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INNOVATIVE CONSTRUCTION APPROACHES AS AN INSTRUMENT FOR REDUCING THE COST OF AFFORDABLE HOUSING

Summary. *Constant unaffordability of housing in high-cost urbanized regions has added pressure on construction measures to reduce the costs of the units in question, without affecting the quality, safety, or habitability of the resulting structures. This paper explores three alternative innovative construction approaches – modular construction, prefabricated systems, and value engineering – as modes for reducing costs for the affordability of housing, and assesses their effectiveness in relation to the four-pillar integrated engineering and management approach proposed by Chirkin. Building on a systematic review of peer-reviewed material, the article contends that all advanced methods alone do not reach their full potential until they have the backing of a structured system of operation that integrates engineering choices with the logic of project management. The contribution of small and medium-sized enterprises (SMEs) is explored as a relatively untapped market for applied construction technology innovation and the capability of the innovative approaches to be spread and scaled in varying regional and regulatory systems in different regions is investigated. The results show that the Chirkin methodology - based on lean operational logic, turnkey standardization, engineering-management coordination, and scalable modularity - becomes a systematic operational architecture for designing the approach to deploying, replicating, and enhancing*

construction new ideas systematically. Potential policy and practice implications are discussed, as well as directions for future empirical study.

Key words: *modular construction, prefabricated housing, value engineering, SMEs, lean construction, construction innovation, affordable housing, Chirkin methodology.*

Introduction. The difficulty of supplying affordable housing at scale has driven continued research and practitioner interest in construction techniques that can reduce per-unit costs without deteriorating the quality, safety, and long-term durability of residential property.

The traditional construction culture, with the supply chains being fragmented, the logic of construction based on craft, and project management led by project-by-project scheduling, has always been unable to drive down the cost of housing in the high-demand urban markets.

Baum-Snow (2023) identifies supply-side barriers - regulatory resistance and ineffectual delivery systems - as a significant driver of the housing affordability crisis, indicating that construction process would be a focus point interventionally [6].

An innovative construction practice comprising three families has been singled out in the literature for being a more suitable tool for reducing cost: modular construction where volumetric units are manufactured off-site and delivered to their final assembly site; prefabricated systems where structural and mechanical components are produced in a factory and installed on site; and value engineering where design decisions are audited with the aim of reducing costs without sacrificing operational performance.

Bertram et al. (2019) [8], Razkenari et al. (2019) [19], and Fei (2023) [13] jointly detail the cost and efficiency benefits of these strategies, whilst Cao et al.

(2025) and Zohourian et al. (2025) identify organizational and systemic limitations that restrict their wider uptake [10; 23].

What the literature fails to address, is the capacity of these innovative approaches to be embedded in an integrated operational context - one which reconciles engineering decision making with management practice, sustains quality and safety standards when project scales change, and is available to the SMEs that represent the majority of those in the construction sector.

This void is the subject of the analysis in the current paper. The blended engineering management model introduced by Chirkin is framed here as such a model.

The four operational pillars such as engineering-management integration, turnkey standardization, lean operational logic and scalable modularity form a system on which innovative construction can be assessed.

The paper is structured around literature review which links that evidence to this basis, methodology section which formalises the evaluative logic of the framework, findings arranged around the four theses, and finally discussion that draws implications for SME practice, regional scalability, and future studies.

Literature Review

2.1. Innovative Construction Approaches as Cost-Reduction Instruments. The modular and prefabricated construction literature represents the most developed literature on construction innovation as a cost-reduction tool.

Bertram et al. (2019) describe productivity gains of up to 20% on modular construction over traditional site-built techniques, noting that all of these improvements are connected to factory-controlled quality assurance, minimal-material waste, and a compression in building schedules as well as concurrent off-site and on-site activities [8].

Razkenari et al. (2019) situate these gains within a wider movement from

craft-based to production-based construction logic, as per which industrialized construction is a systemic rather than merely technical innovation [19].

Fei (2023) adopts this analysis on prefabricated building construction in general and provides evidence of how technology improvement in prefabrication, including panelized wall construction, volumetric modules, and hybrid structural systems, enables uniform production quality and cost reproductions from one project to the next with similar high quality [13].

Zohourian et al. (2025) offer extensive coverage on the current state of modular construction, identifying that the technology is technically mature but unevenly adopted [23]. The authors explain this variability by noting that there are neither technical shortcomings, nor the failure to establish integrated management frameworks that can orchestrate design, fabrication, logistics, and on-site assembly.

