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Cost Reduction Strategies in Residential Construction Through Supply Chain Optimization and Workforce Management

Gocha Kalandadze

Georgia.

Abstract

The article explores cost reduction strategies in residential construction through the joint analysis of supply chain optimization and workforce management. It addresses procurement planning, supplier coordination, logistics capacity, material-flow control, workforce productivity, decentralized site execution, and centralized quality oversight as connected cost-control mechanisms for affordable housing delivery. The article used an integrative review of studies on construction cost overruns, prefabricated and modular supply chains, construction logistics, material management, affordable housing barriers, and additive manufacturing in architecture. The main results are that residential construction costs can be reduced when project organizations improve early cost-risk diagnosis, coordinate suppliers, calibrate transport and inventory decisions, prevent material shortages, reduce rework, and align workforce incentives with both productivity and quality. The synthesis also shows that modular, prefabricated, digital, and additive methods support cost reduction only when managers account for logistics constraints, supplier maturity, training needs, regulatory conditions, and quality control. The article will be useful to researchers, residential developers, project managers, procurement specialists, site managers, and policymakers interested in cost-efficient residential construction and affordable housing delivery without lowering durability or design standards.

Keywords: *Residential Construction; Cost Reduction; Supply Chain Optimization; Workforce Management; Affordable Housing.*

INTRODUCTION

Residential projects lose finances when materials arrive late, supplier prices move after budgeting, storage conditions damage inputs, or crews wait for information and corrected drawings. Design changes, weak procurement timing, poor delivery planning, and rework also turn construction delays into higher housing costs. These losses matter in affordable housing because every avoidable delay, defect, and idle labor hour reduces the room for cost-efficient delivery without lowering durability or design standards.

Recent studies on construction cost overruns, logistics, modular construction, material management, supply-chain resilience, and affordable housing often examine these issues in separate streams. Cost-overrun research highlights risk prediction and management discipline. Logistics and procurement studies examine supplier reliability, transport capacity, inventory buffers, and backup sourcing. Workforce and modular construction studies show how skill gaps, site congestion, and assembly planning affect productivity. This article synthesizes those streams to explain how supply chain optimization and workforce management can work together in residential construction. The article is also informed by the author's practical industry observation in the Georgian residential construction context, where cost-efficient housing delivery often depends on supplier relationships, material-price control, workforce discipline, and direct quality oversight. Georgia and the wider South Caucasus remain underrepresented in international construction management research, which makes the integration of global literature with cautious regional observation useful for future empirical work.

The hypothesis is that coordinated procurement, logistics, material control, workforce planning, and quality oversight reduce cost growth by cutting delays, idle time, waste, and rework. The article contributes a residential cost-control framework that connects cost-overrun risk, supply-chain resilience, material flow, workforce productivity, and affordable housing delivery.

METHODS AND MATERIALS

The article reviews thirteen peer-reviewed studies selected for their relevance to construction cost, supply-chain

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resilience, logistics, material management, modular and prefabricated construction, affordable housing, and additive manufacturing. Each study links at least one operational decision to cost, delay, risk, productivity, quality, or affordability. The review compares how these studies define cost drivers, model uncertainty, and evaluate tradeoffs among procurement cost, logistics reliability, material availability, labor productivity, and housing affordability.

The selected sources use several methodological approaches. Cost-risk and overrun prediction are represented by fuzzy inference modeling in Al-Nahhas et al. [1]. Logistics and material-flow analysis are represented by multi-agent simulation and sustainability assessment in Attajer and Mecheri and Brusselaers et al. [2], [3]. Procurement resilience and disruption response are examined through robust optimization, structural equation modeling, non-dominated sorting genetic algorithms, and Stackelberg game modeling in Chen et al., Cheng et al., Wang et al., and Yu and Sun [5], [6], [10], [13]. Housing affordability and modular construction barriers are covered through simulation-based cost comparison, systematic review, Pareto analysis, interpretive structural modeling, text mining, and clustering in Brysch et al., Khan et al., and Reid [4], [7], [9]. Additive manufacturing supply chains are addressed through PRISMA-guided review, NVivo coding, grounded-theory coding, and intuitionistic fuzzy analytic hierarchy process evaluation in Ma et al. and Xie et al. [8], [11]. Material management and project performance are examined through site surveys and regression analysis in Yildiz et al. [12].

