

COMPARATIVE ANALYSIS OF COST STRUCTURES BETWEEN PREFABRICATED CONCRETE BUILDINGS AND TRADITIONAL CAST-IN-SITU CONSTRUCTION: A CASE STUDY OF BUILDING #3, HUILONGGUAN PLOT 1818-028, BEIJING

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Abstract: Prefabricated concrete construction incurs significant cost premiums over traditional cast-in-situ methods, with the Huilongguan project case (40% prefabrication rate) in Beijing demonstrating a unit cost increase of CNY 443/m² (+43%). Granular cost breakdown reveals the core contradiction: prefabricated component costs (including production and transportation) account for 85% of the increment at CNY 680/m². Although temporary formwork costs decrease by CNY 130/m² and scaffolding expenses reduce by 60%, vertical transportation costs rise by 22%. Key challenges stem from three systemic constraints: 1) Component production hindered by insufficient scale (<50,000 m² projects increase mold amortization costs by 30-50%); 2) Structural labor shifts (certified lifters replace steel fixers but with reduced efficiency); and 3) Low transport efficiency (bulky components limit truckload capacity). Improvement pathways include economies of scale (>100,000 m² projects reduce mold amortization by 8%), standardized design (fewer component types enhance efficiency), and policy compensation (Floor Area Ratio bonuses/VAT rebates). Empirical evidence shows prefabricated masonry can reduce costs by 80%, while schedule compression offsets up to 30% of financing costs. Supply chain integration requires design-production-installation coordination to optimize transport (5-10% of total costs). With scaling and policy incentives, incremental costs are projected to narrow to CNY 200-500/m².

Keywords: Prefabrication cost premium; Economies of scale; Prefabrication rate; GB/T51231-2016; Temporary works optimization; Policy compensation

1 INTRODUCTION

Prefabricated construction, recognized for its energy efficiency, quality control, and schedule compression, has become pivotal in China's construction industrialization. However, its upfront costs significantly exceed those of traditional cast-in-situ methods, particularly due to incremental expenses in prefabricated component production, transportation, and installation—a barrier to widespread adoption. The case of Building #3 at Huilongguan Plot 1818-028 in Beijing demonstrates this challenge: with a prefabrication rate of 30%, the unit cost per square meter was 10%-20% higher than cast-in-situ structures. While this disparity is routinely oversimplified as attributable solely to components, granular cost breakdown reveals critical nuances. Prefabrication reduces labor costs (down by 18%), temporary works expenses (e.g., formwork and scaffolding, reduced by 32%), and finishing costs (down by 9%). Yet, prefabricated components constitute 89.97% of main material costs—directly driving overall expenditure.

Root causes of incremental costs include three key dimensions: First, direct construction cost variances—factory-produced components (e.g., sandwich insulated exterior walls) incur 30%-50% higher unit costs due to mold amortization, plant management, and taxation. Second, supply chain inefficiencies—transportation radius constraints and standardization gaps limit economies of scale. Third, technical management deficiencies—poor on-site interface coordination further inflates costs.

Prior to 2019, data indicated that prefabricated buildings incurred 10%-20% higher costs per square meter than cast-in-situ structures, with cost differentials reaching ¥700-¥800/m² in certain projects. This cost premium primarily stemmed from an immature industrial ecosystem.

(1) Design Phase:

Component detailing design added 15% to incremental costs. The complexity and workload of design increased significantly due to precision requirements for prefabrication, driving up expenses.

(2) Production Phase:

Low mold reuse rates critically elevated component prices. While molds are theoretically reusable for 50 cycles, actual utilization averaged only 30 cycles. Frequent mold replacements substantially raised production costs, maintaining high component pricing.

The Huilongguan project revealed prefabrication's cost paradox: although savings occurred in labor, temporary works, and finishes, shortcomings in component production and supply chains increased overall costs. Pre-2019 industry bottlenecks included inadequate industrial chain support and crude technical management. Future development requires policy-driven standardization, regionalized production, and construction process optimization to unlock prefabrication's long-term economic benefits.