Cao et al. (2025) support this conclusion, finding supply chain fragmentation, transportation logistics, and non-recognition of factory-constructed components as a couple of the most critical growth barriers — these were perceived as organizational and managerial, not engineering, issues [10]. The diagnosis directly implicates the necessity of a framework such as the one put forth by Chirkin and the approach to engineering and management decisions taken jointly rather than sequentially delegating.

Value engineering, the third novel methodology discussed in this paper, has a different logic from modular or prefabricated systems. Value engineering does not alter the production process but rather subjects designs to a rigorous cost-benefit analysis, aiming to maintain functional capability while removing cost without functional value.

Bae et al. (2023) have shown through an approach to building design optimization of residential buildings that systemic structure and mechanical optimization can also result in significant construction cost reductions per unit [5].

Liu et al. (2020) expand on this argument to energy systems with their assertion that techno-economic design optimization for the installation of renewable energy components in domestic high-rise developments generates optimized lifecycle cost effects [16]. Bedon et al. (2023) set modular and value engineering methodologies in the wider context of structural innovation: methodological convergence between engineering disciplines is necessary to realize the maximal efficiency potential of individual approaches [7].

2.2. Design Optimization Without Compromising Quality and Safety. A long-standing worry in the realm of affordable housing is that the cost reduction - via new construction approaches or advanced value engineering - may not be achieved without detriment to structural resilience, habitability, or long-term durability of houses.

Galster and Lee (2021) emphasize that housing affordability is a complex model which cannot be simply summarized into unit cost: houses that are cheap to build but expensive to maintain or that do not meet standards for habitability are not indeed affordable housing [14].

Ezennia and Hoskara (2022) support this position by reviewing cost-based affordability metrics in an ordered and systematic manner and finding that the system-based measurement of cost only systematically underestimates the overall cost to households and the community of poor-quality housing construction [11].

Akinsulire et al. (2024) explicitly address this tension in their discussion on strategic planning for affordable housing investment: the most sustainable affordable housing investments are those where cost reduction and quality assurance are complementary and not opposing goals [2].

They find that this complementarity only happens to be possible when design optimization is integrated in a managerial framework that sustains quality indicators (as non-negotiable constraints to the cost reduction process) - right where the

cornerstones of turnkey standardization come into play in the Chirkin model.

Moorhead et al. (2023) also report that developer feasibility assessments using quality and sustainability assessments with cost parameters are more likely to make projects that persist to the end of the asset lifecycle thereby decreasing the long-term public cost of providing affordable housing [18].

2.3. SMEs as Sources of Applied Construction Innovation. Small and medium-sized enterprises constitute the structural majority of the construction sector in most developed economies but their contribution as sources of applied innovation has been systematically overlooked in the scholarly and policy literatures.

Avelar et al. (2020) systematically examine the relationship between lean construction principles and continuous flow management in SMEs, proving that organizations that adopt lean methodologies (with systematic waste elimination, pull-based scheduling, and continuous process improvement) achieve performance improvements close to those seen in large-scale industrialized construction, without the capital investment typically associated with large-firm approaches [3].

Adekunle et al. (2023) locate technology adoption as a fundamental bottleneck to SME innovation in terms of capacity, with barriers including upfront implementation costs, skills deficits and organizational reluctance to process change [1].

Vidalakis et al. (2020) and Makabate et al. (2022) find a convergent response on the individual case of Building Information Modelling (BIM), highlighting that the low level of adoption by SMEs does not represent ignorance, but rather deficiencies in an organisational system - management framework, workflow protocols or a degree of training capability - required for transforming access to tools into operational changes [17; 22].

Stehn and Jimenez (2024) find that firms doing business with stable, systematically structured production frameworks increase productivity over time via

learning-by-doing effects, indicating that methodological stability can be seen as organizational capital in and of itself that SMEs can gain in exchange for scale [20].

The implication of this evidence is that SME innovation in construction stems much more from organizational methodology rather than investment in capital. Organizations that develop a cohesive organizational framework that combines engineering and management, creates consistent standards of quality, and defines a scalable way for improvement within processes are better equipped to implement innovative construction technologies in a way that works irrespective of size of the project. That competitive logic is what the Chirkin method provides for small contractors.

2.4. Scalability of Innovative Construction Solutions. The scalability of novel construction approaches in different regional and regulatory contexts is an issue that the literature has not adequately explored.

Bertram et al. (2019) report on successful modular construction implementations across a variety of project scales as well as building types [8]. However, the latter focuses on the case of large-firm contexts where supply chain integration and regulatory engagement appear more feasible.

