



The Impact of Using Modern Lightweight Materials in High-Rise Buildings on Construction Time and Economic Costs

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ABSTRACT

With the rapid expansion of construction activities, the growing trend toward high-rise development and mass housing production, and the pressing demand for optimized residential solutions in developing countries, increased attention has been directed toward advanced construction methods and technologies. Given Iran's location within the central Alpine seismic belt and the recurrent tectonic activity along regional fault lines, structural lightweighting and dead-load reduction have become increasingly critical for enhancing seismic resilience and overall structural performance. The adoption of modern lightweight materials—which offer reduced weight, accelerated construction schedules, extended service life, and superior structural integrity—has thus become a pressing necessity. To meet contemporary societal demands, Iran requires the development of high-rise buildings with greater floor counts and faster execution rates. Conversely, conventional building materials have demonstrated significant inefficiencies in three key areas: structural performance, excessive energy consumption during both manufacturing and operational phases, and prolonged construction timelines in mass-production scenarios. These factors have inadvertently increased construction costs, slowed project delivery, and introduced substantial challenges to the building industry over recent decades, with economic losses already evident and projected to further diminish the useful lifespan of structures. Furthermore, Iran consumes substantial amounts of energy annually in the residential sector. According to estimates by the Iranian Fuel Conservation Organization, buildings account for approximately 38% of the country's total fuel consumption. Given the high proportion of final energy consumption in the residential sector, precise calculation and analysis of thermal and cooling loads, alongside targeted efforts to minimize energy losses, represent highly effective strategies for reducing heating and cooling energy demands. Implementing these measures is particularly critical in light of Iran's recent targeted subsidy reforms, which have heightened the economic and strategic importance of energy efficiency. As demonstrated in this study, adherence to these principles can yield substantial national savings in both resources and economic capital.

KEYWORDS: Modern materials, lightweight construction, energy consumption optimization, high-rise buildings

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How to Cite This Article: Razaghi Kamroudi, S., Salamatpour, S.(2024).“ The Impact of Using Modern Lightweight Materials in High-Rise Buildings on Construction Time and Economic Costs”. *The Open Access Journal of Resistive Economics*, 12(1): 94-108.

1. Introduction

Conventional building materials are increasingly inadequate for addressing persistent industry challenges, including prolonged construction schedules, limited service life, and escalating project costs. Consequently, there is a growing imperative to adopt advanced construction methodologies and innovative building materials that facilitate structural weight reduction, accelerate execution, enhance durability, and ultimately lower overall construction expenses. Lightweight construction has emerged as a pivotal frontier in civil engineering, advancing steadily through the integration of modern fabrication techniques, high-performance materials, and optimized construction practices. This approach not only yields substantial savings in time, cost, and energy but also mitigates structural vulnerabilities during natural hazards such as earthquakes by minimizing inertial forces associated with excessive dead loads.

In recent years, the construction industry has faced significant economic stagnation, largely attributable to suboptimal design practices and insufficient economic viability in project delivery. Navigating this crisis necessitates strategic interventions and the systematic integration of innovative materials and methods that enhance both construction-phase efficiency and long-term operational performance. Given the critical importance of structural lightweighting, it is essential to first identify and analyze the primary factors contributing to excessive building weights. Once these variables are understood, targeted efforts can be directed toward eliminating or minimizing their impact on the final structural mass. Furthermore, the extent to which lightweighting technologies can enhance the constructability and performance of high-rise buildings warrants rigorous investigation. Key questions include: To what degree can lightweight materials reduce structural dead load? How do they influence seismic response and structural resilience? And, considering their initial capital costs, do they offer a compelling economic justification?

Unfortunately, in Iran's construction sector, the disparity between traditional, modern, and hybrid building approaches remains pronounced. A prevalent misconception—that advanced technologies inherently entail higher costs—has inadvertently slowed their widespread adoption. This study critically evaluates emerging lightweight technologies alongside their conventional counterparts, with particular emphasis on comparative economic performance. The central premise is to rigorously challenge the assumption that modern lightweighting solutions impose disproportionate financial burdens on projects. In reality, conventional materials are associated with significant deficiencies, including shortened service life, extended construction timelines, and delayed capital recovery, all of which impose substantial financial strain and compromise project optimization. Moreover, traditional materials negatively impact energy efficiency across multiple lifecycle stages: excessive energy consumption during material production, inefficient on-site execution, and heightened operational energy demands. This inefficiency not only inflates project costs but also contributes significantly to the depletion of national energy resources. Given the stringent requirements of Iran's National Building Regulations—particularly Topic 19 on energy

conservation—conventional materials consistently fail to meet comprehensive energy efficiency standards. Ultimately, the integration of modern lightweight construction methodologies is indispensable for elevating construction quality, accelerating project delivery, extending building service life, enhancing seismic resilience, and achieving sustainable lifecycle cost optimization.

