Value Engineering in The Implementation of Kumkang Formwork (Case Study: The Alton Apartment Project in Semarang Indonesia)

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Abstract. Value engineering is usually done by substitution of materials or change in construction method. One of them is in The Alton Apartment Project in Tembalang, Semarang, which is apply Korean technology on aluminum formwork system called Kumkang. The objectives of this study are to calculate the coefficient of worker productivity, to find out the time required to install the aluminum form (Kumkang) compared to conventional one, and to compare the workers' costs for conventional formwork and Kumkang aluminum formwork. The analytical method of the study uses the Value Engineering Method. The calculation of the workers unit price coefficient analysis of aluminum formwork work (kumkang) equal to 0.025 MD, while of the unit price of workers on the formwork according to the Indonesian National Standard Work Unit (AHSP-SNI) equals to 0.330 MD. The time required of the aluminum formwork (kumkang) installation are 2.47 days for 1582.10 m² formwork while the conventional formwork needs 32.6 days for the same volume. The cost calculation shows that the worker cost to install Kumkang Formwork is Rp. 7,200,000 while for the conventional formwork is Rp. 79,200,000. Based on the results, it can be concluded that Kumkang formwork technology is more efficient than conventional system.

Keywords: Value Engineering, Productivity, Kumkang Formwork

1 Introduction

The Alton Apartments have three towers. By looking at the sales conditions of The Alton apartments which have been sold more than 60 percent in towers 1, 2 and 3, the construction of the Alton Apartment Tembalang project requires accelerating project work that is still considering the function, quality, and aesthetics of the building. The innovations of Value Engineering (VE) were carried out to improves the Alton Apartments project cost efficiency and productivity without reducing the targeted quality. One of the Value Engineering applications used by PT. Pembangunan Perumahan (PT. PP) as the contractor of the project was an aluminum formwork system named "Kumkang". It stated that the aluminum formwork system has a higher efficiency than the conventional formwork system. Kumkang aluminum formwork is a new technology, claimed to save time and cost compared to conventional formwork. To prove those claimed, this research was made.

1.1 Purpose of the study

a) To find out the unit price productivity coefficient of the worker using the Value Engineering (VE) method in implementing formwork installation using aluminum formwork (Kumkang)
b) To find out the time required to install the aluminum formwork (Kumkang) and conventional formwork

c) To compare the cost of the workers needed between conventional formwork and Kumkang aluminum form

2 Value Engineering

Value Engineering (VE) in construction is the science of solving problems to increase the value of buildings carried out with a systematic, creative approach to identifying, increasing cost and time efficiency without reducing product quality, function, age, and appearance. It is conducted in eight sequential phases (which may overlap in practice) as follows[1]:

a. Orientation Phase: to refine the problem and prepare for the value study.

b. Information Phase: to finalize the scope of the issues to be addressed, targets for improvement, and evaluation factors while building cohesion among team members.

c. Function Analysis Phase: Identify the most beneficial areas for study.

d. Creative Phase: Develop a large number of ideas for alternative ways to perform each function selected for further study.

e. Evaluation Phase: Refine and select the best ideas for development into specific value-improvement recommendations.

f. Development Phase: Determine the “best” alternatives for presentation to the decision-maker.

g. Presentation Phase: a commitment to follow a course of action for initiating an alternative.

h. Implementation Phase: Obtain final approval of the proposal and facilitate its implementation.

3 Research Methods

The location of this research is in the Alton Apartment Project in Tembalang, Semarang.

3.1 Method of collecting data

a. The primary data in this study are the data from the assembly time calculation of the aluminum Kumkang formwork through direct observation in the project

b. The Secondary Data for this study are from the project shop drawing and project time schedule

3.2 Data analysis method

Data analysis method was performed using the Value Engineering Job Plan method:

3.2.1 Information Stage. At this initial stage, efforts were made to obtain information as much as possible about the innovations carried out on the Alton Apartment project. One of the innovations that can be carried out on the Alton Apartment project is formwork for column and reinforced wall.

3.2.2 Function Analysis Phase. In the analysis phase, this stage function is for estimating the value of the usefulness of a formwork subsystem as an object of VE in the Alton Apartment project.

3.2.3 Creative Stage. This stage is the developing ideas stage to come up with new alternatives that can fulfill the required formwork function.

3.2.4 Evaluation Stage. In this stage, it is needed to do several steps, those are:

a. Analyzing the advantages and disadvantages of each alternative.

b. Perform work sampling analysis using the equation needed such as Work Sampling Analysis, The Data Adequacy Test, Adjustment factor, Looseness factor, Determination of
standard time, The Number of Productive Minutes (NPM), Time required / unit and Normal time (Tn)
c. Unit price coefficient Analysis of workers
d. Calculation of work duration

3.2.5 Development Stage. The development phase objective is to prepare the final written recommendations to choose an alternative.