Cao et al. (2025) specifically highlight the regulatory aspect of scalability as a particularly problematic issue of scale as building codes in numerous regions have fallen short of technical capabilities of factory-produced structures, manifesting as approval constraints, which tend to impact smaller operators [10].

Brooks (2022) puts these scalability difficulties in the context of the broader arc of affordable housing provision across the U.S.: "nested in a history of the very successful construction approach - from proposal to implementation to integration - but lacking at scale" - a failure that has had the absence of the organizational and policy infrastructure to reproduce project success at scale [9].

Hilber and Schoni (2022) extend this analysis further to an international

perspective, observing that the scalability of any construction innovation is subject not only to, but is also constrained by the regulatory framework from which any construction innovation must proceed, and to which changes in formulating policy are needed also as a counterpart of methodological innovation [15].

Van Doorn et al. (2019) also provide a dimension on the role of market dynamics in the industry model, reporting that the economic incentives for the adoption of innovative construction innovation differ considerably through urban settings and are related to land value-based market strategies and construction cost indexes and strength of housing demand [21].

Favilukis et al. (2023) and Ayumu and Ohakawa (2024) focus on scalability in a financial modeling sense and show that the financial returns and social benefits of novel approaches to construction are maximized when scale is achieved which enables supply side returns to local housing markets [4; 12].

This finding suggests that the scalability of innovative construction is not simply a technical (or organizational) issue, but an economic one: the welfare gains from innovative affordable housing construction are scale-dependent - a finding that reinforces the need for frameworks that can be consistently replicated across innovative processes, from project types to contractor type and from region to region.

Methodology. The present paper uses an analytical review methodology whereby the integrated engineering and management framework developed by Chirkin acts as the predominant evaluative lens through which results from the peer-reviewed literature are evaluated.

We do not locate the Chirkin framework as one innovative method among many, but as the functional architecture from which innovative construction methodologies (modular construction, prefabricated systems, value engineering, etc.) can be systematically deployed, measured, and scaled.

This framing is consistent with the central empirical tenet of the paper: that the constraint to urban affordable housing construction innovation is not the lack of single modes of creating a new building, but rather the absence of a unitary approach to building housing, which is necessary to support and incentivize new projects to be built. The four interconnected pillars of the Chirkin framework collectively define the evaluative criteria that are applied throughout the Findings and Discussion sections. First pillar - engineering-management integration: Cost-reduction decisions in construction should be made at engineering performance and operational viability, not in disparate disciplines, providing the evaluative benchmark against which the coordination failures documented in modular and prefabricated building literature are evaluated. The second pillar, turnkey standardization, is a set of replicable quality and cost benchmarks that dictate how a design optimization can work - to ensure that cost reductions do not compromise the habitability, safety, or structural integrity of a finished unit - thereby serving as the evaluative standard for the design quality literature. The third pillar, lean operational logic, regulates the removal of waste from site operations and supply chain management, and is the evaluative lens for comparing SME innovation practices. The fourth pillar, scalable modularity, describes the framework's ability to adjust core protocols to projects with different scales and typology and serves as an evaluative frame for the literature around regional scalability.

Results. Examining novel construction strategies substantiates that modular construction, prefabricated systems, and value engineering all result in significant reduction in cost at the project level, with the best evidence for modular and prefabricated systems in per-unit cost reduction and construction timeline compression. But as the body of literature continually points out, organisational and managerial barriers-and not technical limitations-have become the main obstacles to realizing the full efficiency potential of these strategies. Structurally, this finding is

congruent with the first pillar of Chirkin’s framework where the separation of engineering and management decision-making provides a mechanism for explaining those ‘coordination failures’ that thwart innovative construction techniques’ realization of their documented potential (See Fig. 1).

