

VALUE ENGINEERING FOR STRUCTURAL COST OPTIMIZATION IN HIGH-RISE RESIDENTIAL BUILDING PROJECTS

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Abstract

This study applied the concept of value engineering (VE) to the structural design of a 25-story reinforced concrete residential building in Bangkok, Thailand. The primary objective was to reduce construction costs while maintaining structural safety, serviceability, and overall performance. The VE process focused on major structural components. This review was supported by an updated soil investigation and refined structural modeling, with the results verified against applicable ACI, AISC, ASCE, and local Bangkok regulations. Structural analysis was performed using ETABS for the superstructure, with PLAXIS used to evaluate foundation behavior and soil-structure interaction. The VE study compared the original bidding with the revised design. Several modifications were introduced, including reorganization of the pile groups, revisions to pile cap geometry, foundation level adjustments, standardized column dimensions, and the removal of unnecessary link bars in the shear walls. These changes resulted in measurable cost reductions across multiple elements: columns (23.25%, THB 11,816,969), foundations (29.57%, THB 5,806,858), core walls (13.36%, THB 5,242,750), and piles (10.68%, THB 4,249,119). Subsequent performance checks confirmed that the revised structure satisfied displacement, deflection, and acceleration limits, ensuring acceptable occupant comfort and structural stability. The VE implementation achieved total savings of THB 27.11 million, an 18.14% reduction from the original cost. The final savings were below the initial VE target with additional reductions identified through material reuse and improvements in construction methods. The findings demonstrated that VE is an effective and practical approach for cost optimization in high-rise residential projects without compromising safety or design intent.

Keywords: Cost Reduction; High-Rise Construction; Structural Optimization; Value Engineering

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Introduction

The volatility of the global economy, together with ongoing fluctuations in material prices and construction-related expenditures, has imposed increasing constraints on the efficient utilization of resources in the construction industry (Burke, Hsiang, & Miguel, 2024; Casey, Fried, & Gibson, 2024). Rising production costs and uncertainties in global supply chains have slowed development activities across various sectors and compelled project owners to adopt cost-reduction strategies to maintain financial feasibility (Musarat *et al.*, 2021; Dwivedi, 2025). Value engineering (VE) serves as a systematic and collaborative approach to achieve cost reductions by evaluating alternative design solutions while ensuring that quality, reliability, and structural performance remain uncompromised (Miladi Rad & Aminoroayaie Yamini, 2021; Chen *et al.*, 2022; Goel, 2025). To respond to these challenges, this study applied VE principles to enhance the efficiency of structural engineering works and reduce the costs of key structural components, including piles, foundations, columns, shear walls, elevator cores, and staircases. A 25-story building located in Bangkok, Thailand, was used as a case study, as shown in Figure 1. The existing construction design delivered to the project owner was assumed to be complete and accurate. During the VE process, it is essential to ensure that the structural modifications maintain functionality consistent with the intentions of the original architectural, structural, and building services designs, and all modifications must comply with the standards specified by the original designer.

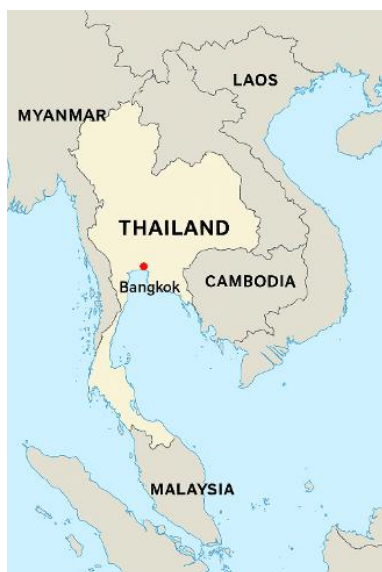


Figure 1. Construction site located in Bangkok, Thailand

Materials and Methods

Design and Project Conditions

The residential high-rise construction project comprised a 25-story building, excluding the rooftop and machine rooms, with a total height of 107.50 m, 33.22 meters in width, and 70.24 meters in length. The parking area was designed as a stacked parking system with seven levels on each side, each level having a floor-to-floor height of 2.80 meters. The residential floors had a typical floor height of 4.00 meters, and the column grid spacing was 7.80×12.41 meters. The underground water tank system extended 5.40 - 6.10 meters below the first-floor level, depending on the floor elevation. The tank cover served as a platform for MEP (mechanical, electrical, and plumbing) services and also as an access point for maintenance.

The project had a total gross floor area (GFA) of 56,100 m², including all residential floors, parking levels, service areas, and ancillary spaces. This area provided the basis for evaluating the structural system and supported the contextual relevance of the VE modifications implemented in this study.

