

# Optimization of Upper Structure Work Cost with Value Engineering Method

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## Abstract

The upper structure is one of the works in the building construction project that significantly affects the construction cost. Cost overruns on the upper structure work are of particular concern to be re-analyzed through the application of *Value Engineering* (VE). The UPI Cibiru Campus Lecture Building Construction Project is a state building construction project with the largest upper structure work cost, 26% of the overall cost, so it has the potential for the application of VE. This research aims to analyze the superstructure work items that contribute significantly to the project cost, find alternative superstructure design, and obtain cost savings on superstructure work after the application of VE. The data used is secondary data in the form of *Detail Engineering Design*, *Bill of Quantity*, and Job Unit Price Analysis. The data analysis technique used is the VE method. The results showed that beam, column, and plate work items were the largest cost contributors with a cumulative percentage of 73.52%. Then, the alternative design that can be done in this project is to replace conventional formwork into semi-system formwork with PVC panels. The cost savings obtained in the upper structure work after the application of VE is IDR 478,642,027 or 4.121%.

Keywords: Value Engineering, Upper Structure, Semi System Formwork, Cost Saving, Building Project

## 1. INTRODUCTION

The work item in a building construction project that significantly affects the construction cost is the superstructure work (Tangkau, Sumajouw, & Malingkas, 2022). Inaccuracies in structural design often occur and are one of the dominant causes of cost overruns (Hase, Maizuar, & Jalil, 2024). *Value Engineering* (VE) is a systematic approach to produce an efficient work design through optimizing or modifying any element that contributes significantly to the overall cost (Torelli, 2011). The UPI Cibiru Campus Lecture Building Construction Project is a state building construction project as an educational facility whose construction budget comes from public funds. Therefore, the cost of this construction project must be used efficiently. The upper structure work is a work item that has the highest cost with a percentage of 26% of the total cost, so that the upper structure work on the UPI Cibiru Campus Lecture Building Construction Project was chosen as the object of study in this study to implement VE.

## 2. METHODS

The method in this research is experimental quantitative with secondary data used in the form of *Detail Engineering Design* (DED), *Bill of Quantity* (BoQ), and Unit Price Analysis (AHSP). The data analysis technique in this study was carried out by applying the *Value Engineering* (VE) method which consists of the information stage, creative stage, development stage, consideration stage, and recommendation stage.

2.1 Information Stage: Obtaining work items that contribute significantly to the overall cost by applying the Pareto distribution law which states that 80 percent of the overall cost is contributed by 20 percent of its constituent components. The information stage is done with *matrix cost model*, *breakdown cost model*, and function analysis.

2.2 Creative Stage: Determining alternatives that can be done as a cost optimization effort through literature studies.

2.3 Consideration Stage: Filtering the alternatives that appear to be developed further. The consideration stage is carried out with profit and loss analysis.

2.4 Development Stage: Developing the selected alternatives into a complete proposal through structural analysis and cost analysis.

2.5 Recommendation Stage: Comparing the existing design with the new design to recommend the most optimal design in terms of cost.

### 3. RESULTS AND DISCUSSION

#### 3.1 Information Stage

From the *matrix cost model*, it is identified that the structural work on the UPI Cibiru Campus Lecture Building Construction Project is the work item with the highest cost of Rp 18,016,231,492 with the largest cost on structural work of Rp 11,613,945.73.