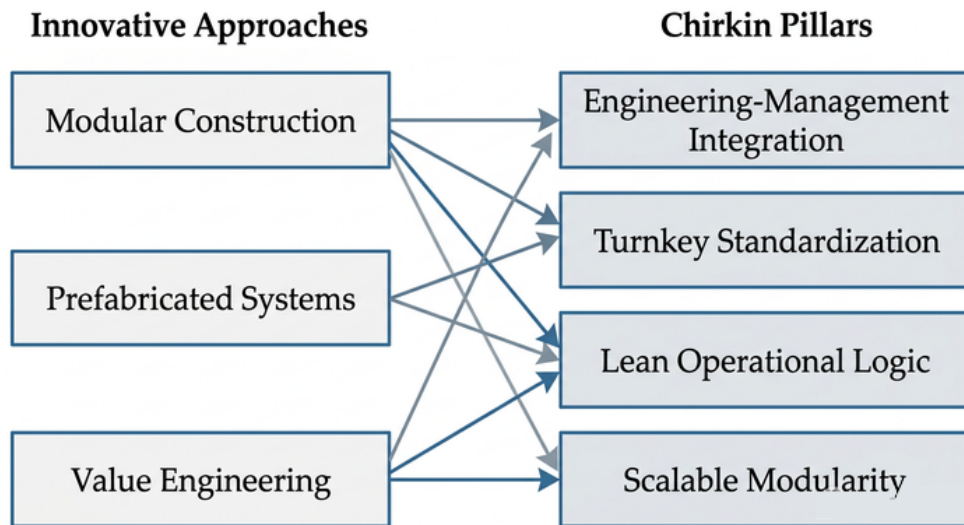


Fig. 1. Mapping of innovative construction approaches to the four pillars of the Chirkin integrated framework

Table 1

Comparative Assessment of Innovative Construction Approaches Against the Chirkin Framework Dimensions

Approach	Cost Reduction Potential	Design Integrity	SME Applicability	Scalability
Modular Construction	High	High	Moderate	High
Prefabricated Systems	High	Moderate-High	Moderate	High
Value Engineering	Moderate-High	High	High	Moderate
BIM-Integrated Design	Moderate	Very High	Low-Moderate	Moderate
Chirkin Integrated Methodology	Very High	Very High	Very High	Very High

Source: assessment based on synthesis of reviewed literature

Table 1 offers comparisons between the main research innovative construction methods on different dimensions based on the Chirkin analysis framework: cost reduction potential; design integrity; SME applicability; and scalability. The Chirkin integrated methodology outperforms on all four dimensions, which is in line with an overall integration framework, rather than a stand-alone approach. On their own, modular construction and prefabricated systems score highly in cost reduction and scalability but only moderately on SME applicability, in line with the barriers described by Adekunle et al. (2023) [1] and Makabate et al. (2022) [17]. Value engineering scores highly on design integrity and SME applicability but only moderately on scalability.

The findings of the study on SME innovation practice identify a significant common factor: smaller contractors who adopted lean methodology or implement turnkey protocols (and integrated scheduling systems) tend to systematically outperform peers of similar sizes adopting ad hoc project management practices. This result is consistent with that of Avelar et al. (2020) [3] and Stehn and Jimenez (2024), indicating that organizational methodology is the key determinant of the quality of performance of SMEs in the affordable housing construction market [20].

Table 2

SME Innovation Practices Mapped to Chirkin Framework Pillars and Documented Outcomes

SME Practice	Chirkin Pillar Engaged	Documented Outcome
Lean workflow adoption	Lean Operational Logic	Reduced waste, faster cycle times
Prefab component integration	Scalable Modularity	Lower per-unit material costs
Turnkey renovation protocols	Turnkey Standardization	Consistent quality benchmarks
Coordinated scheduling & engineering	Engineering-Management Integration	Reduced rework and coordination cost

Source: Practices synthesized from Avelar et al. (2020), Vidalakis et al. (2020), Makabate et al. (2022), and Stehn & Jimenez (2024)

Table 2 shows the mapping of documented SME innovation practices to the main pillars of the Chirkin framework and their relevant outcomes. The mapping highlights that SME practices that target several pillars simultaneously - Coordinated Scheduling and Engineering which engages both engineering-management integration and lean operational logic - yield compounding efficiency gains that are higher than gained with single-pillar interventions. Noting this, this finding offers empirical evidence in favour of integration, rather than individual components, as the primary source of cost-reduction potential for the framework.

On the question of regional scalability, the results are more qualified. This literature alludes to the technical scalability of modular and prefabricated approaches across project sizes and building typologies but consistently points to regulatory non-recognition, supply chain fragmentation and lack of integrated management frameworks as bottlenecks to systemic adoption. The Chirkin methodology directly addresses the last of these constraints; the first two require complementary policy and industry-level interventions.

Discussion. The principle takeaway of this paper-- innovative construction techniques can achieve their full cost-reduction potential only if they are integrated into an operational framework--affects and is relevant for the construction industry, SMEs, policymakers, and researchers regarding the relation between innovation and affordability.

From an industry perspective, new methods in construction development have largely served as an additive rather than an integrative part of existing workflows: new techniques are adopted as supplements to existing workflows rather than as components of a redesigned operational architecture.