3.2.6 Presentation Stage. In this phase, the result of the Value Engineering (VE) study was presented to the owner and other decision-makers.

3.2.7 Implementation Phase. Obtain final approval of the proposal and facilitate its implementation

4 Data Analysis and Discussion

4.1 Information stage
The value engineering analysis is performed on formwork items for column and reinforced wall in The Alton Apartment project in Tembalang, Semarang, because the formwork items are rather complex, varied, and spend long time allocation of work. The Value Engineering application here is intended to replace the materials and work methods. VE application on formwork aims to save time

4.2 Function Analysis
At this stage, the formwork's basic function is being analyzed.

Table 1. Identification of the Basic Functions of Formwork

| Verb        | Noun     | Function |
|-------------|----------|----------|
| To Mold     | Concrete | Primary  |
| To Hold Back| Concrete | Primary  |
| FORMWORK    |          |          |
| To Install  | Formwork | Secondary|
| To Uninstall| Formwork | Secondary|
| To Move     | Formwork | Secondary|

Table 1 shows Identification of the Basic Functions of Formwork. With this table, conventional formwork replacement materials are also expected to have the same function.

4.3 Creative Stage
Ideas or alternatives to upper structure formwork are to replace materials and work methods by replacing conventional formwork with aluminum formwork (Kumkang)

4.4 Evaluation stage

4.4.1 Analyzing the advantages and disadvantages of each alternative. In this stage we need to analyze the advantages and disadvantages of each alternative. The advantage and disadvantage of conventional formwork are shown on table 2

Table 2. The Advantages and Disadvantages Analysis of Conventional Formwork

| CONVENTIONAL FORMWORK | ADVANTAGE | DISADVANTAGE |
|------------------------|-----------|--------------|
| The Conventional formwork material is easy to find on the market. | Requires a long time for the installation and removal of formwork. |
Conventional formwork is easy to use on the structures in which its dimensions changeable. The conventional formwork materials are not durable, it can only be used 2-3 times usage. Conventional formwork produces many waste materials such as multiplex, nails, and wires waste. The casting result from the conventional formwork is less precise, so it has more finishing work required.

Table 2 shows that there are more disadvantages than advantages for conventional formwork. While the advantage and disadvantage of Kumkang Aluminium formwork are shown on table 3

**Table 3. The Advantages And Disadvantages Analysis Kumkang Aluminium Formwork**

| ADVANTAGE | DISADVANTAGE |
|-----------|--------------|
| The installation and removal process of the formwork is easier and faster | More expensive |
| The implementation of the work is directly installed into a single unit structure item from columns, beams, plates, walls, and stairs as one system. | Requires a special workforce to install the formwork |
| Kumkang aluminum formwork can be used up to 250 times usage | The formwork shipping process from Korea is quite a time consuming |
| The casting results of the aluminum formwork Kumkang are more precision. | |
| The labor required to install formwork is far less than conventional formwork | |

Table 3 shows that Kumkang aluminium formwork has more advantages than the disadvantages. Using Kumkang aluminium formwork will be more profitable for the project

**4.4.2 Work Sampling Analysis.** This analysis use the uniformity data testing, this data testing is used to measure how closely they resemble a uniform distribution [2]. Data collection was carried out as many as 96 observations for each workday of each workforce in 7 days of observation. UL and LL calculations for workers i. productive percentage ("p"̅) = 93.45% or 0.9345 and number of observations made ("n"̅) = 96.

a. Upper Limit (UL) :

\[ UL = \bar{p} + 3 \sqrt{\frac{\bar{p} \left(1-\bar{p}\right)}{n}} \]  

UL = 1,010

b. Lower Limit (LL)

\[ LL = \bar{p} - 3 \sqrt{\frac{\bar{p} \left(1-\bar{p}\right)}{n}} \]  

LL = 0,859

UL and LL calculations UL and LL calculations are used to control the percentage of worker productivity.
Table 4. Control (%) Productivity Aluminum Forms (Kumkang) Workers

| Day     | Worker I | Worker II | Worker III | Worker IV | Worker V |
|---------|----------|-----------|------------|-----------|----------|
| 1       | 93.75    | 94.79     | 94.79      | 92.71     | 94.79    |
| 2       | 93.75    | 94.79     | 92.71      | 93.75     | 91.67    |
| 3       | 92.71    | 93.75     | 93.75      | 94.79     | 93.75    |
| 4       | 93.75    | 93.75     | 91.67      | 94.79     | 94.79    |
| 5       | 94.79    | 94.79     | 91.67      | 94.79     | 93.75    |
| 6       | 91.67    | 93.75     | 94.79      | 93.75     | 94.79    |
| 7       | 93.75    | 93.75     | 91.67      | 93.75     | 93.75    |

Table 4 shows that the values of the percentage of productive workers are in the range of the Upper Limit (UL) and Lower Limit (LL) with the number of observations for 7 days.

