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The Efficiency of Cost Management of Design Process for University Buildings to Achieve Sustainable Performance

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ABSTRACT

Optimum cost, performance and quality are the main drivers in building construction. Methods that have been developed so far have not comprehensively addressed building sustainability outcomes. However, there has been increased awareness of the importance of value engineering (VE) and sustainable development within the construction industry. Both subjects play crucial roles in realizing quality, reliability and durability as well as enhancing performance throughout the life cycle of a project. They also help to improve service related outcomes within budget constraints, achieve a more efficient use of resources, and accomplish an optimum combination of whole-life cost and quality to satisfy the owner and user requirements.

This research reviews the requirements for designing a sustainable building and describes the Value Engineering program, including the different phases of the job plan. Then it explores conceptual linkage between the two that relate to achieving best value over the whole life cycle of a project. Finally, this research proposes a method for improving the building sustainability.

The proposed method utilizes the job plan of the Value Engineering program together with a database that contains up-to-date information on construction systems and materials as a gear for studying and analyzing the sustainability requirements.

Keywords: Value Engineering, Sustainable construction, Performance worth, whole live value, Job plan

1. INTRODUCTION

The rapidly increasing human population is placing an increasing strain on the planet's available resources, possibly to a point beyond the long-term capacity of the earth, Along with climate issues, including a warming atmosphere. These potential problems have caused concern and require action, sustainability efforts, to improve the environment (Dylan, 2012; Hodges, 2005; Kirk, 2003; Zhao, Li, & Stanbrook, 2014).

Sustainable efforts can be directed in many directions; however, the buildings and supporting systems in our cities, the urban infrastructure, are large systems that impact our resources all across our nation (Malekpour, Brown, & Haan, 2015).

Colleges and universities are recognizing the impact of their campuses on the environment; after all, most large universities are very similar to small cities in their function and use of resources (Alshuwaikhat & Abubakar, 2008; McMillin & Dyball, 2009; White, 2014).

Many colleges and universities, including the Universities in New Administrative Capital of Egypt, are increasing sustainable efforts on their campuses. Egypt's government has already started the construction of eight international universities in the New Administrative Capital.

We can see the progress through some Universities that already are in progress (e.g., The Swedish University, Universities of Canada in Egypt, and The European University in Egypt).

Optimum cost, performance and quality requirements for buildings, their components and/or materials are the main objectives in almost every construction project. This has led to Value Engineering being proposed as a potential tool or methodology to deliver sustainable building projects.

As conventional practices of Value Engineering, the project value was translated to a monetary term as a ratio of cost to benefits. However other researches defined value in-terms of use, exchange/ replacement, esteem value and cost. That’s why we need a proper cost management application implemented in construction projects effectively.
Application of value engineering for sustainable development can increase the value of projects through the analysis of its functions.

1.1 Problem Statement

1) Lack of proper funding for governmental universities creating a challenging atmosphere to build facilities with the stakeholders needs, as well as improving the sustainability of the university facilities.
2) The conventional Value Engineering methods needs improvement to result in a sustainable building with optimum performance to its worth.

2. Sustainability

Sustainable Development is defined as "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs"(WCED 1987). Sustainable development integrates a variety of subjects: environmental quality, economic constraints in addition to social equity and cultural issues (Hajek 2002).