2 PROJECT PROFILE AND COMPARATIVE SCHEME DESIGN

2.1 Project Overview

The case study focuses on Building #3 at Huilongguan Plot 1818-028, Beijing—an 18-story shear wall structure with two basement levels and a total floor area of 12,300 m². With a 40% prefabrication rate, key prefabricated components include composite floor slabs (60% application rate) composed of 130mm thick precast base plates with cast-in-situ topping layers manufactured under factory conditions, fully prefabricated staircases (100% application rate), and sandwich insulated exterior walls integrating exterior cladding, insulation cores, and inner structural panels. Structural design complies with GB/T 51231-2016 Technical Standard for Precast Concrete Buildings, utilizing C30-C40 concrete with seismic fortification intensity set at 8 degrees. The project's location in Changping District constrained component transportation within a 100-km radius to optimize logistics costs.

2.2 Comparative Schemes

Two construction approaches were analyzed:

Scheme A (Traditional Cast-in-Situ) employed timber formwork recycled four times with construction sequences encompassing on-site rebar placement, formwork erection, and concrete pouring. It utilized full-area scaffolding systems with ready-mixed concrete delivered via pumping. Labor allocation strictly followed Beijing's quota standards. Scheme B (Prefabricated Construction) involved factory production covering mold amortization, curing, and QA processes. On-site operations utilized tower cranes for component installation, with composite slabs requiring 60mm cast-in-situ topping after placement. Precast stairs connected to main structures via reserved reinforcement, while exterior walls employed grout-filled sleeve connections. This approach reduced on-site formwork volumes by 70% and scaffolding requirements by 50%.

2.3 Comparison Basis and Boundaries

Analysis was confined to above-grade structural elements (shear walls, beams, slabs, stairs), explicitly excluding foundations, finishes, and MEP systems due to their minimal cost differential impact—though prefabrication reduced plastering costs by RMB 5-10/m² in finishes. Valuation adhered to Beijing Construction Valuation Basis (2012 edition) with material prices sourced from December 2018 Beijing Cost Information (rebar: 3,800 CNY/t; C30 concrete: 380 CNY/m³) [1]. Prefabricated component costs encompassed production (15% mold amortization), transportation (0.8 CNY/t·km), and installation expenses. Temporary works costs followed "Class I Project" standards where formwork and scaffolding amortization were included. Overhead and profit were assessed at 15% of base costs, with statutory fees applied per Beijing regulations.

2.4 Parameters and Key Assumptions

Table 1 Professional Cost Comparison

Parameter Category	Scheme B (Prefabricated)	Scheme A (Cast-in-situ)
Composite Slab Cost	¥1,650/m ³ (including cast-in-situ layer)	¥229.6/m ² (flat slab)
Precast Staircase Cost	¥1,850/m ³	¥25.67/m ²
Sandwich Insulation Wall Panel	¥2,400/m ³ (30%-50% premium)	-
Labor Cost	¥60/m ² (installation)	¥95/m ² (formwork labor)
Temporary Works Savings	50%-70% reduction in scaffolding/formwork	-
Economies of Scale	60% component repetition; 8% mold cost reduction	-

3 DETAILED COMPARATIVE ANALYSIS OF COST STRUCTURES

This section systematically compares the cost compositions of two construction methodologies through itemized cost breakdowns, revealing the origins of incremental expenses and providing data-driven insights for cost optimization.

3.1 Comparison of Quantities-Based Works Costs (Unit: CNY/m²)

Quantities-based works costs constitute the primary cost differential. As shown in Table 1, the cast-in-situ scheme (A) and prefabricated scheme (B) exhibit differentials of CNY -30/m² and CNY -40/m² in concrete and reinforcement works, respectively, primarily due to reduced on-site pouring in prefabrication. However, prefabricated components costs (including production and transportation) become the critical incremental factor at CNY 680/m², accounting for 85% of the total CNY 480/m² variance. This phenomenon aligns with empirical evidence nationwide: a Nantong project reported CNY 1,435/m² PC component cost increments, while a Chengdu project documented CNY 811.71/m² increases in civil works costs due to PC installation, confirming that prefabricated components dominate cost escalation. Notably, prefabrication reduces temporary formwork costs by CNY 130/m² through composite slab applications, partially offsetting component-related expenses [2].

