3-29-2018

Value Engineering and Its Applications in Civil Engineering

Mohamed Abdel-Raheem

Victoria Burbach

Ahmed Abdelhameed

Grecia Silva Sanchez

Linda Navarro

Value Engineering and Its Applications in Civil Engineering

Mohamed ABDEL-RAHEEM[1], Victoria Burbach [2], Ahmed ABDELHAMEED[3], Grecia SANCHEZ[4], Linda Navarro [4]

1 Assistant Professor, Department of Civil Engineering, University of Texas Rio Grande Valley, 1201 W University Dr, Edinburg, TX 78539; PH (956) 665-3038; email: mohamed.abdelraheem@utrgv.edu
2 Graduate Student, Department of Civil Engineering, University of Texas Rio Grande Valley, 1201 W University Dr, Edinburg, TX 78539; PH (956) 665-3038; email: victoria.burbach01@utrgv.edu
3 Assistant Professor, Department of Civil Engineering, Al Shorouk Academy, Cairo -Egypt; email: ahmed.abdelhameed@gmail.com
4 Undergraduate Student, Department of Civil Engineering, University of Texas Rio Grande Valley, 1201 W University Dr, Edinburg, TX 78539; PH (956) 665-3038; email: grecia.silvasanchez01@utrgv.edu, linda.navarro01@utrgv.edu

ABSTRACT

Value Engineering (VE) can be a very valuable tool in the field of civil engineering and the construction industry. VE has tremendous benefits in both cost-saving and project improvement areas. Between the pay-offs and wide variety of applications, it is unsurprising that more firms are adopting the principles of VE in the design and construction phases of their projects. Many studies have been conducted on the invention of new tools for VE while others focused on the application aspect of VE in different engineering domains. This paper presents an overview of VE and its applications in the field of civil engineering. The study should prove useful for future researchers who wish to update their knowledge with the latest status of the state of art of VE application in civil engineering.

INTRODUCTION

Value Engineering (VE) was created during World War II as a remedy for the shortages of labor and materials. The implementation of VE goes through eight steps, which are: preparation, information, analysis, creation, evaluation, development, presentation, and follow-up. VE describes the process of defining alternative solutions that can provide the same functions at an equal or better level as the originally presented idea while simultaneously reducing costs and adding benefits. The process of implementing VE is shown in Figure 1.

Though VE started in manufacturing engineering, it spread quickly to other disciplines and had made its way into the construction field by 1970. This shift into the construction industry brought two significant changes to VE: 1) it started the utilization of a 40-hour workshop to carry out a VE study, and 2) two different thought processes for the implementation VE were created (Palmer, et al., 1996). As the idea of VE became more widely accepted in the construction industry, it was applied to many different situations and scenarios, and the number of tools available to aid VE workshops has grown. Currently, VE is being widely used in the US and UK construction industries; also, China has begun to utilize the VE methodologies.

In the last 60 years, VE has pushed its way into the construction field with its creative solutions and cost reducing potential. As such, much research has been done on the topic, many tools have been created and used, and many new applications of VE have been tried (Arditi and

Mochtar, 2000). However, a comprehensive literature review had yet to be written on the subject of VE and civil engineering. This paper aims to give the reader a thorough understanding of VE itself, the VE study or workshop, the tools available to help a VE study thrive, various possible applications of VE, and the global perspective of VE.

PROBLEM

VE is a complex and multi-faceted topic with multiple components that needs to be considered in a VE study. Furthermore, the possible and current applications of VE within the construction industry are many and widespread. While numerous papers have been published on various aspects of the subject, there is no cohesive literature review paper bringing all VE topics together for analysis.

OBJECTIVE

The main aim of this paper is to present an overview of the application of VE in civil engineering, and update the reader on the current status of VE research in civil engineering. As such, all of the previous literature on VE application in civil engineering was reviewed in order to give a clear and concise description of what VE is and how is can be utilized and implemented, as shown in Figure 2.

METHODOLOGY

The methodology adopted in this study is comprised of five main steps, which are: 1) collection of related literature, 2) literature review, 3) defining a classification system, and 4) reporting the most important findings of each study. The literature reviewed was grouped into the following categories: 1) the VE study/workshop, 2) VE Tools, 3) VE application in sustainable construction, 4) VE application in temporary facilities, 5) VE application in infrastructure, and 6) the application of VE on a global scale. These categories were determined based on the areas of concentrations of previous studies. Due to the limitation of space, the paper will cover only the first four categories.

