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Enhancing the Evaluation Phase of Value Engineering in Construction Projects Through Application of Choosing by Advantages (CBA)

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Value engineering (VE) is a systematic methodology used by a multidisciplinary team of professionals to provide value to the owner of a project, product, or service. This value can manifest in reduced cost, improved performance and quality of systems or overall project saving. The success of a VE methodology depends on the team conducting good function analysis, using correct creativity approaches, and employing better evaluation tools. Noteworthy is that the use of conventional VE methodology has shown various limitations where project owners may end up not getting the needed value. Thus, this research assessed the evaluation phase of VE and then proposed and demonstrated a new evaluation technique in VE called Choosing by Advantages (CBA) on a small case study project. The CBA concept was presented to the VE practitioners and then a survey questionnaire was administered to them to get their feedback about the concept relative to improving construction project outcome. The results showed a user-friendly and accepted CBA tool which could be used in VE methodology by construction project teams to provide the needed project value. This research contributes to the VE studies body of knowledge especially those focusing on improving construction project value and overall outcome.

Key Words: Construction Project, Decision-making, Value Engineering, Choosing by Advantages

Introduction

Value engineering (VE) is a strategic methodology that focuses on functions to deliver projects at the lowest overall cost (Sharma and Srikonda, 2021; Wao, 2015). VE can also be defined as a systematic and function-oriented tool that employs multidisciplinary team of professionals working in an organized workshop to provide value by improving the quality and performance of systems, projects, or services at the lowest overall life cycle cost (Lin et al., 2023; Wao, 2017). Noteworthy, the 'value' concept does not have a universal interpretation. In fact, value can be construed to reflect one's feelings and can be subjective in that what is valuable for an individual may not necessarily be valuable to another. And most people mistakenly believe that what costs more is worth more or has a high value. However, value is not synonymous with cost. Value may mean a ratio of positive and negative aspects of a project, process or service which drives into another concept called worth. To measure worth, the system is first translated into its functions and reference data are used to determine the cost of each function. The cost of the basic function and the required secondary functions determines the worth. The value or worth of the function is the lowest overall price or cost to accomplish a given function. This is what value engineering or value analysis is about.

Started at General Electric, a major defense contractor, by L.D. Miles around 1948, VE is a strategic, systematic, and function-oriented technique that can be used to meet owner's project requirements at the lowest overall or optimum life cycle cost. In developing and providing meaning to value at General Electric where they faced scarcity of materials to produce products, Miles upheld that resources were to be sought only where they were needed most and could function best (Miles,1947). That is, products are bought for a specific purpose, namely, for what they can do best including providing the best aesthetic appeal to the users (Wao, 2016; Miles,1947).

The VE concept has improved significantly to date through incorporation of value adding techniques in the VE job plan and through the analysis of functions using Function Analysis and System Technique (FAST) VE methodology. Specifically, VE job plan phases that have been examined and improved including the function analysis and identification phase of VE by using methods such as performance-worth (PW) method (Wao, 2016), creativity phase improvement using neuro-linguistic programming (NLP) method (Wao, 2018) and evaluation phase using choosing by advantages (Wao, 2017). However, this latter VE phase improvement approach utilized both the students training as well as evaluation by sustainability faculty experts to evaluate students VE final reports which were assessed after students receiving training in an academic course and then developing VE reports. There was no feedback on the evaluation tool by those from the construction industry for validity.

Therefore, this current research extended this through identifying the limitations in the conventional VE method, finding ways to address the limitation, and then involved those from the construction industry to provide their viewpoints. The research also demonstrated its application using a small case study project. In essence, the purpose of this research was to refocus the conventional VE process to improve project outcomes using CBA in the evaluation of project alternatives. The objectives were to identify the limitations in the VE evaluation phase and find ways for redress. The guiding standards reviewed were the SAVE-International job plan through the SAVE International Value Management Body of Knowledge (VMBOK) of 2020 and the American Society for Testing and Materials (ASTM) standard E1699-20, also known as the Standard Practice for Performing Value Engineering (VE)/Value Analysis (VA) of Projects, Products and Processes. The VE evaluation phase is a key part of the VE job plan since it will aid in providing useful solutions for integration in projects, and so this study focused on it relative to providing better project outcomes.

