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Review Article

Review Current Value Engineering Studies Towards Improve Automation within Building Information Management (BIM)

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Abstract *- Value Engineering (VE) is still challenging in its application, despite the volume of studies efforts up to this day. Many studies tried to automate the VE process in the area of material selection and design aspect. However, the VE currently relies on shared experts' knowledge and information, making it a more subjective method. This limitation makes VE implantation more challenging and avoidable, as reported from formal studies. This paper aims to review the recent VE studies more comprehensively to answer two objectives. The first objective is to identify the most rote limiting VE application challenges in the construction industry. The second objective is finding the existing VE automation knowledge gap. The author used the googles scholar database to collect more than 60 papers. The selection criteria followed in this study is to extract the papers from the last five years that fit with achieving the two study's objectives, including challenges and solutions. The paper identified three limiting Value Engineering challenges and responded with selected solutions extracted from current research. Also, the paper identified five main VE automation challenges and gaps. This paper suggests improving the Value of Engineering automation by considering the five challenges and gaps as guidance for future research.*

Keywords *- Value engineering, Value management, Life cycle cost, Sustainability, Building information modelling, function analysis.*

1. Introduction

The concept of Value Engineering (VE) was introduced in 1940 during War Ware II [1],[2]. The VE methodology evolved with time, and it is attracting the attention of the construction market. The concept of Value Management (VM) is introduced later to improve the VE process by establishing a common understanding of the design issues to be identified and agreed upon by the project stakeholders [3]. The survey study by [4] concluded that 80% of the respondents from various industry segments were interested in applying VE in their future projects. [5] mentioned that applying VE has several advantages: gaining financial benefits to the client, improving communication, and encouraging local material usage. [6] affirmed that applying VE to a large project can save at least 10%, particularly in mega and minor projects. According to [7], adopting a VE study for temporary construction facilities could significantly save costs. [8] emphasized that applying VE in the Malaysian construction industry can increase profit and improve productivity in general.

Although the advantages of VE in the construction sector, many challenges are reported from previous studies, as will be discussed in this paper [9]. Several researchers realized that the VE concept in many projects is confused with the concept of cut costs. The confusion causes ignoring the quality aspect of design changes and considering only the initial cost. [10] emphasize that people's thinking must change to accept the change in construction materials to cut down the rising construction costs without compromising the quality that increases the construction value. In addition, it is argued by [11] that the clients' understanding of the VE concept is essential as it is not just merely considering the cost. Thus, VE should consider the relationship between value, function, quality, and cost from a broader perspective. [12] defined different VE phases to clarify: information phase, function analysis, creative phase, function analysis, evaluation phase, life cycle, and cost analysis. In addition, another cause of confusion is the overlap between VE and other techniques such as Lean Construction (LC) and Risk Management (RM). This confusion of understanding VE can lead to deficiency in applying VE due to its absence of the institution's strategic objective and not to be measured its performance.

The main other reported challenges are the lack of VE culture in most public firms, and VE is too complicated and theoretical to be implemented. Accordingly, the VE implementation depends on expert knowledge to feed the VE process with the material value and design change. This knowledge dependency is, in turn, makes the VE results in inconsistency, and it is not easy to apply. As a result, VE integration with Building Information Modelling (BIM) becomes limited, and there is an urge to be improved. One of the barriers to the practical application of BIM in construction is the absence of standards and domestic-oriented tools [13].

Therefore, VE is one of the construction areas that should be standardized to overcome the limitations implemented widely. To standardize VE to be automated within BIM applications, VE areas are required to be standardized. Such standards can be applied to material selection criteria (including quality), building function, Life Cycle Cost (LCC), sustainability aspect, and others such as RM and LC. This paper first reviews the current studies related to VE classified based on supporting arguments of the two study's objectives: first to address the cause of VE application limitation and second to address the challenges and gap of current VE automation. Based on this review, the author identified three main challenges on responding to the first objective and five main challenges on responding to the second objective. The author identified the corresponding answer from reviewing the current studies for each challenge related to the first objective based on studying these challenges. Also, the author identifies the gap between all the five classified VE automation challenges and suggests a general solution to improve the current research area by considering all the five challenge gaps toward reaching a more comprehensive VE automation. The sole purpose of this paper is to review more studies and suggest guidelines for future studies. The overall future goal of these guided studies is to develop a new BIM dimension related to VE used during the design phase and assess the decision-makers to reach optimal building value.

