Refocusing Value Engineering for Sustainable Construction

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Value engineering (VE) can provide value in projects by improving the performance, quality, and saving on cost of systems. However, some bias may occur in the VE application. In this research, the value methodology was analyzed and over-emphasis on cost was identified as a limitation in the conventional VE. Specifically, the aim of the research was to refocus the conventional VE to improve building sustainability outcomes. Performance worth (PW) method was developed to address the limitation. Both the conventional VE and PW approaches were examined using a case study building. Masters students prepared VE final reports using the two methods that were then evaluated by faculty sustainability experts who rated the contribution of each of the recommended systems to building sustainability. SAS v9.4 was used to analyze the data. The hypothesis was that the PW approach would provide better building sustainability outcomes. The results showed that PW could be better than conventional VE relative to improving sustainability outcomes. Thus, it could be a valuable inclusion in the VE methodology to improve sustainability outcomes.

Key Words: Function Analysis, Performance worth, Sustainable Construction, Value Engineering

Introduction

Green construction, sustainability, healthy buildings, eco-efficiency, resource efficiency, and high performance buildings are some of the terms defining the contemporary wave of events focusing on sustainable construction and development (Onsarigo et al., 2014). The main goal in construction is to meet the needs of the present population without jeopardizing the ability of the future generation to meet their own needs in the environment.

Sustainable buildings are healthy buildings constructed in a resource efficient manner using ecologically focused construction principles (Kibert, 2013). Green Globes, Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) are some of the common tools used in assessing the level of building sustainability. Essentially, sustainable building construction employs practices that increase the efficiency by which buildings use water, energy, and materials and have the ability to protect and restore human health and environmental quality over the life cycle of buildings (Abdulaziz, 2006). The end benefits could be optimized building life cycle energy performance and improvement in indoor environmental quality that enhances occupants' comfort and productivity. In spite of the benefits associated with sustainability, building owners may not readily accept sustainable strategies because they may result in increased first cost. Sustainability goals could increase total building cost by about 30%, a scenario that could make project owners hesitant to pursue sustainability objectives in construction (Morris, 2007). Despite the increased first cost, pursuing and integrating sustainability principles in building construction can significantly reduce life cycle cost (Kibert, 2013).

Critical analysis shows that the future generation may face building environmental problems that need a timely address. One of the avenues to address the looming problems could be employing a robust decision support system that enhances sustainable building construction. However, achieving the needed building sustainability goals can be challenging because it requires sufficient resource allocation in addition to using robust and superior evaluation techniques for the systems. The goals could be linked to high performance aspects of buildings that require a tool to measure and/or improve the performance outcomes. Value engineering (VE) is a potential tool that can improve building sustainability outcomes because it focuses on the performance and quality improvements as well as savings on cost. However, the existing or conventional value engineering process maybe deficient in this endeavor.

The principle of value engineering came into existence in 1947 by L.D. Miles. He introduced it as a systematic, organized, strategic, multidisciplinary team and function-oriented tool to improve performance of systems or services at the lowest cost. Miles was working at General Electric, a major defense contractor, where they faced shortages of the strategic materials required to produce products during World War II. With value and management in mind, Miles constructed a function analysis concept, later called value analysis or engineering (VA/VE). He stressed on the idea that products are bought for a specific purpose, namely, for what they could do best, including providing the best aesthetic quality to user (Wao, 2014; Abdulaziz, 2006; Miles, 1947). A group of practitioners formed the Society of American Value Engineers (SAVE) in 1959 (Wao, 2014). The aim of SAVE was to further the principles of VE. The original initiators were engineers hence the name value engineering. When the society grew larger, SAVE-International came into existence in 1996 (Wao, 2014; Abdulaziz, 2006). Currently, its application is in projects that are costly, repetitive or those requiring design modifications (Wao, 2014).

Using VE to develop the most preferred systems can be a viable avenue for better building sustainability outcomes. However, critical analysis of the conventional VE process shows limitations in some of the VE phases, especially when the goal is to improve building sustainability outcomes (SAVE international, 2015; ASTM E1699-14). Thus, the purpose of this research was to refocus the conventional VE process to improve building sustainability outcomes. The objectives were to identify the limitations in the function analysis phase of VE and determine possible avenue for redress by developing a new VE method. The hypothesis was that the new approach would result in better building sustainability outcomes. The significance of the study was to provide owners and professionals with a value-focused tool to improve performance of systems that can cut across other projects as well.