The review procedure had four steps. The first step identified cost-related mechanisms in each study, including supplier delay, inventory exposure, transport capacity, material handling, rework, skill shortages, and quality-control constraints. The second step classified these mechanisms into supply-chain, logistics, workforce, quality, and affordability categories. The third step compared where the studies agreed or diverged on cost-resilience tradeoffs, industrialized construction, and workforce capability. The fourth step synthesized those findings into a residential cost-reduction framework focused on the connection between supply-chain decisions and workforce outcomes. The author's earlier work with construction-related materials, including metallic-plastic windows and doors, also provides practical background for understanding supplier dynamics, procurement timing, and material cost exposure in residential development. Add

RESULTS AND DISCUSSION

Residential projects lose cost control before site work begins when teams underestimate risk, approve inefficient layouts, or start procurement without enough price and delivery visibility. Al-Nahhas et al. show that cost overrun can be anticipated through structured factor-based prediction that combines expert weighting, risk factors, and project-specific probabilities [1]. Brysch et al. show that design configuration changes affordability through cost per unit and space efficiency [4]. Reid's barrier mapping links affordable housing problems to project management, technical knowledge, and inefficient design-and-construction processes [9]. These studies place early cost-risk visibility, design discipline, and barrier diagnosis at the start of residential cost control. Figure 1 visualizes the article's core synthesis that residential construction cost reduction should be understood as a staged process of uncertainty control rather than simple price cutting.

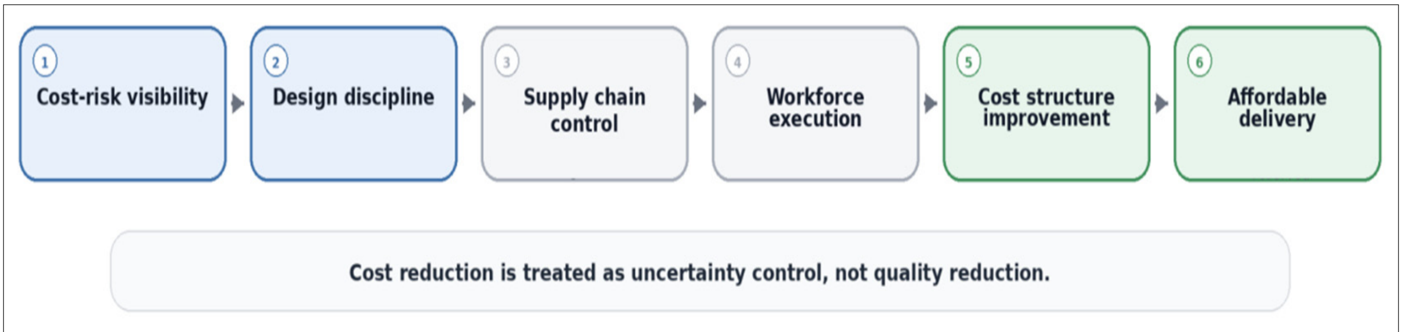

Figure 1. Integrated Pathway from Cost-Risk Visibility to Affordable Residential Delivery (the author's illustration)

Figure 1 presents the pathway from cost-risk visibility to affordable delivery. The sequence links design discipline, supply-chain control, and workforce execution to fewer delays, lower hidden costs, reduced idle time, and less rework. Quality control remains part of the pathway because cost reduction in residential construction has to protect durability and design standards.

Supply-chain cost control depends on lean flow and resilience. Chen et al. show that backup sourcing, backordering, and inventory decisions create different cost effects under supplier-capacity and demand uncertainty [5]. Backup sourcing can protect project continuity, but higher material prices and transport costs can make it expensive. Inventory buffers can absorb demand volatility, while carrying and storage costs limit their use [5]. Wang et al. show that the best recovery strategy changes with disruption severity: mild disruption can be managed through redundancy, moderate disruption requires inventory and backup supply, and severe disruption increases the value of backup suppliers [10].

