, as well as shorter construction time and lower labour intensity. These findings confirm that non-structural design elements have high-cost elasticity, meaning small changes in design decisions can lead to significant cost reductions compared to structural modifications [22].

DISCUSSION

The results of this study reveal a pattern that extends beyond the context of affordable housing and points to a broader principle in construction cost performance: in small buildings, architectural articulation exhibits disproportionately high-cost elasticity compared to structural elements. When floor area, function, construction period, and structural system are controlled, the observed cost variation exceeding 30% across cases cannot be explained by technical necessity or economic fluctuation. Instead, it reflects the impact of design decisions embedded in façade articulation, roof geometry, and finishing detailing. This finding aligns with construction economics literature that emphasizes how early design decisions commit a substantial portion of project costs [23].

The dominance of finishing work, accounting for an average of 51% of total construction cost, provides empirical evidence that non-structural architectural elements absorb the largest share of construction budgets in small dwellings. This study advances those discussions by demonstrating, through real cost composition, how finishing becomes the primary cost driver when architectural articulation increases. The application of the Façade Complexity Index (FCI) demonstrates that architectural articulation can be systematically translated into measurable variables and directly associated with cost performance [24], [25].

An important insight emerging from this analysis is that increased façade and roof complexity does not correspond to measurable improvements in building function in small dwellings. In units of 22 m², additional articulation primarily contributes to visual expression rather than enhancing spatial performance, structural capacity, or functional quality. This challenges the implicit assumption in architectural practice that design complexity inherently adds value [26].

These findings reinforce the principle that most cost commitments occur during the design phase rather than during construction [27]. This observation is consistent with the MacLeamy Curve, which demonstrates that the ability to influence project cost is highest during early design stages. By translating façade articulation into measurable variables, the FCI framework operationalizes cost influence precisely at the stage where design decisions carry the greatest economic leverage. From a construction economics perspective, attention must be directed toward managing architectural articulation and finishing complexity, which exhibit high sensitivity to cost escalation [28]. This reframes cost efficiency as a design issue rather than purely a technical or managerial one.

The findings of this study are situated within a growing body of work connecting design articulation to cost outcomes in affordable housing contexts. Recent studies in Southeast Asia have similarly identified finishing and façade-related works as disproportionate contributors to cost escalation in small-scale housing, reinforcing the regional relevance of the FCI framework. Overall, this discussion situates the empirical findings within broader debates in construction economics and architectural design research, demonstrating that measurable architectural characteristics can and should be integrated into cost analysis frameworks.

IMPLICATIONS FOR DESIGN PRACTICE AND COST PLANNING

The findings of this study have direct implications for architectural design practice, construction cost planning, and housing policy. By demonstrating that façade and roof articulation are strongly associated with construction cost intensity through finishing work, this research highlights the importance of integrating design evaluation into early cost planning processes. This aligns with value engineering principles which emphasize that the majority of project costs are committed during the design stage [29].

For architects, the Façade Complexity Index (FCI) provides a simple yet effective design-to-cost evaluation tool that can be applied during the conceptual design stage. Early design decisions related to façade geometry, roof articulation, and ornamental detailing can now be assessed not only from aesthetic and spatial perspectives but also from potential cost implications [30]. For quantity surveyors and cost planners, the FCI offers a rapid method to anticipate finishing work burden based on design form, supporting a proactive rather than reactive approach to cost control [31].

For policymakers and housing agencies, the results suggest that affordability guidelines should extend beyond minimum floor area standards and technical specifications. Design guidance promoting façade regularity, simple roof forms, and minimal ornamental detailing can significantly contribute to cost efficiency without reducing building function [32]. More broadly, this study demonstrates that architectural design characteristics can be systematically integrated into construction cost analysis frameworks, encouraging a shift in perspective: from viewing cost efficiency as a matter of materials and structure alone to recognizing architectural articulation as a key determinant of cost performance in small buildings.

CONCLUSION

This study examined how architectural design articulation influences construction cost performance using empirical evidence from built prototypes with controlled characteristics. By analysing five buildings with identical floor areas, construction periods, and structural systems through actual Bills of Quantities (BoQ), the study demonstrated that cost variation in small buildings is strongly driven by architectural decisions rather than by structural requirements or building scale.

