ABSTRACT

Construction projects are done by conventional methods by generating flow chart of input, process and output. However there is no programmed system to implement value engineering (VE) in construction projects. Clients require more than technical expertise and problem solving. They expect customer service and value for money. Client satisfaction is a fundamental issue for construction participant who must constantly seek to improve their performance. Recently, value engineering has received considerable attention from engineers and clients. Value engineering is a creative, systematic effort directed at analyzing functional requirements of a project for the purpose of achieving essential functions at lowest total cost over life span of project. Through a group investigation, using experienced, multidisciplinary teams, value and economy are improved through the study of alternate design concepts, materials and construction methods without compromising the functional requirements and quality. This paper covers generalized concept of value engineering along with its applications in different stages. It also discusses on various benefits of VE along with a case study of practical project of basement raft.

KEYWORDS: Value engineering, construction, function, quality, cost, value, project, phase

1. INTRODUCTION

Recently, value engineering (VE) has considerable attention from clients and civil engineers. Currently there is no any systematic process to implement VE in construction projects. But nowadays awareness of importance of VE has grown within construction industry. VE plays an important role throughout the life of project by realizing quality, reliability, durability and enhanced performance. Value engineering is a disciplined procedure designed to seek out optimum value of both initial and long term investment.

2. VALUE ENGINEERING

2.1 What is Value Engineering?

Value engineering is a systematic application of recognized techniques which identify the functions of the product or service, establish the worth of those functions, and provide the necessary functions to meet the required performance at the lowest overall cost. Value engineering concentrates on the effectiveness through stating functions, goals, needs, requirements and desires.
Value (V) = Function (F) /Cost (C)

where V is Value, F is sum of total function performance and C represents cost paid for it. The relation of F and C shows that the lower the cost for optimum function, the better the value.

2.2 History

Value engineering concept was started by Mr. Lawrence D. Miles during 1940’s. He worked for General Electric Company (GEC), USA which faced scarcity of strategic material needed to produce their products during world war-II. Mr. Mile was appointed in GEC in purchasing department. At that time there was shortage of steel, copper, bronze and other materials. GEC wanted to expand its production of turbo supercharger for B24 bombers from 50 to 1000 per week. Miles was assigned the task of purchasing material to permit this. Often he was unable to obtain specific material, so he thought to obtain an alternative which can perform the same function. Miles observed that many of substitutes were providing equal and better performance at the lowest cost and from this incident evolved the concept of value engineering.

3. VE STAGES FOR APPLICATIONS

Value engineering can be applied during any stage of a project cycle. VE may be applied more than once during life cycle of construction project. Early application of VE helps in more organized implementation of project activities, thus reducing overall cost by avoiding any major changes right in the beginning. If the application of VE is done in later stages it may result in higher project cost.

VE is applied in an organized process known as VE job plan. The purpose of job plan is to assist a study team to identify and focus on key project functions in a systematic manner, in order to create new ideas that will result in value enhancements. The VE job plan consists of five phases as below:

3.1 Information Phase

In this phase maximum information is collected from various aspects of project regarding identification of problems to be solved and gathering of information on background, function and requirements of the project. At the beginning of VE study it is important to:

- Understand the background and decisions that have influenced the development of design.
- Define owner’s objective and criteria governing the project.
- To analyze issues of project
- To discuss project cost and schedule data
- To prepare cost and energy models

VE team recognizes low quality area and high cost area and sets target quality improvement and cost savings.

3.2 Creative Phase

This phase involves generation of ideas and listing of those creative ideas from review of project. VE team thinks in creative way to provide necessary functions within the project. Large number of ideas are obtained through creative proposals and brainstorming. In team everyone is encouraged to participate. Evaluation of ideas is prohibited in this phase. The VE team is looking for quantity and grouping of ideas, which will be screened in the next phase.

3.3 Evaluation Phase

In this phase of project, VE team together with client defines the criteria for evaluation. It involves:

- Analysis of ideas resulting from creative phase.
- Ranking of ideas by VE team.
- Irrelevant or non-worthy ideas are discarded.
- Selection of ideas which represents greatest potential for cost saving and improvements.
A weighted evaluation is applied in some of the cases to account for impacts other than cost such as quality, safety, reliability, time, constructability, aesthetics, serviceability, durability, maintainability, etc.

