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Improving Cost Efficiency of Hospital X Phase 1 Foundations using Value Engineering

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ABSTRACT

The foundation is a key structural component that requires careful design and analysis. Selecting an appropriate foundation type was essential to achieve adequate structural capacity while maintaining efficiency in cost and construction time. In the Phase 1 construction of the Hospital X main building, the initial design adopted a spun pile foundation installed using a Hydraulic Static Pile Driver (HSPD). However, field investigations identified a lens layer approximately 3 meters thick at a depth of 7 meters, which posed a significant constraint because the HSPD system was unable to penetrate this layer effectively. To overcome this limitation, an alternative solution was proposed in the form of a bored pile foundation constructed using an in-situ drilling and casting method. The alternative was evaluated using the value engineering approach to assess its feasibility in terms of performance and cost efficiency. The results indicated that the proposed design provided improved structural performance, with the load-bearing capacity increasing from 152 tons in the spun pile system to 215.14 tons in the bored pile system. In addition, the cost analysis showed a reduction from Rp 9,878,513,907 for the 600 mm spun pile foundation to Rp 8,861,663,857 for the 800 mm bored pile foundation, resulting in savings of Rp 1,016,850,050 (10.29%). These findings demonstrated that the application of value engineering enhanced both technical performance and economic efficiency in foundation design.

Keywords: *Value engineering; Foundation; Bored pile; Spun pile; Cost; Hospital building.*

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INTRODUCTION

The selection of an appropriate foundation system is a critical determinant in structural engineering, as it directly affects load transfer efficiency, structural stability, and overall project performance [1], [2]. In deep foundation projects, particularly in Indonesia where soil stratigraphy varies significantly, the choice between spun piles and bored piles becomes decisive for achieving optimal structural performance, cost efficiency, and timely project delivery [3], [4], [5].

Spun piles are *prestressed precast concrete piles* installed using Hydraulic Static Pile Drivers (HSPD). Their primary advantages include rapid installation, minimal site disturbance, and reduced vibration, making them suitable for projects in urban or sensitive environments [6],

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[7]. However, spun piles exhibit limited ductility under lateral and seismic loads, and their performance can be affected by high SPT soils or variable stratigraphy [8]. Innovations such as thin steel confinement have been proposed to improve lateral capacity and structural resilience [8].

In contrast, bored piles are *cast-in-situ deep foundations*, constructed by drilling, installing reinforcement, and pouring concrete [1], [9]. This method allows flexibility in diameter and depth, enabling adaptation to heterogeneous soil conditions and achieving higher bearing capacity through combined side friction and end bearing [2], [10]. Field and numerical studies highlight that bored pile performance is highly sensitive to empirical design methods and soil variability, necessitating careful geotechnical assessment to ensure reliability [11], [12].

Despite the theoretical advantages of both systems, practical challenges often arise due to discrepancies between design assumptions and actual soil conditions. In the Phase 1 construction of Hospital X, spun piles were initially selected for their anticipated efficiency in cost and installation time. However, soil investigations revealed a rock lens at depths of 7–10 meters with SPT values exceeding 40, exceeding the penetration capacity of HSPD equipment and preventing piles from reaching design depth [3], [4]. Pre-boring can overcome this limitation, but it increases construction cost and project duration, potentially affecting the overall project schedule [5], [10]. The building of the Hospital X project is shown in Figure 1.