The structural system comprised reinforced concrete, with post-tensioned slabs 0.30 meters thick and column heads (drop panels) 0.55 meters thick. The columns and walls of the main stairs, fire escape stairs, and elevator cores resisted wind and seismic loads as part of the building frame system. The foundation system comprised isolated and combined footings, supported by bored piles (wet process), with a length of 61.00 meters. The design loads are presented in Table 1.

Table 1. Design Loads

Area/Usage	Load Type	Load (ksc)
General parking area	SDL	50
General parking area	LL	50
General residential area	SDL	350
General residential area	LL	300
Machine room	SDL	500
Machine room	LL	800
Green area	SDL	500

*Bangkok Metropolitan Administration (BMA) Design Code for Building Construction

The applicable standards governing building design and evaluation include steel reinforcement properties (SD40, SD50, SR24), defined according to the mechanical requirements specified in Thai Industrial Standard TIS 24-2548. The structural steel design followed the specification for structural steel buildings (American Institute of Steel Construction [AISC], 2005, 2016), the reinforced

concrete design followed the building code requirements for structural concrete and commentary (American Concrete Institute [ACI], 2014), and the load determination followed the minimum design loads for buildings and other structures (American Society of Civil Engineers [ASCE], 2005). The structural design and VE evaluation also adhered to the relevant regulations issued by the Bangkok Metropolitan Administration (BMA). These include the BMA Ordinance on Building Control, which governs allowable building heights, structural safety requirements, fire protection provisions, and construction practices within Bangkok's jurisdiction. The project also complied with the Bangkok City Plan (Comprehensive Plan), which specifies land-use zoning, building envelope restrictions, site coverage, and required setbacks for developments located in designated urban zones. For wind load considerations, a lateral load evaluation was performed in accordance with ASCE 7-05 (ASCE,

2005), while local wind conditions were verified against the Thai Wind Code TIS 1229 to ensure that wind speed assumptions remained consistent with Bangkok's regional wind characteristics. These local regulations collectively established the governing framework for safety, zoning compliance, and structural performance within Bangkok and were applied to validate both the original and VE-optimized designs. The concrete properties and reinforcement steel used for the design are shown in Tables 2 and 3.

The VE process relied on finite-element analysis using software tools selected according to the structural function of each component. PLAXIS 2D/3D was employed to evaluate the bored pile system, pile-soil interaction, and foundation behavior under vertical and lateral loading. SAFE was used to verify the behavior of the post-tensioned slabs and assess the changes in foundation elevations and pile cap geometry. The analysis of the superstructure including columns, shear walls, lift cores, and stair walls was performed using ETABS, which provided global structural response parameters such as story drift, interstory deflection, and rooftop acceleration. For steel components and miscellaneous structural elements, SAP2000 was utilized to verify member capacity and ensure compliance with design code requirements. This software framework formed the analytical basis for validating each VE modification before the cost comparison.

Value Engineering Concept

After obtaining the necessary information and clarifying the project goals from the value engineering outcomes, the next step identified potential structural modifications. At this stage, the contractor and the structural engineer act as the core team to generate viable ideas. Problem-solving principles were applied to develop and categorize the proposed alternatives based on their types, potential impacts, and methods of implementation, with the resulting ideas summarized in Table 4.

In this study, value engineering was systematically structured into four sequential phases to ensure a comprehensive evaluation and optimization of the structural design. Each phase served a distinct purpose in gathering information, developing feasible alternatives, fostering creative solutions, and analyzing the outcomes. The flowchart below (Figure 2) illustrates the process, highlighting the key activities and objectives within each phase.

Table 2. Concrete Properties for the Design

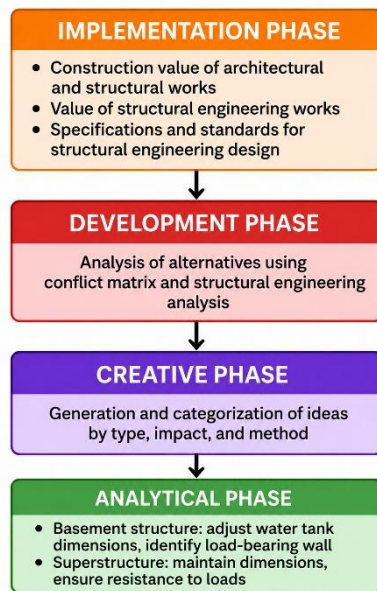
Pile (Cylinder 28 days)	Concrete Strength, f'_c (ksc)
Foundation (Cylinder 28 days)	320
Underground slab (Cylinder 28 days)	320
Post-tensioned slab (Cylinder 28 days)	320
Columns (28 days)	320
shear walls (Cylinder 28 days)	550
First floor slab (Cylinder 28 days)	450
Underground water tank wall and cover (Cylinder 28 days)	320
Design Criteria Document issued by the original structural engineering consultant (2024).	