4.4.3 The Data Adequacy Test. The calculation sample of the data adequacy of workers for worker I

\[ N' = \frac{1600 \ (1-\bar{p})}{\bar{p}} \]  

\[ N' = 112.10 \]

The results of the calculation data have the value of N’ is 112.10. It shows N’ (112.10) < N (672), means the data are sufficient. The data adequacy Test calculations from the total number of workers are presented in table

Table 5. The Data Adequacy Test

| Worker | N  | N’   | Description |
|--------|----|------|-------------|
| I      | 672| 112.10| N’ < N     |
| II     | 672| 103.96| N’ < N    |
| III    | 672| 114.83| N’ < N    |
| IV     | 672| 114.83| N’ < N    |
| V      | 672| 100.38| N’ < N    |

The table 5 shows that the data are sufficient, because all of the N’ value are below the N value.

Adjustment factor. This adjustment factor is one of the assessments used to calculate the standard time determination of a worker. Based on the observation, the adjustment factor was 0.19 or 19%.

4.4.4 Looseness factor. This observation shows that workers may not work all day without interference. Workers may take time for personal needs, for rest and inevitable obstacles that are human in nature. Looseness factor is the time needed by trained workers to achieve real work performance if it works normally [3]. The value of the looseness factor in this research is equal to 22.50%.

4.4.5 Determination of standard time. Before determining the standard time calculation, there are several calculations such as productive percentage, the number of productive minutes, time required/unit and normal time needed.

Total earning = 3142 per 5 minutes = 15710 minutes
Number of observations = 3360 per 5 minutes = 16800 minutes
a. Productive Percentage (PP)

\[
PP = \frac{\text{Productive number}}{\text{Surveillance number}} \times 100 \%
\]

\[ PP = 93.51 \% \approx 0.9351 \]

b. The Number of Productive Minutes (NPM)

\[ NPM = PP \times \text{the observation minutes number} \]

NPM = 15709.68 minutes

c. Time required / unit

\[ \frac{NPM}{\text{number of units produced}} = 9,929 \text{ min/m}^2 \]

d. Normal time (Tn)

\[ Wn = \text{Time required } \times \text{Adjustment factor} \]

\[ Wn = 9,929 \times 0.19 \]
\[ Wn = 1,886 \text{ min/m}^2 \]

e. Standard time (Ts)

Data that has been collected and has undergone a process of testing data uniformity, data sufficiency, and calculation of adjustment factors and allowance factors for workers/operators is then used to calculate standard time [4].

\[ Ts = Tn + (\text{Looseness factor } \times Tn) \]

\[ Ts = 1,886 + (0.285 \times 1,886) \]
\[ Ts = 2,423 \text{ min/m}^2 \]

4.4.6 Unit Price Coefficient Analysis. The workers unit price coefficient analysis is performed to determine the productivity level of workers. The smaller the coefficient, the least amount of workers is needed to complete the job in a certain area.

a. Unit Price Coefficient Productivity Analysis of Workers For Aluminum Formwork (Kumkang)

Standard time (Ts) = 2.423 minutes / m²

Total hours worked (A) = 8 hours, work

Number of workers (B) = 5 workers

Number of hours worked a day (C)

\[ C = \frac{Ts}{(60 \times 8)} \]

\[ C = 0.00505 \text{ day} \]

60 is the number of minutes in 1 hour overall work time of worker (D)

\[ D = C \times B \]

\[ D = 0.025 \text{ Man Day (MD)} \]
b. Unit Price Coefficient Of Workers For Conventional Formwork

From the "Indonesian national standard (SNI)" unit price analysis table, the workers coefficient of conventional formwork is shown in table 6.

| No | Description          | Code | Unit | Coeff. |
|----|----------------------|------|------|--------|
| A  | Workers              | L.01 | MD   | 0.330  |
|    | Worker               |      |      |        |
|    | Handyman             | L.02 | MD   | 0.330  |
|    | Foreman              | L.03 | MD   | 0.033  |
|    | Foreman Supervisor   | L.04 | MD   | 0.033  |

The Coefficient Analysis of Workers' calculation shows that the coefficient for Aluminum Formwork (Kumkang) is equal to 0.025, which is much smaller than Conventional Formwork, which is equal to 0.330. It shows that Conventional Formwork needs more workers than Aluminum Formwork (Kumkang) to finish the same amount of the installation area.

