WEP Warwick Evans Publishing

Academic Journal of Management Science and Engineering

ISSN: 3080-9827 (Print), ISSN: 3080-9835 (Online)
Volume 1, Number 6, Year 2026
DOI: https://doi.org/10.62051/ajmse.v1n6.01



Research on Cost Control of Prefabricated Construction Projects

Panhan Wang

Shanghai University, Shanghai, 200444, China

ABSTRACT

This study develops a data-driven cost-control framework for a prefabricated concrete project in Shenzhen by integrating BIM, value engineering, and earned value management. Expert ratings identified design changes, construction methods, interdisciplinary coordination, and formwork turnover as the principal cost factors. BIM reduced component types from 69 to 44 and supported the closure of 136 clashes before fabrication, avoiding an estimated CNY 45,000 in change-related expenditure. Under consistent scenario assumptions, production, transportation, and direct installation labor costs decreased by approximately 12%, 15%, and 33%, respectively. Value engineering identified aluminum formwork as the preferred alternative, with a value coefficient of 1.3429. Earned value reviews showed that cumulative cost and schedule variances became positive in week 12, while CPI and SPI reached 1.0438 and 1.0277 in week 16. The case demonstrates a traceable cost-control loop, although the absence of a control project limits causal attribution.

KEYWORDS

Prefabricated Building; Project Cost Control; Building Information Modeling; Value Engineering; Earned Value Management; Case Study.

1. INTRODUCTION

Prefabricated construction transfers part of on-site work to factories, shifting costs from cast-in-place materials and wet trades toward detailed design, formwork, component production, transportation, lifting, and interdisciplinary coordination. Once front-end decisions produce nonstandard components or conflicts in reserved openings and embedded items, the effects propagate along the supply chain: small-batch production increases formwork amortization, inconsistent component dimensions reduce vehicle load factors, and on-site modifications cause rework and equipment waiting. Therefore, simply comparing construction settlement amounts is insufficient to explain cost variances in prefabricated projects; control points must cover both design and execution.

Vasishta et al. compared prefabricated and cast-in-place buildings in terms of life-cycle environmental impacts and costs, showing that construction methods cannot be assessed at a single stage [1]. Liu et al. analyzed the evolution of collaborative networks in prefabricated projects in Shanghai and revealed the role of interorganizational collaboration in technology implementation [2]. Dou et al. reviewed technological innovation in prefabricated construction using patent data and knowledge graphs, emphasizing the value of integrating dispersed knowledge [3]. Tatari used Bayesian networks to identify dependencies among cost risks in prefabricated construction [4]. Naranje and Swarnalatha mapped RFID status information to CAD models, providing a visual approach to tracking component supply chains [5]. Together, these studies address life cycles, organizational networks, technological knowledge, risks, and logistics information, demonstrating that costs in prefabricated construction arise from multiple interconnected stages.

Content from this work may be used under the terms of CC BY-NC 4.0 licence (https://creativecommons.org/licenses/by-nc/4.0/).
Published by Warwick Evans Publishing.

Chinese studies have focused more on the high costs and management adaptation involved in project implementation. Cui discussed the boundaries of BIM application in construction cost control [6]. Liu applied BIM to the digital management of construction costs for prefabricated concrete buildings [7]. Zhu et al. proposed a whole-process control approach covering detailed design, production, transportation, and construction [8]. Zhang et al. examined the roles of BIM in quantity takeoff, coordination, and construction management [9]. Fei summarized cost-control difficulties in collaborative design, production, and site management [10]. Zhao discussed control priorities from the perspectives of contractors, component manufacturers, and lifting equipment [11]. Li analyzed the effect of BIM on construction costs through a case study [12].

Regarding the identification of influencing factors, Wu developed a cost-factor system for prefabricated buildings and proposed control measures [13]. Zhang emphasized the effects of the assembly rate, production, and lifting factors on project costs [14]. Gao further examined the prioritization of key factors and corresponding management responses [15]. Han embedded BIM in whole-process cost management [16], whereas Qu analyzed BIM applications in the design and construction-management stages [17]. These studies provide a basis for tool selection, but factor identification, design-stage prevention, alternative comparison, and process correction are often discussed separately. Evidence linking measures to cost accounts and work packages is also rarely presented within a single case. This study addresses three questions: Which factors should receive priority in cost control? How do design standardization and clash closure translate into costs at different stages? How can construction variance identification, alternative comparison, and periodic review form a feedback loop? The study contributes a case-based mapping of factors, components or alternatives, WBS work packages, and performance indicators, while explicitly reporting the estimation boundaries and attribution limitations.