Table 3. Reinforcement Steel for the Design

Element/Usage	Steel Type and Size	Yield Strength, f_y (ksc)
Pile longitudinal bars	SD40: DB20, DB25	4000
Foundation, wall, column, underground slab, first floor, post-tensioned slab, and underground tank wall	SD50: DB25, DB28, DB32	5000
	SD40: DB10, DB12, DB16	4000
	SR24: RB6, RB9	2400

Table 4. Value Engineering Ideas Categorized by Type of Structural Member

VE Items	Modification	Impact of Performance	Software Used
Bored Pile	Regroup piles / reduce quantities	Reduced pile count while maintaining axial & lateral capacity	PLAXIS
Foundation	Adjust pile cap thickness / foundation elevation	Reduced volume; verified punching shear & flexural capacity	SAFE
Column	Standardize column sizes	Reduced formwork & reinforcement variation; drift satisfied	ETABS
Shear Wall	Remove unnecessary link bars	Simplified detailing; shear & wall flexure adequate	ETABS
Bored Pile	Regroup piles / reduce quantities	Reduced pile count while maintaining axial & lateral capacity	PLAXIS

**Figure 2. Framework of the Value Engineering Methodology**

Design Criteria

Criterion 1: Relative Displacement of the Building. The structural analysis showed that the maximum relative displacement of the building at its full height was less than the allowable limit of 8 cm. The displacement criteria consider the functionality of the building as well as potential damage to the primary and secondary structural elements. Additional considerations include creep, shrinkage, and temperature-induced effects. The calculation of the lateral drift for slender buildings accounts for the effect of vertical loads acting on a laterally displaced structure, known as the P-Delta effect. The drift at the top of the building, under combined vertical and lateral loads, must not exceed 1/500 of the total building height.

Criterion 2: Lateral Deflection. The building must be designed in such a way that lateral deflection due to wind and seismic loads does not exceed the specified limits. The design considers the usability of the building and potential damage to primary and secondary structural components, as well as the effects of creeping, shrinkage, and temperature changes. Similar to Criterion 1, the calculation of lateral deflection in slender buildings must include the P-Delta effect, ensuring that the maximum drift at the top of the building, under combined vertical and lateral loads, does not exceed 1/500 of the building height.

Criterion 3: Acceleration at the Top of the Building. The building's design must limit vibrations to prevent discomfort or dizziness of the occupants. The severity of building vibrations, which affects occupant comfort, is measured as the maximum horizontal acceleration at the top of the building. For residential buildings, the maximum horizontal acceleration must not exceed 0.15 m/s², and for commercial buildings, it must not exceed 0.24 m/s². From the structural model analysis, the maximum lateral displacement at the top of the building under lateral loads can be calculated using appropriate structural analysis techniques. The preliminary design for buildings with uniformly distributed mass and a linear fundamental mode of vibration must employ these criteria.

Results and Discussion

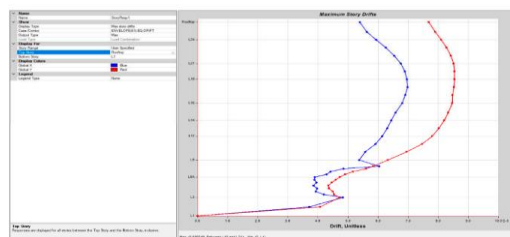
Structural Load Conditions

Structural load conditions can be categorized into two components as vertical loads and lateral loads. The vertical loads follow the original design specifications. Value engineering ensures that the structural components carrying vertical loads

possess sufficient capacity to support the building loads specified in the original design. This creates opportunities for the value engineering designer to adjust the compressive strength of the concrete as appropriate. A preliminary estimation suggested that the quantity of reinforcement steel could be reduced by 30%. The lateral loads at the top of the building must comply with the specified design requirement limits.

This section should contain “Results” and the interpretation of the results in relation to existing knowledge.

Requirement 1: Relative Displacement of the Building. The analysis results determined that the maximum relative displacement was at the 20th floor, calculated using the 4 meter height of the 19th floor, as shown in Figure 3.

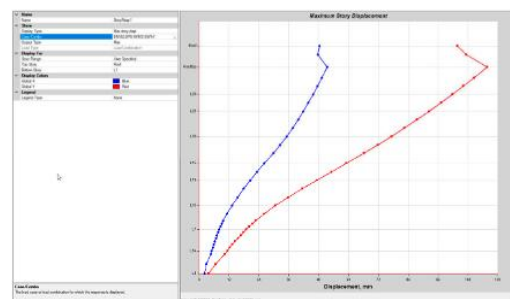


Max. Drift (0.0085mm., L19-L21) Min. Drift (0mm., L1)

Figure 3. Maximum relative displacement of the building

Therefore, the maximum relative displacement at the 19th floor was $0.008549 \times 4.00 = 3.42$ cm, and the maximum relative displacement at the 21st floor was $0.020 \times 4.00 = 8.00$ cm.

