Computing the maximum value engineering for a building construction costs using linear programming applications.

K Siripob¹ and C Vuttichai²
1 Ph.D. Student, Civil Engineering Department, Faculty of Engineering
King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand.
2 Asst. Prof. Dr, Civil Engineering Department, Faculty of Engineering
King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand.

E-mail: siripob.k@gmail.com

Abstract. Value Engineering is an effective technique for reducing costs, increasing productivity and improving quality. Value engineering is a technique directed toward analyzing the functions of an item or process to determine best value or the best relationship between worth and cost functions. Building construction costs comprises 2 major components as materials cost and labor cost. Linear Programming (LP) is a quantitative technique by means of a mathematical modeling technique designs to solve allocation problem (resource allocation) to achieve the maximum profit or lowest cost. Therefore the authors bringing the advantages of both as value engineering and linear programming combined to work together in order to be able to effectively reduced building construction costs or create maximum value engineering that can be best used in the construction projects. Aim of this paper shows the reduction of building construction cost as to achieved the targets for reducing building construction cost or maximum value engineering as much as possible that leads to efficiency of cost reduction by used of principles of value engineering to apply with using linear programming for the reduction of building construction costs based on the material costs and labor costs to serve construction resource reallocation by consideration is made only 3 type construction materials as concrete, rebar and formwork because of 3 type are main component of building construction materials.

Keywords — Value engineering, Linear programming, Construction Costs, Cost function, Worth function.

1. Introduction

Value engineering is a systematic, interdisciplinary examination of factor affecting the cost of a product so as to devise means of achieving the specified purpose at the required standard of quality and reliability at the target cost. At present, for current construction project in several countries it has applied the value engineering popularly, it can reduce the construction costs. The major aim of value engineering is to systematic identification and elimination of unnecessary cost of building construction cost or businesses whereas those products or work can have the same quality, function, and reliability just like before the value engineering is applied. Relative equation is as below.

\[ \text{Value} = \frac{\text{Function}}{\text{Cost}} \] (1)

Equation(1) illustrated for value engineering is a technique directed toward analyzing the functions of an item or process to determine best value or the best relationship between worth and cost functions of items or products.

1.1. Definition of cost function and worth function and their relation.

Function cost is price that can perform function. Emphasis is placed on basic functions or sometimes function worth can be defined as one man’s price is another man’s cost. Function worth is the lowest
cost to provide a given function. Emphasis is placed on basic functions or the lowest cost that can contribute basic functions.

**Figure 1.** The relationship between cost function with worth function in value engineering process.

Figure 1. that illustrated to the relationship between cost and worth function by applying Value Engineering. Cost function which represents the initial costs of the building project which included material costs and labor costs after that will be applied value engineering with various conditions. The resulted will be worth function which meaning to the construction cost is reduced but the functions are remains the same.

1.2. **Linear programming.**

Linear programming (LP) has proven its efficiency to mathematically model many problems aiming at the maximization or minimization of certain function (objective function) that is linearity dependent on set of variables related to each other through a set of linear constraints. Linear Programming (LP) is a quantitative technique by means of a mathematical modeling technique designs to solve allocation problem (resource allocation) to achieve the maximum profit or lowest cost. The linear programming can be applied with many types of work such as budget allocation, production cost reduction planning, investment and including to construction. Structure of a linear programming model that consists of one objective which is a linear equation that must be maximized or minimized. From constraint equation that specifies restriction of objective function, optimal solution comprises values of decision variables; for example, x1, x2, x3, to xN ,etc. The values of decision variables are non-negative and the objective function must be in the form of a linear equation and each constraint must be a linear equation or a linear inequality. Components in Linear programming are shown to below. :

1.2.1 **Objective function.**

The objective of a linear programing model will be to maximize or minimize some numerical value; for example, the best outcome from maximum investment or optimal profit or maximum saving for this paper that meaning to maximum value engineering.

1.2.2 **Decision variables.**

Determination of decision variables is essential because a problem may be specified with various variables. It can be said that decision variables are the variables which will decide output such as x1, x2, x3, x4,…..xN when xN refers to the quantity of each type of materials which are required for this paper.
1.2.3 Constraints.
The objectives of problem can be achieved the optimum or minimum more or less depend on constraints or restriction such as resource restrictions, budget or cost for construction, requirements rule, regulation, policy or condition of problems.