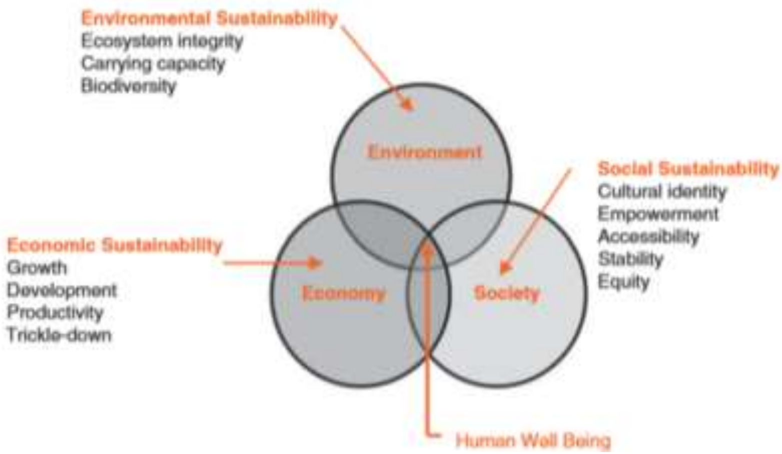


Fig. 1 – Sustainable Development

Sustainable/ Green Building Construction

Green building construction, sustainable construction can refer to the qualities and characteristics of buildings constructed using sustainable construction principles, that is, healthy buildings constructed in a resource efficient manner using ecologically focused principles (Kibert, 2008). Specifically, green building construction is the practice aimed at increasing the efficiency with which buildings use energy, water, and materials and their effectiveness in protecting and restoring human health and environmental quality throughout the life cycle of building, that is, siting, design, construction, operation, maintenance, renovation, and deconstruction (Abdulaziz, 2006b).

Sustainable materials are increasingly becoming more affordable by owners, sustainable building design elements are becoming widely accepted in the construction designs and building owners are beginning to demand and value green building features and sustainable construction goals (Morris, 2007).

Sustainability on higher education Campuses

Large higher education campuses are comparable to small cities in the resources they need to operate and their impact on the surrounding environment (Ashuwaikhat & Abubaker, 2008).

Designing and constructing sustainable buildings and also maintaining reasonable construction costs; however, can prove to be a challenge, as colleges and universities operate in an environment of committees that are typically not quick to make decisions (Sinclair, 2009). Building for environment and economic sustainability, building environmental assessment, environmental status model, and Leadership in Energy and Environmental Design program (LEED) are measurement tools that assess the sustainable value of different aspects of the design and construction of new facilities by scoring each component (Haapio & Viitaniemi, 2008). Green building was implemented by the USGBC through the LEED rating system. Thus, LEED has been a useful decision tool in gauging the level of sustainability of green buildings (Matthiessen & Morris, 2004).

3. Value Engineering

SAVE International defines VE as a systematic application of recognized techniques which identify the function of a product or service at lowest overall cost (Rohn, 2004; SAVE, 2007). The prime objective of VE has been to reduce cost while maintaining or improving performance and quality requirements. Other important objectives, reducing construction time, ensuring safe operations, and ensuring ecological and environmental goals are met (Abdulaziz, 2006; Rohn, 2004). SAVE international methodology stated that the main objective of Value Engineering is to improve the Value of the project: Value = Performance / Cost.

Value engineering concentrates on the effectiveness through stating functions, goals, objectives, needs, requirement and desires. Then define the quality features that make the product more acceptable. Finally, generate VE Proposals that meet the requirements at the least possible Life Cycle Cost. VE is a balance between Function, Quality and Cost.

Value Engineering Applicability

Value engineering methodologies can be applied during any stage of a projects design development cycle. However, the greatest benefit and resource savings are typically achieved early in the development and conceptual design stages, where the basic information of the intended product is established, but before major design and development resources are spent.

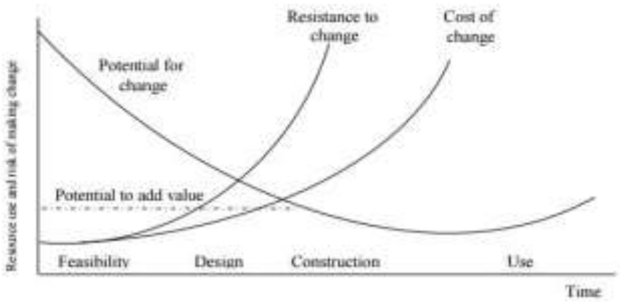


Fig. 2 - Change in Opportunities with time

VE may be applied more than once during the life of the project. Early application of VE helps to get the project started in the right direction, and repeated applications help to refine the projects direction based on new or changing information. Note that the later that a VE study is conducted, the higher the cost of change will be to implement the improvements. The VE methodology can be used in 3 stages of building project:

- Planning and design, which is the most important stage to apply VE.
- Construction
- Maintenance and operation.

The VE process should not add time to the schedule, that is, it should not affect the critical path of the project schedule.

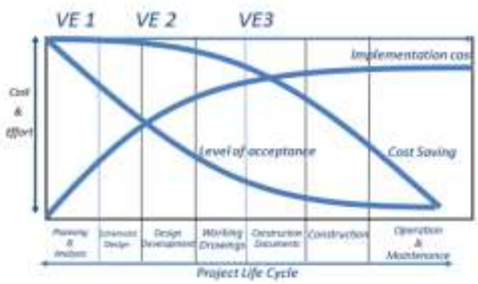


Fig. 3 – Project Life cycle

A VE team of 5-7 members with diverse areas of expertise and wide range of experience has been found to typically give the best results. The team needs to include experts who are knowledgeable in management, cost, procurement, financing, construction, and operation of similar buildings in the study.