Logistics and information flow shape hidden cost. Cheng et al. link prefabricated supply-chain delays to manufacturing risk, on-site risk, information gaps, and organizational response capacity [6]. Attajer and Mecheri show that transport capacity has to be calibrated to project demand because too little capacity creates delay penalties and too much capacity adds fixed cost [2]. Yu and Sun show that platform coordination and cooperative decision-making can improve supply-chain performance where participants otherwise make fragmented decisions [13]. Residential projects reduce avoidable cost when procurement teams, suppliers, logistics planners, and site managers share reliable information before shortages reach the site [2], [5], [6], [10], [13]. Table 1 organizes the article's supply-chain resilience argument by showing that different disruption conditions require different procurement and logistics responses.

Table 1. Supply Chain Resilience Strategies by Disruption Severity

Disruption condition	Preferred strategy	Main cost benefit	Main cost risk
Normal or low disruption	Lean procurement, supplier coordination, transport optimization, digital visibility	Avoids excess inventory and unnecessary fixed logistics cost	Fragile if supplier or transport disruption occurs
Mild disruption	Limited redundant inventory, short-term buffering, improved information sharing	Prevents small shortages from stopping work	Holding cost and storage exposure
Moderate disruption	Combined inventory buffer and backup supplier access	Balances continuity and flexibility	Higher procurement cost and coordination burden
Severe disruption	Backup supplier strategy, flexible transport, contingency procurement	Protects schedule continuity under major supply loss	Backup suppliers may carry higher unit prices and startup costs
System-wide fragmentation	Platform coordination and cooperative decision-making	Improves total system performance and transparency	Implementation cost and need for participant cooperation

Table 1 shows that resilience is a cost-sensitive matching process. Low disruption favors lean procurement and transport optimization. Higher disruption pushes managers toward buffers, backup suppliers, and contingency procurement. These tools reduce stoppage risk, but they also add holding costs, storage exposure, higher supplier prices, or coordination burden.

Labor cost depends on how crews use time, materials, and site space. Yildiz et al. show that material supply, handling, and stock-and-waste control affect project performance [12]. Poor storage and material shortages create extra movement, waiting, fatigue, and idle time. Reid links modern construction methods to shorter duration and fewer on-site contractors, while also showing that inadequate training and weak technical understanding limit those gains [9]. Attajer and Mecheri connect advanced prefabrication with lower on-site labor demand [2]. Khan et al. identify skilled labor shortages, limited technical expertise, quality-control problems, logistics difficulty, and weak industry collaboration as barriers to modular construction in affordable housing [7].

Workforce management reduces residential cost when it targets the losses that crews experience on site. Trained crews make fewer installation errors. Correct material staging reduces walking and searching time. Assembly planning prevents paid labor from waiting for components, drawings, or instructions. Quality checks reduce rework before defects spread across repeated units. These workforce gains depend on the supply chain because crews can only work productively when materials, information, and site access arrive in the right sequence [2], [7], [9], [12].

Digital and additive construction methods extend cost control beyond direct labour and material savings. Ma et al. report that the literature on 3D printing in construction most often links the method to lower costs, lower material consumption, and improvements in supply-chain performance; at the same time, they point out that adoption is still held back by practical problems with implementation, weak decision-support tools, and the need to retrain workers [8].Xie et al. add that supply chains for additive manufacturing in architecture need separate resilience assessment, since their industrial structure is more complex than in conventional construction [11]. The practical value of these methods therefore depends not only on waste reduction or supply-chain redesign, but also on trained labour, technical standards, reliable decision support, and quality control [8], [11].

Residential projects pay for broken flow through delay, rework, idle crews, damaged materials, and weaker affordability. Late deliveries and poor storage raise site cost. Delayed information leaves workers waiting or installing from outdated instructions. Missing backup suppliers expose the schedule to shortages. Weak technical skills increase defects when teams adopt industrialized methods. Supply-chain management and workforce management therefore belong in the same cost-control framework [5], [6], [7], [9], [12]. The layered illustration is shown on Figure 2.