Requirement 2: Lateral Deflection. The analysis results of the structural model indicated that the maximum lateral deflection occurred at the rooftop height of 108.40 meters, as shown in Figure 4.



Max. Drift (115.756 mm., Rooftop) Min. Drift (2.19 mm., L1)

Figure 4. Maximum relative displacement of the building

The maximum observed lateral deflection at the rooftop was 115.70 mm or 11.60 cm, and the allowable maximum lateral deflection was $108.40/500 = 0.217$ m or 21.70 cm.

Requirement 3: The Rooftop. The building model was evaluated to ensure that the vibrations at the top of the building would not cause the occupants to experience any discomfort or dizziness. The severity of the building's vibrations has a direct impact on user comfort.

The structural model analysis indicated that the maximum lateral deflection was at the rooftop height of 108.40 meters. The maximum horizontal acceleration at the rooftop in the X-axis direction was 0.0123 m/s^2 , with 0.0185 m/s^2 in the Y-axis direction. Both these values were within the allowable limit of 0.15 m/s^2 , ensuring that the building's vibrations would not cause the occupants to experience any discomfort or dizziness.

Bored Pile Design

Original issue

The original design incorporated an excessive number of bored piles due to a conservative estimation of vertical and lateral loads. The pile arrangement also exhibited redundancy in certain zones, resulting in unnecessarily high material quantities and prolonged construction time.

VE alternative

The piles were reorganized to optimize load sharing among adjacent pile groups and the total pile quantity was reduced. The revised layout maintained adequate tributary areas while addressing inefficiencies in the original grouping.

Structural check and analysis

The modified pile layout and reduced pile quantities were evaluated using PLAXIS to assess long-term settlement behavior, axial pile capacities, and soil-structure interaction. Settlement predictions were compared against serviceability limits prescribed in the BMA regulations safety and code compliance.

The revised pile system satisfied the required Bangkok regulatory safety factors for axial and lateral performance. Long-term settlement and bearing pressure remained within acceptable limits, confirming that the reduction in pile quantity did not compromise performance.

Cost impact

The optimized pile design reduced the total cost from THB 39,785,760 to THB 35,536,641, with significant savings from reduced material quantities.

Construction impact

Reducing the number of piles required less drilling, resulting in a reduced construction schedule and fewer equipment mobilizations.

Details of the grouping of the bored piles are shown in Table 5. Pile length reductions were validated using PLAXIS by assessing axial capacity, lateral stiffness, and settlement under service and ultimate loading conditions. The modified pile configurations met the required safety factors and displacement limits specified by the Bangkok design code.

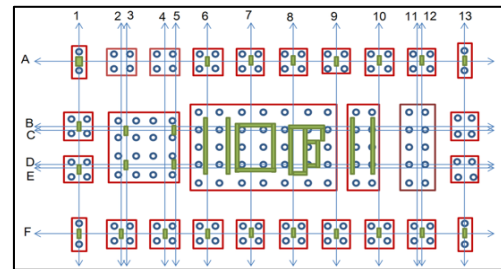
Table 5. Comparison between Bored Pile Works in Design Bid and Value Engineering Approaches

Item	PILE Dia.1.00 m	PILE Dia.1.20 m	PILE Dia.1.35 m
Bored Pile Works in the Design Bid			
Circular Pile	1.00 ×	1.20 ×	1.35 ×
Longitudinal	56.00 m	56.00 m	56.00 m
Reinforcement	12-DB32, SD50	20-DB32, SD50	25-DB32, SD50
Spiral Tie	RB9@200 mm, SR24	RB9@200 mm, SR24	RB9@200 mm, SR24
Concrete (Cylinder Strength)	Fc' = 280 ksc	Fc' = 280 ksc	Fc' = 280 ksc
Bored Pile Works in Value Engineering			
Circular Pile	PILE Dia. 0.80 m	PILE Dia. 1.20 m	-
Longitudinal	20-	25-	-
Reinforcement	DB28,SD50	DB28,SD50	-
Spiral Tie	RB9@200 mm SR24	RB9@200 mm SR24	-
Concrete (Cylinder Strength)	Fc' =280 ksc.	Fc' =280 ksc.	-

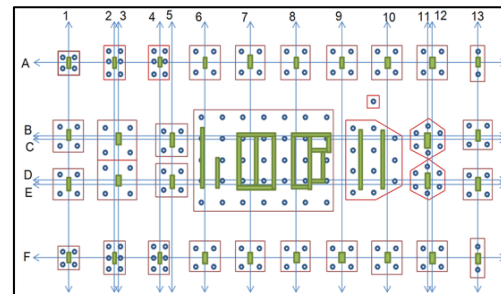
A comparative review of the original design and the revised VE design indicated significant changes in the foundation layout, primarily resulting from the optimization of bored pile diameters and capacities. In the original bidding design, the pile groups were arranged based on the initial structural analysis and previously available geotechnical data, leading to larger numbers of piles in certain locations to meet load requirements, as shown in Figure 5.