The guiding standards employed in this research were the SAVE-International job plan and the American Society for Testing and Materials (ASTM) standard E1699-14, also known as the Standard Practice for Performing Value Engineering (VE)/Value Analysis (VA) of Projects, Products and Processes. Ideally, the functional identification and analysis phase is key in the VE job plan. This study focused on this phase with the objective of identifying potential limitations and avenues to alleviate them relative to sustainable building design and construction.

Literature Review

The Function Analysis System Technique (FAST) in Value Engineering

The success of a VE exercise is dependent on the success of the analysis of the functions of systems using FAST in addition to a multidisciplinary team of professionals who have good relationship and communication. 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. Attention to functions makes the VE process unique and different from other problem solving techniques (SAVE International, 2015, Wao, 2014). Specifically, function analysis identifies necessary functions and potentially unnecessary costs of a specific aspect of a project. Thus, it is important to spend a significant amount of time on function analysis. This is 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.

Developed in 1964 by Charles Bytheway, FAST identifies the basic and secondary functions of systems (Bytheway, 2007). ASTM E1699-14 defines basic functions as necessary items for the project to perform and fulfilling them is a need in developing alternatives of any system. Secondary functions are supporting functions that enhance performance. That is, they describe features, attributes or approaches that enhance the basic functions.

Functions of systems discovered by a team can be recorded logically using the FAST (Nick et al., 2000). FAST and the use of function as a basic language assist in understanding ‘how’ and ‘why’ things work by eliciting discussions. 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 sequential procedure of function analysis is to select building components, define the needs and desires (functions) that the systems are to provide, classify the functions, allocate cost to each function, and analyze the importance and expected performance level of the functions (ASTM E2013-12). The process involves describing the function using an action verb followed by a measurable noun thereby defining and quantifying it effectively.

Understanding Value, Cost and Cost-Worth in Value Engineering

Value is a reflection of one's feelings. It can be subjective in that what is valuable for one may not necessarily be valuable to another. It is a mistaken belief that when something costs more, it is worth more. That is, it has a high value. However, value is not similar to cost. One can define it as a ratio of positive and negative aspects of a project. In order 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 determine the worth.

The value or worth of the function is the lowest overall price or cost to accomplish a given function. ASTM E1699-14 states that the VE team sets the cost targets or the worth for each system function. The worth is the VE team's estimation of the least cost required to perform the required function. The cost is the estimated cost for providing the function in a specific case. Comparing function cost to function worth assists in identifying areas for potential value improvements. Dividing the estimated cost for a given system 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.

Understanding the FAST, value, and worth show that the main goal of VE is to save cost. Some studies have shown the utility of VE methodologies that result in about 5-35% cost savings with a return on investment (ROI) of about 200-222% (Chung et al., 2009). A study on building sustainability and ROI reported ROI as the most important factor driving green building. Lower cost was identified by governmental organizations while building owners reported benefits attached to savings in energy, water, wastes and lower operating costs of green buildings (Wao, 2014; Smart Buildings, 2012). VE can be used to achieve the savings for specific building systems. For example, VE can be used to select 1) energy efficient Heating Ventilating and Air Conditioning (HVAC) and lighting systems that save energy, 2) curtain walls and window systems that induce user indoor comfort and save energy, 3) waterless plumbing systems that save water, 4) flooring systems that result in better sustainability outcomes.

Value Engineering in Sustainable Building Construction

VE and sustainability could be the best combination of green building principles and life cycle cost that satisfies owners' needs throughout the building life cycle (Abdulaziz, 2006). This combination encourages the use of tools to create purposeful realistic cost changes rather than allowing changes to happen accidentally in projects. It links with SAVE International's VE methodology and techniques that improve planning for sustainable construction during the conceptual, design and construction stages especially for sustainable facilities (Wao, 2014; Abidin & Pasquire, 2007). Ideally, the objective of VE is to examine all possible cost items by identifying avenues to optimize life cycle costs without necessarily compromising the functions of specific items (Uddin, 2013).