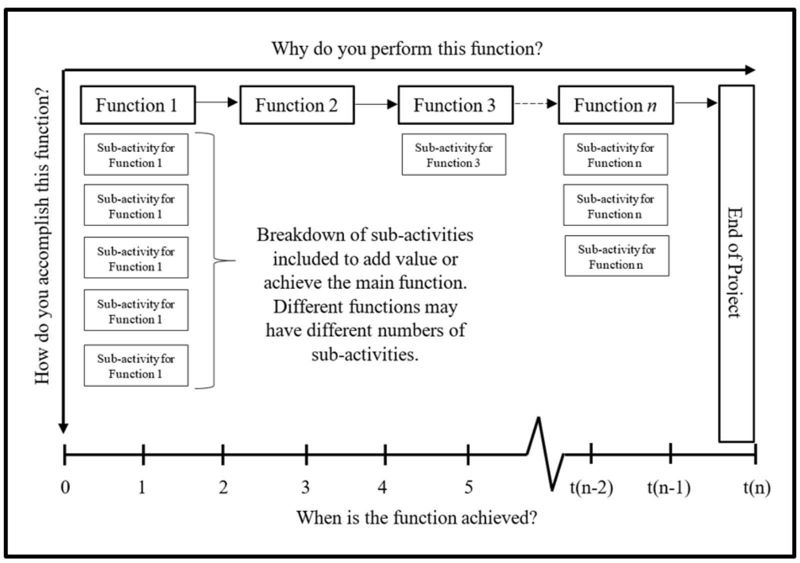

Figure 1. Scope of a VE study

THE VE STUDY/WORKSHOP

Properly conducting a VE study or workshop is the first and most important step when undergoing the VE process. A VE workshop includes the client and a group of experts from different fields in order to make a plan that fulfills all the necessary functions of the project at the lowest possible cost. Those involved in the VE study are responsible for creating the design that will later be implemented in order to yield the same or better project behavior at a lower total price (Leung et al., 2002).

Shen and Liu (2003) investigated the theory that the key to conducting a VE study is to identify the critical success factors (CSFs) early on. By selecting and limiting the critical factors, it can be assured that the study remains focused and that an adequate amount of time can be dedicated to each factor. To define a general list of CSFs, a questionnaire was sent out to VE practitioners in various disciplines. Fifteen success factors were identified and further grouped into four categories that conveyed the gist of the critical elements. These four clusters were: 1) value management team requirements, 2) clients' influence, 3) facilitator competence, and 4) relevant departments' impact. The study concluded that the proper planning of a VE study can ensure that the whole study will run smoothly. Also, despite the fact that a VE workshop is made up of a multidisciplinary team, each member should have at least basic knowledge of VE practices to yield a successful end result.

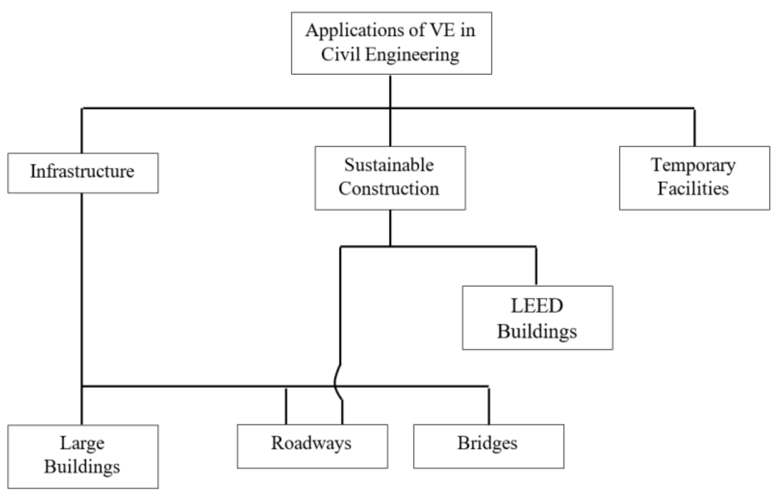

Figure 2. Areas of application of VE in civil engineering

The identification of CSFs for VE studies established the basis for the development of a comprehensive model to evaluate the overall success of a VE workshop. Some studies focused on the evaluation of portions of the VE study, but none of these studies presented a model for the comprehensive evaluation of VE workshop. Chen (et al., 2010) developed criteria that could be utilized to create this model.