Literature Review

Value Engineering and Multi-Criteria Decision-Making Methods

Good analysis of functions of systems by an engaging VE team that has members showing good rapport with each other to develop practical solutions in projects is a clear characteristic of a successful VE process (Wao, 2017). This team employs rigorous effort in evaluating systems to select good solutions from different alternatives. Typically, the team lists the evaluation criteria consisting of advantages and disadvantages of each alternative then rank order them. Ideally, the evaluation phase of VE is critical since the selected options will be included in the project, and so the correct, proper and sound decision support system is needed that will be used to select solutions that meet the project requirements. Different stakeholders and construction professionals may have different ideas about decision support system (DSS). Ideally, a DSS is an interactive method that assists its users in judgment and arriving at good solutions. It serves in informing the decision-making process by assisting users to know the importance of the different decisions they make (Wao, 2017).

Project decisions may need sound DSS since they involve multiple criteria and significant tradeoffs between short term and long-term pay-offs that may require life cycle cost (LCC) or life cycle analysis (LCA). This may elicit VE propositions that assign quantifiable values on qualitative features in their project value assessments. Consideration for DSS may include the relative advantages associated with them, cultural compatibility, ease of understanding, and observeability of results and outcomes. Overall, DSS must be created that allows quick and effective evaluation of different options to arrive at investment decisions that allow meeting the goals.

Multi-Criteria Decision-making Methods (MCDM) is one of such DSS. In construction projects, owners may employ MCDM to select systems that give them the needed value. Many variations of them have similarities and may include Goal Programming (GP), Utility Theory (UT), Weighted Product Method (WPM), Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), among others.

GP focuses on finding valuable, realistic, and feasible solutions. It differs from other conventional methods of optimization by its adherence to 'satisficing' principle rather than optimizing (Hassan and Loon, 2012). UT assumes that maximizing utility or value function is the top goal which also depends on specific criteria. Its strength is its ability to capture risks (or uncertainties) in the decision-making process (Chastian, 2010). WPM is based on the idea that the score of an alternative is equal to the sum of the performance of an alternative under each criterion multiplied by the relative weight assigned to that criterion (Sarika, 2012). AHP gives a framework to structure decision problems by representing and quantifying elements, relating those elements to overall goals, and then evaluating alternative solutions (Wao, 2017). It starts by developing alternative options, specifications of values and criteria, and concludes with evaluation and recommendation of options (Lin et al., 2023; Wao, 2017; Farkas 2010). The structure consists of three levels. Goals are set at the top level, followed by criteria at the second level, and alternatives at the third level. TOPSIS is based on two alternatives; an ideal alternative with the best attributes with maximum benefits and minimum cost attributes and the negative ideal alternative which has the worst attribute values characterized by minimum benefit attributes and maximum cost attributes. TOPSIS will select the alternative that is the closest to the ideal solution and farthest from the negative ideal solutions (Chakraborty, 2022).

In overall, the MCDM use pair-wise comparison of criteria in addition to weighting, rating and calculating (WRC) method to arrive at preferred solutions. Conventional VE process may incorporate one of these MCDM in the evaluation phase of the VE exercise. Usually, the weighted product method is used in most projects because of its ease of use compared to other methods and also some VE experts have not taken time to learn other easy and sound techniques (Wao, 2018). Noteworthy is that the current VE methodology is seen to exhibit some limitations in the VE evaluation phase.