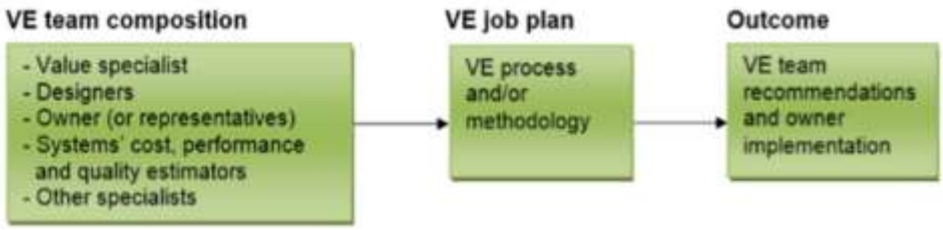


Fig. 4 – VE team composition

Value Engineering Job Plan

Value studies are conducted in three stages, Pre-Study, VE workshop and Post-Study. The purpose of the 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 improvements.

Fig. 5 – VE Job Plan

Different VE studies use different steps or phases. The American Society for Testing and Materials (ASTM) standard E1699-10 defines the VE process as eight phases and pre-workshop preparation step (ASTM E1699-10).

The exact number of phases is not critical but it is important that all the important steps in the VE process are captured. These key steps are:

1. Information Phase
2. Function Analysis Phase
3. Creative Phase
4. Evaluation Phase
5. Development Phase
6. Presentation Phase
7. Implementation Phase

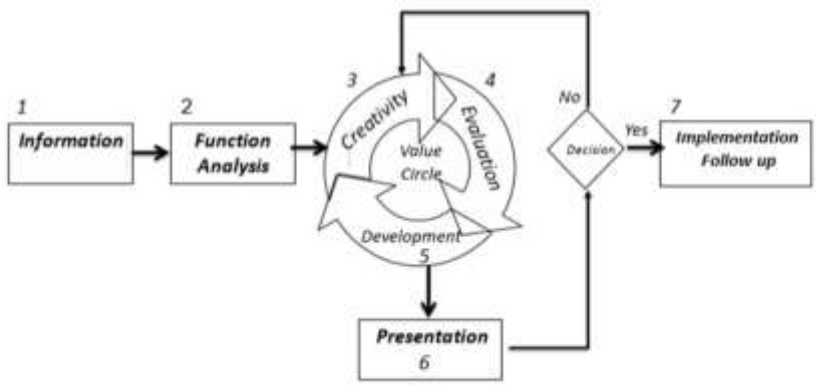


Fig. 6 – VE Job Plan phases

The Function Analysis System Technique (FAST) in Value Engineering

Function analysis aids in understanding the systems by moving the team from a general understanding to specific inner understandings that could lead to better end-value. (SAVE International). FAST identifies the basic and secondary functions of systems (Bytheway, 2007). Thus, it is important to spend a significant amount of time on it because the most important function is not always visible and that an unsound choice from a range of alternatives can lead to a different solution leading to high cost.

Functions are described as words, and FAST links words into sentences and develops arguments using a graphical FAST diagram. Verb-noun pairs are used as basic linguistic elements to obtain a clear understanding of the specific system under study. FAST builds consensus in the VE team on where, why and how the systems being analyzed fit in the scheme of the building or project (Wao, 2014). The FAST diagram helps the users calculate the ratio of total cost to critical path function cost, i.e., the VE value index.