VE workshops use elements of teamwork, functional analysis, cost-worth, and a systematic application to reduce costs and add value to a project. Yet because an emphasis can be placed on saving money; some issues such as team origination, VE methodology, and interaction between all parties involved in the project are neglected. However, through the development and use of the aforementioned model, VE teams could improve their processes through self-diagnosis.

The model was developed in two phases. The first phase focused on rating the importance of each Nominated Performance Assessment Criteria (NPAC) related to the VE study performance assessment. The outcome of this phase was the identification of eight performance assessment criteria (PAC), which are: 1) constructability of recommendations, 2) integration and coordination ability of team leader, 3) team leader's ability to control job plan and schedule, 4) completeness and clarity of recommendations, 5) team leader's conformation to the six-phase job plan, communication, 6) coordination, consensus level during VE workshop, 7) professional level of VE workshop team members, and 8) team leader satisfaction with workshop goal. Additionally, the study identified four performance assessment aspects (PAAs) that were linked to their assessment criteria. These aspects are: 1) the satisfaction with VE workshop results, 2) VE workshop team composition and capability, 3) VE workshop job plan, and 4) VE workshop team participation. Phase 2 focused on the determination of the weight of importance of the PAAs to create a VE workshop performance assessment table for the workshop performance measurement. Upon completion of these phases, the model was implemented and could effectively report feedback on the overall gains resulting from the VE study as well as areas that required improvement.

Throughout the literature, it is apparent that good team communication has always been a critical factor for the success of a VE study. Leung et al. (2002), however, formed a hypothesis that the emergence of low level conflicts during key portions of the study could actually increase the success of a VE workshop. The idea was that by creating and managing a conflict between two factions of the VE team, they would be more likely to come up with inventive solutions to the problems being posed in the study. The study concluded that by introducing a moderate level of task conflict an optimum result was reached in the VE study.

VE studies are key to the overall success of VE methodologies, thus the research done on the subject showcases many ways that value can be added to a VE workshop itself. By setting clear goals and standards from the start, picking team members with good attitudes and creative minds, and self-evaluating past VE studies performed by the team, the VE study can be set on the right path.

VE TOOLS

As the use and implementation of VE has grown tremendously through the last decade, more tools have been developed to facilitate the implementation of VE principles and decision making in the workshops. These tools aim at identifying ways to add value to the project while simultaneously cutting costs.

Benefit-cost analysis (BCA) or function-cost analysis (FCA)

In a VE, usually different alternatives that have the potential of adding value and cutting costs are presented. The BCA and FCA are methodologies that provide a systematic process for comparing the proposed alternatives. There are two simple steps to use these methods: 1) determine the basic and secondary functions of the project, and 2) compile matrixes that compare the alternatives. The basic functions are the elements of the project that absolutely must be accomplished although innovation in achieving these functions is encouraged. On the other hand, secondary functions are bonuses; they are the aspects that attract clients. They are also the areas that allows for the most innovation and cost-saving. The benefits (savings) and costs of implementing the alternatives are then calculated. A ratio of benefit to cost (B/C) that has a value greater than one indicates that the benefits on implementing the alternative outperforms the cost of implementation. The output of conducting BCA and FCA is the selection of an alternative that both improves the performance or solves a problem, with better or equal results to the original plan, and lowers the costs relative to the original plan.

Function Analysis System Technique (FAST)

FAST diagrams use graphical techniques to show the logical relationships between functions of a project based on the questions "How" and "Why". By organizing the functions in this way, it becomes easier to identify and clarify all the necessary project functions. By making the functions clearer, it is easier for groups to communicate and find alternatives for the functions laid out. Furthermore, it becomes easier to see how functions are related and thus how one found solution can address multiple problems.