Limitation of the Conventional Value Engineering Evaluation Phase

The SAVE-International VE job plan as shown in the VMBOK (2020) and the ASTM E1699-20 are the two main value methodology standards that define the steps for VE. Conducting good VE exercise requires good teamwork, great communication as well as execution of good evaluation techniques (Wao, 2023). Figure 1 shows the job plan with the evaluation phase as the area in focus.

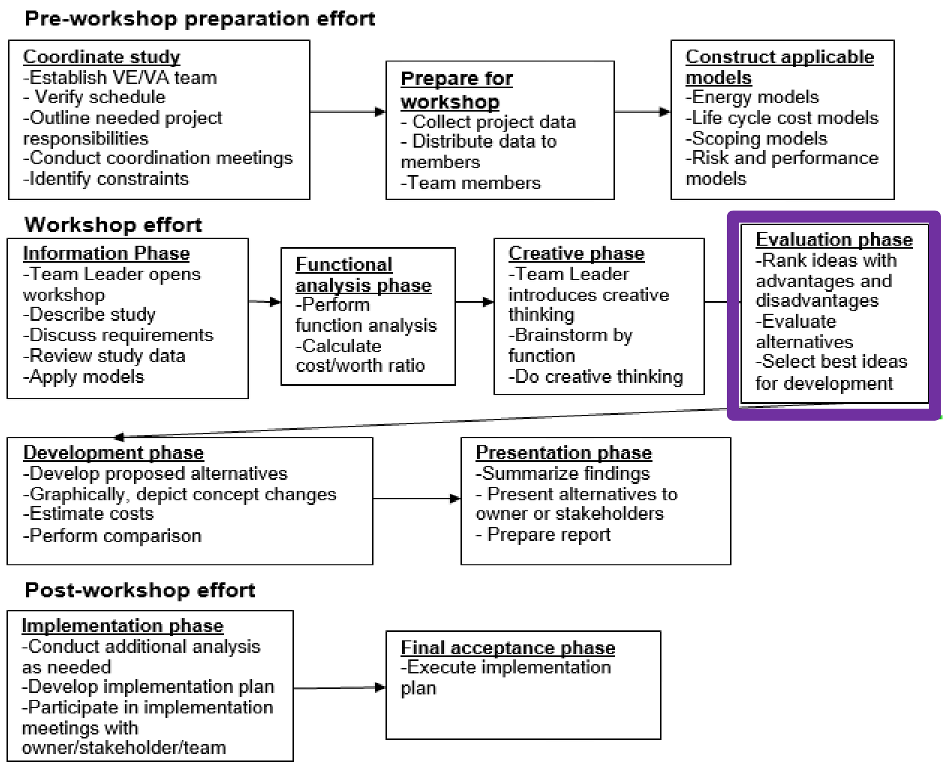

Figure 1. VE job plan with evaluation phase in focus as marked in purple box shown.

Conventional VE using ASTM E1699-20 and SAVE-International job plan has characteristics that may impair VE goals. MCDM also has these traits. Thus, the weighted analysis method usually used in VE might be limited in achieving project goals. The limitations according to Wao (2017) and Wao (2015) are:

- *Use of pair-wise comparison to determine relative importance of each alternative*: Using pair-wise comparison of criteria to select the best system usually operates on abstract terms that may not yield sound outcomes.
- *Abstract allocation of weights to criteria*: The conventional VE relies on abstractions. In pair-wise comparison of criteria from quality model, it awards positive value to a criterion that has positive preference and zero (0) to one with negative preference. Further, where the difference between two criteria is zero (0), it assumes equal preference and awards one (1) or equal rating for both. Interpreted differently, when two criteria are compared, it awards a zero (0) when the result after the pair-wise comparison is a negative value and one (1) when the summation of weights equal to zero. These abstractions require the team to fill in the gaps caused by missing information to arrive at decisions not associated with relevant facts.
- *Using advantages and disadvantages to rank alternatives*: Evaluating the alternatives considers both the advantages and disadvantages. This can be incorrect as an advantage of one alternative may be a disadvantage of another alternative. This can introduce double or multiple counting of advantages leading to errors in evaluation and final outcome.