Zohourian et al. (2025) and Cao et al. (2025) both work in this regard in the modular construction industry, observing how organizations and companies needing to coordinate off-site fabrication to on-site assembly struggle with their own

management capacity with the new production logic even as they have yet to update their operational fabric [10; 23].

Consequently, the gap is ever widening between the measured efficiencies of modular construction at the project-level and the efficiencies of the real projects being constructed - a gap the engineering-management integration pillar of Chirkin methodology uniquely aims to bridge.

The value engineering literature provides a complementary diagnostic. Bae et al. (2023) [5] and Liu et al. (2020) prove that optimum results of design optimization emerge from the complete project scope process rather than to the isolated components [16].

This systemic application needs the level of the shared decision environment that a Chirkin methodology turnkey standardization pillar introduces—an aggregation of quality and cost metrics applicable to all the design choices, making sure that optimising at the piece level does not result in diseconomies at the system level.

Without this type of framework, value engineering risks devolving into a number of detached cost-cutting choices that compromise the structural or functional integrity of the completed unit, and ultimately, the very thing that Galster and Lee (2021) and Ezennia and Hoskara (2022) note as the systematic mode of failure of poorly run affordable housing projects (See Fig. 2) [11; 14].

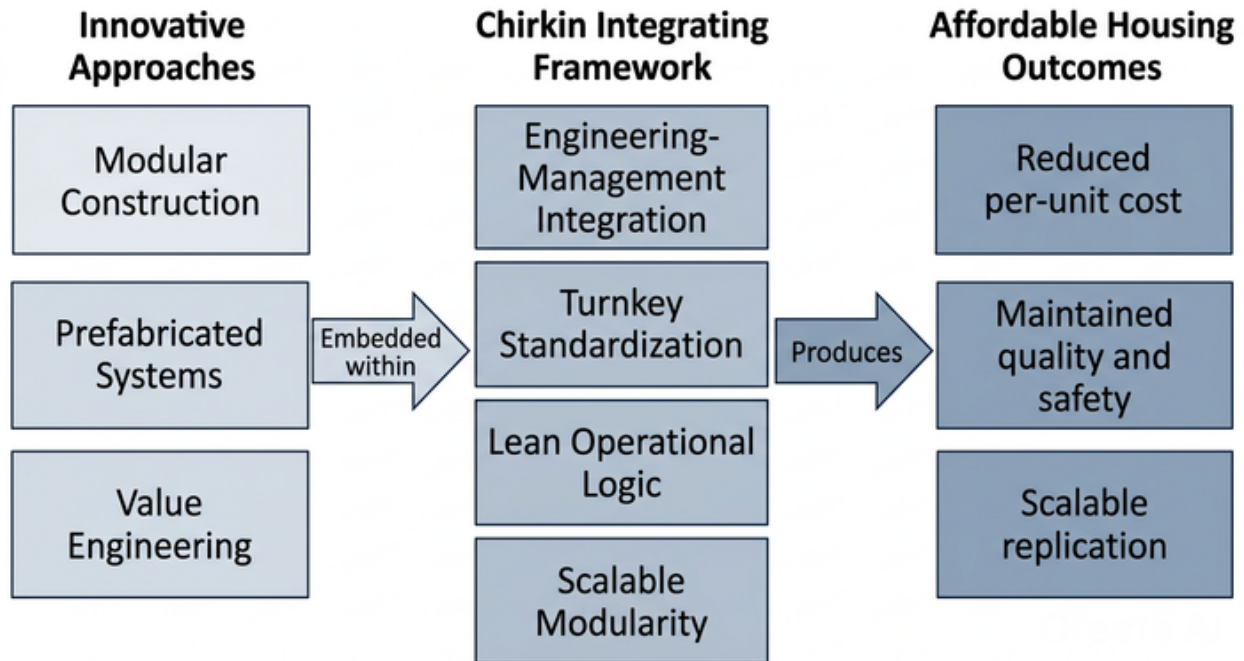


Fig. 2. The relationship between innovative construction approaches, the Chirkin integrating framework, and affordable housing outcomes

The SME section of the analysis should be the focus, being the aspect that is the most closely associated to the applications of the Chirkin methodology in practice.

The reviewed literature consistently places SMEs as the largest and least-resourced actors in the construction industry, in terms of resources for their own operation (infrastructure, capital) and capability to adopt technology, to develop and carry out the integrating frameworks that innovative construction models require. Adekunle et al. (2023) call this a barrier problem [1]; Vidalakis et al. (2020) [22] and Makabate et al. (2022) [17] classify it as a problem of the frame/a framework.