2. Value Engineering (VE) Definition and Value Management (VM)

Before we proceed with the paper discussion, VE and VM need to be clarified. VE is an organized attempt to provide the required facility at the lowest total costs, consistent with performance, reliability, and maintainability [14]. The current construction practices require a great effort to balance money, time, and quality. The Society of American Value Engineers defines VE as the systematic application that identifies and provides the necessary function reliably at the lowest overall cost. VE improves service value by modifying and enhancing functions. In general, the real objective of VE is value improvement, which is defined as the ratio of function to cost. Therefore, value can be improved [15].

As an extension to the VE concept, VM focuses on establishing and adding measurable value while focusing on functional drivers and objectives before seeking solutions to improve overall innovation. VM is defined by [3]as "A structured process of dialogue and debate among a team of designers and decision-makers during an intense short-term conference." Thus, VM aims to develop a common understanding of design goals, select the best actions, and establish a common decision framework [3]. This paper will use the VE and VM as interchangeable terms between them.

3. Research Methodology

In the area of VE, there are numerous studies primarily focused on improving the VE implementation. This study reviews more than 60 studies to assess the challenges and difficulties associated with VE implementation and highlight the predefined solutions. The author used the googles scholar database to collect these papers. The selection criteria followed in this study is to extract the papers for the last five years that fit with achieving the two study's objectives, including challenges and solutions. The following section linked all the selected studies related to each VE-challenged issue and identified solutions. This linking aims to collect and understand the VE challenges in limiting its application and automation.

4. Challenges and Solutions for Improving VE Implementation

There are many factors still hurdling VE implementation globally. At the same time, the BIM implementation obstacles are contributed the most by the awareness and the slow uptakes by the player involved in the current industry [12]. There is a demand to review the current studies with having two objectives to improve the VE and BIM implementation. Objective 1 is to investigate the main challenges associated with the reported fact of limiting the VE application in the construction industry. The second objective is to investigate the main challenges associated with having less effective VE automation.

4.1. Objective 1- Studying the Challenges of Limiting VE Application

Difficulties in applying VE are a fact that is mentioned in various VE studies directly or indirectly. This fact affected three challenges: lack of VE experts, difficulty fixing the entitlement of sharing the cost-saving caused by VE among the contract parties during the construction stage, and less measuring VE company performance, which discourages employees from applying it. The shortage of the first challenge of applying VE (shortage of VE Experts) causes the VE method to be less objective and subjective, preventing from following a standard systematic method and having consistent results. The second and third challenges cause a lack of motivation to apply VE either because of difficulty fixing the benefit entitlement of the VE cost-saving during the construction phase or discourage company employees from applying VE since it is not part of the company performance measure. Consequently, these three challenges can be overcome by responding to three corresponding solutions respectively. These solutions are improving the VE automation process, fixing construction contract terms to keep VE be motivated to apply during the construction phase, and including VE as part of measuring institutional performance to keep VE be motivated to apply for all project phases. The following sections explore the studies that support these three challenges and solutions.

4.1.1. Challenge 1: lack of motivation to apply VE because it takes effort and depends on knowledge sharing

VE has been applied in many countries with different experiences and challenges because it depends on sharing knowledge. [16] studied more than 800 papers in VE published between the years 2000 to 2015, concluded that the United States of America (USA) and China are the leading countries in this field. The following three paragraphs are a study review from different regions in the world.

In Asian countries, several researchers studied the challenges of VE implementation. In Southeast Asia, Cheah [2] concluded in their survey study that there is a lack of understanding of VE concepts among industrial practitioners. [17] presented an application of VE in Sri Lanka with emphasis to have a standard practice to increase the VE practice. In addition, [18] mentioned that the hinder to implementing VE is the absence of VE experts. In Malaysia, [4] assert that VM knowledge and practice during the VE workshop reduce VE benefits. [8] also studied in the Malaysian country and emphasized that knowledge and technical skills are required to construct a project effectively.