Kirk et al. (2004) concluded that sustainability agenda in building design and construction could be guided by a structured VE job plan. In that case, sustainability can be a basic function for the building system. Multidisciplinary teams working together in a coordinated VE process would raise the chances of considering sustainability principles in the building project. The process can employ Pareto's law that states that 20% of the items make up 80% of the total cost and this can assist in selecting sustainable systems and materials based on their functions. Life cycle assessment should be central in this process to realize long-term values and/or benefits.

Initiating sustainable construction principles depend on the willingness of the project owner. In fact, considering sustainability issues in a VE process depends entirely on the interest and commitment of the owner and the knowledge of the VE team. Building owners should be motivated towards green building construction. The green features need to motivate project owners towards seeking superior building sustainability outcomes. However, the motivating green features can differ from one project owner to the other. Consider the following examples. A hospital building board may opt for green features or a green building because green features promote healing, e.g., through outside views, while commercial office property managers may promote a green initiative to speed up lease-out and thus lower carrying costs. Federal agencies may desire green ideas in buildings to improve employee morale and increase retention through favorable indoor environmental conditions while owners may focus strictly on the financial benefits of building green such as low energy costs (Wao, 2014; Wilson, 2005).

Overall, the process needs to ingrain sustainability principles early in the project and maintain its focus throughout the decision-making and execution phases of the project (Leung & Liu, 1998). Tools supporting sustainability must develop to realize overall success in sustainable construction. In light of this, Abdulaziz (2006) proposed potential combination of VE and sustainable construction by developing potential sustainability practices to follow in the VE job plan. The process could reduce life cycle cost but could also overlook the performance and quality parameters, e.g., energy issues in buildings. Thus, the VE process needs re-assessment to address sustainability completely.

Limitations of the Function Analysis Phase of the Value Engineering Job Plan

It is evident that VE focuses predominantly on saving the overall costs. Most building owners are more inclined to reduce first cost and so they may over-emphasize the cost reduction aspect, subsequently compromising other prime objectives of improving quality and performance levels. Over-emphasis on cost stems from the ASTM E1699-14 that focuses on cost. The standard, also called the conventional VE process, has sections and subsections detailing the cost worth process in VE. Section 7.3.2 of the ASTM E1699-14 describes the importance of relating function to cost and offering approaches for improvement in the event of cost escalation. In addition, ASTM E2013-12 describes value using cost reduction approach. Therefore, it is evident that sustainability goals may be overlooked during VE study. More attention is usually on the cost (money) of systems rather than performance or quality improvements (Wao, 2015). Thus, alternative systems for evaluation during the VE process are selected based on cost-to-worth ratios and not performance-to-worth basis. This could introduce bias in the VE outcomes.

Approach to Counter the Limitation in the Function Identification and Analysis Phase

In the conventional VE practice, cost-worth is first-cost driven. Cost-worth ratio identifies the systems that require detailed review in the subsequent VE steps, i.e., to determine those building systems that may need improvement based on their cost-worth ratios. Meeting the sustainability goals in construction require refocusing the conventional VE process. Owners have a tendency to over-emphasize cost reduction at the expense of performance or quality improvement. The cost-worth analysis typically occurs in the workshop-function analysis phase. ASTM E2013-12 stipulates that FAST data help in identifying the building system's alternatives with respect to their function costs. Therefore, the first step in improving the performance or quality outcome is to improve the guiding standard.

ASTM E1699-14 subsection 7.3.2.5 of the function identification and analysis phase defines worth as the VE team's estimation of the least costs. That is, the initial cost, presented in the cost estimate, needed to perform a specific system function. Subsection 7.3.2.6 stipulates that the cost-worth ratio is calculated by dividing the design professional's cost for each system or functional group by the basic worth (the VE team's cost estimation). If the resulting ratio is greater than 1:1 (cost is higher in the estimate than the VE team's estimate), then there is potential opportunity for cost improvement. Greater ratio implies greater chance for improvement using first-cost approach.

However, worth can also be defined as the VE team's best or highest estimation of quality or performance as defined by the selected quality and performance indicators for the project system. The quality-worth or performance-worth (PW) maybe calculated by dividing the projected performance indicators by the VE team's target worth as represented by quality and performance indicators. Ratio less than 1:1, i.e., less performance or quality realized from the design than the VE team's estimate implies a potential opportunity for improvement.