The Chirkin methodology addresses all of these framings concurrently: providing a predefined operational framework SMEs can adopt and fine-tune to their own project context will lower the organizational investment needed to exploit the efficiency gains provided by novel construction solutions.

The lean construction literature provides valuable lessons from their work. Avelar et al. (2020) show that SMEs implementing lean principles achieve comparable efficiency gains to larger firms by adoption of capital-intensive technology [3]. Stehn and Jimenez (2024) build on this by describing the additive character of these gains: in situations of systematic methodological consistency firms enhance performance over time via organizational learning, ultimately translating methodological consistency to a competitive advantage that replaces financial scale [20]. The lean operational logic pillar of the Chirkin methodology presents the specific mechanism by which these benefits of the method work, while the scalable modularity pillar ensures that - not only the innovation techniques associated with each methodology - the methodology has the potential for reproducibility across varied projects in size and complexity.

Scalability findings deserve careful interpretation. There is a clear distinction between two dimensions of scalability that is too often described within the literature and which are often conflated: technical scalability, the ability of an innovative approach to be broadly implemented for varying project sizes and typologies; and systemic scalability, the ability of a particular approach to be broadly embraced throughout the sector, to achieve supply-side effects on housing markets. The reviewed evidence provides evidence for the technical scalability of the approaches but begs the big question of systemic scalability under regulatory constraints, fragmented supply chains, and the organizational limitations of SMEs. Through its parametric design, the Chirkin methodology addresses the organizational layer of systemic scalability directly: as the core protocols of the framework are maintained in both project types and projects, but project-specific parameters are modified through a structured customization process, SMEs that have internalized the methodology will be able to implement it consistently across a portfolio of projects accumulating organizational learning and supply chain relationships that gradually

reduce the barriers to innovative construction adoption.

But on a policy and industry level, the regulatory and supply chain dimensions of systemic scalability require complementary interventions. Both Hilber and Schoni (2022) and Brooks (2022) pinpoint regulatory reform – specifically the update of building codes to include factory-built construction and the restructuring of approvals protocols to modular developments – as a required condition for the systemic adoption of innovative construction methods [9; 15]. Van Doorn et al. (2019) and Favilukis et al. (2023) argue the financial incentives and subsidy structures have to be shaped to encourage the methodological innovations to be rewarded rather than purely subsidy dependent methods rather than merely to support unit production, if the efficiency gains associated with novel methodologies are to translate into authentic affordability gains [12; 21]. Last and not least, the design quality and safety aspect of the design need special examination in the SME practice.

The fear that cost-reduction using innovative construction methods may result in a reduction in habitability or structural integrity is not only valid - it is documented in Galster and Lee (2021) and Ezennia and Hoskara (2022) where cost-driven construction decisions yield cheap units that also require costly maintenance, but also that do not keep in good habitability over time [11; 14]. This risk is dealt with directly within the turnkey standardization pillar of the Chirkin methodology that sets quality benchmarks as a mandatory constraint on all cost cutting decisions - a means of governance that secures that innovative constructions methods are integrated into a quality assurance framework, not imposed in arbitrary cost cutting.

Akinsulire et al. (2024) and Moorhead et al. (2023) respectively, demonstrate that this quality-constrained cost-optimization generates projects with higher long-term sustainability, making the case for standardization as a pillar of any serious affordable housing innovation initiative (See Fig. 3) [2; 18].