Theory of inventive problem solving (TRIZ)

Utilizing TRIZ techniques provides a method to increase human innovation. This is done by identifying the problems, then contemplating the ideal solutions. Special focus is given to how more function can be pulled for a lesser cost. Mao (et al., 2009) used TRIZ during a VE workshop case study. In the case study, team members aimed to eliminate compromises when finding and proposing alternative solutions. This is done by applying one or more of the 40 inventive principles (previous general solutions).

Zhang (et al., 2009) also utilized TRIZ techniques throughout their project in order to begin the development of a knowledge management system (KMS). As various construction problems were solved with TRIZ methods, the solutions were added to the KMS. Therefore, when future VE studies run into a similar problem, they can reference the KMS in order to begin finding their own creative solution.

BIM-based idea bank

Building Information Modeling (BIM), integrates existing data formats, improves design quality, assists in an easy understanding of the project itself, and provides visualization to users for problem-solving. Some of the issues encountered in the creativity phase in VE studies stem from the difficulty of retrieving and reusing previous VE data. This is because there is a lack of a structured database management system. Rather than an unstructured brainstorming session, a BIM idea bank will allow VE study participants to think more broadly. It is hard to visualize an idea based on 2D data.

Park (et al., 2017) focused on creating a database management system developed to avoid both time-consuming tasks and the need for VE participant's experience. Park and his team focused on introducing the BIM-based VE idea bank. The study aimed at integrating a data-model-based VE Idea Bank with BIM. The first step is to save VE ideas into a VE template, where this template will be stored in a VE Idea Bank. The template is determined as an Omniclass classification consisting of idea contents, space, elements, work results, and material, so the user may compare previous VE ideas and their results in order to generate of new ideas. The second step focuses on linking the Omniclass classification of BIM objects with the use of Revit software. BIM objects group elements with common and specific parameters. Finally, the integration of BIM and VE Idea Bank is achieved by linking each VE template to BIM objects in order to visualize the VE ideas for the effective and efficient evaluation of ideas.

The idea of the BIM-VE Idea Bank demonstrated the stimulation of problem-solving ability, a better understanding of the VE study areas, the storage of previous projects, and the ability to reuse VE ideas. However, the program had issues to be fixed. Nevertheless, it demonstrated the great potential offered to improve VE study efficiency.

Group decision support systems (GDSS)

GDSS improves the ability of groups to communicate by guiding discussion and helping the analysis of decisions. Luo et al. (2010), proposed the application of GDSS to VE studies during the construction briefing. Each person could link into the VE workshop anonymously in order to contribute ideas. All the linked-in members could communicate with one another through a server in order to add to or point out flaws in others' ideas. This takes away the pressure of a face-to-face VE studies, where some may feel sidelined if other team members have more dominate voices.

Electre III model

Marzouk (2011) examined the way VE relates functions, quality, and cost of a project to maximize profits and enhancing the life-cycle in the construction industry. His research focuses on the implementation of ELECTRE III, which is an outranking method to facilitate evaluation of alternatives. An outstanding difference from its past versions (ELECTRE I, II, IV and TRI) is its ability to deal with inaccurate and imprecise data. The ELECTRE III model starts with the estimation of concordance indices, which provides a concordance index (C (a, b)) for each pair of alternatives (a & b) and compare the performances of each one. There are three associated thresholds which are: indifferent (q), preference (p), and veto (v). The veto threshold for each criterion provides a discordance index (D_j (a, b)) into the outranking relations. The discordance indices are then estimated. Consequently, the credibility score is calculated with concordance and discordance results. ELECTRE III is a complex computer process with the purpose of aiding in making hard decision.

INFRASTRUCTURE

Infrastructure projects are an area where the application of VE is very much needed. These projects are generally large-scale, which requires long design process and high budgets. Yet, they are characterized by the multiple areas where costs could be reduced. The long design time of infrastructure projects allow for the consideration of alternative solutions to any required project functionality. Also, the variety of materials in use makes infrastructure projects excellent candidates for the successful implementation of VE. For example, Shahhosseini et al. (2017) preformed a VE case study on the water supply to a refinery. Through VE, 41% of the overall cost could be saved and the environmental damages of running pipe could be reduced.