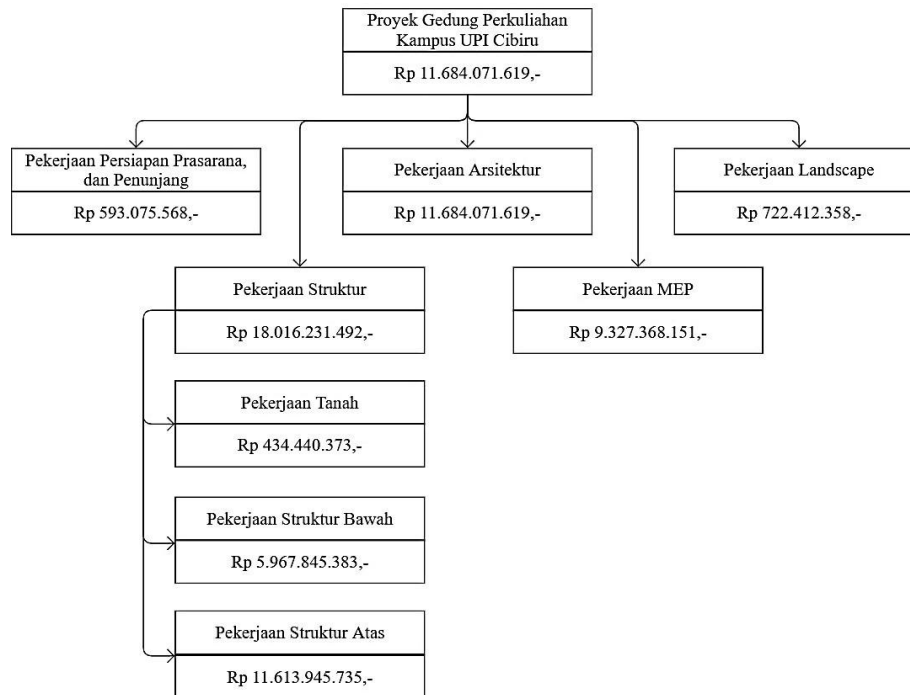


Figure 1: Matrix Cost Model of UPI Lecture Building Construction Project Cibiru Campus

From the *breakdown cost model*, it is identified that three items of structural work have the highest cost weight, namely beam work with 27.35%, column with 26.60%, and plate with 19.57%. These three work items have a cumulative percentage of 73.52%, close to 80 percent, so these three work items are selected to proceed to the next stage.

Table 1: Breakdown Cost Model of Upper Structure Work

Work Item	Cost	Weight	Cumulative
Beams	Rp 3.176.558.737	27,35%	27,35%
Column	Rp 3.089.019.989	26,60%	53,95%
Plates	Rp 2.272.692.273	19,57%	73,52%
Concrete Wall	Rp 1.684.811.533	14,51%	88,02%
Steel Frame Roof	Rp 798.307.740	6,87%	94,90%
Stairs	Rp 373.934.361	3,22%	98,12%
Structure of R. Genset	Rp 160.138.308	1,38%	99,50%
Separator Beam Lift	Rp 58.482.794	0,50%	100,00%
Total	Rp 11.613.945.735	100,00%	

Function analysis is carried out to classify *basic functions* (B) and *secondary functions* (S), so that it is known which work elements are suitable for further VE analysis. The *cost* value is obtained from the project RAB. Meanwhile, the *value of worth* is obtained from reducing the *cost* value by multiplying the average value of the percentage of savings obtained from previous studies with the *cost* value.

Table 2: Analysis of Beam Work Function

No	Component	Function			Cost (Rp)	Worth (Rp)
		Verb	Noun	Type		
1.	Concrete	Channelize	Load	B	Rp 583.107.919	Rp 583.107.919
2.	Pembesian	Channeling	Load	B	Rp 1.721.296.469	Rp 1.721.296.469
3.	Formwork	Support	Concrete	S	Rp 872.154.349	Rp 475.919.853
Total					Rp 3.176.558.737	Rp 2.832.361.241
<b>C/W Ratio</b>					<b>1,143</b>	

Table 3: Column Work Function Analysis

No.	Component	Function			Cost (Rp)	Worth (Rp)
		Verb	Noun	Type		
1.	Concrete	Channeling	Load	B	Rp 497.849.955	Rp 497.849.955
2.	Pembesian	Channeling	Load	B	Rp 684.975.416	Rp 684.975.416
3.	Formwork	Support	Concrete	S	Rp 1.083.129.018	Rp 624.274.421
Total					Rp 2.265.954.388	Rp 1.807.099.792
<b>C/W Ratio</b>					<b>1,109</b>	

Table 4: Analysis of Plate Work Function

No.	Component	Function			Cost (Rp)	Worth (Rp)
		Verb	Noun	Type		
1.	Concrete	Channelize	Load	B	Rp 524.269.956	Rp 524.269.956
2.	Fixing	Channeling	Load	B	Rp 1.881.196.685	Rp 1.881.196.685
3.	Formwork	Support	Concrete	S	Rp 683.553.349	Rp 379.657.082
Total					Rp 3.089.019.989	Rp 2.785.123.723
<b>C/W Ratio</b>					<b>1,254</b>	

### 3.2 Creative Stage

The work components in the beam, column, and slab works that will be subjected to further VE analysis are formwork components. Meanwhile, the existing formwork component, which is used in the review project, is (A0) conventional formwork, so the alternatives that appear in this research are (A1) semi-system formwork and (A2) system formwork.

### 3.3 Consideration Stage

Based on previous studies; (Mahrizal, 2024), (Khamim, Riyanto, & Zenurianto, 2020), (Tamtana, 2020), (Pratama, Anggraeni, Hidayat, & Khasani, 2017), the cost of (A2) system formwork is more expensive than (A1) semi-system formwork. Therefore, this research will focus on the development of alternative (A1) semi-system formwork. *Phenolic plywood* panel is a multiplex whose surface is coated with sheets of phenol formaldehyde film. This material is very commonly used for panels in semi-system formwork. Meanwhile, PVC panels are *polyvinyl chloride-based* panels that are produced in solid or hollow form. This material is starting to be recognized for its use in semi-system formwork. The following is a profit and loss analysis of the two formwork panel materials.