2. RESEARCH DESIGN

2.1. Case Project and Cost Baseline

The case project is a fire station in Shenzhen with a gross floor area of 4,825 m² and a prefabricated concrete frame structure. Project assessment documents record a prefabrication rate above 35%. The principal prefabricated elements include composite beams, composite slabs, internal and external wall panels, and staircases, all supplied by an external manufacturer. Because the prefabrication rate and assembly rate differ in their evaluation objects and calculation bases [18-19], this study retains the prefabrication rate stated in the project documents and does not treat the two measures as interchangeable. The fire station has dense mechanical, electrical, and plumbing systems, requiring extensive checks of reserved openings, embedded items, and interdisciplinary interfaces. The use of externally supplied components also creates direct interfaces among design parameters, production batches, transportation, and lifting, making the project suitable for tracing cost transmission across the design-supply-construction chain.

The project's 2022 target-cost estimate reported a unit cost of CNY 2,242/m² for the prefabricated scheme and CNY 1,480/m² for the conventional cast-in-place scheme. The difference on a consistent basis was CNY 762/m², equivalent to 51.49% of the cast-in-place cost. The difference mainly reflected increases in PC component-related items, while underground works, cast-in-place reinforced concrete, floors and ground finishes, plastering, electrical works, and water supply and drainage decreased to varying degrees. The estimate used the project's chargeable floor-area basis, which differs from the gross floor area of 4,825 m². Because the anonymized data did not retain a breakdown of the chargeable floor area, this study only compares unit costs within the same estimate and does not infer the total contract value. PC component installation in Table 1 is already included in the civil-works subtotal and is not added again.

Table 1. Comparison of Major Costs Between Prefabricated and Cast-in-Place Schemes (CNY/m²)

Cost item	Prefab.	Cast-in-place	Diff.
Civil works (subtotal)	2129	1317	+812
Of which: underground works	161	197	−36
Cast-in-place reinforced concrete	299	758	−459
PC component installation (source-table item)	1435	—	+1435
Floors and ground finishes	13	45	−32
Roofing and waterproofing	21	27	−6
Plastering and miscellaneous works	84	158	−74
Preliminaries and other items	115	126	−11
Electrical works	82	117	−35
Water supply and drainage	31	46	−15
Project total	2242	1480	+762

Note: Civil works is a subtotal, and the items beneath it are components of that subtotal. Difference = prefabricated - cast-in-place. 'PC component installation' is the item name used in the original project cost estimate. Because the data do not further separate component supply from on-site installation, CNY 1,435/m² is not interpreted as pure installation labor cost.

2.2. Identification of Key Factors Through Expert Ratings

A list derived from the literature and project interviews produced 20 indicators across the design, production, transportation, and construction stages. Thirteen experts with experience in prefabricated projects rated importance on a five-point scale, where 5 indicated 'very important' and 1 indicated 'not important at all.' Let f_{ij} denote the number of experts assigning rating i to indicator j, with N = 13. To reflect both importance and dispersion of opinions, the mean score $\bar{x}_j$, sample standard deviation s_j, and coefficient of variation CV_j were calculated, and each mean score was normalized as importance w_j.

$$\bar{x}_j = \frac{1}{N}\sum_{i=1}^{5} i f_{ij} \tag{1}$$

$$s_j = \left[\frac{\sum_{i=1}^{5} f_{ij}(i-\bar{x}_j)^2}{N-1}\right]^{\frac{1}{2}} \tag{2}$$

$$\mathrm{CV}_j = \frac{s_j}{\bar{x}_j} \tag{3}$$

$$w_j = \frac{\bar{x}_j}{\sum_{k=1}^{20} \bar{x}_k} \tag{4}$$

A higher $\bar{x}_j$ indicates that experts consider the factor more important, whereas a lower CV_j indicates greater agreement. The value w_j is used only to compare resource priorities within the same indicator set. This treatment preserves the ordinal information in the ratings and avoids interpreting the entropy of the frequency distribution directly as importance. Table 2 reports the frequencies for ratings 5-1, the mean scores, coefficients of variation, and normalized importance values to facilitate recalculation.

A mean score of at least 4.00 and a CV of no more than 0.25 were used as management-attention thresholds for this case. Design changes (4.62), construction methods and technologies (4.46), interdisciplinary coordination and number of formwork reuse cycles (both 4.23), vehicle loading scheme, and lifting cost (both 4.00) entered the priority group. These thresholds are case-specific

resource-allocation rules rather than statistical significance criteria. The high rankings of design changes and interdisciplinary coordination support BIM-based prevention before fabrication. Because production, transportation, and construction factors also entered the priority group, subsequent analysis must use WBS and periodic performance data to evaluate how front-end alternatives perform during execution.