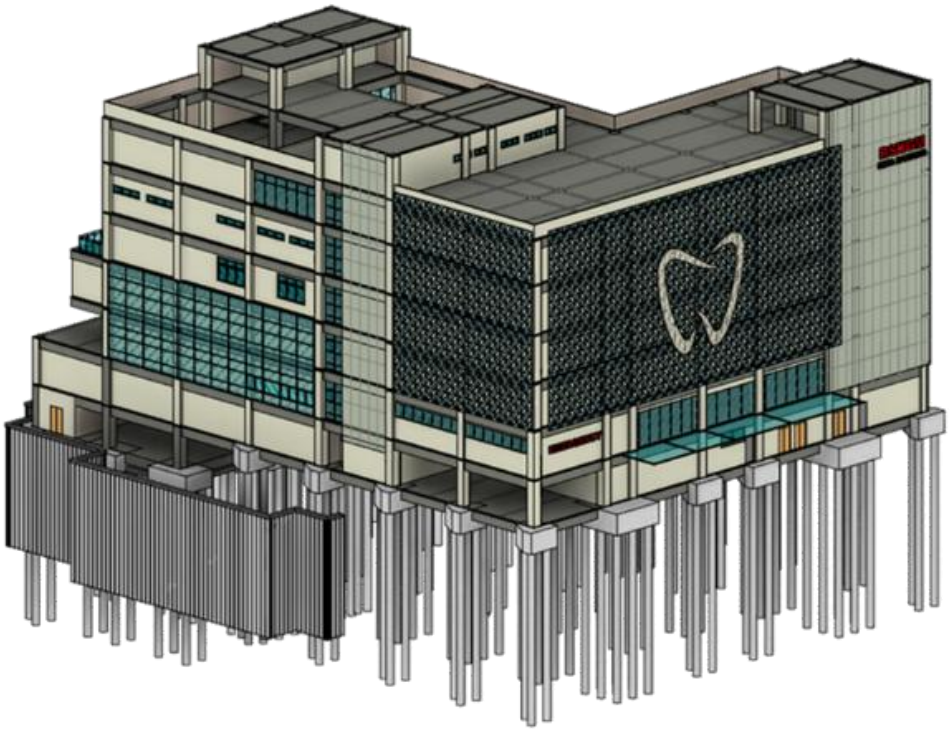


Figure 1: 3D Model of Hospital X Project

Previous studies have explored alternative foundation solutions to address similar constraints. For instance, bored piles have successfully replaced mini piles in several projects, demonstrating enhanced feasibility and reliability under complex geotechnical conditions [12], [13], [14]. Comparative analyses using Value Engineering (VE) indicate that bored piles may reduce installation costs by approximately 1.77% compared to spun piles [6], while other studies report savings up to 9.09% in infrastructure projects [7], [15]. Nevertheless, most

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research primarily focuses on cost and schedule metrics, with limited attention to functional performance, bearing behavior, and construction risks [8], [16], [17]. The general process of bored pile construction is illustrated in Figure 2.

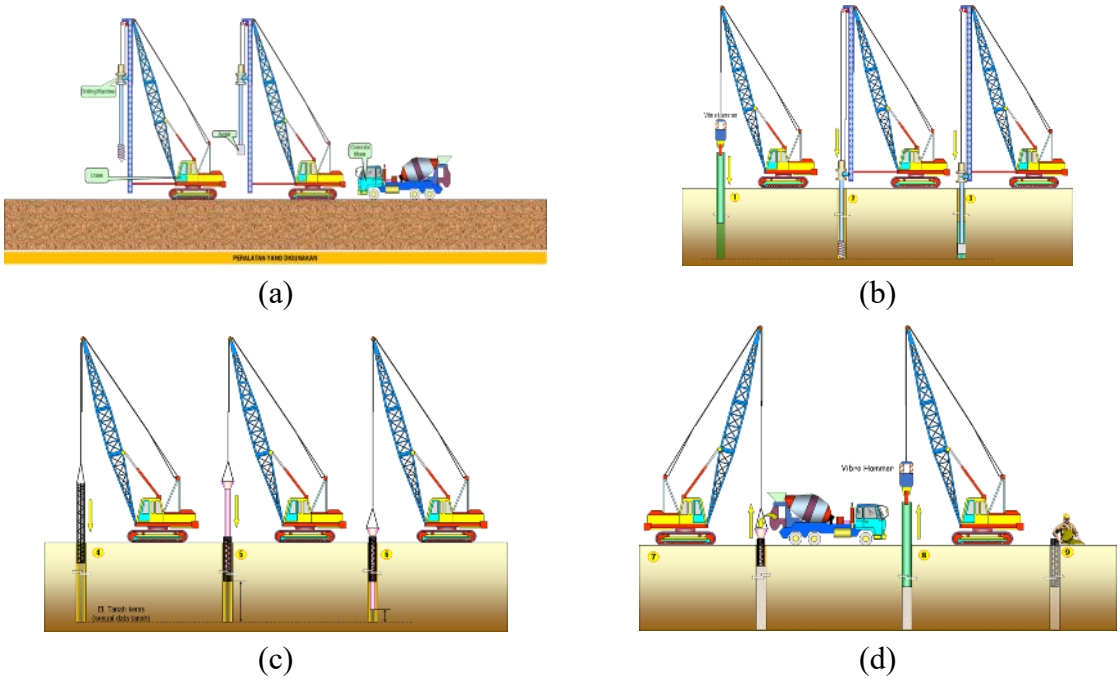


Figure 2: Bored pile foundation process illustration, (a)–(d) showing successive stages of the work

To address this knowledge gap, Value Engineering (VE) provides a structured methodology to optimize the relationship between function, cost, quality, and time, enabling more informed decision-making in foundation selection [7]. VE allows the assessment of whether bored piles can provide superior performance compared to spun piles, particularly under challenging soil environments. Furthermore, international studies emphasize probabilistic and reliability analyses as essential for evaluating deep foundation performance under uncertain soil conditions [18], [19].

This research therefore aims to:

1. Identify factors affecting cost and time efficiency in deep foundation works under complex geotechnical conditions.
2. Evaluate the application of Value Engineering in optimizing foundation system selection for the main building of Hospital X.
3. Provide evidence-based recommendations to support reliable, cost-effective, and technically justified decision-making in projects with similar soil challenges.

The expected outcomes of this study are improved understanding of deep foundation performance, enhanced guidance on foundation selection in practice, and a framework for integrating value engineering principles in geotechnically complex construction projects [2], [9], [14].