VE can also be applied to the construction of roadways whether it is a new construction or rehabilitation. Lee et al. (2009) preformed a VE case study of a toll plaza. As it stood, the toll plaza needed expansion due to long queuing times. However, officials were hesitant to add to the toll plaza thinking that it might worsen the delays. Another concern was the limitation of the space availability. The VE team brainstormed a number of possible solutions for these issues. These alternatives were winnowed down, and the optimal solution was selected.

Gabr et al. (2017) also utilized VE practices in the design of a roadway. The study had three objectives: 1) selection of environment-friendly material that can reduce decrease carbon dioxide emissions during their installation, 2) estimating cost of all alternatives, and 3) utilization of agricultural waste as rice hush ash (RHA) as an alternative to limestone in asphaltic concrete. The VE analysis recommended the substituting the crushed gravel of the base layer with natural gravel, which will significantly reduce CO_2 emission due to transportation. Also, 40/50 asphalt was concluded to be more environment friendly compared to the 60/70 that was originally proposed for use. The study concluded that RHA was a viable substitute for limestone because it is cheaper and environmental friendly, yet it achieves the same level of performance.

Bridges are another type of projects where VE techniques can easily be implemented. Rani (2017) used a study to apply VE to a concrete conventional bridge by construction implementation method. The study addressed three main phases for VE that were encountered before the determination of the best alternatives. These phases were: 1) creative phase, analysis phase, and recommendation phase.

SUSTAINABLE CONSTRUCTION

Sustainable construction is another area where VE practices thrive. Sustainable construction often comes with high start-up cost, which makes clients hesitant to pursue sustainable measures. As such, VE focuses on the entire lifecycle costs, which helps make sustainable construction more appealing. Wao (et al., 2016) focused on the ability of VE to address environmental concerns. Two groups of students analyzed a LEED building in order to identify area were further improvements could be made. The students identified the HVAC, plumbing, lighting, windows, flooring, and ceiling systems as areas that could typically be improved on using VE with a lens of sustainability. The potential savings in these areas could be up to 30% of the project cost.

TEMPORARY FACILITIES

VE methods can be used through the different phases of the project. Trigunarsyah and Hamzeh (2016) saw the potential to add value and reduce costs during the mobilization phase. VE could be applied to the construction of temporary facilities especially those constructed in remote areas. By applying VE techniques to a temporary facility located at power plant construction site 100 miles from the nearest city, the cost of electricity alone was reduced by 60%. Thus, it was proven that preforming a VE study even for temporary facilities may be in the company’s best interest.

APPLICATION OF VE ON A GLOBAL SCALE

While VE has become a widely used tool throughout the US and UK, other places are barely beginning to implement the technique, while still other areas have met VE with resistance.

Shen and Liu (2004) appraised the concept of VE in China. The study showed that only 4% of the VM studies concentrated in the construction industry. One of the obstacles seen in China was the conservative attitude towards quality, which led to disregarding an idea that could save money and time of the project because of the fear of possible impact on quality. The study indicated that the lack of guidance in implementing VM in construction project was due to the misconception that it is mainly for the manufacturing sector.

Other areas of Asia have resisted the implementation of VE (Cheah et al., 2005). In a study, a questionnaire surveyed the opinions of 54 industrial practitioners randomly selected on the reasons for the limited application of VE in the construction field. The study concluded that the Southeast Asian (SEA) construction industry has not adopted applications of VE in the construction field because of the lack of VE education and misconception of its principles (Cheah et al., 2005).

Kissi et al. (2016) draws the focus to the struggle that developing countries face when trying to implement VE. Empirical questionnaire survey was used, and the participants were invited to assess their perception of 22 challenges identified from literature. Construction and consulting firms located in Ghana were the ones that participated in the survey. The study recommended to incorporate VE clauses in the contract provisions of public projects as this would help the clients have a better understanding of the VE methodology and its anticipated outcomes.

FINDINGS

Throughout this literature review, the importance of the VE study could not be overstated. It must be stressed that without a properly conducted and monitored VE workshop, there is no chance of viable alternative solutions being found or implemented. The VE study must be carefully controlled if the optimum solutions are to be found.