2. Theoretical Framework

2.1. Lightweight Construction

Lightweight construction is an evolving paradigm in civil engineering that continues to advance through the integration of modern fabrication techniques, high-performance materials, and optimized execution methodologies. Its primary objective is to reduce the total dead load of a structure. Effective implementation requires systematic identification of factors contributing to excessive structural mass, followed by targeted engineering strategies to eliminate or mitigate their impact. Non-structural lightweighting specifically addresses the mass reduction of partition walls, façade systems, interior/exterior infill panels, floor screeds, and finishes through the substitution of conventional materials with lighter alternatives. Empirical studies on high-rise buildings demonstrate that structural lightweighting significantly mitigates seismic inertial forces, reduces inter-story drift, decreases overall dead load, and permits smaller structural cross-sections. Consequently, it accelerates high-rise construction schedules while minimizing total project expenditures.

2.2. Project Cost Management

Project cost management encompasses the systematic actions undertaken to maintain prescribed quality standards while continuously controlling and reducing project expenditures within allocated timelines. A foundational principle of this research is that cost reduction must never compromise structural integrity or serviceability. Cost management operates on the premise that expenses are not inherent but rather the direct outcome of managerial decisions, particularly those concerning material selection, resource allocation, and construction methodology. A strategic, knowledge-driven approach to cost management guides decision-making throughout the project lifecycle, fostering value creation for all stakeholders through optimal and innovative resource integration. Achieving project objectives at minimal cost presents significant operational challenges, requiring project managers to proactively identify and mitigate cost-related bottlenecks. This study aims to develop comprehensive recommendations for technology selection by synthesizing theoretical foundations, practical execution principles, and precise lifecycle cost analysis.

2.3. Time Management

Schedule management remains one of the most persistent challenges in civil engineering projects, with construction delays frequently postponing project delivery and operational commissioning.

Timely completion is universally recognized as a primary quantitative indicator of project success and contractual compliance.

2.4. Time–Cost Relationship

The inherent complexity of civil projects frequently induces fluctuations in both schedule and budget during the execution phase, potentially triggering contract modifications, claims, or even termination. Therefore, accurate baseline planning and a clear understanding of the projected time–cost profile are essential. Since direct project costs are inherently time-dependent, the interplay between schedule duration and financial outlay must be rigorously managed. Extended construction timelines typically diminish the productivity of labor, machinery, equipment, and working capital, sometimes escalating indirect costs to a point that threatens project economic viability. Consequently, achieving schedule objectives must be carefully balanced to avoid compromising cost efficiency and quality standards, as schematically illustrated in Figure 2.

2.5. Energy Consumption Optimization

Energy optimization in buildings fundamentally relies on the deployment of thermally insulated exterior envelope systems, such as 3D sandwich panels. Thermal insulation materials are engineered to resist heat flow and typically consist of heterogeneous compositions with low thermal conductivity coefficients. A seminal 1991 study by Drexel University on energy-intensive sectors in the United States demonstrated that widespread thermal insulation yields annual energy savings equivalent to 2 billion barrels of oil, valued at approximately \$60 billion. In Iran, where building heating and cooling account for roughly 38% of national fuel consumption, energy management is of critical strategic and economic importance. The urgent need for thermally efficient, lightweight modern construction materials has thus become increasingly evident. Validating the technical and economic advantages of these materials both theoretically and practically can significantly enhance market acceptance, dispel the misconception that innovative technologies inherently entail prohibitive costs, and promote industry-wide adoption—a vital