Alleviating the Limitation in the Evaluation Phase by using Choosing by Advantages

Introducing a sound decision support system can alleviate the limitations in the conventional VE method (ASTM E1699-20 section 7.3.4). This will remove the unsound DSS characterized by the MCDM. The sound DSS will improve processes largely and Choosing by Advantages (CBA) decision making method can be the method used to lead VE team to achieve the required project goals.

CBA is based on the premise that decisions must be made based on relevant facts and that only 'advantages', and not both 'advantages and disadvantages', are to be used during the evaluation process (Suhr, 1999). This is because a disadvantage of one alternative can be an advantage of another alternative in the same evaluation plan and vice versa. And so, listing both advantages and disadvantages may lead to double or multiple counting of factors, omissions, distortions, and confusion thereby leading to unsound decision outcome. Specifically, CBA is based on the principle of comparing system's alternatives based on their importance of advantages. Also, CBA requires decision-makers to continue learning and skillfully using sound methods of decision-making.

On the contrary, CBA does not use the WRC principle of MCDM which is also seen in the conventional VE method that also focuses on using abstract terms, abstract allocation of weights to criteria, pair-wise comparisons of criteria, and use of both advantages and disadvantages in evaluating alternatives. This is because it considers these approaches unsound methods which do not yield sound outcomes over the life cycle of projects. And so, integrating CBA in the VE evaluation phase will enhance project outcomes. The VE team will engage in evaluating alternatives using a method that incorporates both quantitative and qualitative factors in the decision process. Sound decisions made will provide the value that is noticeable in cost, performance, and quality improvements. Thus, the project owner can obtain the best value (or outcome) for the lowest economic investment over the life of a project using a sound VE approach. A research method is stated to validate this viewpoint.

Research Methods

Aim, Objectives and Hypothesis

The aim of this research was to improve the VE methodology for better project outcomes. The objectives were to 1) identify the limitations in the evaluation phase and find redress 2) demonstrate the use of CBA in small case study project which is then presented to VE practitioners and 3), assess the effect of the new VE method through survey of VE practitioners. The hypothesis was that the new method would provide better project outcomes. The significance of the study was to provide project owners and practitioners with a tool that would provide them with better value in projects.

VE Practitioners and Presentation of CBA

Various MCDM were assessed, and CBA method was chosen after critical analysis. CBA operation was presented to the VE practitioners who had been requested to take part in the research. The research required them to be offered CBA presentation and then they would be sent a survey questionnaire to provide their opinions about CBA method relative to improving project outcomes. Before this process began, a written informed consent to participate in this research was sought from them and the Institution Review Board (IRB) facilitated this process since the research involved human subject participants. The CBA idea was presented to them in detail.

A small case study project example detailed out how CBA can be applied in projects.
Four words in CBA vocabulary represent four of the concepts that make sharp difference between sound and unsound decision making as presented by Suhr (1999). They are below;

- A factor: is an element, or a component of a decision; it is a container for criteria, attributes, advantages: FACTORS ARE NOT DEVELOPED PRIOR TO THE ALTERNATIVES.
- A criterion: is a decision rule, or guideline; any standard which guides decision making.
- An attribute: is a characteristic or consequence of one alternative.
- An advantage: is a difference between the attributes of two alternatives.

CBA can add its sound decision-making practices, the alternative generating processes from a VE job plan. (i.e. function and creative phases) and the evaluation phase.