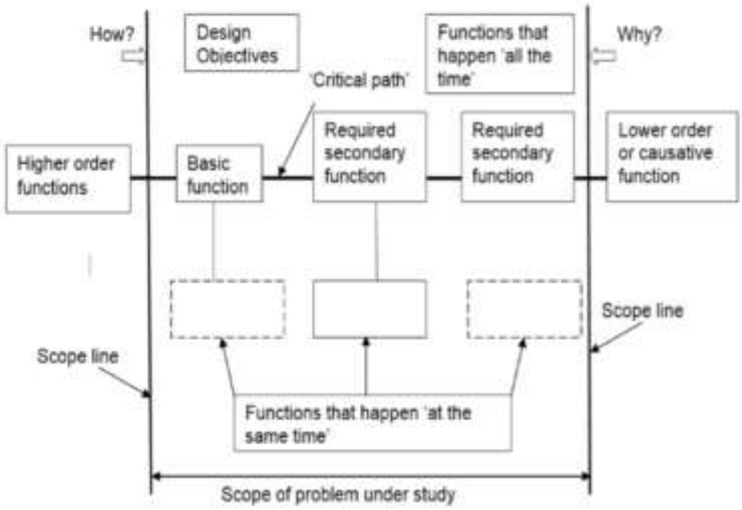


Fig.7 – FAST Diagram

The Concept of Value in Value Engineering

Value could be confused with cost or price. It is a mistaken belief that when something costs more, it is worth more. Miles (1962) concluded that value analysis is the efficient identification of unnecessary costs. Thus, value can be considered as a composite of quality and cost. The ratio of quality to cost can be treated as the value of a product, service, or system.

Achieving true value is met by analyzing functions of systems and resources available for use to fulfill the functions. SAVE International (2007) recommends that the function should be measured by performance requirements while resources to be measured in materials, labor, prices or cost, time.

Typically, value is maximized by optimizing the equation:

Value = function ÷ cost (performance ÷ cost), (function ÷ resources)

The main goal is to achieve a ratio of 1:1 or greater which represents good value. Four types of value are important in VE. These are: use value, esteem value, cost value, and exchange value. Use value relates to the use of the product or system while esteem value relates to value accruing from owning a product. Cost value relates to costs required to produce a building product. Exchange value relates to the properties or qualities that enable people to exchange a product or system for something else.

Cost, Worth, and the Cost-worth Ratio

The cost can be comprised of initial and life cycle costs. However, worth is different. To measure worth, the product or service 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 determine the worth. The worth is the VE team's estimation of the least cost required to perform the required function. The VE team sets the cost targets or the worth for each system function (ASTM E 1699-10). Comparing function cost to function worth helps in identifying areas for potential value improvement in projects. Dividing the estimated cost for a given system or functional group by the VE team's benchmark cost for providing the function constitutes the cost-to-worth ratio. A ratio greater than 1:1 presents potential opportunity to improve value of a system or project.

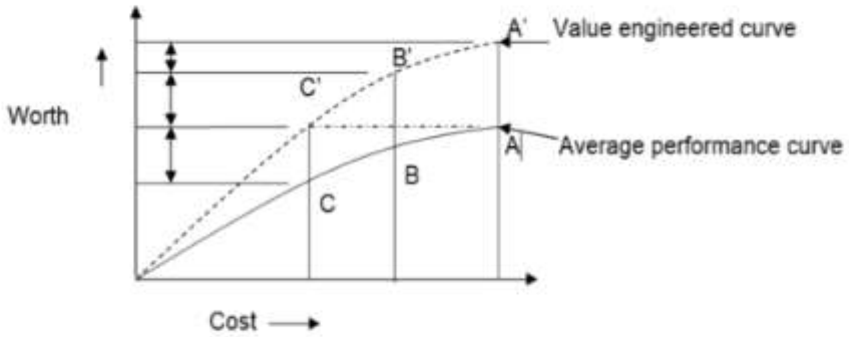


Fig.8 – Cost to Worth Ratio

The value estimates depend on the accuracy of the available information and the thoroughness of the VE study. The VE team and the design professionals should be in full agreement on the systems requiring value improvement.

Some studies have shown that utilizing VE methodologies have resulted in about 5-35% cost savings with a return on investment (ROI) of about 200-222% (Chung et al., 2009). Other studies show that well executed VE processes could have savings of up to 25-35% (Smith, 2009) while others have shown cost reductions in the range of 15 -20% (Heggade, 2002).

Decision Support System for green Building construction

Green building construction requires an effective decision making tool to facilitate the selection of best building systems from alternatives available. This will aid in constructing a building which is most sustainable, profitable, and cost effective (Pan et al., 2011). Decision analysis is applicable to green building decisions because they typically involve multiple criteria and stakeholders, and significant tradeoffs between short term and long term pay-offs (Baker & Ewing, 2009).