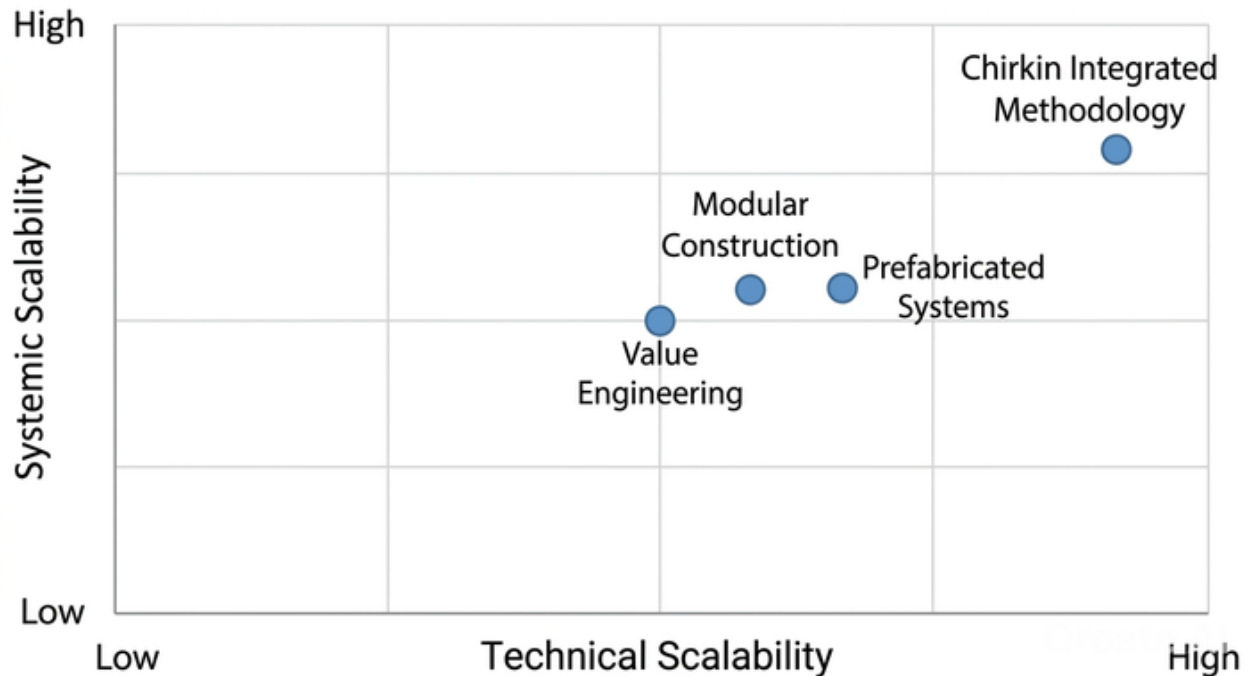


Fig. 3. Scalability dimensions of innovative construction approaches: technical versus systemic scalability, and the role of the Chirkin framework

Conclusions. This article has discussed new approaches to construction - modular construction, prefabricated systems, and value engineering - as avenues for reducing the cost of affordable housing, and contrasted with the four-pillar integrated engineering and management framework as defined by Chirkin.

The fundamental conclusion is that every creative approach yields significant cost savings at the project level, but their real value comes from being embedded in an integrating operational approach that integrates engineering and management decisions, preserves quality standards, uses lean operational logic and is scalable as a model for replication across the process.

The purpose of the Chirkin approach is to precisely fill this integrating role, enabling SMEs - the key actors in construction - to benefit from improvements in efficiency in new construction methods, such as using advanced building solutions without the capital investment or the firm's organizational scale that is typically seen

in their uptake.

Together, the lean construction and industrialized building literatures show that methodological consistency is an organizational capital that accumulates over time, allowing smaller contractors to build competitive advantages in the affordable housing sector at the end of a series of learning rather than a scale calculation.

The scalability of the innovative construction solutions in different regional spaces will largely depend on such complementary policy interventions - regulatory reform, new building codes, financial incentive architectures rewarding methodological innovation.

We recommend that for future research, the performance claims of the Chirkin framework be empirically validated through controlled projects, longitudinal evaluations of SME capability development and cross-regional comparative surveys of the regulatory and market context which acts as a mechanism for the scalability of these innovative construction approaches.

References

1. Adekunle, S., Aigbavboa, C., Ejohwomu, O., & Ogunbayo, B. (2023, July). Barriers to the adoption of emerging technologies for sustainable construction in SMEs. In 11th World Construction Symposium (pp. 21-22). <https://doi.org/10.31705/WCS.2023.90>
2. Akinsulire, A. A., Idemudia, C., Okwandu, A. C., & Iwuanyanwu, O. (2024). Strategic planning and investment analysis for affordable housing: Enhancing viability and growth. *Magna Scientia Advanced Research and Reviews*, 11(2), 119-131. <https://doi.org/10.30574/msarr.2024.11.2.0114>
3. Avelar, W., Meirino, M., & Tortorella, G. L. (2020). The practical relationship between continuous flow and lean construction in SMEs. *The TQM Journal*, 32(2), 362-380. <https://doi.org/10.1108/TQM-05-2019-0129>