Implementation of VE in African countries is also reported to be challenged. As a result of the lower efficiency of VE implementation, [19] introduced a framework to improve VE practices in Nigeria. Moreover, [20] focused on selecting building materials impacting the Building LCC within the Nigerian building sector. Through construction and firm consulting survey in Ghana, [9] founded 22 VE application challenges. One of the significant VE challenges in this study was that VE is too challenging to start developing countries [21] discussed in their study that the VE adaption in South Africa is due to the miscommunication between the project stakeholders.

Middle East countries have their experience regarding VE implementation [22] reported that 85.3% of respondents in their survey study did not adopt VE and did not receive any VE training in Egypt. They concluded in their study that there is a lack of VE implementation in Egypt's residential building sector due to a shortage in VE implementation skills. In Oman, [23] assert the importance of VE in the Omani construction sector to suggest initiating sustainable measures for the industry. They suggested practices to overcome this issue. From reviewing these studies, it can be concluded that there is a necessity to have a systematic approach for implementing VE and be automated to encourage practitioners to use it.

4.1.2. Challenges 2: lack of motivation to apply VE because of having legal concerns during the project construction

One of the development factors of the VE to VM concept is to improve the VE implementation during the construction phase by sharing the understanding of design problems and agreeing on the solutions by all project stakeholders[3].[24] mentioned that the earlier VE performed at the stage of a project cycle, the more significant cost reduction can be obtained than if performed in the following stages of the project. However, the difficulty of making the changes will be more significant in the latter stage of the project, accompanied by rising costs to make changes in the design. Another issue associated with implementing VE during the construction course is defining the responsibility and interest of implementing VE.

Typically, applying the VE during the design stage does not impact the construction contract in a competitive contract, such as a lump-sum or Bill Of Quantities (BOQ) contract. However, as soon as the contract is signed, the project owner's interest in VE becomes low, and the contractor's interest in implementing VE becomes high to save cost and profit [24] stated that many standard contracts regulate VE implementation to handle these VE project interest responsibilities. Another contract example of regulating the project contract party's responsibilities associated with VE changes in design and materials is the standard contract construction for engineering work and building the Federation Internationale des Ingenieurs-Conseils [25] Article 13.2. This contract term gives the contractor the right to claim half of the saving in the contract value if VE changes without prior agreement and understanding how the savings contract value would be shared (Federation Internationale des Ingenieurs-Conseils, [25]). A general solution to this challenge is to fix the contract terms to encourage applying VE in the overall project execution period.

4.1.3. Challenge 3: lack of motivation to apply VE

Because it is not measured within company strategy performance.

One solution to overcome the VE lack of motivation challenge is to use VE as encouragement tools for the construction project participants to measure the success of implementing VE in the construction sector. [26] suggested providing the contractor incentives to submit VE proposals during the implementation of relatively large projects. Key Performance Indicators (KPIs) are a known indicator of institutional performance [27]. In the area of VE, several studies set KPIs for a purpose to measure the VE performance. In a recent study, [28] investigated the VE KPIs used in the Sri Lanka construction industry in different construction stages.[29] identified a series of KPIs to measure the success of construction megaprojects.

As discussed before, several VE studies suggested solutions to overcome the encouragement of applying VE. The leading tactical solution is encouraging the companies and owner agencies of the construction project to keep the VE as an objective in their strategy by establishing KPIs metrics to measure the institutional success. Such actions will be reflected broadly on the whole institutional employees and keep VE part of their priorities. Having such KPIs is also encouraging the contract department to resolve the VE entitlement part of their contract. In addition, it will be reflected on employee training and enhance the VE knowledge.