3.4 Development Phase

During this phase many of ideas are expanded into workable solutions. It consists of:

- Preparation of alternative designs and life cycle cost comparison of original and proposed designs.
- Description of recommended design change.
- Each recommendation is presented with description, sketches, basic design concepts, technical information and cost summaries.
- Selected ideas are developed into proposals so that owner and other project stakeholders understand the intent of proposal and benefits to the project.

3.5 Presentation Phase

In this phase presentation of recommendation is prepared in the form of a report. The team for presentation consists of client, consultants and other stakeholder representatives. The VE team members describe the recommendations and basis that went during development phase. VE report is shared with client and designers. This begins the evaluation by the client and designer of the VE report. After incorporating client’s comments a preliminary proposal implementation action plan is prepared.

4. VE APPLICABILITY

VE can be applied at any stage in a project, even in construction. However, the earlier it is applied the higher the return on the time and efforts invested. Thus, the greatest benefit and resource saving is achieved in planning and conceptual stage. At this point major information is established but before major design and development resources are spent.

![Figure 1: The stages of VE application](image)

The three main stages of a construction project and VE application is as shown in figure 4.1.

4.1 Planning and Schematic Design (VE1)

The first VE study VE1 is applied during the planning and schematic design stage to define the project goals, functions, objectives, requirements, design criteria and scope of work. Benefit of
starting VE at this stage is that project will be developed with fewer changes, redesigns and greater understanding by all parties of what final function will be. Independent teams can bring alternative and creative solutions from other similar projects.

4.2 Design Development (VE2)

The second VE study VE2 is applied in design development stage to generate detailed VE proposals and alternatives to the design and to define technical systems. In this stage of VE, multiple design alternatives are considered and the most cost effective and overall efficient alternative is selected. Suggestions by other personal like constructor, designers are also taken for improvement.

4.3 Construction (VE3)

During this phase value engineering is still possible though the use of VE change proposal. But application of VE at this phase is generally costly and difficult to implement due to resistance to change.

4.4 Benefits of VE

Value engineering is used:

- To determine best design alternative
- To reduce cost
- To identify problems and develop solutions for them
- To improve quality
- To increase reliability, availability and customer
- To save time
- To increase safety

5. CASE STUDY

To understand the value engineering concept a case study of basement raft has been considered as a practical case study.

Basement layout of 5-story residential building is shown in Figure2 and Figure 3. Initially, for the design of basement raft, inverted beam and slab system is proposed by structural consultant as shown in Figure2. Slabs and beams are designed for upward soil and water pressure. After analysis, design of slab and beams is done using IS3370 and un-cracked permissible stresses as given in code. These conservative permissible stresses take care of leakages likely to happen in slab and beam. The schematic section through footing and raft is shown in Figure4. It can be seen from the figure that murum filling and PCC is required to prepare the floor finish. Also concreting has to be done in two stages. During first stage raft slab is cast and in second stage remaining part of inverted beam is cast using beam shuttering.

After these drawings are prepared, value engineering team is involved to find some other alternative solution for the same problem. In general, structures can be designed by different ways of structural framing systems. So in second alternative flat slab system is proposed for design of basement raft as shown in Figure 3. For the design of flat slab, limit state design approach is considered and crack width calculations are done. The crack width is limited to 0.2mm to prevent leakages as per code. The schematic section through footing and raft is shown in Figure 5. It can be seen from figure that murum filling and PCC is getting avoided in this proposal. During design phase, reinforcement spacing is kept same with same diameter of bar. Any extra reinforcement required at higher bending moment zone is given separately. This is done for simplicity of laying of the reinforcement. Different performance criteria have been used to compare the two alternatives as shown in Table1. Weightage for each parameter is given as below:

\[ \begin{align*}
1 & \quad \text{Acceptable} \\
2 & \quad \text{Good} \\
3 & \quad \text{Excellent}
\end{align*} \]

Using these points’ total score is found out to find the best solution.
Figure 2: Beam Slab Proposal