Table 2. Expert Ratings of 20 Cost Factors

Stage	Cost factor	Freq. (5-1)	Mean	CV	w/%
Des.	Assembly rate	0/5/8/0/0	3.385	0.150	5.15
Des.	Degree of component segmentation design	0/3/8/1/1	3.000	0.272	4.56
Des.	Degree of component standardization	0/5/6/2/0	3.231	0.224	4.91
Des.	Designer competence and experience	1/3/9/0/0	3.385	0.192	5.15
Des.	Interdisciplinary coordination	3/10/0/0/0	4.231	0.104	6.43
Des.	Design changes	8/5/0/0/0	4.615	0.110	7.02
Prod.	Number of formwork reuse cycles	5/6/2/0/0	4.231	0.171	6.43
Prod.	Skill level of production workers	2/4/6/1/0	3.538	0.248	5.38
Prod.	Component production efficiency	0/4/8/1/0	3.231	0.185	4.91
Prod.	Production scale	0/0/2/7/4	1.846	0.373	2.81
Prod.	Production cost of prefabricated components	1/4/7/1/0	3.385	0.227	5.15
Trans.	Transportation distance	0/2/8/3/0	2.923	0.219	4.44
Trans.	Transportation mode	0/4/7/2/0	3.154	0.218	4.80
Trans.	Vehicle loading scheme	4/5/4/0/0	4.000	0.204	6.08
Trans.	Location of prefabrication plant	0/2/5/4/2	2.538	0.381	3.86
Constr.	Construction methods and technologies	8/3/2/0/0	4.462	0.174	6.78
Constr.	Site layout	0/1/3/8/1	2.308	0.326	3.51
Constr.	On-site component management	0/1/4/7/1	2.385	0.322	3.63
Constr.	Project management staff competence	0/0/3/6/4	1.923	0.395	2.92
Constr.	Lifting cost	2/9/2/0/0	4.000	0.144	6.08

Note: Frequencies are reported in the order 5, 4, 3, 2, and 1; N = 13. The displayed w values are normalized from the mean scores and sum to 100.00%.

2.3. Data Sources and Consistency Checks

The case data comprise the project target-cost estimate, component segmentation records, a clash-closure register, a formwork-alternative evaluation sheet, and biweekly cost and schedule reports from September to December 2022. Three consistency rules were applied. First, Table 1 distinguishes the civil-works subtotal from its components; PC component installation is not added again, and the scheme difference is recalculated as 2,242 - 1,480 = CNY 762/m². Second, the expert-rating statistics are recalculated directly from the five-level frequencies in Table 2, using unrounded values throughout. Third, cumulative and period earned value indicators are calculated from BCWS, BCWP, and ACWP, and warning decisions use unrounded results rather than readings from plotted curves.

Interpretation is limited to what the source data support. The reductions of 12%, 15%, and 33% are scenario estimates for production expenditure, transportation expenditure, and direct installation labor cost, respectively, and cannot be summed as an overall project cost reduction. The CNY 45,000

avoided expenditure is an estimate from the clash register rather than a settlement saving. CPI and SPI describe cumulative and period performance during the monitoring window and do not provide a causal estimate for any single measure. After anonymization, the cost data no longer retained a complete breakdown of chargeable floor area, taxes and fees, or component supply costs; these omissions define the boundary of case verification.

2.4. Stage-Based Control Framework

The control framework comprises expert ratings, BIM-based design prevention, initial earned value identification, value engineering comparison, and periodic review (Figure 1). Expert ratings answer where management resources should be prioritized. BIM places standardization, interdisciplinary coordination, and quantity feedback before fabrication. Earned value management identifies execution variances by WBS work package. Value engineering compares the functions and costs of alternatives triggered for review, and subsequent cumulative and period indicators test the direction of adjustment. Component codes, alternative costs, and WBS cost accounts serve as data interfaces in this chain; the framework is not a simple juxtaposition of software and methods.

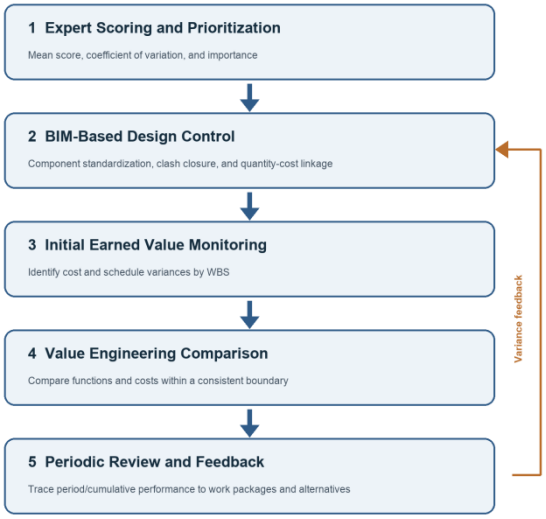


Figure 1. Continuous Decision and Feedback Framework for Cost Control in Prefabricated Projects