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METHOD

The main concept of the Value Engineering (VE) methodology lies in the notion of value. According to the SAVE standard (2007), value is defined as the relationship between functions and the resources required to achieve them. In general, value can be represented as follows (Equation 1):

$$\textbf{Value} = \frac{\boldsymbol{Function}}{\boldsymbol{Cost}} \quad (1)$$

In this context, functions are measured by the performance required by the client, while resources are quantified in terms of materials, labor, cost, time, and other inputs needed to fulfill the function. Dell'Isola (1982) [20] stated that the core concept of the Value Engineering (VE) methodology revolves around value, function, and cost, which can be expressed as follows (Equation 2):

$$\textbf{Value} = \frac{\boldsymbol{Function + Quality}}{\boldsymbol{Cost}} \quad (2)$$

Where:

Function : Specific tasks or work that must be performed

Quality : The requirements or expectations of the owner or user

Cost : The life cycle cost of a product or project, representing the total effort and expenditures involved in developing, producing, and applying the product

Alternative relationships can be described as follows:

Value (V) = →/↓: Cost decreases while function and quality are maintained.

Value (V) = ↑/→: Function or quality, or both, are improved while maintaining cost.

Value (V) = ↑/↓: Function or quality is improved with a reduction in cost.

Value (V) = ↑/↑: Both function and quality are increased, accompanied by higher cost.

Additional relationships are illustrated by Carlos Fallon [21] (Equation 3):

$$\textbf{Value} = \frac{\boldsymbol{Worth}}{\boldsymbol{Cost}} \quad (3)$$

Where:

Value : Defined as the most cost-effective way to achieve a set of functions that satisfy the desired and expected needs of the user.

Worth : The requirements or expectations of the owner/user.

Cost : The life cycle cost of the product or project, representing the total expenditures throughout its development, production, and application.

The Value Engineering (VE) process is referred to as a VE study, which is a sequence of activities conducted on an object (project, process, or product). This process involves defining functions, developing and evaluating ideas, and producing a VE proposal. Typically, the study is conducted in the form of a workshop [22]. The stages of a VE study are illustrated in Figure 3.

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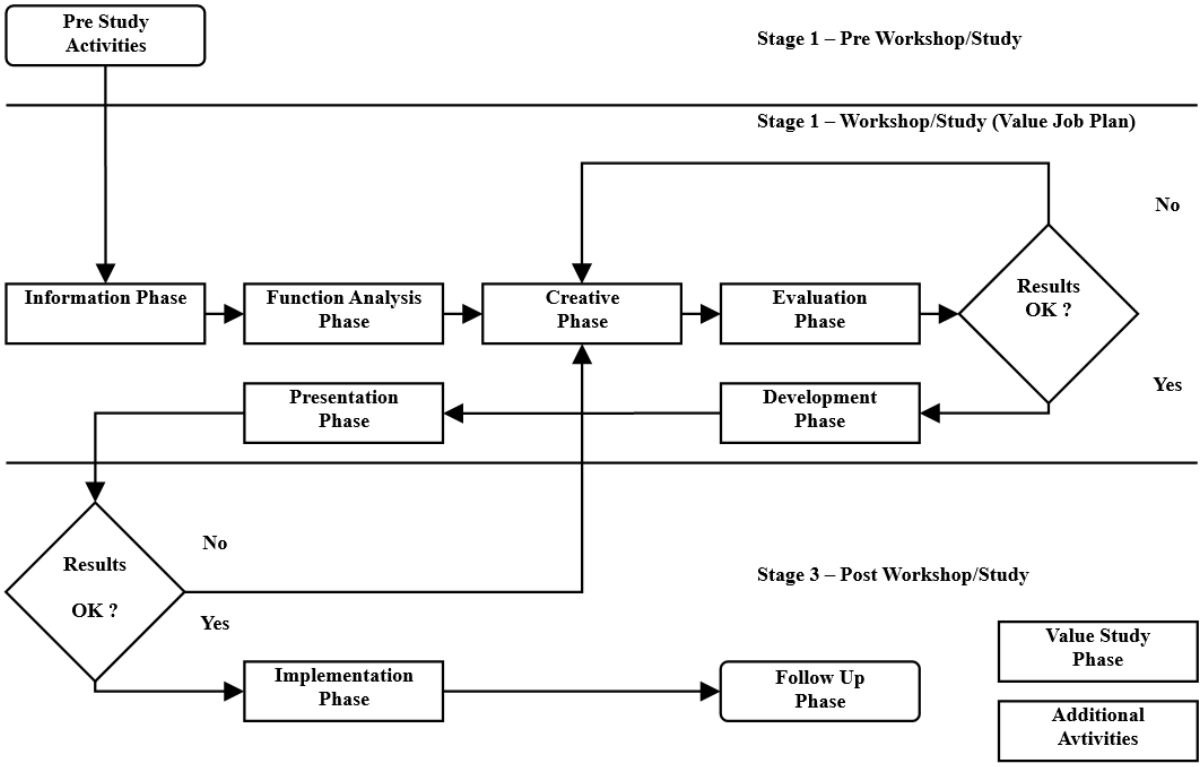


Figure 3: Value Engineering Study [23]

Pre-Workshop Activities

According to the Value Standard Body of Knowledge [23], the pre-workshop phase includes: defining the scope and objectives of the VE study, collecting project data and key documents such as drawings, specifications, and reports, identifying and prioritizing strategic issues, forming the VE team, obtaining team commitment, reviewing project costs, and gathering user or stakeholder input. Based on the collected information, the VE team develops project models and diagrams, schedules the workshop, and clarifies requirements for a successful study.