Making these changes in the job plan will consider all the VE objectives (cost, performance and quality improvement) in a project. The VE team will discuss PW in addition to cost-worth. Thus, the project owner can obtain the best value (or project outcome) for the lowest economic investment over the life of a project using VE.

Research Methods

Research Aim, Objectives and Hypothesis

The aim of this research was to refocus the conventional VE process to improve building sustainability outcomes. The objectives were to 1) identify limitations in the function identification and analysis phase and find redress, 2) evaluate the impact of the new VE method to sustainability. The hypothesis was that the new method would result in better building sustainability outcomes. The significance of the study was to provide owners and practitioners with a value-focused tool to improve performance and quality of systems. Case study aided in assessing the VE methods.

Case Study Stage One

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 (approximately 90% complete).

Building performance requirements. Some of the owner's performance requirements were:

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

Student Involvement in the Case Study Building: The VE course students made two field trips to the CTR building. This was to familiarize with the building and to have opportunities to discuss the project with the construction team and to determine the project requirements. Students with LEED certifications were the VE team leaders.

Research experimental design and sample size. 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 as shown in Table 1.

Table 1. Summary of research experimental design involving VE students (N = 13).

Method 1	Method 2
Team 1A	Team 2A
Team 1B	Team 2B
Total = 6 students	Total = 7 students

The methods employed in the study were as follows:

- 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.
- 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.

Students team training and analysis of building systems. Teams 1A and 1B were the control group and did not receive training. Teams 2A and 2B received training in using PW. 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.

Case Study Stage Two

Thereafter, VE reports were sent for independent evaluation by four different faculties who were experts in sustainable construction and development. They were not required to be VE experts but had to be experienced in working with LEED rating system. 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.

Data Analysis and Potential Assumptions

SAS v9.4 aided in the data analysis involving descriptive statistics, Analysis of Variance (ANOVA), and pooled *t*-test. The average measures were quantified using descriptive statistics. One-way ANOVA utilizing Duncan's Multiple Comparisons Test was conducted at $p = 0.05$ to find the level of statistical significant difference between the two VE methods. The interpretation of *p*-value is to reject the null hypothesis if $p < 0.05$ implying a statistically significant difference in the statistical statement or fail to reject the null hypothesis if $p > 0.05$ suggesting not enough evidence to reject the null hypothesis. Further test with pooled *t*-test would follow if the result between the methods is statistically significant. Assumptions underlying univariate statistical analyses were taken into consideration.

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. Tables 3, 4 and 5 show the results.

Descriptive Statistics of the Recommended Building Systems

Table 3. Summary of the ratings of the contribution of systems to sustainability

	Method 1			Method 2		
Category	N	Mean	Std	N	Mean	Std
Energy and Atmosphere(EA)	18	2.56	1.38	21	3.43	1.21
Materials and Resources (M&R)	14	2.14	0.95	13	1.69	1.11
Indoor Environmental Quality (IEQ)	12	2.17	0.83	10	2.70	1.06
Sustainability Measure	44	2.32	1.22	44	2.75	1.35

On average, method 1 teams developed systems with good contribution to EA credit ($M = 2.56$, $SD = 1.38$). Method 2 teams developed systems with relatively better contribution to EA ($M = 3.43$, $SD = 1.21$), IEQ ($M = 2.70$, $SD = 1.06$) and sustainability measure ($M = 2.75$, $SD = 1.35$). Thus, VE method 2(PW) could be better than method 1.

Analysis of Variance and t-test of the Ratings

ANOVA test showed that EA was statistically significant, [$F(1, 37) = 4.44$, $p = .042$]. The summary is in Table 4.

Table 4. Summary of ANOVA results

Source	Df	Error	Corrected Total	Sum of Squares Error	Mean Square Error	F-value	Sig.
EA	1	37	38	61.59	1.66	4.44	***0.042***
M&R	1	25	26	26.48	1.06	1.29	0.267
IEQ	1	20	21	19.32	0.89	1.75	0.201
Sustainability Measure	1	86	87	131.80	1.53	2.68	0.106

The statistical significance of EA in Table 4 shows that the systems had more contribution to energy efficiency in buildings when compared with other systems. In order to determine how each VE method contributed to the energy efficiency, the EA credit was investigated further using Duncan's Multiple Range Test. Table 5 gives the summary.