Multi-Criteria Decision Methods (MCDM) have been used in VE for selection of building system alternatives which provide best value for owners. In relation to VE, MCDM refers to situations where there exists more than one objective or goal. Typically, these objectives do conflict and the team must arrive at decisions by taking them into consideration. MCDM involves the selection of multiple alternatives to achieve an overall result based on the appropriateness of those alternatives when compared to a set of criteria. The decision criteria are weighted in terms of their value (Farhad, 2006).

An example of a decision support framework is the Choosing by Advantages (CBA) framework developed for the US Department of Agriculture's Forest Service to help make complex resource allocation decisions in multiple stakeholder situations (Suhr, 1999). Neuro-Lingusitic Programming (NLP) may assist creativity and aid in value improvement (Elder & Elder, 1998).

Risk in Value Engineering

A project needs to have maximum value and minimum uncertainty (Dallas-2006). Therefore, in order to achieve the best value, risk management should be applied in VE process even in a simple way in construction projects.
Qualitative Risk Assessment
A Simple, qualitative risk assessment is a useful tool to obtain the best value from a project, process, or product. It's completed by a VE Team and needs to be considered in value equation even without a separate risk workshop. Functions with risk exposure can be brainstormed and mitigation measures identified. "No construction project is risk free. Risk can be managed, minimized, shared, transferred, or accepted. It cannot be ignored" (Sir Michael Latham, 1994)

Risk Management benefits to the VE process

- Enhancement of Value & possible cost savings by providing balanced solutions
- Risk Management means Cost Avoidance.
- Risk finds "Show Stoppers" VE can help solve, Identify targets & enhance brainstorming in early stages

4. Value Engineering and Sustainable Construction

Sustainability and VE can be considered to be the best combination of green building principles, life cycle cost (LCC), and quality that satisfies human needs throughout the life cycle of project (Abdulaziz, 2006). A structured VE job plan can be used to steer the sustainability agenda in building construction. For example, sustainability can be a basic function for the building project or system. Multidisciplinary teams working together in a coordinated VE process would raise the chances of sustainability being considered effectively in the building project.

Sustainable construction is concerned with delivering better long-term value for the construction industry's stakeholders including end users. Sustainable construction means balancing value, risk and waste within project parameters; taking into account factors such as: land use, materials types, and construction techniques, regeneration and community needs. When considered in terms of sustainable development, construction projects may require a shift aware from tradition standpoints: from short term to long term; from shareholders to stakeholders; from product to service; from local to global; and from cost to value (Hayles 2004).

VE can be used as a vehicle for achieving sustainable construction but must be applied during the early stages of a project. VE is relatively unrestricted in its ability to indicate areas of potential saving that are not readily apparent. Often, VE can generate significant funds in initial installation and operating costs (Dell'Isola 1997). The sustainable decision is that which uses professional judgment and vision to distinguish between capital expenditure and operational expenditure. The vital objective is to give the client the maximum value for every the capital invested. VE plays a significant role in managing value to meet its goals. It can provide the networking required for improving coordination and communication. In other words, VE facilitates management of both value and costs (Dell'Isola 1997).

Using the VE methodology can result in improved profit and will continue to pay increased dividends to shareholders for years to come (Dell'Isola 1997). Isaacs and Kurtz (2004) stated that 'VE is a process that can be used to evaluate the functionality of any project, process or system.

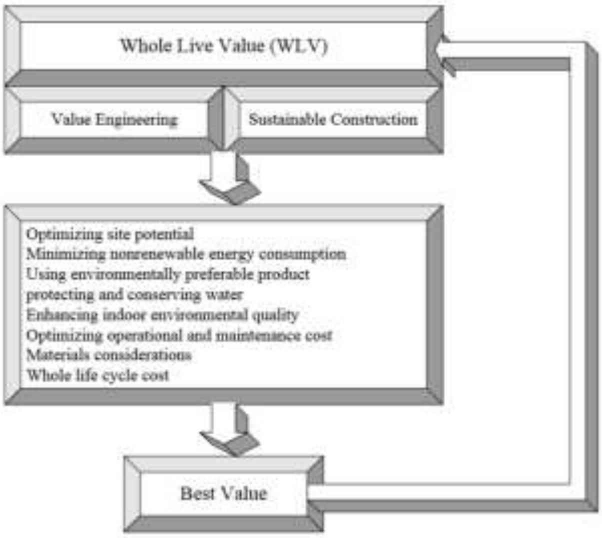


Fig.9 - conceptual objectives for VE and sustainable construction

The VE-SC linkage through project phases

All phases of this job plan are required and are performed sequentially. The activities performed in each phase may vary in number to fit the study topic or time constraints, but it is the outcome achieved at the end of each phase that marks the reliability and quality of the VE performance. During the conduct of a study, new data and information learned may require the study team to return to earlier phases or activities.