Figure 3: Flat Slab Proposal

Figure 4: Section through Footing and Raft (Beam Slab Proposal)

Figure 5: Section through Footing and Raft (Flat Slab Proposal)
<table>
<thead>
<tr>
<th>SR. NO</th>
<th>CRITERIA</th>
<th>BEAM-SLAB PROPOSAL</th>
<th>FLAT SLAB PROPOSAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>REMARKS</strong></td>
<td><strong>REMARKS</strong></td>
</tr>
<tr>
<td>1</td>
<td>Ease of Construction</td>
<td>* Overall tedious construction sequence and many centering activities.</td>
<td>* Overall simpler construction sequence and lesser' centering activities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Reasons:</strong></td>
<td><strong>Reasons:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>* 3-Stage concreting due to inverted beams and inverted footings.</td>
<td>* Only one stage concreting due to flat slab &amp; down stand footing with dead shuttering(Bricks).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Tedious reinforcement works due to inverted beam reinforcement like number of stirrups, curtail bars, different dia. bars.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Number of construction joints at raft slab and beam junction.</td>
<td>* Simple and uniform reinforcement layout, not much variation in diameter.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Design methods</td>
<td>*Working stress design with un-cracked stresses by code leads to more concrete and steel material due to high stresses * Conventional and conservative.</td>
<td>*Limit state design with crack width calculation check. * Leads to lesser concrete and steel due to crack width calculations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Construction Time</td>
<td>Construction time is more due to:</td>
<td>Construction time is less due to:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* 3-Stage concreting</td>
<td>* One stage concreting only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Murum Backfilling</td>
<td>* No backfilling, No PCC, No beams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Time required for compaction is more due to number of pockets.</td>
<td>* Simpler raft reinforcement layout</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* PCC above murum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Beam reinforcement is time consuming activity due to stirrups, curtail main bars.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Durability</td>
<td>Less durable as wear and tear surface is PCC instead of RCC</td>
<td>More durable as wear and tear surface is covered with RCC raft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Material cost</td>
<td>More due to-</td>
<td>Less due to-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Point no.2 above.</td>
<td>* Point no.2 above.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Backfilling material required to fill the pocket in between inverted beams.</td>
<td>* Backfilling material not required as there are no pockets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* PCC required above murum backfilling to achieve smooth and hard surface for parking</td>
<td>* PCC not required on raft top as concrete finish itself acts as flooring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Shuttering required for beams.</td>
<td>* Shuttering not required as there are no beams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Labor cost</td>
<td>* Skilled labor required.</td>
<td>* Medium skilled labor required due to simple work.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Expert supervision for different activity quality checks required.</td>
<td>* Less fitters and carpenters required due to straight bar cutting and very less shuttering work. Also reinforcement is done with uniform spacing all over raft with extra bars required at supports.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* More fitters and carpenters required due to number of bar bending and cutting activities, shuttering for beams</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Quality</td>
<td>*Less due to labor intensive work.</td>
<td>*Overall good due to simple work for labour.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Inverted beam creates many construction joints between raft slab &amp; beam junction due to 3-stage concreting.</td>
<td>* No construction joint as concreting is in one stage only</td>
</tr>
<tr>
<td>8</td>
<td>Cost Savings</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approx. 5 lacs (~Rs.100/sft of raft)</td>
<td>Approx. 5 lacs (~Rs.100/sft of raft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TOTAL SCORE 10</td>
<td>TOTAL SCORE 20</td>
</tr>
</tbody>
</table>

**Table 1. Performance Comparison of Two Alternatives**
6. CONCLUSION

It was discussed that using value engineering methods by multidisciplinary team, value and economy are improved through study of alternative design concepts, material and construction methods without compromising functional requirement and quality. A second look at the design produced by architect and engineers gives the assurance that all reasonable alternatives have been explored. From case study it is seen that different parameters of value engineering alternatives helps to find best solution. Flat slab proposed during value engineering alternative show that it is good constructability, cost effective and saves time of construction. Thus, value engineering assures best value will be obtained over life cycle of the building or structure.

7. REFERENCES

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