3.2. Objective 2 – challenges of automation of VE and following VE agreed on a standard to be measured with a systematic approach

As discussed from the previous three challenges of limiting applying VE, VE reported in several countries to be challenging. An observation from these studies can deduce that the root challenge of limiting VE application is the lack of a following systematic approach, and VE depends heavily on knowledge sharing. The VE process is complicated because of has many variables of defining material criteria (including quality), LCC, and building function. In addition, it needs to consider the interaction between VE and other areas such as LC, RM, and sustainability. As a result, the method depends heavily on communication and interaction among project practitioners and extracting experts' knowledge. This complicated process caused applying VE avoidable, as implied in the VE studies. The primary cause of this inconsistent procedure is the absence of a standard and agreed-on methodology to simplify the VE process. This standard and methodology are required to automate the VE within BIM and attain a fast result with reasonable accuracy. In general, three main parts of the VE process require setting and measuring the agreed material selection criteria, building function, weight factor, and estimated LCC. Other identified interaction VE areas (such as sustainability, RM, and LM) will affect the last three main VE parts required to be measured. In the following section, five identified VE automation challenges extracted from several reviewed studies are discussed. Then a general recommendation is introduced in this paper to improve the VE automation to fill the five challenges gap.

3.2.1. Challenge 1: automate the VE with agreed automation systems such as BIM.

The new trend of Industry 4 is to automate most of the engineering selection process [30]. The VE process is one of the engineering processes that require automation as a result of process complexity. Several researchers studied the feasibility of applying BIM in the area of VE. [31] applied BIM in megaprojects to simplify the VE process and demonstrate its benefits. [12] studied the challenging factors of implanting BIM in VE with substantial saving optimized cost.

To save cost and energy, [32] analyzed the relationship between cost and energy saving for residential buildings by using BIM simulation technology combined with VE. [33] enhanced BIM with Life Cycle Assessment (LCA) methodology to evaluate the construction materials. [34] outlined an automated BIM environment framework for selecting optimal building components with considering sustainability aspects. [12] a value index for each material alternative by applying the function analysis, risk analysis, and LCC analysis within BIM Model for renovation work. [35] proposed a procedure for updating and retrieving BIM object values to exchange information between the designer and the owner. This study is helpful for the automation of the VE process technically. Thus, many studies link BIM to the VE process (in whole or part) in response to this gap. However, none of these studies integrates VE efficiently with BIM, and there is an urge for studies to improve this research area.

BIM is not the only automation tool used for VE implementation. Several researchers conducted studies to automate the VE process using other computerized tools than the BIM tools. [36] automated a decision-making process using an object-oriented model to overcome the uncertainty and vagueness of expert knowledge on selecting construction methods. [26] also proposed a model to support the knowledge creation process within the VE process. [37] proposed a neuro-linguistic programming (NLP) approach to aid in the creativity phase of VE. [10] used scheduling software to demonstrate the principle of VE. In a more recent study on the facilities selection process, [30] proposed a Multi-Criteria Decision Analysis (MCDA) with the corresponding selection criteria utilizing an Industrial Internet of Things (IIoT) platform.

A general solution from discussing the previous studies is to recommend the automation of VE to be integrated with BIM since it becomes recommended practice. It has been noticed recently, an increase in BIM application in the construction area. Thus, BIM has become a trend in the area of construction management.

3.2.2. Challenge 2: set selection materials criteria to be automated

One of the significant challenges in VE implementation is selecting a building material with optimized value in quality, building function, and LCC, including sustainability and risk. [38] stressed the importance of selecting building materials that satisfy the project objectives and standards, including cost, energy consumption, and environmental impacts. In this study area, many researchers studied the selection of different materials with different selection techniques [39]; [40]; [41] as an example of these selection material study efforts, [62] the faced building using selection criteria by considering the sustainability aspect. For an example of selecting building material, [62] proposed another framework for selecting a structural system for a wooden public building.

Regarding the challenge of setting material quality criteria, building materials have various criteria to select. Internationally, many quality standards such as ISO, ASTM, and others help regulate material quality standards [46]. Some countries established their standards, such as Saudi Standards, Metrology, and Quality Organization

(SASO), to define the minimum specification for materials and equipment (SASO, 2020). Such a standard could be a good base for measuring the criteria quality. The challenge in selecting materials is setting agreed standard criteria between all varieties of international standards. The other benefit of having an agreed standard is facilitating the automation of the material selection process within the BIM environment. [46] applied international material standards for integrating BIM with existing asset management systems. [47]; [65] studied the integration between material selection and BIM. Recently, Alrahhal [42] suggested a BIM framework for selecting building flooring materials. They suggest selection criteria based on material quality, durability, maintainability, constructability, and others.

Generally, there is an urge to have agreed on the selected and measure material selection criteria for each country. Hence, it is recommended in this paper to have these standards impeded within material information objectives within BIM.