Table 2 Quantities-Based Works Cost Comparison

Item	Scheme A (Cast-in-situ)	Scheme B (Prefabricated)	Differential
Concrete Works	320	290	-30
Reinforcement Works	420	380	-40
Prefabricated Components	-	680	+680
Formwork Costs	180	50	-130
Subtotal	920	1,400	+480

3.2 Comparison of Temporary Works Costs

Temporary works costs demonstrate structural divergence:

- (1) Vertical transportation expenses increase by 22% (CNY 35/m² to CNY 43/m²) in prefabrication due to intensified tower crane usage, consistent with data from seismic intensity zones of 7 degrees where crane cost increments range CNY 28-48/m², reflecting universally elevated machinery utilization.
- (2) Scaffolding costs decrease by 60% (CNY 75/m² to CNY 30/m²) as prefabricated components reduce on-site construction, highlighting industrialization's efficiency in auxiliary works.
- (3) Other temporary costs (safety measures, etc.) show <5% variance, indicating convergence in non-core expenditures.
4. Overall temporary works savings of CNY 37/m² represent a rare cost-optimized aspect in prefabrication, though insufficient to offset quantities-based works increments.

3.3 Overall Cost Comparison

Integrating quantities-based and temporary works costs, the cast-in-situ total reaches CNY 1,030/m² versus prefabricated at CNY 1,473/m²—a CNY 443/m² (+43%) premium. This aligns with documented increments of CNY 597.5/m² in Nantong and CNY 700-800/m² in Shenyang, validating the consistent cost premium of prefabricated concrete structures. Incremental magnitude depends on project scale, prefabrication rate, and seismic requirements: in seismic zones of 6-8 degrees, typical increments range CNY 200-500/m², with the Huilongguan case at the upper limit—potentially attributable to its higher prefabrication rate.

Table 3 Overall Cost Comparison

Scheme	Quantities-Based Costs	Temporary Works Costs	Total (CNY/m ²)
Cast-in-situ (A)	920	110	1,030
Prefabricated (B)	1,400	73	1,473
Differential	+480	-37	+443

The Huilongguan case demonstrates a CNY 443/m² cost premium for prefabricated concrete structures over cast-in-situ methods, with core inefficiencies rooted in prefabricated component production and logistics (85% of the increment). Despite significant savings in formwork and scaffolding, elevated vertical transportation costs and quantities-based works increments drive overall cost increases. This conclusion reflects nationwide empirical patterns, indicating that current prefabrication advancement must prioritize component cost reduction [3-5]. Future progress requires optimized component design, scaled production, and policy support to gradually narrow cost gaps with traditional construction.

4 ANALYSIS OF KEY COST VARIANCE FACTORS

4.1 Dominant Variance Characteristics

Prefabricated construction exhibits incremental-cost dominance with localized savings. The Huilongguan project illustrates this distinctly:

4.1.1 Core cost increments

Prefabricated components (including production/transport) constituted 47.6% of structural costs. Sandwich insulation wall panels cost 30%-50% more than cast-in-situ equivalents, while composite slab differentials reached ¥53.31/m². These premium component costs drove overall expense growth.

4.1.2 Localized savings

Savings emerged in multiple areas:

- (1) Masonry: Replacing brickwork with precast elements reduced wet-trade work by 80%, cutting costs from ¥35/m² to ¥7/m².
- (2) Temporary works: 70% formwork reduction lowered timber formwork amortization by ¥28/m², while halved scaffolding needs saved ¥6.52/m².
- (3) Labor: Reduced field binding operations decreased labor costs by ¥28/m².

However, these combined savings (~¥130/m²) offset only 59% of the incremental component costs (¥220/m²). Consequently, Huilongguan's final cost remained ¥91.78/m² higher than cast-in-situ structures, confirming prefabrication's cost-incremental nature [6].

4.2 Root Causes of Cost Increments

4.2.1 Production and logistics bottlenecks

- (1) Insufficient economies of scale: Mold amortization comprised 15%-20% of costs for projects <50,000m² (18% for Huilongguan slabs), dropping to <12% for projects >100,000m².
- (2) Transport inefficiencies: Oversized components (e.g., 3m × 4m wall panels) reduced truckload capacity by 40%, with costs surging 15% beyond 100km radii (e.g., Beijing-Tianjin transport costs rose from 8% to 12% of component value).

4.2.2 Structural labor cost shifts

- (1) Trade substitution: Rebar binding work decreased 50%, but rigger demand increased (30% wage premium), yielding only 13% net labor reduction.
- (2) Productivity loss: Non-standard components (e.g., customized stairs) required 40% more installation time, negating workforce reductions.

4.2.3 Indirect cost impacts

- (1) Higher equipment costs: Tower crane utilization rose 20%, increasing rental fees by ¥28-48/m².
- (2) Schedule compression benefits: Factory prefabrication shortened on-site construction by 30%, reducing overhead by ¥12/m² and financing costs by ¥8/m².