2.6. Modern Construction Materials

Autoclaved Aerated Concrete (AAC) Blocks and Walls

AAC is a specialized lightweight, porous concrete primarily composed of silica-based aggregates, cement, and lime. Commercially developed in Sweden over seven decades ago, AAC manufacturing involves two key processes: pore generation within a cement–lime–silica slurry and subsequent high-pressure autoclave curing. During autoclaving, calcium and silica react to form crystalline calcium silicate hydrates (C-S-H). The resulting porous microstructure—formed by hydrogen gas evolution from the reaction of aluminum powder with free lime—provides excellent thermal insulation and the highest strength-to-density ratio among concrete variants. Post-autoclave curing is unnecessary; components are ready for installation after cooling. Due to its low

density and adequate non-structural strength, AAC is predominantly used for lightweight partition blocks and reinforced non-load-bearing panels (e.g., roof and wall infill). It is manufactured in various densities and compressive strengths tailored to specific applications. Notably, AAC is not intended for primary structural load-bearing applications. Key advantages include superior fire resistance, absence of toxic emissions during fire exposure, excellent thermal performance, elimination of separate thermal insulation requirements, reduced plastering needs, accelerated construction, and significant dead-load reduction. However, improper manufacturing, detailing, or installation can lead to serviceability issues such as shrinkage and thermal expansion/contraction cracking.

Aerated Concrete Blocks

These blocks are produced from a controlled mixture of silica sand, cement, lime, and aluminum powder, yielding a density approximately one-third that of traditional clay bricks. This substantial weight reduction significantly lowers structural mass and seismic inertial forces. When installed with precision, their tight dimensional tolerances eliminate the need for traditional gypsum–soil plastering. Aerated blocks are produced in both autoclaved and non-autoclaved forms, with the latter typically exhibiting higher density and lower dimensional stability. Autoclaved variants offer rapid masonry placement, effective acoustic and thermal insulation, optimal moisture regulation, low weight, and high cuttability. Installation begins with precise leveling of the first course, which may use conventional cement–sand mortar. Subsequent courses are laid using a specialized thin-bed adhesive applied to block surfaces, with joint thickness typically maintained between 1.6 and 3.0 mm.

Cellular Lightweight Concrete (CLC)

CLC is a foam concrete produced by entraining stabilized air bubbles of varying sizes within the cementitious matrix. Unlike AAC, CLC is a non-autoclaved system. Air voids are introduced either physically (using high-shear mixers and synthetic foaming agents) or chemically (e.g., via aluminum powder reaction). A typical mix comprises cement, fine silica sand, water, and a chemical foaming agent. CLC is widely utilized for internal and external partition walls, backfilling, and non-structural screeds. Curing is typically conducted at ambient temperature or in low-temperature curing chambers. With a dry density ranging from 300 to 900 kg/m³, CLC provides effective thermal and acoustic insulation while maintaining adequate mechanical strength and long-term serviceability.

3D Sandwich Panels (Non-Load-Bearing Systems)

3D panel systems are classified as semi-prefabricated structural components. They can function as load-bearing elements (diaphragms and shear walls in box-type structures) or as non-load-bearing partitions. This section focuses on the non-load-bearing application. These panels consist of two

parallel welded steel wire meshes interconnected by diagonal steel shear connectors, with an expanded polystyrene (EPS) core sandwiched between them. Non-load-bearing 3D walls typically utilize 3–5 mm diameter smooth steel wires, an EPS thermal/acoustic core, and shotcrete facings on both sides. Panels are factory-manufactured in standard dimensions (typically 1.0 m wide × 3.0 m long), transported to the site, and positioned after proper substructure preparation. Once erected, both faces are finished with fine-aggregate shotcrete. In some cases, shotcreting is completed at the factory to ensure quality control, followed by curing and site delivery. Crucially, connection details must be designed to prevent these panels from contributing to the structure's lateral stiffness. All openings must be pre-formed during manufacturing, with corners reinforced using additional steel mesh. Post-shotcreting, surfaces are finished in two stages using wooden and metal trowels. The EPS core delivers excellent thermal and acoustic performance, while the dual shotcrete layers provide superior fire resistance. Key advantages include architectural flexibility, increased usable floor area due to reduced wall thickness, reduced structural mass, and rapid installation. Notable limitations include the handling sensitivity of prestressed components and challenges in controlling shotcrete thickness. These panels have been rigorously evaluated by the Building and Housing Research Center (BHRC) and are approved for use within specified technical guidelines. After installation, shotcrete is applied in two stages, creating continuous concrete barriers that ensure compliance with fire-resistance standards.