4.4.7 Calculation of Work Duration

a. Aluminum Formwork (Kumkang)

Worker coefficient (k) = 0.025 OH
Work volume (V) = 1582.10 m²
Number of workers (N) = 16 workers

\[ T = \frac{k \times V}{n} \]  

(11)

\[ T = 2.47 \text{ days} \approx 3 \text{ days} \]

b. Conventional Formwork

Handyman's coefficient (k) = 0.330 OH
Number of workers (N) = 16 workers
Work volume (V) = 1582.10 m²
Calculation of the duration of the implementation of formwork work

\[ T = \frac{k \times V}{n} \]  

(12)

\[ T = 32.6 \text{ days} \approx 33 \text{ days} \]

The calculations shows that the work duration to install aluminum formwork (Kumkang) is much shorter to finish the same amount of the installation area.

4.4.8 The Cost Calculation of The Formwork Workers

Handyman fee per day = Rp 150,000,-
Number of Handyman for each kind of formwork (N) = 16 workers
Workers Cost = Number of Handyman (N) x Handyman fee per day x Time duration (T)

Aluminium form (Kumkang) Workers Cost

\[ = 16 \times \text{Rp.}150,000 \times 3 \text{ days} \]
\[ = \text{Rp.} 7,200,000 \]

Conventional Formwork Workers Cost

\[ = 16 \times \text{Rp.}150,000 \times 33 \text{ days} \]
\[ = \text{Rp.} 79,200,000 \]

The calculations shows that the Formwork Workers Cost to install aluminum formwork (Kumkang) is much cheaper.
4.5 Development Stage

The results of the calculation of aluminum formwork (kumkang) and conventional formwork are presented in the form of table 7.

Table 7: The Summary of the calculation of formwork workers to Install Aluminum (Kumkang) and Conventional Formwork

|                  | Aluminium form (kumkang) | Conventional |
|------------------|---------------------------|--------------|
| Productivity Coefficient | 0.025 MD                  | 0.33MD       |
| Duration         | 3 days                    | 33 days      |
| Cost             | Rp. 7,200,000             | Rp 79,200,000|

Tables 7 show that the Kumkang Aluminum formwork has more advantages than the conventional ones because Kumkang aluminium formwork is more efficient, time saving and cost saving.

4.6 Presentation Stage

In this phase, the result of the Value Engineering (VE) study was presented by PT. PP as the contractor to the owner and other decision-makers.

4.7 Implementation Stage

Kumkang Formwork is applied for slab, beam, column and reinforced wall in Alton Apartment Project

![Figure 1. Installation of Aluminium Formwork “Kumkang”](image)

Kumkang Aluminium Formwork is applied to mold slab, beam, column and reinforced wall because of its advantages in saving time and cost.

Kartohardjono, in his research, found that the Value Engineering process on the wall work with several alternatives obtained savings between 20.17% -20.97%[6]. Kembunan also found that the percentage of cost savings is about 24.5% of the initial cost, obtained from the alternatives of the red brick walls, plaster walls, and ceiling works [7]. While Hendrianto, Sugiyarto, and Setyawan found that by using Value Engineering, cost-saving in column structure works is 12.58% while ladder jobs save 8.19% [8]. This proves that this research is in line with previous studies where value engineering can save time and costs shown in Table 7

5 Conclusion

a. The calculation of the workers unit price coefficient analysis on the aluminum formwork (kumkang) get a coefficient of 0.025 MD, smaller than the coefficient of unit price of workers on formwork work according to the Ministry of PUPR (2016) of 0.330 MD. It shows that Conventional Formwork needs more workers than Aluminum Formwork (Kumkang) to finish the same amount of the installation area.
b. The duration calculation of the aluminum formwork (kumkang) gets that the installation work has a duration of 3 days, while the duration of the conventional formwork installation is 33 days. The time difference is 30 days. It shows that the work duration to install aluminum formwork (Kumkang) is much shorter to finish the same amount of the installation area.

c. The Cost Calculation of the formwork workers shows that the worker cost to Install Form Aluminum (Kumkang) is Rp. 7,200,000 while that the worker cost to Install Conventional Formwork is Rp 79,200,000. It shows that the worker cost to Install Form Aluminum (Kumkang) is cheaper.

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