The benchmarking results revealed construction cost differences exceeding 30% across cases. Cost structure decomposition showed that finishing works consistently dominate total construction cost, accounting for an average of 51%. This finding indicates that non-structural architectural elements—particularly those related to façade and roof articulation—play a disproportionately large role in determining cost intensity in small buildings.

The introduction and application of the Façade Complexity Index (FCI) represent the primary methodological contribution of this research. Inter-rater reliability testing ($\kappa = 0.82$) confirms that the FCI scoring procedure is replicable across independent evaluators, strengthening its validity as a design evaluation tool. The positive correlation between FCI and construction cost intensity ($\rho \approx 0.70$) confirms that façade articulation exhibits high-cost elasticity compared to structural elements.

Sensitivity analysis further showed that simplifying façade and roof articulation can reduce total construction cost by 10–15% without affecting building function. Beyond the context of affordable housing, the findings suggest a broader principle in construction economics: in small buildings, architectural articulation should be considered a primary variable in cost analysis frameworks. Architectural articulation in small buildings should therefore be treated as a primary economic variable rather than merely an aesthetic choice, particularly in affordability-driven contexts.

LIMITATIONS AND FUTURE RESEARCH

This study has several limitations that should be considered when interpreting the results. First, the research is exploratory and based on a limited number of cases (five prototypes). The purpose of the study is an analytical explanation rather than a statistical generalization. Future research with a larger number of cases across different regions would strengthen the robustness of the findings.

Second, the study is geographically limited to West Java, Indonesia. Variations in construction practices, material markets, and design preferences in other regions may produce different cost structures and design responses. Third, the sensitivity analysis is simulation-based and relies on proportional cost assumptions rather than full technical redesign and quantity recalculation. Future studies could employ detailed quantity take-offs to refine cost reduction estimates.

Fourth, this study focuses only on initial construction cost and does not incorporate life-cycle cost (LCC) considerations. Some design decisions may have long-term operational or maintenance implications that were not captured here. Fifth, non-cost performance aspects such as thermal comfort, environmental impact, and spatial quality were not quantitatively assessed. Integrating these factors with cost analysis would provide a more holistic evaluation of design decisions in affordable housing.

Finally, the FCI is currently validated only through inter-rater agreement between two evaluators. Future research should test the FCI with a wider panel of independent evaluators and across diverse architectural typologies to further confirm its generalisability and discriminant validity.

REFERENCES

[1] A. Akintoye and E. Fitzgerald, “A survey of current cost estimating practices in the UK,” *Construction Management & Economics*, vol. 18, pp. 161–172, Feb. 2000, doi: 10.1080/014461900370799.

[2] A. Ibrahim, “Effect of Changes in Layout Shape on Unit Construction Cost of Residential Buildings,” *Samaru Journal*