1.2.4 Non Negativity Restriction.
All variables in a linear programming must not be less than zero.

2. Method
This paper presents realistic linear Programming models that define the variables and problem constraints also objective function for maximize value engineering of building costs. Firstly, it should understand what is operation research and linear programming where it’s mathematical modeling is a cornerstone to solve more problems and making a decision before a final decision can be reached.

2.1. Linear programming applications.
Therefore, it is advisable to describe maximum value engineering of building construction cost or optimization materials as a mathematical programming problem, and to solve it using LINGO (release17.0).

Figure2 explained the procedure of linear programming applications to finding the objective function consisting of the 6 variable that is called the cost function with the concrete quantity (x1), rebar quantity (x2) and formwork quantity (x3). Besides, it has used Lingo-R17 software to solve this problem, and the gaining result is the worth function with the concrete quantity(x4), rebar quantity (x5) and formwork quantity(x6). Therefore, the most important answer is the objective function that is the maximize value engineering of building costs.
2.1.1 Decision variables. Which are as follows.

**Table 1.** Cost function variables

| No. | Details                | Unit  |
|-----|------------------------|-------|
| x1  | Concrete quantity      | (m³.) |
| x2  | Rebar quantity         | (kg.) |
| x3  | Formwork quantity      | (m².) |

**Table 2.** Worth function variables.

| No. | Details                | Unit  |
|-----|------------------------|-------|
| x4  | Concrete quantity      | (m³.) |
| x5  | Rebar quantity         | (kg.) |
| x6  | Formwork quantity      | (m².) |

2.1.2 Objective function. This integrated model is developed to maximize value engineering a construction building costs, as described below.

\[
2500(x_1-x_4) + 22(x_2-x_5) + 500(x_3-x_6) + 350(x_1-x_4) + 6(x_2-x_5) + 150(x_3-x_6)
\]

Equation (2) represent to the objective function which illustrated will be able to maximum value engineering for building construction costs under all constraints and only 3 types of construction material as concrete, rebar and formwork by that including material costs and labor costs which have a unit costs for material cost and labor cost, that are the assumption datas used in table 3 as follow:

**Table 3.** Unit costs of construction.

| Materials                | Unit | Material (THB) | Labor (THB) |
|--------------------------|------|----------------|-------------|
| Concrete quantity        | (m³.)| 2500           | 350         |
| Rebar quantity           | (kg.)| 22             | 6           |
| Formwork quantity        | (m².)| 500            | 150         |

2.1.3 Constraints. This model, we have constraints all 16 equations as follows.

\[
2500x_1 + 22x_2 + 500x_3 \leq 1,000,000 \quad (3)
\]

\[
350x_1 + 6x_2 + 150x_3 \leq 500,000 \quad (4)
\]

\[
2500x_4 + 22x_5 + 500x_6 \leq 500,000 \quad (5)
\]
\begin{align*}
350x_4 + 6x_5 + 150x_6 & \leq 100,000; \quad (6) \\
x_1/x_3 & \leq 6; \quad (7) \\
x_1/x_2 & \leq 0.008; \quad (8) \\
x_2/x_3 & \leq 20.8; \quad (9) \\
x_4 & \geq 0.7x_1; \quad (10) \\
x_5 & \geq 0.7x_2; \quad (11) \\
x_6 & \geq 0.7x_3; \quad (12) \\
x_1, x_2, x_3, x_4, x_5, x_6 & \geq 0; \quad \text{(Non negativity)} \quad (13)
\end{align*}

Where:

3 is the material cost (THB.) of building construction costs which is assumption data before value engineering process.

4 is the labor cost (THB.) of building construction costs which is assumption data before value engineering process.

5 is the material worth (THB.) of building construction costs which is assumption data.

6 is the labor worth (THB.) of building construction costs which is assumption data.

7 is the relationship between concrete quantity with formwork quantity before value engineering process which is cost function.

8 is the relationship between concrete quantity with rebar quantity before value engineering process which is cost function.

9 is the relationship between rebar quantity with formwork quantity before value engineering process which is cost function.

10 is the value engineering of the concrete quantity which will be reduced no more than 30% of original quantity which is worth function.

11 is the value engineering of the rebar quantity which will be reduced no more than 30% of original quantity which is worth function.

12 is the value engineering of the formwork quantity which will be reduced no more than 30% of original quantity which is worth function.

13 are the all variables to be nonnegative.