3.2.3. Challenge 3: define building material function to be automated

Determining the project or material function, which requires creativity and skill, is one of the challenges highlighted by several researchers. [4] determine in their survey study that clarifying the project needs and improving the brief project impacts the project function. [5] mentioned that one of the VE utilization factors is not generating new ideas that define the project function. [48] discussed the impact of lacking information for generating ideas that affect defining project functions.

To improve defining the project and material function [26], proposed a knowledge-based model to improve creative thinking in defining the function process. Finally, [37] analyzed the traditional VE procedure and proposed a neuro-linguistic programming (NLP) approach to improve the VE creativity phase relative to green building design and construction. A general solution of defining material function is to calculate the criteria ranking weight according to the priority of building function [42].

There is a necessity to study the methodology and the weight of adjusting the MS score based on Building Function. Function Analysis System Technique (FAST Diagram, used in determining the material function) analysis and Analytic Hierarchy Process (AHP) methods could be used in just adjustment [45].

3.2.4. Challenge 4: consider Sustainability and LCC in the VE evaluation process

Building sustainability has a significant impact on VE in calculating the LCC with considerable energy saving. [57] used a case study to demonstrate that 20% to 30% saving element cost could be attained. In addition, they are mentioned that implementing VE can save 7% of the project cost as well as saving in energy consumption can be achieved. In India, [61] concluded in their study that VE can enhance the living economic standard with increased quality of life while maintaining the ecological balance.

To improve integrating sustainability aspects with LCC analysis, [33] introduced a method to consider the elements of energy, environment and LCC material with the Life Cycle Assessment (LCA). In addition to considering energy in LCC, [55] considered three other elements: water, environment, and human health. [51] proposed a numerical model for evaluating values by assessing building elements' performance LCC analysis. In Indonesia, [50] studied the improved impact of the VE method for achieving optimized green building rating tools and LCC. Using BIM simulation technology combined with VE, [32] studied the relationship between cost and energy saving in the architectural design process using residential building examples, as mentioned before.

Some researchers studied the importance and necessity of integrating sustainability and VE in selecting building materials, not only in the aspect of LCC. In Hong Kong, [66] studied the potential for integrating sustainability considerations into the VE processes. The study indicated that the weak point of this integration is the lack of sustainability experts.

Several other studies introduced innovative solutions to integrate sustainability with VE effectively. [64] developed the Performance Worth (PW) method to address the limitations of the conventional VE to improve the sustainability aspect. [63] demonstrated the benefit of using the Choosing by Advantages (CBA) method to adopt sustainable design and construction during the VE process. Using an earthwork case study in China, [52] introduced a Green Construction evaluation system derived from two concepts, VE Theory and AHP. [59] introduced a framework for integrating VE and sustainability concepts in the construction industry to improve project value in Sri Lanka.

Although these are an excellent effort to consider the sustainability aspect within the VE process (alone or included within LCC analysis), the absence in these studies is that the final integrated methodology is still not comprehensive and requires subjective judgment information from experts and practitioners. There is an urge to have a comprehensive automated methodology that can be automated in BIM. [49] emphasizes that many BIM Dimension depends on symbolism and should be identified as a symbolized object such as cost dimension. One of these symbolic BIM dimensions is sustainability. Therefore, the VE process must be set as a symbolized object by having agreed factors and data and considering all VE aspects, including sustainability. Several rating systems in sustainability, such as BREEAM, LEED®, CASBEE, and the Australian Green Star, can be used to define and measure the sustainability criteria for selecting materials [43].

3.2.5. Challenge 5: consider LC and RM with the VE evaluation process

VE and LC are two interchangeable methods, and both complete each other although the differences in philosophy and scope. Both approaches share the same value delivery goal and misuse cost reduction techniques [56]. [53] emphasized the importance of managing knowledge with the LC and VE techniques to impact project delivery positively. [44] studied the synergy between LC and VE concepts to minimize the overlap between the two methods to develop a new approach called Lean Integrated Value Engineering (LiVE). Within the LC concept, Target Value Design (TVD) is introduced as a project delivery method with targeting cost and VE [58].