3. BIM-BASED DESIGN-STAGE COST CONTROL

3.1. Model Organization and Information Interfaces

Following consistency requirements for building information modeling applications [18], the case adopted a workflow of drawing integration, three-dimensional modeling, component segmentation, interdisciplinary checking, quantity extraction, and pricing feedback. AutoCAD was used to organize the source drawings; Revit supported parametric modeling of architectural, structural, and prefabricated components; Navisworks integrated multidisciplinary models and supported clash detection; and the Glodon quantity and pricing platform received quantity and budget data. Component IDs were maintained across segmentation, clash reports, and bills of quantities. Model versions and bill cut-off dates were recorded together, allowing design adjustments to be traced to specific components and reviewed before fabrication.

3.2. Cost Transmission Through Standardized Segmentation

Component segmentation was constrained by building function, structural behavior, road turning radii, vehicle clearances, lifting capacity, and connection details. Common dimensions were adjusted to a 300 mm module: prefabricated slab types decreased from 35 to 22, wall types from 32 to 21, and two staircase types were consolidated into one standard type. The total number of component types decreased from 69 to 44. Repetitive components were entered into a parametric library, reducing duplicate modeling and nonstandard formwork.

The project compared the pre- and post-standardization alternatives under consistent quantity and price assumptions. The average production unit price of prefabricated wall panels decreased from approximately CNY 1,500/m³ to CNY 1,300/m³, a reduction of 13.33%. Combined with a CNY 200-300/m³ reduction in the unit cost of prefabricated beams, the weighted scenario estimate indicated an approximately 12% decrease in production expenditure. Vehicle load per trip increased by approximately 20%; under the theoretical assumption of a fixed cost per trip, the unit transportation cost decreased by 16.67%, while the project estimate was approximately 15% after accounting for partial loads and route constraints. Average installation time per component decreased from 30 min to 20 min. At the original equivalent labor rate, direct installation labor cost decreased from approximately CNY 25 to CNY 16.7 per component, a reduction of approximately 33.2%, excluding lifting equipment and waiting costs. All three figures are stage-specific scenario estimates; they cannot be summed and do not represent an overall project cost reduction.

3.3. Clash-Closure Loop and Early Quantity Integration

Table 3. BIM-Based Design-Stage Cost Control Results

Control item	Verifiable record	Cost basis
Component standardization	69 types -> 44 types	Scenario estimate: production expenditure approx. -12%; transportation expenditure approx. -15%; direct installation labor approx. -33%
Clash detection	136 clashes closed	Register-based estimate of approx. CNY 45,000 in avoided change-related expenditure; not an audited settlement value
Quantity linkage	Model-BOQ-pricing	Changes synchronized with procurement batches and budget versions

Note: Reductions are stage-specific scenario estimates under consistent quantity and price assumptions. The 33% reduction applies only to direct installation labor, and the three percentages must not be summed.

After the architectural, structural, and mechanical, electrical, and plumbing models were integrated, 136 clashes were recorded. They mainly involved door or window openings and structural beams, MEP services and prefabricated components, and inconsistencies in reserved openings and embedded items. Each record was linked to a component ID and responsible discipline and closed through a detect-locate-modify-review workflow. Project summary data estimated avoided change-related expenditure at approximately CNY 45,000. The anonymized data did not retain clash-tolerance thresholds, duplicate-handling rules, or itemized cost estimates; therefore, the 136 clashes should be interpreted as register entries and CNY 45,000 as a management estimate rather than an audited settlement value. Clash closure was completed before fabrication.

The detailed model was imported into the civil-works quantity platform through a plug-in. Quantities of prefabricated components, concrete, and other items were extracted by work area and period and

linked to the local pricing schedule. The management value lies not only in faster quantity takeoff but also in synchronizing design changes with procurement batches, transportation plans, and budget revisions, thereby keeping cost feedback within an adjustable design window.

3.4. Conditions for Releasing Design Outputs to Production

Design outputs should not be released merely because the model is complete; they must also be producible, transportable, and installable. Before fabrication, the project should verify unique component codes, consolidate principal specifications, check road and vehicle clearances, review lifting points and installation space, and confirm that architectural, structural, and MEP clash records are closed. Bills of quantities and model versions must be archived together so that subsequent procurement or budget changes can be traced to the corresponding version.