3. Results.

This problem solving by the mathematical model using LINGO (Release17.0) software.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Figure 3 is all equations which is input in Lingo from the software release(17.0) for solve the objective function that is the maximize value engineering of building costs under all constraints are concern cost function and worth function.}
\end{figure}
Table 4. The resulted of x1, x2, x3 are cost function variables.

| No. | Materials | Quantity | Unit   |
|-----|-----------|----------|--------|
| x1  | Concrete  | 71.37    | (m³)   |
| x2  | Rebar     | 8,922.13 | (kg.)  |
| x3  | Formwork  | 428.949  | (m²)   |

Table 5. The resulted of x4, x5, x6 are worth function variables.

| No. | Materials | Quantity | Unit   |
|-----|-----------|----------|--------|
| x4  | Concrete  | 49.96    | (m³)   |
| x5  | Rebar     | 6,245.49 | (kg.)  |
| x6  | Formwork  | 300.26   | (m²)   |

From table 4 and table 5 are a resulted of all decision variables that shows the resulted of worth variables (x4, x5, x6) are reduced from the cost variables (x1, x2, x3) according to the all constraints and represents the difference between the cost and worth variables in Table 6.

Table 6. As show the materials quantity reduced between cost function and worth function.

| No.     | Materials | Quantity | Unit   |
|---------|-----------|----------|--------|
| x1-x4   | Concrete  | 21.41    | (m³)   |
| x2-x5   | Rebar     | 2,676.64 | (kg.)  |
| x3-x6   | Formwork  | 128.69   | (m²)   |

Table 6 illustrated the materials quantity reduced between cost function and worth function that can be reduced the quantity of construction materials as concrete, rebar, and formwork by using linear programming application that is able to reduce the amount of concrete 21.41 m³ (x1-x4) reduced rebar was 2,676.64 kg. (x2-x5) and reduced formwork be 128.69 m³ respectively. The objective function is 219,618.4 THB, as figure 5 which meaning to the maximum value engineering for a building construction costs under all constraints, that value displayed to a benefit for reduced of building construction costs and including construction materials that are reduced the quantity of materials as concrete, rebar, and formwork which benefit to resources and costs management for building construction.

4. Conclusions.
The objectives function can be meet the targets which depend on all constraints and decision variables. The resulted of materials quantity will be worth function which meaning to the construction cost is reduced but the functions are remains the same. Therefore, the value Engineering is an effective technique for reducing of building construction cost by apply with linear programming which resulted shown to achieved the targets for reducing building construction cost as much as possible that leads to
efficiency of maximum value engineering and the resulted of all decision variables which is benefit for resource management of construction projects. The future research in the field of value engineering of construction for, that can used to goal programming to be applied with the value engineering for construction to solved the best results of all goals under the corresponding conditions.

5. References.
[1] Barry Render, Ralph M. Stair, Jr, Michael E. Hanna, and Trevor S. Hale, *Quantitative Analysis for Management*, 12th edition, (published by Pearson Education @ 2015.)
[2] Alphonse Dell’Isola, PE, *Value Engineering: Practical Application for Design, Construction, Maintenance & Operations*, (Construction Publisher & Consultants)
[3] Wayne L. Winston, *Operations Research Applications and Algorithms* 3rd Edition, (Publisher: Duxbury Press)
[4] Robin Cooper and Regine Slagmulder, *Target Costing and Value Engineering*, Copyright @1977 by The IMA Foundation for Applied Research, Inc. (published by Productivity Press, a division of Productivity, Inc.)
[5] Alphonse J. Dell’Isola, *Value Engineering in the Construction Industry* 2nd edition, (Copyright @1974 by Construction Publishing Company)
[6] Hamdy A. Taha, *Operations Research An Introduction*, 9th Edition, (publishing as Prentice Hall, Copyright @2011 Pearson Education, Inc., One Lake Street, Upper Saddle River, New Jersey, The United States of America.)
[7] John Kelly and Steven Male, *Value Management in design and construction*, The economic management of projects, 1st edition 1993
[8] Anderson, Sweeney and Williams, *An Introduction to Management Science, Quantitative Approaches to decision Making*, 7th edition, (copyright @1994 by West publishing company.)
[9] S. Christian Albright, Wayne L. Winston, and Christopher Zappe, *Data Analysis & Decision Making with Microsoft Excel*, 3rd edition (copyright @2006 by The Thomson Corporation.)