Workshop Activities

The VE workshop consists of six phases:

a) **Information Phase:** Gather detailed project information, including design, constraints, and cost projections.
b) **Function Analysis Phase:** Identify and analyze project functions to determine which have potential for value improvement.
c) **Creativity Phase:** Generate alternative ideas to achieve project functions through simplification, modification, or enhancement while maintaining functionality. Brainstorming encourages creative thinking without practical limitations.
d) **Evaluation Phase:** Narrow down ideas to those with the highest potential to improve project outcomes.
e) **Development Phase:** Further analyze selected alternatives and develop complete VE proposals.

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f) **Presentation Phase:** Present VE findings to management and stakeholders, including project identification, functional analysis, proposed design changes, cost adjustments, and total savings. This phase supports informed decision-making for strategic project goals.

Post-Workshop Activities

Post-workshop activities include implementation, ensuring agreed VE alternatives are applied, and follow-up to evaluate outcomes and enhance future VE applications. Fundamental questions addressed include What have we learned about creating or improving optimal value.

VE Tools and Techniques

Common VE tools include:

- **Quality Function Deployment (QFD):** Captures and prioritizes customer requirements throughout design and production.
- **Voice of Customer (VOC):** Directly gathers user requirements for value creation [24].
- **Benchmarking:** Compares processes and performance to competitive standards [25].
- **Tear-Down Analysis:** Breaks down project components to evaluate and improve value.
- **Pareto Analysis:** Identifies critical items contributing to the majority of costs.
- **Design for Assembly (DFA):** Simplifies and optimizes assembly to maximize value.
- **Function Analysis Tools:** Random Function Identification, FAST Diagram, Function Tree, Cost-to-Function Analysis, and Value Index for identifying functions with potential for improvement.
- **Creativity Tools:** Ground Rules, Brainstorming, Checklist, TRIZ, Delphi, and Value Matrix for generating and evaluating alternative ideas.
- **Choosing By Advantages (CBA) and Life Cycle Costing (LCC):** Used in development to select the most cost-effective design alternatives (ASTM E-1699, 2005).

RESULTS AND DISCUSSION

Results

The technical data of the spun pile foundation constitute primary data used to compare the spun pile foundation with the bored pile foundation. The detailed technical specifications of the spun pile foundation are as follows:

Foundation Type	: Spun Pile Foundation
Concrete Strength	: f'c = 52 MPa
Pile Diameter	: 600 mm
Pile Length	: 18 meters

Bearing Capacity per Pile:

Compressive Capacity	: 152 tons
Tensile Capacity	: 23 tons
Design Lateral Capacity	: 36 kN
Ultimate Lateral Capacity	: 49 kN

The project drawings are drawings used by the contractor as a guideline for carrying out the

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work. In this study, the project drawing used as the basis for calculation and analysis is the foundation layout drawing. The Spun pile foundation layout can be seen in Figure 5.

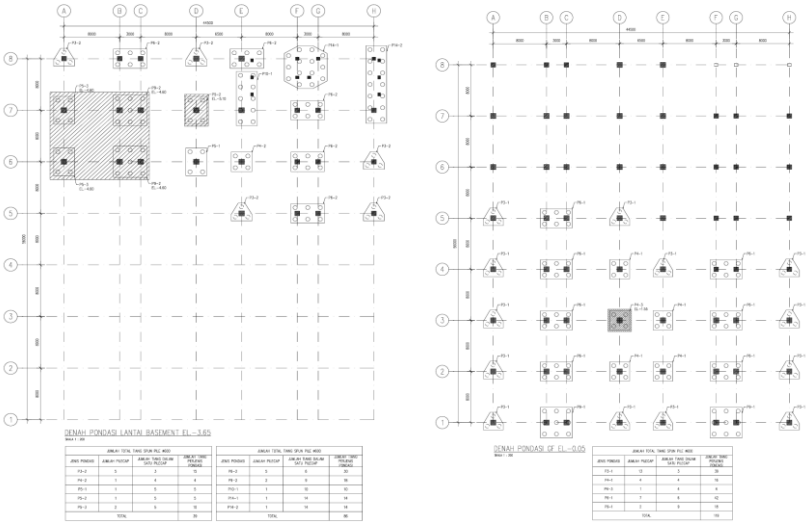


Figure 4: Detail Engineering Design Foundation Plan

The cost budget plan is a critical process in any project, serving as the foundation for preparing financing proposals and establishing the overall budget framework. In this case, the submitted cost budget plan only covers the spun pile foundation works. A detailed breakdown of the cost budget for the spun pile works is presented in Table 4.