The following will demonstrate how CBA can be used in a project. In this small case study project, the team is to choose from four different houses on four different lots using CBA tabular method. For clarity, the following factor definitions were developed by the VE team in the decision-making process based upon reviewing the four alternatives during the evaluation phase of VE (Adams, 2004);

- *Time*: the period in months, from now until the date of occupancy of the house.
- *Privacy*: it is important that the lot has two access from two streets but being too close to the intersection is undesirable.
- *Color*: the combination of colors used on the exterior of the house.
- *Additional rooms*: the number of additional rooms that could easily be created by subdividing existing bedroom or study areas.
- *Electronics*: installed electrical wiring and equipment to facilitate a wide variety of communication, security, and entertainment.

The following are the steps in CBA (Adams, 2004; Suhr, 1999);

- Step 1. *Identification of factors*
  These are based on the areas where the evaluators find significant differences. The factors are not developed prior to the alternatives. It is important that the evaluators collect as much information as possible about the alternatives.
- Step 2. *Summarizing the attributes*
  Summarize the attributes for each one of the factors. Sometimes they are measurable (as with time or privacy), sometimes they are not. CBA is created specifically to accommodate both types of factors.
- Step 3. *Deciding the advantages*
  First, the evaluators underline the least preferred attribute, then the positive difference between the least preferred and other attributes is entered for each factor.
- Step 4. *Establishing a scale of importance*
  First, the evaluators circle the most preferred advantage for each factor and then choose the paramount advantage (i.e., one of the most preferred advantages). To this advantage is assigned a quantity of 100.
- Step. *Deciding the importance of each advantage*
  First, the evaluators rate each circled advantage against the paramount advantage (e.g., an evaluation of 70 would mean that that advantage is 70% as important as the paramount

advantage. Complete deciding importance ratings for each of the circled advantages and then proceed to assign importance ratings for all other un-circled advantages.
Several things to notice here: first, the judgments are subjective, and this is as it should be since CBA was intended to incorporate quantitative and qualitative metrics equally. Second, the importance of each advantage is measured against one paramount advantage. Third, there is a tendency to interpret the results as meaning that one factor is more important than the other. This is WRC thinking. Rather, it is the importance of advantages of one alternative over another that is being compared. There is a great difference.

- *Step 6-Choosing the preferred alternative*
  Sum the importance numbers for each alternative. The highest sum is the preferred advantage and this sum is underlined twice. Figure 2 shows the process to the selected alternative.

FACTORS	ALTERNATIVE							
	BASELINE		ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3	
1.TIME Attributes	12MON		14 MON		18 MON		13 MON	
Advantages	6MONTH EARLY	80	4 MONTHS EARLY	60			5 MONTHS EARLY	68
2.PRIVACY Attributes	CLOSE TO CORNER		10' BUFFER		150' FROM CORNER		FRONT ROAD ONLY	
Advantages	0' SEP.	10	10' SEP	20	150' SEP	90		
3.COLOR Attributes	GREEN AND TARN		GREY AND WHITE		BLACK AND WHITE		CORAL AND WHITE	
Advantages	MUCH MORE COLORFUL	70	ABIT MORE COLORFUL	20			MORE COLORFUL	40
4.ADD. RMS Attributes	1		0		2		3	
Advantages	1 MORE	30			2 MORE	60	3 MORE	85
5.ELECTR. Attributes	NONE		SURROUND SOUND		SUR SOUND AND CABLE		FULL ELECTR.	
Advantages			SLIGHTLY BETTER	40	BETTER	75	VERY MUCH BETTER	**100**
TOTAL IMPORTANCE		**190**		**140**		**225**		**293**

Figure 2. Choosing the most preferred alternative 3 based on the evaluation using CBA.

VE Practitioners and Survey Questionnaire

The VE practitioners requested to be in the research were then given a survey questionnaire to offer their feedback about the CBA VE method. Specifically, they were sent an online survey questionnaire via Google forms to gather their opinions about the limitations of conventional VE method and the proposed CBA approach for improving VE for better project outcomes. The survey entailed collection of the practitioners' demographic data, e.g., years in construction and getting involved with VE, whether they accept the limitations in conventional VE process, agreement with the CBA process to improve outcomes, and satisfaction with the VE methods to improve outcomes.