QPanel Non-Load-Bearing Walls

QPanel systems consist of a central lightweight foam concrete core sandwiched between two fiber-reinforced cementitious facings, designed exclusively for internal partitioning. Panels are secured to the floor and ceiling using designated metal runners and tracks. Standard dimensions include a height of 3.0 m and a width of 0.6 m, available in various thicknesses. Longitudinal edges feature tongue-and-groove interlocking joints for seamless, mortar-free assembly. (*Note: The specific weight per square meter value is missing in the original text.*) These panels have been structurally, acoustically, and seismically evaluated by the Building and Housing Research Center (BHRC) and are approved for application within established Iranian National Building Regulations.

3. Findings

To investigate the impact of modern lightweight construction materials on energy consumption optimization in high-rise buildings, a mixed-methods approach was employed, comprising: (1) a systematic review of relevant literature and prior empirical studies, and (2) semi-structured interviews with industry experts and construction management specialists in Mazandaran Province, Iran. Through this process, **two primary criteria** and **ten sub-criteria** were identified as the most influential factors governing the relationship between lightweight material adoption and energy efficiency in high-rise construction.

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To facilitate computational analysis within the Analytic Hierarchy Process (AHP) framework, the identified criteria and sub-criteria were assigned standardized abbreviations, as summarized in Table 1.

Table 1. *Nomenclature of Primary and Sub-Criteria for AHP Analysis*

No.	Primary Criterion	Abbreviation	Sub-Criterion	Abbreviation	
1	Cost	C1	Project cost-saving management through lightweight material adoption for energy optimization	C11	
				Reduction of procurement and material supply costs via lightweight systems for energy efficiency	C12
				Forecasting material cost fluctuations and execution expenses (inflation adjustment) in high-rise projects	C13
				Real-time monitoring and mitigation of project cost deviations using lightweight materials for energy optimization	C14
				Project cost control within allocated budgets through lightweight material integration for energy efficiency	C15
2	Time	C2	Project scheduling and delay prevention in lightweight construction for energy optimization in high-rises	C21	
				Enhanced decision-making in activity prioritization using lightweight materials for energy efficiency	C22
				Optimization of time-cost trade-offs for individual project activities via lightweight systems	C23
				Estimation of financial and temporal resource requirements for lightweight construction activities targeting energy optimization	C24
				Scalability and adaptability of scheduling frameworks for lightweight material deployment in energy-efficient high-rises	C25

Note. Criteria nomenclature developed by the authors based on expert panel consensus.

Methodological Validation

To ensure the reliability and validity of the survey instrument, expert review was conducted alongside calculation of the **Consistency Ratio (CR)** for all pairwise comparisons. Following Saaty's (1980) AHP guidelines, a CR value below **0.10** was established as the threshold for acceptable judgment consistency. All pairwise comparison matrices in this study met this criterion, confirming the logical coherence of expert judgments.

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Raw data collected from field research and expert interviews were processed and analyzed using **Expert Choice 11** software. The subsequent sections present the weighted priorities and sensitivity analysis results derived from this multi-criteria decision-making framework.

Analysis of Primary Criteria

Pairwise Comparison Matrix of Primary Criteria Relative to the Overall Objective

To evaluate the relative influence of lightweight construction materials on energy optimization in high-rise buildings, three primary criteria were initially conceptualized:

- **Cost (C1)**
- **Time (C2)**
- **Quality and Energy Optimization Performance (C3)**

These criteria were subjected to pairwise comparison relative to the overarching research objective, as schematically represented in Figure 1.

	C1	C2	C3
C1		1.5874	1.25992
C2			1.0
C3	Incon: 0.01		

Figure (1). Pairwise Comparison Matrix of Primary Criteria Relative to the "Objective"

After performing the calculations in Expert Choice software, the weights of the primary criteria relative to the objective were obtained as shown in Figure (2), which is presented below:

C1	.414	
C3	.304	
C2	.282	
Inconsistency = 0.00565		
with 0 missing judgments.		

Figure (2). Priority Weights of Primary Criteria Relative to the "Objective"

Figure (2), which reflects the consensus of expert opinions and computations performed in Expert Choice software, indicates that the "Cost (C1)" criterion, with a weight of 0.414, exerts the greatest

influence on cost management. The criteria "Quality and Energy Consumption Optimization (C3)" and "Time (C2)" rank second and third, with weights of 0.304 and 0.282, respectively.