Table 4: Spun pile foundation budget cost work plan

NO	WORK DESCRIPTION	UNIT	VOLUME	UNIT PRICE	TOTAL PRICE
	DEEP FOUNDATION AND PROTECTION WORKS				
1	Installation of 600 mm Spun Pile	m'	4,392.00	Rp 1,247,630.00	Rp 5,479,590,960.00
2	Cutting of Spun Pile Head	point	244.00	Rp 89,070.00	Rp 21,733,080.00
				TOTAL PRICE	**Rp 5,501,324,040.00**

Creative Phase

The creative phase in value engineering analysis involves generating new ideas. The proposed alternatives may take the form of reductions, simplifications, or modifications to a particular work item, while still maintaining its intended function. The alternative designs proposed in this study are presented in Table 5.

Table 5: Alternative Foundation Work

CREATIVE PHASE	
Project	Phase 1 Hospital X Project
Location	Jl. Aruna, Husein Sastranegara Subdistrict, Cicendo District, Bandung City, West Java
Work Item	Foundation Works
Function	To receive loads from the superstructure and transfer them into the ground.
Initial Design	
Spun pile foundation by using *Hydraulic Static Pile Driver* (HSPD)	
Alternative Design	
Foundation works by using Bored Pile	

The proposed ideas are subsequently used to establish the design criteria (preliminary design)

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with the following data:

Foundation Type	: Bored Pile Foundation
Bored Pile Concrete Grade	: K-450
Pile Diameter Options	: D600, D800, D1000
Planned Pile Length	: 18 meters

Planned Pile Bearing Capacity:

Compression	: 152 tons
Tension	: 23 tons
Design Lateral Capacity	: 36 kN
Ultimate Lateral Capacity	: 49 kN

Analysis Phase

The analysis phase is carried out based on the alternatives or ideas generated during the creative phase, followed by a detailed evaluation process. The advantages and disadvantages of the bored pile alternative are summarized in Table 6.

Table 6: Advantages and Disadvantages Analysis

Project	**: Construction of Hospital X Building Phase 1**
Location	: Jl. Aruna, Husein Sastranegara Subdistrict, Cicendo District, Bandung City, West Java
Work Item	: Foundation Works
Function	: To receive loads from the superstructure and transfer them into the ground
No.	**Alternative**
1	**Bored Pile Foundation**
Advantages	**Disadvantages**
The foundation can penetrate lens layers	Risk of borehole collapse in sandy soil conditions
Diameter and depth can be varied according to project requirements	Concrete quality is difficult to control due to in-situ casting
Capable of carrying high bearing capacity depending on diameter and depth	Work area may become muddy and untidy during rain or in water-bearing soil
Casting is carried out in-situ without waiting for precast curing time	Higher concrete waste due to mixing with slurry at initial stage
Does not require large stockyard space for foundation materials	Excavated slurry must be removed and disposed of outside the project area
Faster construction time as it does not depend on precast curing period	

In this study, the foundation review was conducted using bored pile foundations with simulated diameters of 600 mm, 800 mm, and 1000 mm. Technical data of the planned bored pile foundation proposed by the contractor can be seen in Figure 5.

Project	:	**RS Bandung**
Pile Properties		
Type	:	Bored Pile
Shape	:	Circle
Diameter	:	0,6 m
Area	:	0,28 m^2
Perimeter	:	1,88 m
Length	:	18,00 m
Unit Weight	:	22 kN/m^3
SF	:	2,5 -

Project	:	**RS Bandung**
Pile Properties		
Type	:	Bored Pile
Shape	:	Circle
Diameter	:	0,8 m
Area	:	0,50 m^2
Perimeter	:	2,51 m
Length	:	18,00 m
Unit Weight	:	22 kN/m^3
SF	:	2,5 -

Project	:	**RS Bandung**
Pile Properties		
Type	:	Bored Pile
Shape	:	Circle
Diameter	:	1 m
Area	:	0,79 m^2
Perimeter	:	3,14 m
Length	:	18,00 m
Unit Weight	:	22 kN/m^3
SF	:	2,5 -

Figure 5: Technical Data of Bored Pile Design

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From the technical data in Figure 5, the calculation results of the axial bearing capacity of the bored pile for each pile diameter were obtained using soil data from the bore log test results, as shown in Figure 6.