Based on the profit and loss analysis, PVC panels were selected for further development for several reasons: (1) The service life of PVC panels is longer than *Phenolic Plywood* panels; (2) Because the service life is longer, the costs required tend to be more economical; (3) PVC panels can be recycled; (4) Quite easy to find on Java Island; (5) Good material resistance, not easy to crack or break, does not absorb water, does not rot easily, and is strong against direct sunlight. In addition, according to research conducted by (Irawan, 2024), the cost of formwork with PVC panels is 4.4% cheaper than with *Phenolic Plywood* panels.

Table 4: Profit and Loss Analysis of Formwork Panel Material

No.	Alternative	Advantage	Disadvantage
A1.1	Phenolic Plywood Panel	<ol style="list-style-type: none"> <li>Cheaper unit price</li> <li>Easy to cut and shape</li> </ol>	<ol style="list-style-type: none"> <li>Limited service life of 5 - 10 times</li> <li>Vulnerable to water if the phenolic coating is damaged and Vulnerable to extreme weather if exposed to direct exposure</li> <li>Short lifespan so waste appears faster</li> <li>Considering the lifespan, the costs incurred will be higher</li> </ol>
A1.2	PVC panel	<ol style="list-style-type: none"> <li>Long service life can be used more than 60 times</li> <li>Recyclable</li> <li>Not easy to crack or break, does not absorb water, does not rot, and is strong against sun exposure</li> <li>Due to its long service life, the cost required is smaller</li> <li>Due to its longer lifespan, it reduces the frequency of formwork waste</li> </ol>	<ol style="list-style-type: none"> <li>Unit price is more expensive</li> <li>Difficult to cut special shapes</li> <li>May cause plastic pollution if the waste is not managed properly</li> </ol>

### 3.4 Development Stage

#### Structure Analysis

Strength calculation using the following equation.

$$\sigma_{lt} = \frac{M}{W} \dots (i)$$

Where:

M= Bending moment (kg.m)

W = Opposing moment (m<sup>3</sup>)

$\sigma_{lt}$ = Bending stress (kg/m<sup>2</sup>)

Calculation of deflection using the following equation

$$\delta = \frac{5}{384} \frac{qL^4}{EI} \dots (ii)$$

Where:

$\delta$ = Deflection that occurs (m)

q = Load evenly distributed (kg/m)

L= Span length (m)

E= Modulus of elasticity (kg/m<sup>2</sup>)

I = Moment of inertia (m<sup>4</sup>)

Table 5: Resume of structural analysis of components in semi-system formwork

Item	$\sigma_{lt}$ occurred kg/m <sup>2</sup>	allowable $\sigma_{lt}$ kg/m <sup>2</sup>	Control $\sigma_{lt}$	$\delta$ occurs m	$\delta$ allow m	Control $\delta$
<b>Column Formwork</b>						
18 mm PVC panel	139973,96	1019711	OK	0,0006876	0,0009259	OK
Hollow Pole 30.30.1.6	4653087,7	8000000	OK	0,0000403	0,0013889	OK
<b>Beam Formwork</b>						
18 mm PVC Turret Panel	257569	1019711	OK	0,00045553	0,0005556	OK

18 mm PVC Bodeman Panel	126507	1019711	OK	0,000223736	0,0005556	OK
Hollow Suri 60.60.3	7830954,2	8000000	OK	0,001586758	0,0033333	OK
Hollow girder 75.75.3	4779944,6	8000000	OK	0,000777305	0,0041667	OK

**Plate Formwork**

18 mm PVC Panel	456046	1019711	OK	0,000560104	0,0009259	OK
Hollow Suri 60.60.3	6056120,2	8000000	OK	0,000851046	0,0027778	OK