The VE-modified design used updated soil investigation results and recalculated structural reactions to determine the optimal pile size and grouping. Results suggested that certain pile groups could be substituted with piles of larger diameter and higher load-bearing capacity, effectively reducing the total number of piles required without compromising structural safety. These key modifications led to a reduction in pile quantities in several grid locations, with the number of piles per pile cap reduced due to the adoption of larger

diameter bored piles capable of carrying higher vertical and lateral loads.



(a)



(b)

Figure 5. Comparison of Bored Pile Foundation Arrangements between Original Design Bid Scheme (A) and Value Engineering (B)

Adjustment of pile cap geometry

The pile caps were redesigned to accommodate the new pile arrangement, resulting in smaller cap dimensions in certain locations and modified reinforcement to suit the revised load paths. Optimized load distribution

The redistribution of the pile groups ensured that the axial and lateral loads from the superstructure were more efficiently transferred to the foundations, minimizing differential settlement risks.

Improved cost efficiency

The VE approach reduced the total drilling length, concrete volume, and reinforcement usage while maintaining compliance with safety and performance standards, resulting in significant cost savings. The redesign of the VE-based foundation streamlined the bored pile system by leveraging updated site data, refined structural modeling, and modern construction practices to achieve a balance between safety, constructability, and cost-effectiveness.

The feasibility of the revised pile grouping and reduced pile quantities was verified using PLAXIS, ensuring that axial capacity, settlement, and lateral pile-soil behavior remained within allowable limits.

Foundation Design

Original issue

Several pile caps exhibited unnecessary depth, largely due to an earlier arrangement of the underground water tank that imposed additional artificial constraints. After revising the tank's position, the pile cap depths no longer aligned with the actual structural requirements, resulting in excessive concrete volume and self-weight.

The VE modification involved adjusting the depth of the affected pile caps, which reduced the self-weight contribution of the foundation. The structural forces across the affected regions were recalculated to ensure compatibility with the superstructure.

Structural checks and analysis

The foundation performance was reassessed using SAFE to verify punching shear, flexural capacity, soil bearing pressure, and slab stiffness. The adjustments were validated according to standard foundation design procedures, ensuring that all structural checks met the required thresholds for safety and serviceability.

Safety and code compliance

All the revised foundation components remained compliant with Bangkok building regulations, with punching shear and bearing capacity satisfying minimum requirements.

Cost impact

The foundation works cost decreased from THB 19,634,896 to THB 13,828,038, driven primarily by reductions in concrete volume and reinforcement.

Construction impact

The shallower pile caps reduced the excavation depth and soil protection requirements, while simplifying formwork installation and improving construction efficiency.

These modifications under the value engineering approach achieved cost reductions, improved constructability, and optimized resource utilization while maintaining compliance with safety and performance standards, as shown in Figure 6.

The modifications to the pile-cap geometry and foundation elevations were analyzed using SAFE, with results confirming adequate punching shear resistance, flexural capacity, and serviceability performance.

Column Design

The original issue column design layouts showed varying sizes and significant reinforcement congestion, resulting in inefficient use of materials, increased formwork variation, and difficulties during construction.

The VE alternative column dimensions were standardized across multiple floors by regrouping similar load conditions and adjusting reinforcement to meet minimum code requirements, thereby reducing unnecessary variation and over-reinforcement. Structural check and analysis.

Using ETABS, the VE-adjusted columns were checked for axial load ratios, moment capacity, and overall stability. Story drift was one of the key criteria that was evaluated. The calculated maximum allowable drift at rooftop was 21.70 cm, while the ETABS analysis showed an actual drift of 11.60 cm, demonstrating clear compliance.