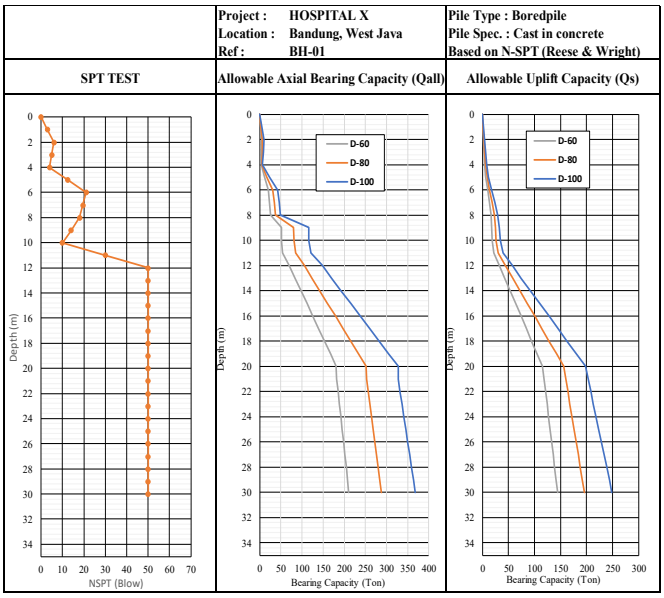


Figure 6: Recapitulation of Allowable Bearing Capacity Based on BH-01

The figure presents three graphs describing the relationship between soil depth, geotechnical characteristics, and bored pile performance based on BH-01 data. The first graph shows NSPT values against depth, indicating softer soils at 0–10 m and denser, competent layers from 12–30 m (NSPT ~50). The second graph illustrates the axial compressive bearing capacity for pile diameters of 60 cm, 80 cm, and 100 cm, showing that capacity increases with depth and diameter, with 100 cm performing best. The third graph depicts the uplift (tensile) capacity, which also rises with depth and diameter but remains lower than compressive capacity due to reliance on shaft friction. Overall, both embedment depth and pile diameter are key factors in optimizing bored pile foundation performance.

With a planned bored pile foundation depth of 18 meters, the calculation results of the allowable bearing capacity from each bore log point yield the allowable capacities for each pile diameter at every bore log location, as presented in Table 7.

Table 7: Recapitulation of Allowable Axial and Uplift Bearing Capacity

No.	Foundation Diameter	Bore Log Point
		BH-01
		(ton)
	Allowable Axial Capacity	
1	Dia 600	153.21
2	Dia 800	215.14
3	Dia 1000	282.49
	Allowable Uplift Capacity	
1	Dia 600	94.63
2	Dia 800	128.16
3	Dia 1000	162.69

This was followed by a comparison of the pile group bearing capacity for each pile cap. Based

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on these comparisons, a further evaluation was performed by comparing the number of foundation points between spun pile foundations and bored pile foundations, with the results presented in Tables 8 to 10.

Table 8: Bored Pile Diameter 600 mm (BH-01)

Joint Node	DESIGN			REVIEW DESIGN			CHECK
	Spun Pile D600 mm			Bored pile D600 mm			
	Number of Piles in 1 PC (Pile Cap)	Allowable Bearing Capacity of a Single Pile (Qall SP)	Total pile bearing capacity for 1 pile cap (Qgroup SP)	Allowable Bearing Capacity of a Single Pile (Qall BP)	Total Bearing Capacity of Piles in One Pile Cap (Qgroup BP)	Total Bearing Capacity of Piles in One Pile Cap	Qgroup BP ≥ Qgroup SP
	(points)	(ton)	(ton)	(ton)	(points)	(ton)	
1	3	152	456.00	153.21	3	459.63	101%
2	4	152	608.00	153.21	4	612.84	101%
3	5	152	760.00	153.21	5	766.05	101%
4	6	152	912.00	153.21	6	919.26	101%
5	9	152	1368.00	153.21	9	1378.90	101%
6	10	152	1520.00	153.21	10	1532.11	101%
7	14	152	2128.00	153.21	14	2144.95	101%

Table 9: Bored Pile Diameter 800 mm (BH-01)

Joint Node	DESIGN			REVIEW DESIGN			CHECK
	Spun Pile D600 mm			Bored pile D800 mm			
	Number of Piles in 1 PC (Pile Cap)	Allowable Bearing Capacity of a Single Pile (Qall SP)	Total pile bearing capacity for 1 pile cap (Qgroup SP))	Allowable Bearing Capacity of a Single Pile (Qall BP)	Total Bearing Capacity of Piles in One Pile Cap (Qgroup BP)	Total Bearing Capacity of Piles in One Pile Cap	Qgroup BP ≥ Qgroup SP
	(points)	(ton)	(ton)	(ton)	(points)	(ton)	
1	3	152	456.00	205.36	3	616.09	135%
2	4	152	608.00	205.36	3	616.09	101%
3	5	152	760.00	205.36	4	821.45	108%
4	6	152	912.00	205.36	5	1026.81	113%
5	9	152	1368.00	205.36	7	1437.53	105%
6	10	152	1520.00	205.36	8	1642.89	108%
7	14	152	2128.00	205.36	11	2258.98	106%

Table 10: Bored Pile Diameter 1000 mm (BH-01)

Joint Node	DESIGN			REVIEW DESIGN			CHECK
	Spun Pile D600 mm			Bored pile D800 mm			
	Number of Piles in 1 PC (Pile Cap)	Allowable Bearing Capacity of a Single Pile (Qall SP)	Total pile bearing capacity for 1 pile cap (Qgroup SP)	Allowable Bearing Capacity of a Single Pile (Qall BP)	Total Bearing Capacity of Piles in One Pile Cap (Qgroup BP)	Total Bearing Capacity of Piles in One Pile Cap	Qgroup BP ≥ Qgroup SP
	(points)	(ton)	(ton)	(ton)	(points)	(ton)	
1	3	152	456.00	205.36	3	616.09	135%
2	4	152	608.00	205.36	3	616.09	101%
3	5	152	760.00	205.36	4	821.45	108%
4	6	152	912.00	205.36	5	1026.81	113%
5	9	152	1368.00	205.36	7	1437.53	105%
6	10	152	1520.00	205.36	8	1642.89	108%
7	14	152	2128.00	205.36	11	2258.98	106%

Based on the evaluation of the number of bored pile points against the required allowable bearing capacity, the selected diameter is 800 mm, with the following considerations:

- The allowable bearing capacity for the 800 mm diameter is more efficient, ranging from 1–10% above the required capacity.