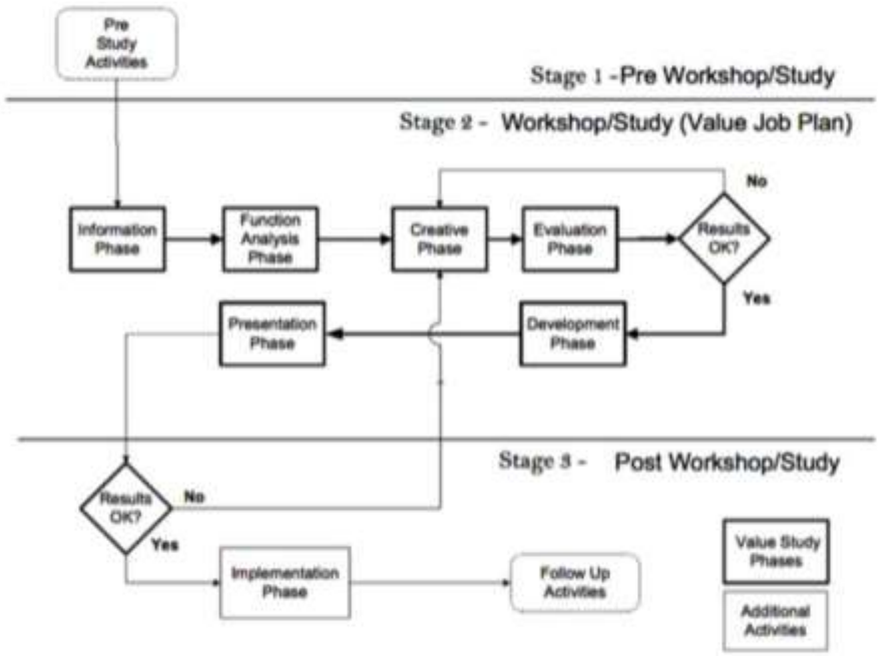


Fig. 10 - Value Study Process flow by SAVE International

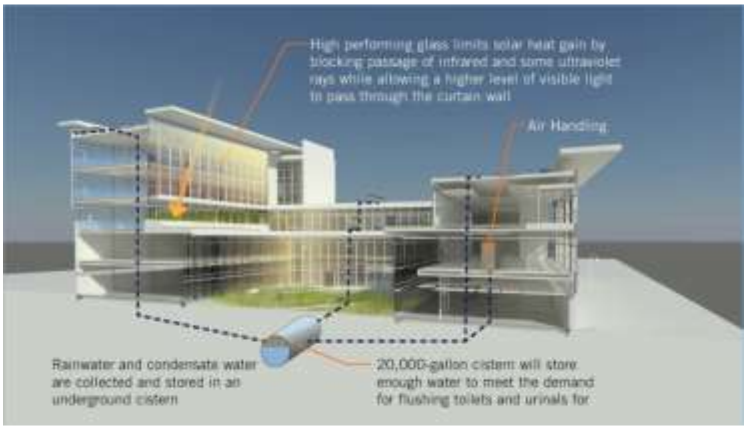
The linkage between VE and Sustainable Construction (SC) could be realized during the information phase, the creativity phase and the evaluation phase of the SAVE International Standard VE Job Plan.

5. Illustrative Example (University of Florida Clinical Translational Research Building)


Area: 120000 square feet, year: 2013

A sustainable building at the University of Florida (UF), Gainesville, Florida, was identified for case study. Master's level students in a construction management educational program analyzed the building and prepared VE final reports comprising of recommended systems. Thereafter, Faculty sustainability experts evaluated these reports.

Case Study Building Project Description UF focuses on sustainability and has more LEED certified buildings than other universities in the USA (Pantazi, 2010). This motivated the selection of a building with sustainability objectives for the case study. The Clinical and Translational Research (CTR) building was selected. The goal of designing the building was to meet the highest standard of sustainability as set by LEED Platinum Plus accreditation, i.e., a level higher than LEED Platinum. The $45 million 120,000 square feet CTR building project was in the construction stage.