Table 5. Duncan's Multiple Range Test for the energy and atmosphere LEED credit category

Duncan Grouping	Mean	Sample size (N)	VE Methods
A	3.43	21	2
B	2.56	18	1

Different letter grouping showed that method 2 was superior and significantly different from method 1 in achieving sustainability outcomes. This difference was further investigated using pooled *t*-test statistics which showed a statistically significant result at $p = 0.5$, [t (37) = -2.11, $p = .042$].

Discussion and Conclusion

Obtaining maximum benefit or value has been the main objective of implementing VE in sustainable building construction projects. The benefits can manifest in various ways, e.g., design improvements, cost savings, continuous improvement, inclusion of new materials, improved construction methods, employee enthusiasm from participation in decision making processes, improved skills accruing from team participation, optimized quality and performance requirements, and superior functional reliability and system performance. A well-structured VE job plan can aid in generating alternatives of building systems that contribute to greater performance and quality outcomes while costing less from a life cycle assessment or analysis standpoint. It is important to note that deeper understanding of functions of systems can positively affect sustainability outcomes in projects that use VE.

Using FAST to analyze functions of systems in VE has shown a more inclination to cost reduction at the expense of improving performance and quality of systems. This may tend to bias VE towards not considering its other potential goals. Building owners, VE team, and construction professionals may subconsciously pay more attention to cost reduction when making construction decisions without considering other equally more important performance and quality objectives of construction. VE should link a building system to its expected performance and/or quality requirements and find potential areas for improvement respectively. For example, the concept of sustainable building design and construction can be an avenue to address quality or performance requirements of building systems. In this case, VE could significantly enhance performance and quality outcomes of green buildings.

Since the performance of systems can be assessed best through the functions of systems, investigating the operations and goals of FAST is paramount. This research focused on the function identification and analysis phase of VE process to yield better value in sustainable construction.

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. The recommended building systems can have direct savings in water and energy and could positively influence indoor environmental conditions that closely affect the indoor comfort of occupants.

Faculty experts in sustainable construction and development offered their feedbacks that were used to infer the contribution of the VE methods to sustainability. The findings as summarized in Table 3 showed that the systems developed had greater contribution to EA credits than the other two categories assessed ($M = 3.43$, $SD = 1.21$). Considering this, PW could be better than conventional VE in achieving sustainability outcomes. The ANOVA results in Table 4 was statistically significant for the EA credit, [F (1, 37) = 4.44, $p = .042$]. This implied that on average, the recommended systems would rate significantly higher for EA credit than the other credits. The result would improve sustainability outcomes since EA accounts for 33/110 points in LEED v4, the highest of all the LEED credit categories. In addition, it depicted the development of more energy efficient systems that had more contribution towards sustainability. This result aligns with the current desire for high performance (low energy consuming) buildings especially in new construction and renovation projects. It also aligns with the research that identified energy savings as a goal in sustainable construction. Building systems developed using VE method 2 (PW) in Table 3 contributed relatively well across the LEED categories assessed. Noteworthy, the statistically significant test result using Duncan's Multiple Range Test and pooled *t*-test showed PW method recording higher rating in EA credit as shown in Table 5. This means that the students developed HVAC and lighting systems that are energy efficient thus contributing to the higher EA savings. It is logical to deduce from the faculty ratings that PW (method 2) had a relatively better sustainability outcome than the conventional VE (method 1). Therefore, PW could achieve superior sustainable building outcomes just as cost-worth approach in method 1 can identify high cost areas in conventional VE. The difference with PW is that the high sustainability areas may be retained or recommended for inclusion in sustainable construction while the high cost areas may be eliminated in the cost-worth approach.

In conclusion, this research investigated the potential approach that could be integrated in the VE methodology to improve its outcomes. It determined and assessed the PW method in the function analysis phase of the VE job plan in comparison to the conventional VE method. The faculty evaluation phase concluded that PW method could be a better approach in achieving building sustainability goals than conventional VE method. Thus, the PW idea could be a worthwhile inclusion in the VE function analysis phase to re-orient the VE teams, construction professionals and project owners from the routine thinking of cost reduction to inclusion of performance and quality improvement method. All the VE goals would be met while utilizing life cycle analysis approach to attain the required outcomes.