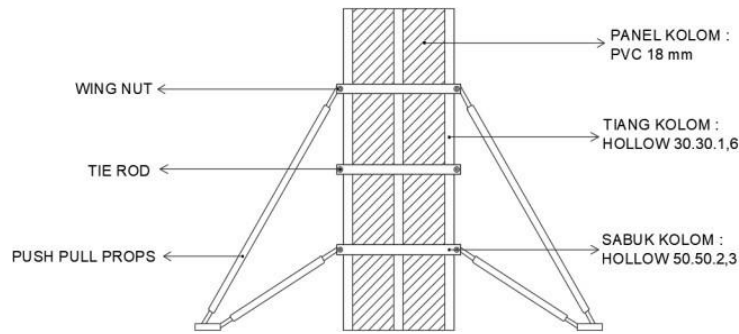


Figure 2: Semi-system Column Formwork

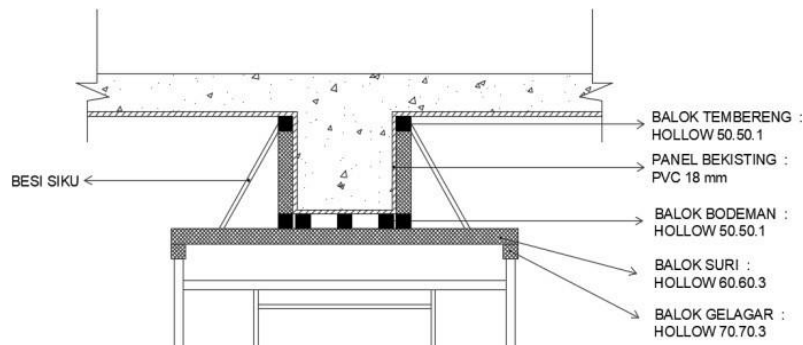


Figure 3: Semi-system Beam Formwork

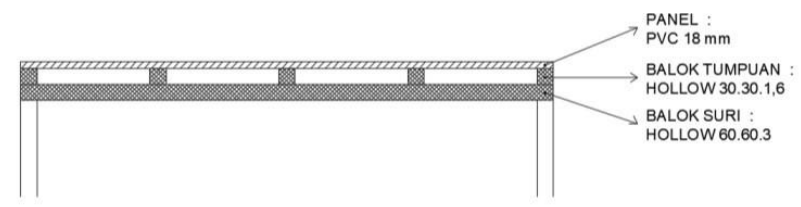


Figure 4: Semi-System Plate Formwork

*Cost Analysis*

Analysis of Unit Price of Work (AHSP) in this study refers to SNI 7394: 2008 and AHSP on the review project. For coefficients that are not found in SNI or AHSP project, obtained from the calculation of material analysis. While unit prices that are not found in the SNI or AHSP project, are obtained from searching material brochures. The *over head* and *profit* are determined at 7.5% in accordance with the AHSP of the review project.

Table 6: Unit Price of Semi-System Formwork of Columns, Beams, and Plates

Work Item	Unit Price
1 m2 Column Formwork	Rp 1.106.336
Installation of 1 m2 Column Formwork	Rp 117.006
Erection of 1 m2 Beam Formwork	Rp 1.710.939
Erection of 1 m2 Beam Formwork	Rp 117.006
Erection of 1 m2 Plate Formwork	Rp 1.243.148
Installation of 1 m2 Plate Formwork	Rp 117.006

Based on the unit price of the semi-system formwork work, the following is a cost comparison of (A0) conventional formwork work with (A1) semi-system formwork work for columns, beams, and plates.

Table 7: Cost of Semi-system Formwork for Columns, Beams, and Plates

Component	A0	A1	Difference	Percentage
Column Formwork	Rp 683.553.349	Rp 564.708.997	Rp 118,844,351,867	17,39%
Beam Formwork	Rp 872.154.349	Rp 777.650.945	Rp 94.503.404,249	10,84%
Plate Formwork	Rp 1,083,129,018	Rp 824.572.598	Rp 258,556,386,187	23,87%

### 3.5 Recommendation Stage

After the cost analysis, it was found that (A1) semi-system formwork with PVC panels, resulted in lower costs compared to (A0) conventional formwork. Therefore, the replacement of formwork from conventional formwork to semi-system formwork with PVC panels can be recommended. The cost savings obtained in the upper structure work after the application of *value engineering* can be seen in the following table.

Table 8: Upper Structure Cost Savings After *Value Engineering*

Work Item	Cost Before VE	Cost After VE	Difference
Column	Rp 3.089.019.989	Rp 2.970.175.638	Rp 118.844.352
Beams	Rp 3.176.558.737	Rp 3.082.055.333	Rp 94.503.404
Plates	Rp 2.272.692.273	Rp 2.007.398.002	Rp 265.294.271
Upper Structure Work Cost Savings			Rp 478.642.027
			4, 121%

## 4. CONCLUSION

Based on the analysis conducted on the application of *value engineering*, the results obtained on the upper structure work of the UPI Cibiru Campus Lecture Building Construction project are as follows.

- The top structural work items that contribute the most cost to the UPI Cibiru Campus Lecture Building Construction Project are beam, column, and plate work with a cumulative percentage of 73.52%.
- The selected design alternative that can be done to optimize the cost of beam, column, and slab work is to replace conventional formwork with semi-system formwork with PVC panels.
- The amount of cost savings obtained on the upper structure work after the application of value engineering is IDR 478,642,027 or 4.121%.

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