Building performance requirements, some of the owner’s performance requirements were:

- Building image and marketing: LEED Platinum Plus certification.
- Energy performance: Building energy efficiency was one of the major requirements.
- Sustainability goal: building systems that met UF sustainability standards.
- Carbon neutrality: The University’s goal of becoming carbon neutral by 2025.

The VE course students made two field trips to the CTR building. Students with LEED certifications were the VE team leaders. The students were divided into four teams that were then randomly assigned in two VE methods of two teams each. Three to four students were in each team with a total number of 13 students.

The methods employed in the study were as follows:

1) Method 1 (Control VE method): The teams employed the conventional VE method that entailed developing quality model, pair-wise comparisons of criteria, and weighting, rating, and calculating method. They employed cost-worth approach in the function analysis phase and in evaluating systems.
2) Method 2 [Conventional VE method and Performance-Worth (PW) method]: The teams utilized the conventional VE approaches except in the function identification and analysis VE phase where they incorporated the performance-worth approach in place of cost-worth.

Teams conducted value analysis of the systems, prepared the VE final reports and presented their findings and recommendations. The reports were collected and then analyzed. The purpose of this was to find similar recommended systems developed with sustainability goal.

Thereafter, VE reports were sent for independent evaluation by four different faculties who were experts in sustainable construction and development. Sustainability experts (N = 4) were required to evaluate the VE reports using LEED criteria. Three LEED credit categories (energy and atmosphere, materials and resources, and indoor environmental quality) were in consideration because of their abilities to accumulate more points towards building sustainability certification. A rating scale was developed to assist in documenting the contribution of each system towards sustainability. The rating scale was: somewhat fair contribution = 1, fair contribution = 2, good contribution = 3, very good contribution = 4 and excellent contribution = 5.

The evaluation or rating system provided the data to assess the effectiveness of the two VE methods in attaining better building sustainability outcomes. This was analyzed statistically.

Results; Faculty Evaluation of the Students VE Final Reports:

VE reports showed some similar systems developed. These were curtain walls, HVAC, plumbing, lighting, window, flooring, and ceiling systems. Of the possible LEED credit categories under LEED v4, energy and atmosphere, materials and resources, and indoor environmental quality were in focus. In addition, sustainability measurement variable was generated by aggregating the data from the three categories. This was to determine how the two VE methods performed relative to improving the overall sustainability outcomes.

- On average, method 1 teams developed systems with good contribution Method 2 teams developed systems with relatively better contribution and sustainability measure. Thus, VE method 2(PW) could be better than method 1.
- Different letter grouping showed that method 2 was superior and significantly different from method 1 in achieving sustainability outcomes.

- The systems developed and recommended by students (e.g., curtain walls, Heating Ventilating and Air Conditioning (HVAC), plumbing, lighting, window, flooring, and ceiling systems) had direct contribution to the specific LEED credit categories of EA, IEQ and M&R. These credit categories can contribute more points towards sustainability as measured by LEED.