The tools used during a VE study have grown much more extensive and all-encompassing in the last 60 years. While all the tools are methods to help identify functions and find the best alternative solution, the way they go about finding that solution is very different. There are the tools that have been standard since the beginnings of construction VE such as BCA, FCA, and FAST. Now though, there are also new tools seeped in technology, such as the BIM-Based idea bank or the KMS where those conducting VE studies can refer to past solutions or ideas.

VE techniques have now been utilized in many different areas within the construction field. However, it became apparent throughout this literature review that VE is most useful in larger projects, where the design process is more extensive. This is because larger projects often require more materials and labor which opens up the project to the possibility of finding more alternative solutions where money can be saved.

And finally, though VE saw its start in the US it spread easily into the UK and has begun to see some implementation in China. However, VE is still struggling to get a foothold in developing countries where there are few VE experts or people who trust the idea of setting aside time to just possibly find an idea. That said, construction VE will likely be implemented everywhere eventually due to its many benefits.

CONCLUSION

While VE is a complex topic with many aspects that require separate studies. This paper aims at providing broad overview of the subject and its many applications. There are many tools that can be applied when conducting a VE study. These tools will help to ensure that the workshop will be successful by providing a framework for the thought process. As these tools become more widely available and easier to use, more possible applications for VE have been explored. VE has been applied to a wide range of civil engineering topics. By conducting this literature review, it is the hope that others can move forward with a more comprehensive perspective of VE when conducting further research on the subject.

REFERENCES

Abdelghany, M., Rahwan, R., Abotaleb, I., Fathy, A., & Albughdadi, A. (2015). Value engineering applications to improve value in residential projects. Retrieved June 6, 2017.

Arditi, D., & Mochtar, K. (2000). Trends in productivity improvement in the US construction industry. *Construction Management and Economics, 18*(1), 15-27. Retrieved June 5, 2017.

Cheah, C. Y., & Ting, S. K. (2005). Appraisal of value engineering in construction in Southeast Asia. *International Journal of Project Management, 23*(2), 151-158. Retrieved June 5, 2017, from Science Direct.

Chen, W. T., Chang, P., & Huang, Y. (2010). Assessing the overall performance of value engineering workshops for construction projects. *International Journal of Project*

Management, 28(5), 514-527. Retrieved June 5, 2017, from Science Direct.

Fathoni, U., Zakaria, C. M., & Rohayu, C. O. (2013). Value engineering awareness study for sustainable construction in Malaysia. *IOP Conference Series: Earth and Environmental Science, 16*. Retrieved June 17, 2017.

Gabr, S. E., El-Korany, T., Etman, E. E., & El-Din Fahmy Taher, S. (n.d.). Relevance of value engineering towards environment friendly roadway projects. *International Conference on Advances in Structural and Geotechnical Engineering*. Retrieved June 5, 2017, from ResearchGate.

Heiza, K., Abo El enen, N., Mahdi, I., & Hawas, M. (2015). Value engineering, value analysis and value management of vertical slip form construction system. *International Conference on Structural and Geotechnical Engineering*. Retrieved June 6, 2017, from ResearchGate.

Kalani, E., Kazem-Zadeh, R. B., & Kamrani, E. (2017). The pathology of the hindrance factors impeding the application of value engineering in the construction industry in Iran and ranking them by use of analytical hierarchy process. *Journal of Human Resource and Sustainability Studies, 05*(01), 57-67. Retrieved June 5, 2017, from Scientific Research Publishing.

Kissi, E., Boateng, E. B., Adjei-Kumi, T., & Badu, E. (2016). Principal component analysis of challenges facing the implementation of value engineering in public projects in developing countries. *International Journal of Construction Management, 17*(2), 142-150. Retrieved June 5, 2017, from ResearchGate.

Lee, M., Lim, J., & Hunter, G. (2010). Performance-based value engineering application to public highway construction. *KSCE Journal of Civil Engineering, 14*(3), 261-271. Retrieved June 17, 2017.

Lee, M., Lim, J., & Hunter, G. (2010). Performance-based value engineering application to public highway construction. *KSCE Journal of Civil Engineering, 14*(3), 261-271. Retrieved June 6, 2017.

Leung, M., Ng, S. T., & Cheung, S. (2002). Improving satisfaction through conflict stimulation and resolution in value management in construction projects. *Journal of Management in Engineering, 18*(2), 68-75. Retrieved June 5, 2017.