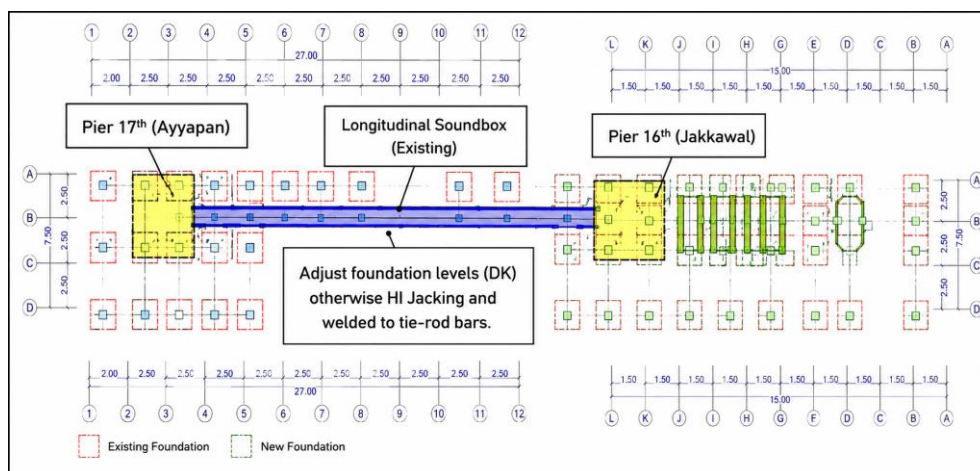


Figure 6. Modification of Foundation Grouping

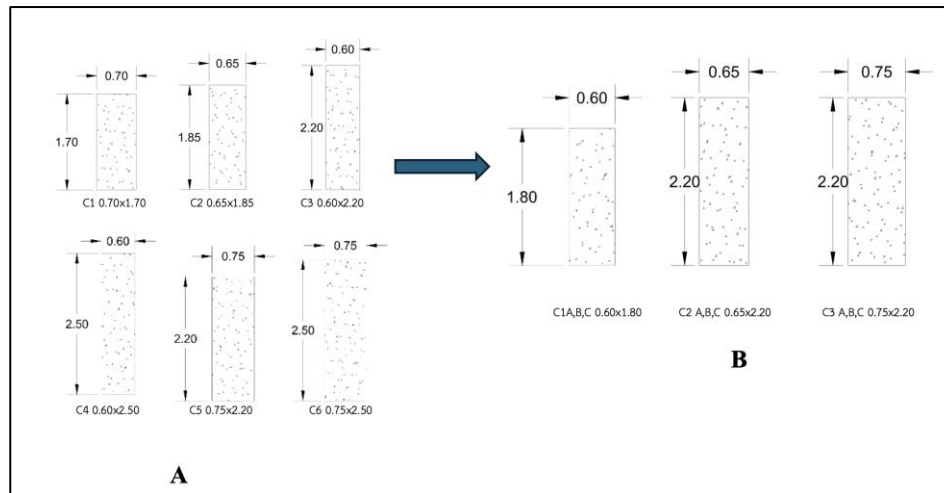


Figure 7. Column sizes for Bidding Design (A) and Value Engineering (B)

Safety and code compliance

All the columns achieved the required strength and serviceability limits under Bangkok regulations and seismic criteria. Column work costs were reduced from THB 50,825,674 to THB 39,008,705, attributable to lower reinforcement usage and reduced formwork variety.

Construction Impact

The standardized column dimensions significantly decreased the number of formwork types required, simplifying construction workflow and reducing fabrication and installation time.

In the value-engineering design, column sizes were standardized within each group to improve constructability, reduce formwork variation, and optimize material usage, while meeting the structural capacity requirements based on the interaction diagram analysis, as shown in Figure 7.

The key modifications included:

1. C1 Group (C1A, B, C) – Cross-section adjusted to 0.60 m × 1.80 m, replacing multiple original sizes.
2. C2 Group (A, B, C) – Cross-section standardized at 0.65 m × 2.20 m.
3. C3 Group (A, B, C) – Cross-section standardized at 0.75 m × 2.20 m.

These changes reduced the number of unique column dimensions, thereby simplifying fabrication, improving construction efficiency, and reducing costs, while ensuring structural performance following the updated load analysis. The reduction details are shown in Table 6. The structural performance of the revised column sections and the modified shear wall and core wall configurations was evaluated in ETABS, with all

VE alternatives satisfying Bangkok design code limits for drift, deflection, and stability.

Table 6. Comparison between Column Works in Design Bid and Value Engineering Approaches

Design Type	Column Group	Dimensions (m)	(fc')
Bidding Design	C1	0.70 × 1.70	450 ksc
	C2	0.65 × 1.85	450 ksc
	C3	0.60 × 2.20	450 ksc
Value Engineering (VE) Design	(C1A, B, C)	0.60 × 1.80	550 ksc
	C2(A, B, C)	0.65 × 2.20	550 ksc
	C3(A, B, C)	0.75 × 2.20	550 ksc

Shear Wall Design for Lift and Staircase

Original Issue

The original design incorporated overly thick wall sections, excessive reinforcement, and redundant link bars, particularly in the lift and stair cores. These details increased material quantities and caused heavy reinforcement congestion. The VE solution removed unnecessary link bars and optimized the reinforcement distribution while maintaining wall thicknesses consistent with actual structural demands.

Structural Check and Analysis

Structural verification in ETABS confirmed that the revised wall configurations satisfied shear capacity, flexural behavior, wall drift requirements, and coupling beam performance. Internal forces were compared to code-allowed capacities to ensure adequate margins of safety.

All the modified wall elements complied with Bangkok regulations and the seismic requirements set forth in DPT 1301/1302-61.

Cost impact wall system costs decreased from THB 39,242,137 to THB 33,999,387, reflecting reductions in reinforcement mass and labor.