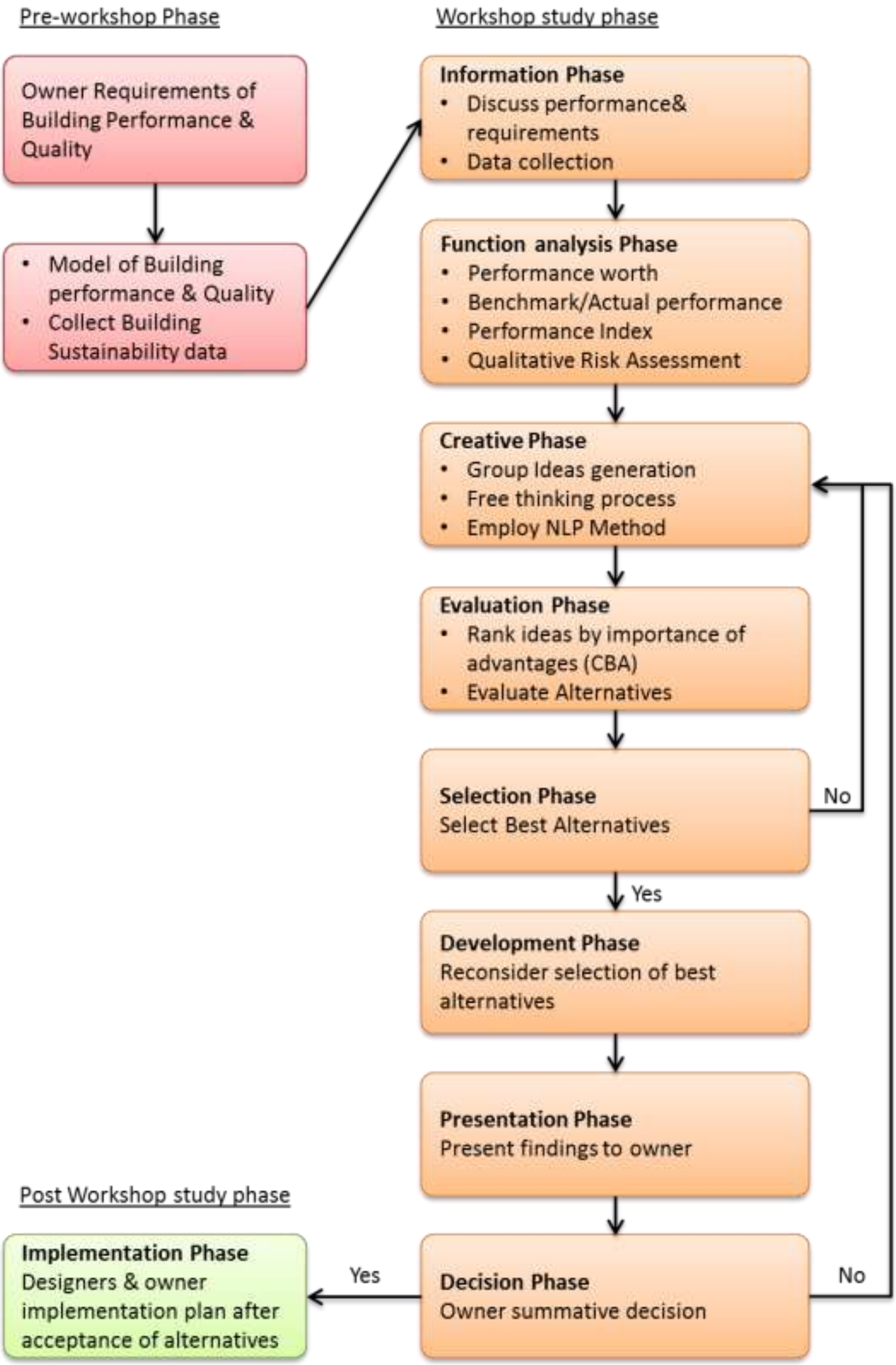
6. Traditional Approach versus Integrated Approach

VE Phases	Traditional VE Method	Integrated VE Method
Function Analysis Phase	• Over-emphasis on cost, sometimes at the expense of performance and quality • Describes a value index, which is cost focused.	• Uses PW approach to re-orient VE from over-emphasis on costs to performance or quality thinking. • utilize a value index with total performance or quality estimate
Function Analysis Phase	• Subjected to risks regarding cost or value of the systems chosen by the VE team.	• Uses Qualitative Risk assessment that provides a balanced solution for possible cost savings and value enhancement.
Creativity Phase	• Does not promote or improve creativity	• Uses NLP to promote or improve VE team effort and idea creation

Evaluation phase	• Uses pair-wise comparisons to determine relative importance of each alternative • Abstract allocation of weights to criteria • Uses both advantages and disadvantages to rank and/or rate alternatives in evaluation.	• CBA does not use pair-wise comparison method & uses factors in place of criteria • CBA does not allow for use of Weighting, Rating and Calculating (WRC) principle of MCDM • CBA focuses on advantages

7. Results & Discussion:

Proposed Conceptual Framework for the Integrated VE Method:



8. Conclusion

Sustainable Campuses play a large role in the society, The energy savings accomplished, in addition to the resources saved and the improved workspaces that sustainable facilities provide, is important to students, faculty, staff, and residents of the area surrounding large campuses. However, the process of building a sustainable facility with limited budgets and multiple stakeholders is challenging. VE Methodology and tools could be considered as an integral part of sustainability analyses.

Different VE methods were developed to counter the limitations towards achieving the sustainability goal. The traditional VE method had various limitations in the basic VE Job plan phases (Function Analysis, Creativity and Development phases). So the methods used were improved by adding some approaches as (Performance worth approach, Qualitative Risk assessment, NLP and CBA).

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