Before disseminating the survey questionnaire, it was pilot tested with 5 conveniently sampled participants with the results showing Cronbach's alpha of 0.87. This index was considered sufficient for reliability of the survey items for this research. That is, they were measuring what they were required to measure. A total of 25 (N=25) people were purposely sampled to take part in the research.

Results and Discussion

The data were mainly quantitative type and was analyzed using SAS studio (2024). The descriptive statistics results were mostly percentage scores and mean(average) measures. The survey questionnaire feedback showed that the practitioners (N=25) were mostly Certified Value Specialists (CVS), professors from universities as well as directors and presidents of construction companies, construction managers, and civil engineers. About 80% of the respondents had over 20 years of experience working in the construction industry while 14% of them had 6-10 years and 11-15 years of experience respectively where all of them (100%) had used VE in their projects. Of those who had used VE in their projects, about 80% of them had over 20 years of experience working with VE while 10% of them had 11-15 years and 16-20 years of experience respectively. This shows that the practitioners were rooted in construction and were better positioned to advise on better improvement.

The respondents were asked whether they accepted (or not) the limitations identified in the conventional VE process as actual or true limitations based on their VE construction industry experiences. Also, they were asked whether or not the identified limitations would negatively impact project outcomes based on their opinions from the presentation and construction field experiences. Considering the responses to the limitations on whether or not they were true or actual limitations, more than half of the respondents (60%) agreed that abstract allocation of weights to criteria was indeed a limitation that would negatively impact project outcomes (M = 3.74). About 40% were neutral concerning the limitation on the use of both advantages and disadvantages in evaluation.

Considering the negative impact of the limitations to construction project outcomes, about half of the respondents (42.9%) disagreed with the limitation pertaining to over-emphasis on cost while about 28.6% strongly agreed that it was actually a limitation relative to negatively impacting project outcomes (Mean = 3.29). Most of the respondents (80%) agreed with the CBA method and they also largely (91%) expressed that it would improve project outcomes. This feedback posed a potential avenue to propose CBA for inclusion in VE methodology for better project outcomes.

The data showed that in as much as VE provides a systematic approach for assessing options to improve performance, techniques such as CBA may work well for value planning studies but not so much to VE studies on projects that are closer to design completion. Some respondents held that CBA does improve the outcomes as it focuses on the attributes to select better options. Also, the qualitative data showed that CBA includes subjective information (abstract rankings) which have the potential to introduce flaws in VE. Specifically, a respondent held that options should be identified early to provide guidance for the VE team especially during brainstorming stage. Further, some held that using both CBA and performance-based VE with criteria-based attributes will allow full approval of the owner towards overall completion of the project, thus meeting owner's project needs.

Conclusion

This research investigated the conventional VE method, identified some limitations in the evaluation phase of VE and then proposed and affirmed the CBA approach to improve project outcomes. It demonstrated how CBA can be used in evaluating project alternatives where both qualitative and quantitative data can be integrated in the decision map to arrive at solutions based on the importance of advantages. The research determined and assessed the CBA method by presenting to the VE practitioners who were then involved in the validation of VE approach that integrated CBA method in VE evaluation phase through a survey questionnaire administered.

Analysis of their feedback showed that they were largely in support of the CBA concept and its overall inclusion in construction projects. The survey questionnaire administration, feedback and analysis result showed a user-friendly evaluation technique whereby the CBA method could be a worthwhile decision-making tool for projects that involve both qualitative and quantitative information. Therefore, it could be used by project teams that may go beyond the Architecture, Engineering and Construction (AEC) industry.

This research contributes to the VE studies body of knowledge especially those focusing on improving project value and overall outcomes of construction projects. Future research may apply the CBA method to a larger project, especially those sustainable construction projects with greater quality and performance goals as required by sustainable building certification.

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