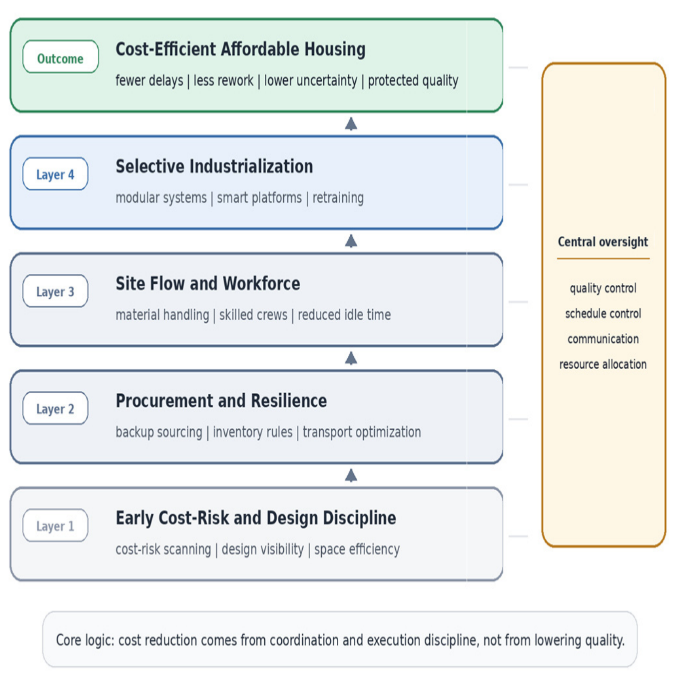

Figure 2. Layered Framework for Residential Cost Reduction (the author's interpretation)

At the first layer of Figure 2, projects require early cost-risk scanning and design-stage cost discipline, as indicated by the predictive and simulation studies [1], [4]. At the second layer, procurement and logistics need resilient structuring through backup suppliers, transport optimization, inventory rules, and transparent information exchange [2], [3], [5], [6], [10]. At the third layer, site operations require disciplined material handling, stock-and-waste control, and workforce allocation practices that prevent crews from losing time to missing or badly stored inputs [12]. At the fourth layer, selective industrialization through modular, prefabricated, or platform-coordinated delivery becomes economically attractive when supported by training, standardization, and cooperative information systems [7], [9], [13].

Taken together, the studies support a residential cost-control framework that links risk diagnosis, procurement, logistics, site execution, selective industrialization, and quality oversight. Central oversight matters because faster execution and lower procurement cost can lose value when defects, rework, or poor documentation appear late in the project.

Residential projects need a hybrid method mix selected by project scale, geography, supplier maturity, financing constraints, approval requirements, and workforce readiness. Modular and prefabricated systems can reduce on-site labor and duration when logistics, standards, and training support them [2], [7], [10]. Platform integration can improve coordination, but implementation cost and participant cooperation shape the feasible model [10], [13]. Collaborative housing design can reduce cost under specific spatial and organizational conditions [4]. Additive systems expand the range of future options, while their cost value still depends on governance, retraining, and supply-chain maturity [8], [11], [13].

In Georgia's context, developers may face supplier concentration, material-price exposure, uneven access to skilled labor, and less formalized construction management systems. THa author's practical industry observation from Georgian residential construction suggests that cost control often depends on ordinary execution details: negotiating reliable supplier terms, ordering materials at the right time, keeping crews productive, delegating daily site decisions, and maintaining direct quality oversight. These observations clarify why the reviewed literature on procurement resilience, logistics, workforce productivity, and quality control has practical value for markets where affordable housing delivery depends on disciplined coordination.

CONCLUSION

The practical significance of this article lies in showing that residential construction cost reduction is most credible when managers act on the full chain linking design, procurement, transport, inventory, site flow, and workforce capability. The hypothesis introduced earlier is supported by the convergence of the reviewed evidence: projects become more cost-efficient when resilient supply-chain strategies are combined with workforce measures that reduce idle time, improve skill fit, support industrialized assembly, and stabilize material availability [2], [7]. The scientific result of the article is therefore a synthesized interpretive framework in which residential cost is treated as the product of coordinated flow reliability across the supply chain and the workforce system [5], [12].

Future research should test this integrated framework against longitudinal residential project evidence, especially by quantifying how training, crew redeployment, material availability, and digital coordination interact under conventional, hybrid, modular, and additive delivery models. Additional work is needed on housing-specific disruption scenarios, the cost effect of retraining during technological transition, smart-platform governance in fragmented supply chains, and decision-support systems for emerging additive methods in residential settings [8].

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