Three process indicators can be established for standardization outcomes: the proportion of standard components, the on-time clash-closure rate, and the model-to-bill quantity variance. The first two indicate whether design coordination is completed before production; the third checks whether cost data are updated with the model. If the project counts detected clashes without recording closure status, or continues to use an obsolete bill after the model is updated, BIM cannot provide effective front-end cost control.

4. DYNAMIC CONSTRUCTION MONITORING AND ALTERNATIVE OPTIMIZATION

4.1. Initial Earned Value Monitoring and Problem Identification

Responsibilities and work packages were decomposed through the WBS. At two-week intervals, the project summarized the budgeted cost of work scheduled (BCWS), budgeted cost of work performed (BCWP), and actual cost of work performed (ACWP), and measured cumulative performance according to the scope-schedule-cost integration principle of earned value management [22]. All three data series came from the same biweekly report and cut-off date. The anonymized records did not specify whether work-package completion was confirmed by the 0/100 method, milestone weighting, or physical quantities; this study therefore recalculates the existing BCWP series without making additional inferences about measurement error. CV and SV measure cumulative absolute variances, while CPI and SPI measure cumulative performance. To reduce dilution of early deviations in cumulative values, period performance was also calculated from increments between adjacent monitoring points.

$$\begin{aligned} \mathrm{CV} &= \mathrm{BCWP} - \mathrm{ACWP} \\ \mathrm{SV} &= \mathrm{BCWP} - \mathrm{BCWS} \end{aligned} \tag{5}$$

$$\mathrm{CPI} = \frac{\mathrm{BCWP}}{\mathrm{ACWP}};\ \mathrm{SPI} = \frac{\mathrm{BCWP}}{\mathrm{BCWS}} \tag{6}$$

$$\begin{aligned} \mathrm{CPI}_t^{(\Delta)} &= \frac{\mathrm{BCWP}_t - \mathrm{BCWP}_{t-1}}{\mathrm{ACWP}_t - \mathrm{ACWP}_{t-1}} \\ \mathrm{SPI}_t^{(\Delta)} &= \frac{\mathrm{BCWP}_t - \mathrm{BCWP}_{t-1}}{\mathrm{BCWS}_t - \mathrm{BCWS}_{t-1}} \end{aligned} \tag{7}$$

CV < 0 indicates a cumulative cost overrun, and SV < 0 indicates a cumulative schedule delay. A CPI or SPI below 1 indicates cost or schedule performance below plan, respectively. Table 4 retains cumulative data for eight monitoring points, and Figure 2 plots the same data. From weeks 2 to 10, the general ordering was BCWS > ACWP > BCWP, indicating that cumulative actual expenditure had not generated corresponding earned value. In week 12, BCWP reached CNY 8.1634 million and exceeded both ACWP and BCWS for the first time. Table 5 calculates performance from unrounded data to avoid misclassifying CPI values close to 1 in weeks 8 and 10 as having reached the baseline.

Table 4. Cumulative Earned Value Data by Monitoring Period (CNY 10,000)

Week	BCWS	BCWP	ACWP
2	289	231.65	258.43
4	374	323.88	336.57
6	472	425.36	430.09
8	581	540.71	541.82
10	700	682.92	683.25
12	805	816.34	807.46
14	914	931.59	916.97
16	1028	1056.47	1012.14



Figure 2. Cumulative BCWS, BCWP, and ACWP

Table 5. Cumulative Variances and Performance by Monitoring Period

Week	CV/(CNY 10,000)	SV/(CNY 10,000)	CPI	SPI
2	−26.78	−57.35	0.8964	0.8016
4	−12.69	−50.12	0.9623	0.8660
6	−4.73	−46.64	0.9890	0.9012
8	−1.11	−40.29	0.9980	0.9307
10	−0.33	−17.08	0.9995	0.9756
12	8.88	11.34	1.0110	1.0141
14	14.62	17.59	1.0159	1.0192
16	44.33	28.47	1.0438	1.0277