4. Ayumu, M. T., & Ohakawa, T. C. (2024). Financial modeling innovations for affordable housing development in the US. *International Journal of Advanced Multidisciplinary Research and Studies*, 4(6), 1761-1766. <https://doi.org/10.62225/2583049X.2024.4.6.4107>
5. Bae, Y., Kim, D., & Horton, W. T. (2023). Development of building design optimization methodology: Residential building applications. *Buildings*, 14(1), 107. <https://doi.org/10.3390/buildings14010107>
6. Baum-Snow, N. (2023). Constraints on city and neighborhood growth: The central role of housing supply. *Journal of Economic Perspectives*, 37(2), 53-74. <https://doi.org/10.1257/jep.37.2.53>
7. Bedon, C., Stochino, F., & Stepinac, M. (Eds.). (2023). *Innovation in structural analysis and dynamics for constructions*. Mdpi AG. ISBN: 978-3036585703
8. Bertram, N., Fuchs, S., Mischke, J., Palter, R., Strube, G., & Woetzel, J. (2019). *Modular construction: From projects to products*. McKinsey & Company: Capital Projects & Infrastructure, 1(1), 1-34.
9. Brooks, M. M. (2022). The changing landscape of affordable housing in the rural and urban United States, 1990-2016. *Rural Sociology*, 87(2), 511-546. <https://doi.org/10.1111/ruso.12427>
10. Cao, Z., Li, P., Zhang, J., Wang, L., Ling, C., Liu, F., & Fan, J. (2025). *Modular building: Technical challenges and scaling opportunities in prefabricated housing*. In *Proceedings of the 2025 2nd International Conference on Civil Engineering Structures and Concrete Materials (CESCM 2025)* (p. 197). Springer Nature.
11. Ezennia, I. S., & Hoskara, S. O. (2022). Applications of housing affordability measurement approaches used in planning affordable housing: A systematic review. *Journal of Building Construction and Planning Research*, 10(1), 1-36.

<https://doi.org/10.4236/jbcpr.2022.101001>

12. Favilukis, J., Mabile, P., & Van Nieuwerburgh, S. (2023). Affordable housing and city welfare. *The Review of Economic Studies*, 90(1), 293-330. <https://doi.org/10.1093/restud/rdac024>
13. Fei, D. (2023). Research and analysis on technological innovation of prefabricated building construction. In *Advances in Urban Construction and Management Engineering* (pp. 447-452). CRC Press.
14. Galster, G., & Lee, K. O. (2021). Housing affordability: A framing, synthesis of research and policy, and future directions. *International Journal of Urban Sciences*, 25(sup1), 7-58. <https://doi.org/10.1080/12265934.2020.1713864>
15. Hilber, C., & Schoni, O. (2022). Housing policy and affordable housing. Centre for Economic Performance, London School of Economics and Political Science. <https://doi.org/10.1093/acrefore/9780190625979.013.829>
16. Liu, J., Wang, M., Peng, J., Chen, X., Cao, S., & Yang, H. (2020). Techno-economic design optimization of hybrid renewable energy applications for high-rise residential buildings. *Energy Conversion and Management*, 213, 112868. <https://doi.org/10.1016/j.enconman.2020.112868>
17. Makabate, C. T., Musonda, I., Okoro, C. S., & Chileshe, N. (2022). Scientometric analysis of BIM adoption by SMEs in the architecture, construction and engineering sector. *Engineering, Construction and Architectural Management*, 29(1), 179-203. <https://doi.org/10.1108/ECAM-02-2020-0139>
18. Moorhead, M., Armitage, L., & Skitmore, M. (2023). Feasibility practices of types of property developers. *Journal of Property Investment & Finance*, 41(1), 92-105. <https://doi.org/10.1108/JPIF-03-2022-0022>
19. Razkenari, M., Bing, Q., Fenner, A., Hakim, H., Costin, A., & Kibert, C. J. (2019, June). Industrialized construction: Emerging methods and

- technologies. In ASCE International Conference on Computing in Civil Engineering 2019 (pp. 352-359). American Society of Civil Engineers. <https://doi.org/10.1061/9780784482438.045>
20. Stehn, L., & Jimenez, A. (2024). Industrialized house building productivity growth. *Construction Innovation*, 24(7), 143-162. <https://doi.org/10.1108/CI-04-2022-0097>
21. Van Doorn, L., Arnold, A., & Rapoport, E. (2019). In the age of cities: The impact of urbanisation on house prices and affordability. In *Hot Property: The Housing Market in Major Cities* (pp. 3-13). Springer International Publishing. https://doi.org/10.1007/978-3-030-11674-3_1
22. Vidalakis, C., Abanda, F. H., & Oti, A. H. (2020). BIM adoption and implementation: Focusing on SMEs. *Construction Innovation*, 20(1), 128-147. <https://doi.org/10.1108/CI-09-2018-0076>
23. Zohourian, M., Pamidimukkala, A., Kermanshachi, S., & Almaskati, D. (2025). Modular construction: A comprehensive review. *Buildings*, 15(12), 2020. <https://doi.org/10.3390/buildings15122020>