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- Work execution is more effective with the 800 mm diameter compared to 1000 mm, as 800 mm augers are more commonly available in the market.
- Using 800 mm bored piles reduces the number of pile points, thereby accelerating the construction process.
- The work volume for the 800 mm diameter is more efficient compared to the 1000 mm diameter.

In addition to cost savings, the proposed alternative foundation reduces construction time by decreasing the number of foundation points. A comparison of foundation points between spun pile and bored pile systems is shown in Table 11.

Table 11: Comparison of Required Number of Piles

Pile Cap Type	Pile Cap Number		Pile Number	
	Spun Pile	Bored Pile	Spun Pile	Bored Pile
	Unit	Unit	Unit	Unit
P1	-	6	-	6
P2	-	7	-	14
P3	18	14	54	42
P4	6	10	24	40
P5	4	2	20	10
P6	12	9	72	54
P7	-	3	-	21
P9	4	-	36	-
P10	1	-	10	-
P14	2	-	28	-
Total	**47**	**51**	**244**	**187**
Deviation		**- 4**		**57**
Percentage		**-8.51%**		**23.36%**

Evaluation Stage

After the foundation design has been completed, the next step is to calculate the work volumes. These volumes include the following:

- Drilling of bored piles with a diameter of 800 mm (N-SPT < 30)
- Drilling of bored piles with a diameter of 800 mm (N-SPT > 30)
- Disposal of excavated soil and slurry waste off-site
- Reinforcement work for bored pile foundations
- Ready-mix concrete casting using a bored pile machine, grade K-450, slump 16 ± 2
- Cutting of bored pile heads

Table 12: Construction Cost of Bored Piles Diameter 800 mm

NO	WORK DESCRIPTION	UNIT	VOL	UNIT PRICE	TOTAL PRICE
	Bored Pile Foundation Works				
1	Drilling of bored piles, diameter 800 mm (N-SPT < 30)	m'	1,683.00	756,242	1,272,755,286
2	Drilling of bored piles, diameter 800 mm (N-SPT > 30)	m'	1,683.00	931,934	1,568,444,922
3	Disposal of excavated soil and slurry waste off-site	m^3	2,537.90	90,000	228,411,379
4	Reinforcement work for bored pile foundations	kg	205,085.48	15,500	3,178,824,922
5	Ready-mix concrete casting using bored pile machine, grade K-450, slump 16 ± 2	m^3	1,691.94	493,747	2,527,324,223
6	Cutting of bored pile heads	point	187.00	459,375	85,903,125
TOTAL AMOUNT					**8,861,663,857**

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The work volumes are calculated using Microsoft Excel software to accelerate the calculation process, and the results of these volume calculations can be seen in Table 12.

The comparison between the number of foundation points using spun piles and bored piles is further assessed by calculating the required volume and cost of the bored pile alternative, then comparing it with the original spun pile design. This analysis evaluates whether the alternative meets functional and cost requirements, with an expected value greater than 1. The results are presented in the cost and worth analysis presented in Table 13.

Table 13: Cost Worth Analysis

No	Description	Verb	Noun Function	Type	Cost	Worth
1	Installation of 600 mm Spun Pile	driving	foundation	primary	9,132,651,600	
2	Cutting of Spun Pile Head	removing	foundation	secondary	21,733,080	
	Pile Head Treatment					
3	Ready-Mix Concrete Casting with Pump (fc = 24.9 MPa)	supporting	load	primary	199,536,377	
4	Reinforcement Works (Deformed & Plain Bars U39 & U24)	transferring	load	primary	524,592,850	
5	Bored Pile Drilling Ø800 (N-SPT < 30)	forming	foundation	primary		1,272,755,286
6	Bored Pile Drilling Ø800 (N-SPT > 30)	forming	foundation	primary		1,568,444,922
7	Disposal of Excavated Soil & Slurry Outside Site	disposing	waste	secondary		228,411,379
8	Bored Pile Reinforcement Works	transferring	load	primary		3,178,824,922
9	Ready-Mix Concrete Casting with Bored Pile Machine K-450 (Slump 16 ± 2)	supporting	load	primary		2,527,324,223
10	Cutting of Bored Pile Head	removing	foundation	secondary		85,903,125
				Total	**9,878,513,907**	**8,861,663,857**
				Cost / Worth	**1.00**	**1.11**

Development Stage

At this stage, the results from the previous analysis are further developed. The data obtained earlier are used as input and processed through a Life Cycle Cost (LCC) calculation. This analysis aims to evaluate the alternative work based on the total cost incurred over the building's service life. The calculation results provide the cost required for the bored pile foundation work. Therefore, the life cycle cost of the alternative using bored pile foundations is presented in Table 14.