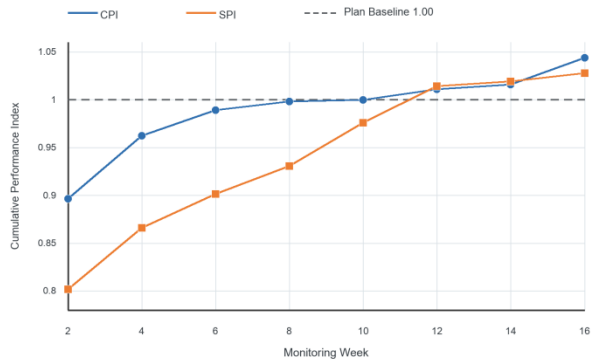


Figure 3. Cumulative CPI and SPI

4.2. Value Engineering Comparison of Formwork Alternatives

Because cumulative CPI and SPI were both below 1 in week 2, the project identified formwork suitability as one of the technical alternatives requiring review. Following value engineering requirements for function-cost analysis and general procedures [20-21], plastic, steel, and aluminum formwork were designated alternatives A, B, and C. Construction efficiency, safety, quality assurance, environmental protection, and operational feasibility were used as functional criteria with weights of 0.350, 0.225, 0.225, 0.100, and 0.100, respectively. The anonymized alternative sheet retained only relative unit costs of 55, 54, and 41, without currency, area of use, or amortization details; these values are therefore used only for normalized comparisons within the case. Let a_j be the weight of function j, s_{jr} the score of alternative r on function j, and c_r the relative unit cost, with g = 5 and R = 3.

$$S_r = \sum_{j=1}^{g} a_j s_{jr} \tag{8}$$

$$F_r = \frac{S_r}{\sum_{t=1}^{R} S_t};\ C_r = \frac{c_r}{\sum_{t=1}^{R} c_t} \tag{9}$$

$$V_r = \frac{F_r}{C_r} \tag{10}$$

The weighted function scores of the three alternatives were 7.400, 7.300, and 8.525, and their relative unit costs were 55, 54, and 41. Using unrounded coefficients, Table 6 gives value coefficients of 0.8690, 0.8731, and 1.3429 for alternatives A, B, and C, respectively; alternative C achieved the highest value within the project's evaluation boundary. When each functional weight was varied by ±10% and the weights were renormalized, the value coefficient of alternative C ranged from 1.3412 to 1.3445 and the ranking remained unchanged. This conclusion applies only to the functional scores and relative-cost boundary of this project; 1.3429 should not be interpreted as an inherent property of aluminum formwork.

Table 6. Value Engineering Results for Three Formwork Alternatives

Indicator	Plastic formwork A	Steel formwork B	Aluminum formwork C
Weighted function score S	7.400	7.300	8.525
Function coefficient F	0.3186	0.3143	0.3671
Cost coefficient C	0.3667	0.3600	0.2733
Value coefficient V	0.8690	0.8731	1.3429

4.3. Corrective Measures and Subsequent Performance

The project used CPI < 0.95 as the cost-warning condition: 0.90 ≤ CPI < 0.95 triggered an orange warning, while CPI < 0.90 triggered a red status and renewed evaluation of the alternative. Warnings were based on unrounded data. In week 2, CPI = 0.8964, indicating red status, and SPI = 0.8016, indicating a concurrent schedule delay. Project records show that alternative comparison and site-organization adjustments occurred after the week-2 warning, but the exact switching date was not retained; week 2 is therefore used only as the observational boundary. The project adopted aluminum formwork and rescheduled component delivery, storage, lifting, installation, and MEP coordination by WBS. Period CPI^(Δ) and SPI^(Δ) from weeks 2 to 4 were 1.1803 and 1.0851, respectively, and all subsequent period indicators exceeded 1. Cumulative CV and SV became positive in week 12, and cumulative CPI and SPI reached 1.0438 and 1.0277, respectively, in week 16.

The cumulative and period series show that variances continued to converge while multiple measures were implemented. However, the single case had no control group, and cumulative indicators may be diluted as subsequent work volume increases; consequently, the entire improvement cannot be attributed to formwork replacement or BIM application. The supported interpretation is that formwork adjustment, optimization of deliveries and work sequencing, and biweekly feedback occurred concurrently with improved performance. Quality and safety indicators must still be

analyzed alongside CPI and SPI. If savings result from reduced inspections or lower material quality, a higher CPI does not indicate better overall performance.

4.4. Joint Interpretation of Cost, Schedule, and Quality

CPI and SPI should be used as a pair. When CPI < 1 and SPI < 1, the project should first examine whether rework, waiting, and resource inputs are simultaneously increasing costs and delaying progress. When CPI ≥ 1 but SPI < 1, it should determine whether cost savings result from insufficient inputs. When CPI < 1 but SPI ≥ 1, it should identify acceleration costs, equipment overtime, and premium-priced procurement. Corrective action can be considered aligned with the overall objective only when both indicators are close to or above 1 and quality and safety records have not deteriorated.

At regular meetings, variances can be decomposed to terminal WBS work packages, with records of the variance amount, responsible discipline, cause category, measure, completion deadline, and next-period review value. If performance remains below the warning threshold for two consecutive periods, the remaining work should be re-estimated rather than merely requiring the site to cut expenditure. In this way, earned value indicators become management records with responsible parties and closure conditions rather than report outputs alone.