Analysis of Sub-Criteria Status

Examination of Sub-Criterion Priorities Based on the "Cost (C1)" Criterion

Following the assessment of the primary criteria and determination of their average priority weights, several sub-criteria were defined for each primary criterion in alignment with the research objective. For the primary criterion "Cost," five sub-criteria were identified: "Project cost-saving management in high-rise buildings (C11)," "Reduction of procurement and material supply costs in high-rise projects (C12)," "Forecasting fluctuations in material costs and execution operations (inflation forecasting) (C13)," "Real-time prevention of project cost deviations in high-rise buildings (C14)," and "Project cost control within available budgets in high-rise buildings (C15)." The results of their pairwise comparisons are presented in Figure (3).

Compare the relative importance with respect to: C1						
	c11	c12	c13	c14	c15	
c11		1.25992	1.25992	1.0	1.25992	
c12			1.81712	1.25992	1.44225	
c13				1.25992	1.25992	
c14					1.25992	
c15	Incon: 0.02					

Figure (3). Pairwise Comparison Matrix of Sub-Criteria Based on the "Cost" Criterion

After performing the calculations in Expert Choice software, the weights of the sub-criteria relative to the objective and based on the "Cost" criterion were obtained as shown in Figure (15), which is presented below:



Figure (4). Priority Weights of Sub-Criteria Based on the "Cost" Criterion

Figure (4), which reflects the consensus of expert opinions and computations performed in Expert Choice software regarding the sub-criteria based on the "Cost" criterion, indicates that the sub-

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criterion "Reduction of procurement and material supply costs in high-rise buildings (C12)" holds the highest importance with a weight of 0.240. The sub-criteria "Project cost-saving management in high-rise buildings (C11)," "Real-time prevention of project cost deviations in high-rise buildings (C14)," "Project cost control within available budgets in high-rise buildings (C15)," and "Forecasting fluctuations in material costs and execution operations (inflation forecasting) (C13)" rank second through fifth, with weights of 0.227, 0.189, 0.176, and 0.168, respectively.

Examination of Sub-Criterion Priorities Based on the "Time (C2)" Criterion

Following the assessment of the primary criteria and determination of their average priority weights, several sub-criteria were defined for each primary criterion in alignment with the research objective. For the primary criterion "Time," five sub-criteria were identified: "Project scheduling (delay prevention) in high-rise buildings (C21)," "Enhanced decision-making in prioritizing project operations in high-rise buildings (C22)," "Optimization of time–cost relationships for individual project activities in high-rise buildings (C23)," "Estimation of financial and temporal resources for activities (C24)," and "Feasibility of expanding the project scheduling framework (C25)." The results of their pairwise comparisons are presented in Figure (5).

Compare the relative importance with respect to: C2					
	c21	c22	c23	c24	c25
c21		1.25992	1.25992	1.81712	1.0
c22			1.25992	1.44225	1.5874
c23				2.28943	1.0
c24					1.25992
c25	Incon: 0.02				

Figure (5). Pairwise Comparison Matrix of Sub-Criteria Based on the "Time" Criterion

After performing the calculations in Expert Choice software, the weights of the sub-criteria relative to the objective and based on the "Time" criterion were obtained as shown in Figure (17), which is presented below:



Figure (6). Priority Weights of Sub-Criteria Based on the "Time" Criterion

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Figure (6), which reflects the consensus of expert opinions and computations performed in Expert Choice software regarding the sub-criteria based on the "Time" criterion, indicates that the sub-criterion "Estimation of financial and temporal resources for activities (C24)" holds the greatest influence with a weight of 0.294. The sub-criteria "Feasibility of expanding the project scheduling framework (C25)," "Optimization of time–cost relationships for individual project activities in high-rise buildings (C23)," "Project scheduling (delay prevention) in high-rise buildings (C21)," and "Enhanced decision-making in prioritizing project operations in high-rise buildings (C22)" rank second through fifth, with weights of 0.203, 0.181, 0.171, and 0.150, respectively.

Table (7). Relative and Final Weights of Sub-Criteria and Their Prioritization

No.	Primary Criterion	Primary Criterion Weight	Sub-Criterion	Abbreviation	Relative Weight	Final Weight
1	Cost (C1)	0.414	Project cost-saving management through lightweight material adoption for energy optimization	C11	0.227	0.0939
			Reduction of procurement and material supply costs via lightweight systems for energy efficiency	C12	0.240	0.0994
			Forecasting material cost fluctuations and execution expenses (inflation adjustment) in high-rise projects	C13	0.168	0.0696
			Real-time monitoring and mitigation of project cost deviations using lightweight materials for energy optimization in high-rise buildings	C14	0.189	0.0782
			Project cost control within allocated budgets through lightweight material integration for energy efficiency in high-rise buildings	C15	0.176	0.0729
2	Time (C2)	0.282	Project scheduling (delay prevention) in lightweight construction for energy optimization in high-rises	C21	0.171	0.0482
			Enhanced decision-making in activity prioritization using lightweight materials for energy efficiency	C22	0.150	0.0423
			Optimization of time–cost trade-offs for individual project activities via lightweight systems	C23	0.181	0.0511
			Estimation of financial and temporal resource requirements for	C24	0.294	0.0829