4.3 Economic Optimization Potential

4.3.1 Scale-driven improvements

- (1) Critical mass breakthrough: Projects >100,000m² (e.g., Wuhan's 200,000m² residential complex) lowered mold amortization to 12%, reducing component costs by 18%.
- (2) Regionalized production: Facilities within 150km radii can compress transport costs from 15% to 10% of component value.

4.3.2 Standardization efficiencies

- (1) Modular design: Component types decreased from 200 to 50 (Vanke case study), raising production-line reuse to 80% and cutting unit costs by 22%.
- (2) Connection optimization: Standardized grout sleeves improved installation efficiency by 35%, reducing labor costs by 15%.

4.3.3 Policy compensation mechanisms

Policy interventions effectively alleviate cost pressures:

- (1) Beijing's 3% FAR (floor area ratio) bonus for $\geq 40\%$ prefabrication rates offsets 8% cost increments.
- (2) VAT refunds under [2015] No. 73 tax policy reduce production costs by 6%.
- (3) Shanghai's ¥100/m² subsidy for $>25\%$ prefabrication coverage defrays 52% incremental costs.

MoHURD's 2018 assessment projects prefabrication costs nearing cast-in-situ levels by 2020 through synergistic application of scale optimization, standardization, and policy incentives. At Huilongguan, implementing these measures would narrow the cost gap from ¥91.78/m² to ¥22/m², demonstrating significant control efficacy.

In summary, incremental costs represent a transitional phase of industrial chain immaturity. Systematic resolution of prefabrication's economic constraints is achievable during 2019-2025 through scaled production, design standardization, and targeted policy support [7-8].

5 CONCLUSIONS AND IMPLICATIONS

5.1 Value of Granular Cost Analysis

Itemized cost decomposition reframes the perception of prefabrication cost disadvantages [9]. As demonstrated in the Huilongguan project, granular analysis clarifies distinctive cost structures and variances.

5.1.1 Localized cost savings

Prefabrication yields significant savings:

- (1) Formwork: Precast elements' inherent formwork properties reduced timber usage by 70%, lowering temporary works costs by ¥28/m².
- (2) Masonry: Precast wall systems diminished wet-trade work by 80%, cutting costs by 80% (from ¥35/m² to ¥7/m²).

5.1.2 Precise incremental cost attribution

Component production/transport accounted for 47.6% of incremental costs. Sandwich wall panels incurred 30%-50% premiums over cast-in-situ equivalents, primarily driving cost increases. Elevated hoisting measures raised tower crane costs by 20%-30%, though 30% schedule compression partly offset overhead and financing expenses [10].

Granular data enables targeted policymaking: Beijing's 2017 policy grants a 3% FAR bonus for $\geq 50\%$ prefabrication rates, while Shaanxi provides regional transport subsidies (¥50-100/m²) to counter supply chain gaps.

5.2 Decision Recommendations

5.2.1 Small-scale projects (<50,000m²)

Prioritize non-cost benefits:

- (1) Schedule: 30% on-site duration reduction saves ~¥8/m² in financing costs at 6% annual interest [11].
- (2) Policy synergies: Combined incentives (e.g., Beijing's 2019 fiscal rewards) offset 15%-20% of incremental costs.

5.2.2 Large-scale projects (>100,000m²)

Scale and standardization drive cost efficiency:

- (1) Mold economics: 60% component repetition slashes mold amortization from 18% to 12% (verified in Vanke projects).
- (2) Design efficacy: Reducing component types from 200 to 50 boosts installation efficiency by 35%, cutting labor by 15% [12].

Optimization note, Prefabrication rates beyond 50% reduce cost efficiency; 40%-50% is the economic inflection point for Northern China residential projects.

5.3 Future Outlook

5.3.1 Enhanced industry chain integration

Design-production integration reduces costs: BIM implementation lowers component tolerance errors from 5mm to 2mm, minimizing on-site adjustments. Transport optimization—compressing regional production radii to 150km (per 2017 MoHURD guidelines)—reduces logistics costs from 15% to 10% [13].

5.3.2 Realized economies of scale

Cost convergence is accelerating: MoHURD's 2017 forecast indicates $\leq 5\%$ cost differentials at 100 million m² annual prefabricated construction volume. Policy-driven equilibrium is achievable [14]:

- (1) VAT refunds ([2015] No.73) reduce production costs by 6%
- (2) FAR incentives and other measures will bridge the cost gap by 2025.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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