Besides the overlap between LC and VE, [54] assert that integrating VE and RM will lead to a better project outcome and avoid duplication. Toward minimizing the risk of selecting optimized material with uncertainty, [60] proposed a decision-making model under epistemic uncertainty to minimize the risk of selecting optimized material with uncertainty.

From reviewing these papers, it appears that the VE automation that follows a systematic approach with defining quality, function, and LCC needs to be considered other interaction VE areas such as LC and RM. One solution for such integration between VE and LC/RM is to consider factors for risk and LC within the VE equations in following a systematic approach.

5. Discussion and Generating Solutions of Objective S 1 and 2 to Overcome all the Identified Challenges

In conclusion, from previewing the previous studies, it can be clear that there is a demand to develop a systematic approach covering all the five challenges simultaneously. Table 1 summarizes all the challenges from both two research objectives and the corresponding solutions to them. It can be implied from the table the substantial gap from reviewing the former research is the absence of standard practice in each country. Therefore, there is a necessity for studies to reduce the VE/VM method's subjectivity to be more objective and follow clear criteria for selecting building materials. In addition, developing a comprehensive VE automation system integrated within BIM will reduce the poor communication and lack of experts in this area, reducing ambiguity issues.

6. Conclusion

More than 60 studies related to VE have been identified to answer two main this paper research questions. The first question is, what are the main challenges that limit VE application as reported from different countries. Three main challenges and corresponding general solutions were identified to motivate the construction industry to apply VE more often. The first main challenge is that the VE process depends heavily on shared knowledge which is difficult to obtain. The new revolution of IOT's moving forward to automate many applications. As a result, a general recommendation is highlighted to improve the current effort of the VE automation process. The second challenge is that the VE application is limited during the construction project course because of the contract responsibilities allocation. The paper addresses general identified studies and contract terms to motivate the contractor to apply VE and benefit from saving costs. The third challenge is the motivation lack within the institutional relation to the construction project. Several studies suggest KPI's that can be used to measure the VE application within the construction institution. Including VE parts of the company's strategic objective will impact the overall company performance.

The second paper's question is related to finding the current VE automation gap and challenges to be addressed in future research. In this regard, five challenges have been identified from observing the previous VE automation efforts. Firs challenge is VE automation system requires to be selected based on a typical construction practice. From reviewing the current VE automation efforts, a general solution to use BIM as a platform to automate VE. The second challenge is related to creating a common agreed reference material selection criterion that can be measured. Such a reference simplifies the selection automation process. According to the VE concept, the selection of construction materials should depend not only on quality but also on building function and its usage and needs. Thus, a demand in simplifying the function process is the third identified automation challenge. Several papers discussed in this paper tried to facilitate this process in order to be improved. However, this process should be agreed upon and follow a systematic approach in order to be programmed. The fourth challenge is to consider the current research effort integrating sustainability and LCC with the VE process. The fifth challenge is to consider the LC and RM within the VE evaluation process. A general solution for studying the second research question is to have a comprehensive VE automation system that addresses all these challenges and gaps.

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Data Availability Statement: The data in this paper has been taken from other literature studies as this is a review paper. The raw data supporting the findings of this paper will be available by the corresponding author on request.

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Table 1. Summary of the concluded challenges from ve studies and proposed identified solutions

Study Objectives	Identified Challenges	General Identified Solutions
Study Objective 1: Finding the root reasons for lacking the motivation to apply VE.	**Challenge 1**: VE takes effort and depends on knowledge sharing.	Develop a systematic automation approach for implementing VE
	Challenge 2: VE has legal concerns during the project construction.	Fix and use the contract terms to encourage applying VE in the overall project execution period.
	Challenge 3: VE is not measured in its strategy performance.	Keep the VE as an objective in institutional strategy by establishing KPIs metrics to measure its success.
Study Objective 2: finding the existing VE automation knowledge gap	**Challenge1**: automate the VE with an agreed automation system such as BIM	Integrate all the five challenges to be automated in one system
	Challenge 2: set selection materials criteria to be automated.	
	Challenge 3: define building material function to be automated	
	Challenge 4: consider Sustainability and LCC in the VE evaluation process.	
	Challenge 5: consider LC and RM with the VE evaluation process	

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