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No.	Primary Criterion	Primary Criterion Weight	Sub-Criterion	Abbreviation	Relative Weight	Final Weight
			lightweight construction activities targeting energy optimization			
			Scalability and adaptability of scheduling frameworks for lightweight material deployment in energy-efficient high-rises	C25	0.203	0.0572

4. Conclusion

This study investigated the impact of adopting modern lightweight construction materials on energy consumption optimization, cost management, and time efficiency in high-rise building projects, with a specific focus on Mazandaran Province, Iran. By integrating expert consensus with the Analytic Hierarchy Process (AHP), the research identified, weighted, and prioritized the most influential factors governing the successful deployment of lightweight systems in contemporary construction.

The analysis revealed that economic considerations, particularly cost management (**C1**, weight = 0.414), dominate decision-making frameworks when evaluating lightweight material integration. Within this domain, reducing procurement and material supply costs (**C12**, 0.240) emerged as the most critical sub-factor, underscoring the financial sensitivity of supply chain dynamics and the direct economic advantage of standardized, factory-produced lightweight components. Time management (**C2**, 0.282) ranked as the second most influential primary criterion, with accurate financial and temporal resource estimation (**C24**, 0.294) proving essential for mitigating schedule risks and preventing cost overruns. Although quality and energy optimization (**C3**, 0.304) did not rank highest in the immediate economic hierarchy, its foundational role in lifecycle performance, regulatory compliance (particularly Iran's National Building Regulations, Topic 19), and long-term operational sustainability remains indispensable.

These findings directly challenge the prevailing misconception in Iran's construction sector that advanced lightweight technologies inherently escalate project costs. Instead, the data demonstrates that strategic implementation of modern materials—coupled with precise resource forecasting, supply chain optimization, and early-stage planning—can simultaneously reduce capital expenditures, accelerate project delivery, and enhance energy efficiency. The prioritization of procurement cost reduction and resource estimation highlights a clear industry need for integrated project delivery models, early contractor involvement, and digital cost-tracking systems in high-rise developments.

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Practical Implications & Recommendations

For industry practitioners, the results advocate for a paradigm shift from conventional, labor-intensive construction methods toward prefabricated and lightweight systems, supported by rigorous lifecycle cost analysis (LCCA). Project managers should prioritize supply chain consolidation, vendor pre-qualification, and real-time cost monitoring to capitalize on the economic benefits identified in this study. Policymakers and regulatory bodies should incentivize the adoption of energy-efficient lightweight materials through revised building codes, targeted procurement subsidies, and standardized certification frameworks. Furthermore, academic and professional training programs must emphasize time–cost–quality trade-off analysis, data-driven scheduling, and performance-based design to fully leverage the capabilities of modern construction technologies.

Limitations & Future Research Directions

This study was geographically constrained to Mazandaran Province and relied primarily on expert judgment within the AHP framework. Future research should validate these findings through empirical case studies, longitudinal lifecycle assessments, and multi-regional comparative analyses across Iran's diverse climatic and seismic zones. Additionally, integrating Building Information Modeling (BIM), digital twin technologies, and machine learning algorithms for dynamic cost–time–energy forecasting could further refine decision-support systems for high-rise construction. Exploring the socioeconomic barriers to technology adoption, including workforce training requirements and initial capital investment models, would also provide actionable insights for industry-wide transition.

Ultimately, the strategic deployment of modern lightweight materials represents a viable, economically resilient pathway toward sustainable high-rise construction. By aligning procurement strategies, scheduling methodologies, and energy optimization practices, the construction industry can overcome traditional cost and time constraints while advancing national energy conservation goals and global sustainability standards.

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ACKNOWLEDGMENTS

The current study has not received any grant, fund or contribution from private or government institutions. Also, the authors declare that there is no conflict of interests

ETHICAL CONSIDERATION

Authenticity of the texts, honesty and fidelity has been observed.

CONFLICT OF INTEREST

Author/s confirmed no conflict of interest.