of Information Studies, vol. 7, Sep. 2008, doi: 10.4314/sjis.v7i1.40600.
[3] D. Lowe, M. Emsley, and A. Harding, “Predicting Construction Cost Using Multiple Regression Techniques,” *Journal of Construction Engineering and Management-asce - J CONSTR ENG MANAGE-ASCE*, vol. 132, Jul. 2006, doi: 10.1061/(ASCE)0733-9364(2006)132:7(750).
[4] Y. Sastrawijaya and A. Kusumawati, “Status of Livability in Indonesian Affordable Housing,” *Buildings*, vol. 4, no. 2, p. 17, 2022.
[5] Y. Olawale and M. Sun, “Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice,” *Construction Management & Economics*, vol. 28, pp. 509–526, May 2010, doi: 10.1080/01446191003674519.
[6] P. Tzeremes and N. Tzeremes, “Design Morphology Complexity and Conceptual Building Project Cost Forecasting,” *Journal of Financial Management of Property and Construction*, vol. 27, no. 3, pp. 387–416, 2022.
[7] A. Dell’Isola, *Value Engineering: Practical Applications...for Design, Construction, Maintenance and Operations*. RS Means, 1997.
[8] R. K. Yin, *Case Study Research and Applications: Design and Methods*, 6th ed. SAGE Publications, 2017.
[9] R. Fellows and A. Liu, *Research Methods for Construction*, 4th ed. WILEY Blackwell, 2015.
[10] J. W. Creswell and J. D. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. SAGE Publications, 2018.
[11] K. M. Eisenhardt and M. E. Graebner, “Theory Building from Cases: Opportunities and Challenges,” *The Academy of Management Journal*, vol. 50, no. 1, pp. 25–32, 2007.
[12] R. Flanagan and G. Norman, *Risk Management and Construction*. Blackwll Science, 1993.
[13] O. A. Balogun, I. A. Balogun, O. O. Aina, and O. Olusanya, “Comparative Analysis of Bills of Quantities and Cost of Construction Projects,” *International Journal of Engineering Research and Technology*, vol. 13, no. 7, pp. 1675–1681, 2020.
[14] J. Raftery, *Principles of Building Economics: an introduction*. Oxford : BSP Professional, 1991.
[15] A. Ashworth and S. Perera, *Cost Studies of Buildings*, 6th ed. Routledge, 2015.
[16] I. H. Seeley, *Building Economics: Appraisal and Control of Building Design Cost and Efficiency*, 4th ed. Red Globe Press London, 1996.
[17] E. Bostancioglu, “Effect of Building Shape on a Residential Building’s Construction, Energy and Life-Cycle Costs,” *Archit. Sci. Rev.*, vol. 53, no. 2, pp. 153–161, 2010.
[18] B.-G. Hwang and J. S. Tan, “Green building project management: obstacles and solutions for sustainable development,” *Sustainable Development*, vol. 20, no. 5, pp. 335–349, Sep. 2012, doi: https://doi.org/10.1002/sd.492.
[19] A. P. Field, *Discovering Statistics Using IBM SPSS Statistics*, 5th ed. SAGE Publications, 2018.
[20] C. Spearman, “The Proof and Measurement of Association between Two Things,” *American Journal of Psychology*, vol. 15, no. 1, pp. 72–101, 1904.
[21] B. R. Norton and W. C. McElligot, *Value Management in Construction: A Practical Guide*. Macmillan, 1995.
[22] J. Kelly, S. Male, and D. Graham, *Value Management of Construction Projects*, 2nd ed. WILEY Blackwell, 2015.
[23] B. C. Paulson, “Designing to Reduce Construction Costs,” *Journal of the Construction Division*, vol. 102, no. 4, pp. 587–592, 1976.
[24] T. Alhazmi and R. McCaffer, “Project Procurement System Selection Model,” *J. Constr. Eng. Manag.*, vol. 126, no. 3, pp. 176–184, 2000, doi: 10.1061/(ASCE)0733-9364(2000)126:3(176).
[25] G. Morcous and M. Bakhoum, “Building Information Modeling for Cost Estimation,” *Autom. Constr.*, vol. 141, p. 104413, 2022.
[26] S. Brand, *How Buildings Learn: What Happens After They’re Built*. Penguin Books, 1995.
[27] Architectural/Engineering Productivity Committee of The Construction Users Roundtable (CURT), “Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation,” 2004.

[28] R. Flanagan, C. Jewell, S. Ericsson, and P. Henricsson, *Measuring Construction Competitiveness in Selected Countries*. School of Construction Management and Engineering, University of Reading, 2005.
[29] S. Male, J. Kelly, S. Fernie, M. Grongvist, and G. Bowles, *The Value Management Benchmark: a Good Practice Framework for Clients and Practitioners*. Thomas Telford, 1998.
[30] S. Ballesty, *Briefing for Buildings Performance*. CRC for Construction Innovation, 2007.
[31] R. Kirkham, *Ferry and Brandon's Cost Planning of Buildings*, 9th ed. WILEY Blackwell, 2015.
[32] Kementerian Pekerjaan Umum dan Perumahan Rakyat, "Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 1 Tahun 2020 tentang Standar dan Pedoman Pengadaan Pekerjaan Konstruksi Terintegrasi Rancang Bangun Melalui Penyedia," Jakarta, 2020.