Table 14: Life Cycle Cost Analysis

Life Cycle Cost			
Project : Construction of Hospital X Building Phase 1			
Location :Bandung City			
Item : Main Building Foundation Work			
	Present Value	**Existing**	**Alternative**
Initial Cost	Construction Cost	9,878,513,907	8,861,663,857
Replacement Cost	The alternative does not require replacement costs	-	-
Operational Cost	The alternative does not require operational costs	-	-
Maintenance	The alternative does not require maintenance costs	-	-
Total Cost		**9,878,513,907**	**8,861,663,857**

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Recommendation Stage

At this stage, the proposed alternative design is presented as an improvement to the original design, covering work specifications through to the planned construction cost. The recommended alternative is shown in Table 15.

Table 15: Recommendation Design

Proposed Design Recommendation			
Project	: Hospital X Project		
Location	: Jl. Aruna, Bandung, West Java		
Work Item	: Foundation Work		
Description	**Initial Design**	**Alternative Design**	**Remark**
Foundation Type	Spun Pile	Bored Pile	
Diameter	Dia 600	Dia 800	
Foundation Bearing Capacity	152 tonnes	215.14 tonnes	Increased Functionality
Construction Cost	Rp 9,878,513,907	Rp 8,861,663,857	Reduced Cost

Discussion

After conducting the value engineering analysis, several considerations support the selection of the bored pile foundation method. The results indicate that the proposed alternative provides both technical and economic advantages compared to the initial spun pile design, particularly under complex subsurface conditions.

- The bored pile foundation is expected to overcome the issue of the lens layer found at a depth of 7–10 meters below ground level, thereby reducing the need for pre-boring work required when using spun pile foundations. This is consistent with previous studies indicating that bored piles are more adaptable to heterogeneous soil conditions and are capable of penetrating hard soil layers without additional preliminary treatment [1], [4], [12].
- The number of foundation points required using bored piles is fewer compared to spun piles, resulting in a reduction of 23.36% in the number of foundation points. This reduction is primarily attributed to the higher load-bearing capacity of bored piles, which allows for more efficient structural design. Similar findings have been reported in comparative studies, where larger diameter piles reduce the total number of required foundation elements [6], [10].
- The cost required to complete the foundation work can be minimized by using the bored pile alternative, with a cost saving of 10.29% compared to the initial (existing) cost. This result supports previous research on value engineering applications in foundation systems, where cost savings ranging from approximately 1.77% to 9.09% have been achieved depending on project conditions and design optimization [6], [7], [15].
- Construction activities on site do not need to wait for the production of foundation elements, as bored piles are cast in situ. This significantly reduces the time required for fabrication and mobilization from casting yards, which is typically necessary in precast systems such as spun piles. This finding is in line with earlier studies highlighting that bored pile construction offers improved scheduling efficiency due to reduced dependency on external production processes [10], [15].
- The overall construction time is shorter because fabrication and concrete casting are carried out directly on site. This contributes to improved project delivery performance, which is one of the key objectives in value engineering, where time, cost, and function

must be optimized simultaneously [2], [7].

Despite these advantages, there are several constraints that may arise during construction and need to be anticipated:

- A dedicated area is required for reinforcing steel fabrication, as bored pile works are carried out in situ. This requirement may affect site layout planning and logistics, particularly in confined construction areas.
- Excavated soil from the drilling process must be disposed of outside the project. The handling and disposal of drilling spoil and slurry have been identified as critical issues in bored pile construction, especially in urban environments [13].
- During concrete casting of bored piles, strict supervision and control are necessary to manage the supply and consumption of fresh concrete. Variability in in-situ casting conditions may affect the quality and integrity of the pile if not properly controlled, as highlighted in previous studies on bored pile performance [11], [16].

Overall, the findings of this study demonstrate that the bored pile foundation provides a more efficient and adaptable solution under challenging soil conditions, while also achieving significant cost and time savings. These results reinforce the effectiveness of the value engineering approach in optimizing foundation design by balancing technical performance, constructability, and economic considerations [2], [9].

CONCLUSION

Based on the results of this study on the implementation of value engineering in the foundation works of the main building project of Hospital X (Phase 1), several conclusions can be drawn. First, the factors influencing cost and time performance in the foundation works, as validated by expert judgment, include construction methods, workforce availability and productivity, procurement processes, weather conditions, as well as communication and coordination among project teams. These variables play a significant role in determining overall project efficiency. Second, the application of value engineering in this case study resulted in a more efficient design alternative. The functional performance of the foundation system improved, as indicated by the increase in load-bearing capacity from 152 tons using a 600 mm diameter spun pile foundation to 215.14 tons using an 800 mm diameter bored pile foundation. This demonstrates that the selected alternative not only meets but exceeds the required structural performance. Third, the implementation of value engineering contributed to a significant reduction in project cost. The initial estimated cost of Rp 9,878,513,907 for the spun pile foundation was reduced to Rp 8,861,663,857 with the bored pile alternative. This represents a total cost saving of Rp 1,016,850,050. Overall, the application of value engineering in this study successfully achieved improved functional performance while simultaneously reducing construction costs, indicating a more optimal and efficient foundation solution.

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