Areas for Future Research

With the relatively smaller sample size used in this research, its outcome would be considered a first step in indicating the PW method as potentially better than conventional VE approach. Further research with more data points would be required to validate this conclusion. In addition, industry professionals or experts should be part of the future study to validate the proposed PW method and to find ways to change the VE process for better sustainability outcomes. The experts would execute the LEED and VE processes better unlike students.

References

Abdulaziz, S. (2006). Value engineering application benefits in sustainable construction. Retrieved January 26, 2016 from http://www.pmi-agc.com/techdocs/The%20paper%20-%20Value%20Engineering%20application%20benefits%20in%20Sustainable%20Construction.pdf

Abidin, N. & Pasquire, C. (2007). Revolutionize value management: A mode towards sustainability. *International Journal of Project Management,* 25, 275-282.

American Society for Testing and Materials (ASTM E2013-12). The standard practice for constructing FAST diagrams and performing function analysis during value analysis study.

American Society for Testing and Materials (ASTM E1699-14). The standard practice for performing value engineering (VE)/ value analysis (VA) of projects, products and processes.

Bytheway, C. (2007). FAST creativity and innovation: Rapidly improving processes, product development and solving complex problems. Retrieved January 26, 2016 from http://www.fastcreativity.com/charlesbytheway.html

Chung, B., Syachrani, S., Jeong, H., & Kwak, Y. (2009). Applying process simulation technique to value engineering model: A case study of hospital building project. *Journal of IEEE Transactions on Engineering Management*, 56, 549-559.

Kibert, C. J. (2013). Sustainable Construction. Green Building Design and Delivery, *John Wiley and Sons,* New Jersey, 2nd edition.

Kirk, S., Park, G., & Dell'lsola, A. (2004). Sustainability/LEED and life cycle costing-Their role in value based design decision making.

Leung, M. & Liu, A. (1998). Developing a value management model - by value-goal system approach. *In Proceeding of the 14th Annual Conference of the Association of Researchers in Construction Management, Hughes, W. (ed.),* Reading: ARCOM, ISBN 0-9534161-0-0, 2, 496-505.

Miles, L. (1947). The cost problem and the value engineering approach.

Morris, P. (2007). What does green really cost? *PREA Quarterly, summer 2007.*

Nick, R., Matthias, H., & Wirtschaftsing, H. (2000). *Value engineering: dissemination of innovation and knowledge management techniques*. Retrieved January 24, 2016 from http://www.adi.pt/docs/innoregio_value_analysis.pdf

Onsarigo, O., Atalah, A., & Roudebush, W. (2014). An introduction to environmental value engineering and the EVE assessment of horizontal directional drilling versus open cut construction (2014). *Pipelines 2014: From Underground to the Forefront of Innovation and Sustainabaility, ASCE 2014.*

Pantazi, A. (2010). UF has most green buildings. The Independence Florida *Alligator News*. Retrieved January 27 from http://www.alligator.org/news/campus/article_a93d0b76-7451-11df-9c53-001cc4c03286.html

Smarter buildings (2012). Green building solutions*. Overview – United Kingdom.* Retrieved January 25, 2016 from http://www.ibm.com/smarterplanet/global/files/smarter_buildings_optimised_building_performance.pdf

Society of American Value Engineers-International: Value methodology standard (2015). Retrieved January 20, 2016 from http://www.value-eng.org/pdf_docs/monographs/vmstd.pdf

Uddin, W. (2013). Value engineering applications for managing sustainable intermodal transportation infrastructure assets. *Management and Production Engineering Review*, 4, 74-84.

Wao, J. (2015). A review of the value engineering methodology: Limitations and solutions for sustainable construction. *55th SAVE International Annual Conference: SAVE Value Summit*, San Diego, CA, USA, June 7-9, 2015. http://dx.doi.org/10.13140/RG.2.1.5183.0884

Wao, J.O. (2014). Value engineering methodology to improve building sustainability outcomes. Retrieved January 27, 2016 from http://gradworks.umi.com/36/47/3647875.html

Wilson, A. (2005). Making the case for green building. *Environmental Building News (EBN),* 14.