Construction Impact

Reduced reinforcement congestion shortened preparation time and improved constructability, particularly in the core wall zones.

The revised design ensured that these structural components retained their capacity to resist both vertical and lateral loads, in full compliance with the applicable design requirements, while maintaining overall structural stability, as established in the value engineering structural model (Figure 8).

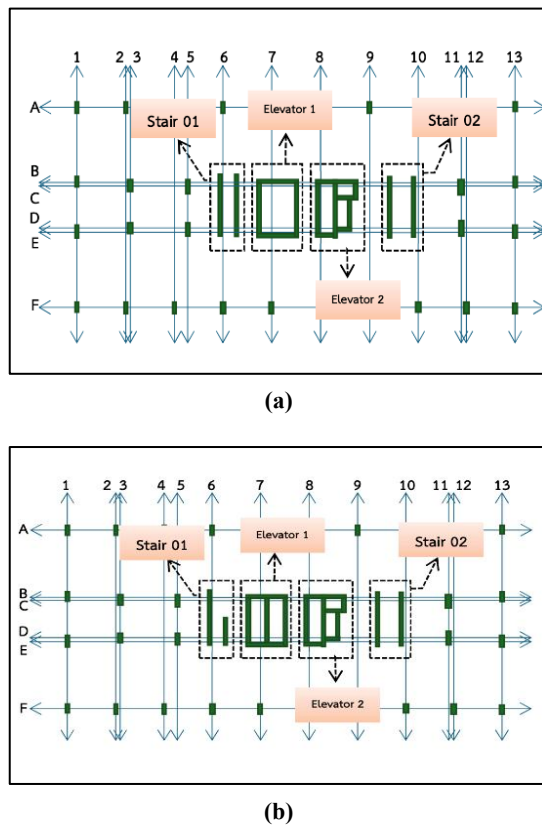


Figure 8. Comparison between Bidding Design (A) and Value Engineering Design (B) of Shear Wall Layout for Lifts and Staircases

Discussion

The VE adjustments implemented in this project were mainly concentrated in areas where the original design appeared more conservative than necessary. After completing the structural checks, most of the modifications had only minor influence on the building's overall structural behavior, while offering measurable reductions in material quantities and construction complexity. This outcome concurred with observations in previous

VE research. Alhumaid *et al.* (2024) noted that many projects contain built-in conservatism that can be safely reduced without altering the intended behavior of the structure, while Rachwan *et al.* (2016) identified foundations and vertical elements as the components most likely to yield meaningful savings, as found in this study.

Reducing the number of piles initially seemed risky, but the PLAXIS analyses showed that the settlement response of the VE model remained almost identical to the original design. Long-term settlement values also remained well within the limits specified by Bangkok regulations, and no abnormal stress concentrations or indications of potential failure were observed. These results suggested that the original pile layout incorporated substantial reserve capacity. The revised configuration met *all* the required safety factors, indicating that the reduction in pile quantities did not compromise structural performance.

The modifications to the pile caps were also supported by the analysis. The depth of several caps was governed by a previous layout of the water tank system. After this layout was adjusted, the caps were re-evaluated using SAFE. Punching shear checks, flexural capacity, and bearing pressures remained within the allowable limits. The foundation system behaved similarly before and after modification, demonstrating that the initial dimensions were more conservative than necessary. The VE revisions brought the foundation components closer to the required capacity without reducing safety.

In the column system, the primary issue was the large number of column sizes and the relatively heavy reinforcement. After standardizing the column dimensions and recalculating reinforcement amounts, ETABS results confirmed that the axial load ratios remained acceptable. The lateral behavior of the building was also largely unchanged. Rooftop drift values in both the original and VE models were well below the limits specified in DPT 1301/1302-61, indicating that global stiffness was effectively maintained. From a construction standpoint, the reduction in the number of column sizes simplified formwork operations and reduced the potential for errors, resulting in practical benefits beyond material savings.

The VE modifications to the shear walls and core primarily involved removing link bars and reducing steel reinforcement in locations where it did not contribute significantly to behavior. ETABS checks confirmed that shear and flexural capacity remained adequate and that coupling beam performance was stable. Drift results showed no significant differences between the two design versions. Despite the reduction in steel quantities, the overall lateral resisting system performed

essentially the same, reinforcing that the VE adjustments were appropriate.

The 18% structural savings achieved was higher than the ranges commonly reported in VE studies. Alhumaid *et al.* (2024) found that VE typically leads to reductions between 5 and 15%, while Rachwan *et al.* (2016) observed similar patterns across various building types. Our results concurred with these studies, and the analyses suggested that several elements in the original design contained more conservatism than required. Updating the design to reflect the revised layout information and current analytical results allowed the project to maintain safety while reducing costs across key structural components.