5. DISCUSSION

5.1. Mechanism of the Design-Construction Feedback Loop

The four analytical components in the case perform different tasks. Expert ratings establish management priorities from mean scores and dispersion of opinions. BIM converts coordination, standardization, and change issues into traceable component and clash records. Initial earned value monitoring locates execution variances. Value engineering balances multiple functions and costs at the alternative level, and subsequent earned value data test execution performance. The connection among these components is not the names of software or methods but traceable data objects: component IDs connect design and production, quantities and alternative costs connect design and construction preparation, and WBS work packages connect construction activities with periodic performance.

This logic explains why design changes and interdisciplinary coordination ranked highly in the expert ratings. Reducing the number of component types first changes formwork quantities and production batch sizes, which then affect loading combinations, transportation batches, and installation proficiency. Clash closure reduces potential on-site cutting, modification, and waiting. Variances observed during construction are not determined entirely by site prices; some may be associated with design parameters and supply-chain arrangements. Moving control forward does not weaken construction accounting; instead, it allows construction data to test design and alternative decisions retrospectively.

5.2. Applicability Conditions and Research Boundaries

This approach is applicable to prefabricated projects with a reasonably clear WBS, periodic collection of actual costs and completed quantities, and at least a basic BIM model during design. If cost bases are inconsistent across contract, procurement, and construction departments, BCWP and ACWP become incomparable. If the component manufacturer does not participate in detailed design, standardization outcomes are also difficult to translate into production savings. Measurement units, work-package codes, component codes, and data cut-off dates should therefore be standardized before warning thresholds are established.

The findings have four limitations. First, the expert sample comprises only 13 participants, and Table 2 reflects subjective judgments in this case rather than fixed weights for other regions. Second, reductions in production, transportation, and direct installation labor costs are scenario estimates, and clash-related expenditure is a register-based estimate; no concurrent comparison project of the same type was available. Third, the anonymized data did not retain complete breakdowns of chargeable floor area, taxes and fees, or relative formwork costs, limiting external verification. Fourth, the earned value series covers only weeks 2-16, and the alternative-switching date was not recorded to the day; the data therefore cannot identify the independent contribution of a single measure or its full-project effect. Future research should expand the project sample and apply quasi-experimental or hierarchical models.

5.3. Implementation Path for Engineering Projects

Comparable projects can deploy the approach at five decision points. After scheme design, expert ratings identify priority factors. At the start of detailed design, component codes, model versions, and measurement rules are standardized. After construction begins, initial earned value data locate abnormal work packages. Value evaluations are then performed for formwork, lifting, or transportation alternatives that trigger review. Finally, cumulative and period CV, SV, CPI, and SPI are calculated at fixed intervals. These five points generate an expert-rating table, clash-closure list, variance register, alternative-evaluation table, and review record, respectively, preventing the methods from remaining a conceptual list.

The project manager sets warning thresholds and allocates cross-departmental resources. The design and technical department maintains models and closes clashes; the contract and cost department maintains the budget basis; the materials and equipment department records component deliveries and actual expenditure; and the construction department confirms completed quantities. Once responsibilities and data objects are defined together, design-stage savings can be identified in production and construction accounts, and construction variances can inform the next component batch and subsequent alternatives.

6. CONCLUSION

(1) On the project's consistent chargeable-floor-area basis and under the 2022 target-cost estimate, the prefabricated scheme had a unit cost of CNY 2,242/m², CNY 762/m² higher than the cast-in-place scheme. The difference mainly arose from PC component-related items, while costs for cast-in-place reinforced concrete, floors and ground finishes, plastering, electrical works, and water supply and drainage decreased, indicating a cross-stage shift in the cost structure. This unit-cost basis is not used to infer the total contract value.

(2) Among the ratings of 20 factors by 13 experts, design changes, construction methods and technologies, interdisciplinary coordination, and number of formwork reuse cycles had the highest mean scores, at 4.62, 4.46, 4.23, and 4.23, respectively. The key factors span the design, production, transportation, and construction chain. The high ratings of design changes and interdisciplinary coordination support moving some control points forward to detailed design.

(3) BIM-based standardization reduced the number of component types from 69 to 44. Under consistent scenario assumptions, production expenditure, transportation expenditure, and direct installation labor cost decreased by approximately 12%, 15%, and 33%, respectively. All 136 clashes were closed before fabrication, and the register-based estimate of avoided change-related expenditure was approximately CNY 45,000. These figures are stage-specific estimates of the standardized alternative and should not be combined as an overall project cost reduction.