Lin, G., & Shen, Q. (2007). Measuring the performance of value management studies in construction: critical review. *Journal of Management in Engineering, 23*(1), 2-9. Retrieved June 5, 2017.

Lin, G., Shen, G. Q., Sun, M., & Kelly, J. (2011). Identification of key performance indicators for measuring the performance of value management studies in construction. *Journal of Construction Engineering and Management, 137*(9), 698-706. Retrieved June 17, 2017.

Luo, X., Shen, G. Q., Fan, S., & Xue, X. (2011). A group decision support system for implementing value management methodology in construction briefing. *International Journal of Project Management, 29*(8), 1003-1017. Retrieved June 17, 2017.

Mao, X., Zhang, X., & Abourizk, S. M. (2009). Enhancing value engineering process by incorporating inventive problem-solving techniques. *Journal of Construction Engineering and Management, 135*(5), 416-424. Retrieved June 5, 2017.

Marzouk, M. (2011). ELECTRE III model for value engineering applications. *Automation in Construction, 20*(5), 596-600. Retrieved June 5, 2017, from Science Direct.

Mukabi, J. (2015). Selected case examples of some value engineering technologies developed and applied in East & Central Africa. *XXVth World Road Congress*.

Naderpajouh, N., & Afshar, A. (2008). A case-based reasoning approach to application of value engineering methodology in the construction industry. *Construction Management and Economics, 26*(4), 363-372. Retrieved June 15, 2017.

Palmer, A., Kelly, J., & Male, S. (1996). Holistic appraisal of value engineering in construction in United States. *Journal of Construction Engineering and Management, 122*(4), 324-328. Retrieved June 5, 2017.

Park, C., Kim, H., Park, H., Goh, J., & Pedro, A. (2017). BIM-based idea bank for managing value engineering ideas. *International Journal of Project Management*, *35*(4), 699-713. Retrieved June 5, 2017, from Science Direct.

Rachwan, R., Abotaleb, I., & Elgazouli, M. (2016). The influence of value engineering and sustainability considerations on the project value. *Procedia Environmental Sciences, 34*, 431-438. Retrieved June 5, 2017, from Science Direct.

Rani, H. (2017). Optimization and effectiveness of bridge construction development based on value engineering. *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development, 7*(2), 15-22. Retrieved June 5, 2017, from ResearchGate.

Shahhosseini, V., Afshar, M. R., & Amiri, O. (2017). Value engineering practices in infrastructure projects: a case study of Ilam Gas Refinery's water transmission system at Reno Mountain, Iran. *International Journal of Construction Management,* 1-13. Retrieved June 5, 2017, from ResearchGate.

Shen, Q., & Liu, G. (2003). Critical success factors for value management studies in construction. *Journal of Construction Engineering and Management, 129*(5), 485-491. Retrieved June 5, 2017, from ASCE.

Shen, Q., & Liu, G. (2004). Applications of value management in the construction industry in China. *Engineering, Construction and Architectural Management, 11*(1), 9-19. Retrieved May 17, 2017, from Emerald Insight.

Trigunarsyah, B., & Hamzeh, K. Z. (2016). Implementing value engineering study for temporary facilities. *Proceedings of the Institution of Civil Engineers - Municipal Engineer*, 1-10. Retrieved June 5, 2017, from ResearchGate.

Wao, J., Ries, R., Flood, I., & Kibert, C. (2016). Refocusing value engineering for sustainable construction. *52nd ASC Annual International Conference*. Retrieved June 5, 2017, from ResearchGate.

Wao, J. O. (2017). Value engineering evaluation method for sustainable construction. *ASCE: Architecture Engineering Institute*. Retrieved June 5, 2017, from ResearchGate.

Yang, J., Baeg, H., & Moon, S. (2014). Utilization of contradiction for creating design alternatives in construction value engineering. *KSCE Journal of Civil Engineering, 18*(2), 355-364. Retrieved June 17, 2017.

Zhang, X., Mao, X., & Abourizk, S. M. (2009). Developing a knowledge management system for improved value engineering practices in the construction industry. *Automation in Construction, 18*(6), 777-789. Retrieved June 5, 2017, from Science Direct.