The results in Table 7 compare the original bidding design and the VE design. Reinforced concrete works indicated a reduction of THB 27,115,696, representing an 18.14% decrease. These savings occurred in several structural components including column work (23.25% reduction; THB 11,816,969), foundation system (29.57% reduction; THB 5,806,858), lift and stair core walls (13.36% reduction; THB 5,242,750), and pile works (10.68% reduction; THB 4,249,119).

Table 7. Comparative Cost Summary Between Bidding Design and VE-Optimized Design

Item	Bidding Design (THB)	Value Engineering Design (THB)	Difference (THB)
Reinforced Concrete Structural Works	304,858,400	277,742,704	27,115,696
Pile Works Reduction (10.68%)	39,785,760	35,536,641	4,249,119
Foundation Works Reduction (29.57%)	19,634,896	13,828,038	5,806,858
Column Works Reduction (23.25%)	50,825,674	39,008,705	11,816,969
Lift and Stair Wall Works Reduction (13.36%)	39,242,137	33,999,387	5,242,750
Reduction in Structural Construction Cost (18.14%)	149,488,467	122,372,771	27,115,696

The reduction in column costs resulted primarily from standardizing cross-sectional dimensions and adjusting reinforcement to match the revised design demands. These outcomes

demonstrated that VE significantly reduced costs while maintaining compliance with structural safety and performance requirements. The magnitude and distribution of savings also aligned with the trends documented by Alhumaid *et al.* (2024) and Rachwan *et al.* (2016), further validating the effectiveness of VE in optimizing structural systems.

The cost reduction achieved through the value engineering design was THB 27,115,696, representing an 18.14% decrease. This was below the project's target reduction of THB 34,597,986 (23.14%) by THB 7,482,290 (5.00%). However, additional cost savings could also be achieved through measures not addressed in this study, such as the reuse of formwork and other related materials. These supplemental reductions could potentially narrow the gap between the value engineering cost saving and the project's target reduction, as shown in Figure 9.

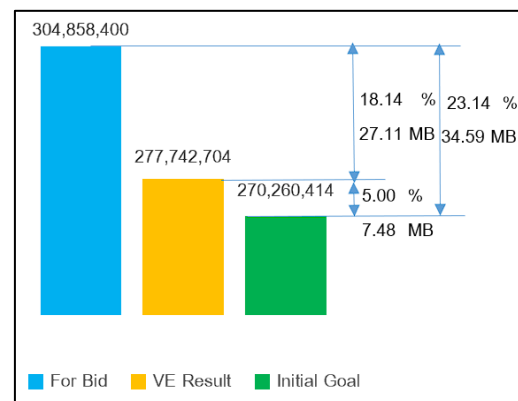


Figure 9. Comparison of Construction Costs between Bidding Design, Value Engineering Design and Project Target

Conclusions

Implementing value engineering in this project realized significant cost savings without compromising the performance of the building. Structural analysis tools were used to validate the acceptability of the VE options. PLAXIS confirmed that the decreased number of piles ensured long-term settlement compliance with Bangkok standards, while SAFE served as the foundation to modify cap depths and verify that punching shear, flexural strength, and bearing pressures stayed within safe limits. ETABS was utilized to analyze the superstructure, focusing on modifications to columns and walls where drift, axial load ratios, and the internal force distributions remained similar to the initial design. SAP2000 handled the steel-related elements, verifying that the updated parts remained

sufficiently robust under their specified loads. Combined these programs enabled the elimination of materials while guaranteeing that the structure maintained its expected performance.

The VE process resulted in a decrease of 18.14%, but this figure did not meet the original goal based on the assumption that numerous structural components exceeded the acceptable limit by 23%. After examination, part of this “excess capacity” proved essential, due to regional code mandates concerning lateral drift. Consequently, the reduction of reinforcement or member dimensions was not as extensive as initially anticipated. In some instances, the initial design was already fairly efficient after considering the modified load paths and altered foundation conditions, resulting in less potential for reduction than originally anticipated.

Aside from the structural evaluations, constructability significantly influenced the VE advantages. Using column dimensions decreased the variety of formwork required at the site, potentially accelerating the construction timeline and easing labor challenges. Comparable enhancements were also seen in the core walls, where eliminating link bars sped up reinforcement installation and reduced overcrowding. These modifications were not explicitly reflected in the analysis models, but they reduced costs by enhancing workflow efficiency and minimizing material waste. Duplicating formwork sizes on floors further strengthened the financial benefits of the VE solutions.

VE proved effective for high-rise residential structures when evaluating constructability and performance simultaneously. The ultimate design upheld drift, settlement, and strength parameters that are essential, in tall buildings subjected to wind and seismic forces. Excess material use was minimized in piles, foundations, columns, and core walls. Results demonstrated that the careful combination of structural modeling tools and practical construction adjustments can improve project value, even when the initial design appears complete. The final savings did not fully meet the original target, but VE provided a practical, structured method for refining high-rise building designs without compromising safety or overall performance.

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