(4) The value engineering comparison produced a value coefficient of 1.3429 for the aluminum-formwork alternative, and the ranking remained unchanged when individual functional weights were

varied by ±10%. In the cumulative earned value series, CV and SV both became positive in week 12, while CPI and SPI reached 1.0438 and 1.0277 in week 16. The results indicate the value of coordinating alternative comparison, site organization, and periodic feedback. However, a single case cannot identify the independent causal effect of any individual measure; application elsewhere requires re-estimation of functional weights, cost boundaries, and warning thresholds.

REFERENCES

[1] Vasishta, T., Mehany, M. H. M., & Killingsworth, J. (2023). Comparative life cycle assessment (LCA) and life cycle cost analysis (LCCA) of precast and cast-in-place buildings in the United States. Journal of Building Engineering, 67, 105921. https://doi.org/10.1016/j.jobe.2023.105921.

[2] Liu, C., Zeng, H., & Cao, J. (2024). Evolution of project-based collaborative networks for implementing prefabricated construction technology: Case study in Shanghai. Buildings, 14(4), 925. https://doi.org/ 10. 3390/ buildings14040925.

[3] Dou, Y., Fu, X., & Li, T. (2025). Knowledge integration and analysis of technological innovation in prefabricated construction. Buildings, 15(2), 240. https://doi.org/10.3390/buildings15020240.

[4] Tatari, A. (2023). Simulating cost risks for prefabricated construction in developing countries using Bayesian networks. Journal of Construction Engineering and Management, 149(6), 04023037. https://doi.org/10. 1061/ JCEMD4. COENG-13259.

[5] Naranje, V., & Swarnalatha, R. (2019). Design of tracking system for prefabricated building components using RFID technology and CAD model. Procedia Manufacturing, 32, 928-935. https://doi.org/10.1016/j.promfg.2019.02.305.

[6] Cui, T. (2021). Research on construction cost control of prefabricated buildings based on BIM technology [Doctoral dissertation]. Liaoning University of Technology. (in Chinese).

[7] Liu, Z. A. (2023). Research on construction cost control of prefabricated concrete buildings based on BIM [Doctoral dissertation]. Beijing Jiaotong University. (in Chinese).

[8] Zhu, M., Zhang, S. J., Sun, J., & et al. (2019). Research on cost control of prefabricated concrete buildings based on BIM technology. Value Engineering, 38(30), 268-270. (in Chinese).

[9] Zhang, Y. D., Liu, Y. J., & Ji, F. J. (2023). Application of BIM technology in cost control of prefabricated buildings. Journal of Hebei University of Architecture, 41(1), 192-195, 231. (in Chinese).

[10] Fei, J. Z. (2024). Difficulties and countermeasures in cost control of prefabricated buildings. Construction & Design for Engineering, (18), 227-229. (in Chinese).

[11] Zhao, J. J. (2024). Key points in cost control of prefabricated building projects. Real Estate World, (11), 104-106. (in Chinese).

[12] Li, H. (2024). Application of BIM technology in construction cost control of prefabricated buildings. Sichuan Cement, (9), 79-82, 151. (in Chinese).

[13] Wu, G. H. (2020). Analysis of cost-influencing factors and control measures for prefabricated buildings [Doctoral dissertation]. Guangxi University. (in Chinese).

[14] Zhang, D. W. (2024). Analysis of cost-influencing factors in prefabricated building projects. China Housing Facilities, (7), 196-198. (in Chinese).

[15] Gao, X. (2022). Analysis of key factors affecting cost control of prefabricated buildings and countermeasures [Doctoral dissertation]. Chongqing University. (in Chinese).

[16] Han, S. W. (2022). Research on whole-process cost management of prefabricated buildings based on BIM technology [Doctoral dissertation]. Zhongyuan University of Technology. (in Chinese).

[17] Qu, L. P. (2019). BIM application in prefabricated building design and construction management [Doctoral dissertation]. China University of Mining and Technology. (in Chinese).

[18] Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2016). Unified standard for building information modeling application: GB/T 51212-2016 [Standard]. China Architecture & Building Press. (in Chinese).

[19] Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2017). Standard for assessment of prefabricated buildings: GB/T 51129-2017 [Standard]. China Architecture & Building Press. (in Chinese).

[20] State Administration for Market Regulation; Standardization Administration of China. (2025). Value engineering-Part 1: General terminology: GB/T 8223.1-2025 [Standard]. Standards Press of China. (in Chinese).

[21] State Administration for Market Regulation; Standardization Administration of China. (2025). Value engineering-Part 2: General procedures: GB/T 8223.2-2025 [Standard]. Standards Press of China. (in Chinese).

[22] International Organization for Standardization. (2026). Project, programme and portfolio management: Earned value management: ISO 21508:2026 [Standard]. ISO.