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Unveiling the Barriers to Value Management Implementation in Building Projects: An Integrated EFA-SEM-ANN Analysis Approaches

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Abstract

Value Management (VM) is a structured method for enhancing the effectiveness of building projects, yet adoption in Jordan remains limited. The study identifies the principal barriers to VM adoption in Jordan's building sector and ranks them to inform policy and practice. A survey of 101 industry stakeholders captured 19 Likert-type indicators. Exploratory factor analysis (EFA) reduced the indicators to coherent barrier clusters; partial least squares structural equation modeling (PLS-SEM) then validated a reflective measurement model and tested links with VM adoption. An artificial neural network (ANN) with k-fold cross-validation quantified predictor importance and assessed out-of-sample error. EFA produced three clusters—standardization and organizational practices, workshop design and participation, and culture and industry environment—explaining approximately 73% of total variance. PLS-SEM supported reliability and convergent/ discriminant validity and indicated that workshop-related and standardization barriers exert the strongest adverse effects on VM adoption. ANN results corroborated these patterns and highlighted workshop dynamics as the most influential predictor. This work presents the first integrated EFA–SEM–ANN analysis of VM adoption barriers in Jordan. The multi-method evidence yields actionable priorities: institutionalize standardized VM procedures, strengthen VM workshop design and participation, and address organizational culture to accelerate VM uptake.

Keywords: Barriers; Value Management; Construction; EFA; SEM; ANN.

1. Introduction

Building projects significantly influence culture, the environment, and the economy throughout their entire life cycle [1, 2]. Buildings consume more than 40% of global energy and account for about 30% of total greenhouse gas (GHG) emissions in both developed and developing nations [3]. Over 40% of the total energy use in Europe and the USA is attributed to buildings [4, 5]. In developing countries, the sustainability of building projects is often secondary [1]. These countries have experienced rapid development; therefore, the building industry plays a crucial role in providing basic living infrastructure [6]. The success of this sector is typically measured by the quality, cost, and time performance of construction projects [7]. Furthermore, in many developing countries, the building industry has undergone significant changes to meet national economic objectives [8]. It has been reported that financial systems in most developing countries are still undergoing improvement [9].

Building projects in these contexts frequently face numerous challenges, including failure to meet required targets, schedule delays, cost overruns, and inadequate sustainability performance [10, 11]. In addition, studies addressing the

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social costs of building projects in urban residential sectors remain limited [12, 13]. Weak initiatives in developing countries have led to issues such as projects completed within budget but behind schedule, or projects being suspended or abandoned due to funding shortages [11, 14]. Overall, the construction industry in many developing countries fails to meet the expectations of governments, clients, and sustainability goals, and thus lags behind other sectors both domestically and internationally [15].

This situation has emphasized the need for "sustainable buildings," which are environmentally friendly and resource-efficient throughout their development processes [1]. Lewis et al. [16] defined sustainability as meeting present needs without compromising the ability of future generations to meet their own needs. Kibert [17] described sustainable construction as the creation of a healthy built environment based on ecological principles and efficient use of resources. Sustainable construction is generally viewed as a process that begins before project execution and continues even after construction professionals leave the site [18]. Wolstenholme et al. [19] emphasized that the construction industry should be modernized through the adoption of effective, integrated, innovative, and sustainable practices. Enhancing sustainability awareness at the earliest stages of a building project is strongly recommended to guide its development effectively [1]. Value Management (VM) can incorporate sustainability considerations during the early planning and design phases of project delivery [20]. The Society of American Value Engineers (SAVE) [21] has recognized VM as a proven mechanism for improving the sustainable value of projects.

VM is an effective tool for managing planning, design, and performance in different building project components [22]. VM originated in the United States post-World War II when Lawrence D. Miles developed it at General Electric [23]. Initially applied in the industrial sector, it was introduced to the construction sector in the early 1960s. The scarcity of certain materials due to the war prompted the search for alternative methods to achieve component characteristics without relying on specific materials [24]. This led to the development of affordable products without sacrificing efficiency. Post-war, this approach was used to eliminate and reduce unnecessary product costs, laying the foundation for value engineering based on functional analysis [25].

VM, also known as Value Assessment (VA) or by the U.S. Value Engineers Association (SAVE), is a multidisciplinary, team-oriented, systematic analytical process to deliver maximum value to the consumer throughout the design and construction phases. It spans the entire project lifecycle, promoting efficient construction techniques [26]. VM is crucial for sustainable development and budget conservation, as it helps cut unnecessary costs. Government policies often focus on improving construction sector efficiency and reducing building costs [27].

VM is a process that ensures the highest value in design and construction through consumer awareness. This is vital for successful building techniques throughout a project's lifecycle. VM can stimulate and cut unnecessary expenses while incorporating sustainable development into programs and budgets [27]. Given that the government is a major client in construction projects, VM's ability to enhance efficiency and reduce costs aligns with governmental objectives. Chilakamarri et al. support that VM maximizes performance and efficiency without compromising value [28]. Globally, VM is recognized as a strategy for achieving value for money and higher productivity. Ellis et al. found that applying VM at an early project stage could reduce capital expenditures by 10–25 per cent, with previous studies indicating a 5–10% reduction in project building costs [29].

VM is common in many countries but less so in developing nations. For instance, VM adoption is still in its infancy in China and Malaysia, and its application is limited in South-East Asia and South Africa. Malla concluded that VM adoption in construction is slow in Myanmar and Nigeria and only recently introduced in Nepal [30]. There is a lack of systematic research on VM knowledge and application in Jordan. Most Jordanian stakeholders lack sufficient VM knowledge, hindering its implementation. Practitioners sometimes compromise performance and basic functions to cut costs, and uncoordinated teams fail to provide innovative solutions. The Jordan building sector reflects issues common to many developing countries [31, 32]. VM was widely used in established building industries in the USA, UK, Hong Kong, China, and Australia in the 1970s, with significant improvements in its implementation. In developing nations, however, weak project supply sectors lead to client dissatisfaction [33]. Since VM aims to achieve cost value by controlling costs and eliminating unnecessary resources, processes, and times, it is a crucial strategy for success.

Although previous studies discussed VM benefits, activities, and technological efficiency in several developed countries, few efforts have been made to determine VM implementation in developing countries [1]. Therefore, VM methods have not received comparable coverage in the majority of developing countries, including Jordan. Despite the advice to embrace VM and the growing awareness among building professionals, VM adoption remains limited, and it was found that while small VM seminars were well-run, research on virtual obstacles in developed and globalized nations is still ongoing [34]. Identifying factors hampering VM implementation is essential for overcoming obstacles and promoting VM techniques in the industry [1].

The existing literature on VM implementation largely focuses on developed countries, leaving a significant gap in understanding the barriers developing countries face, particularly in the Jordanian construction industry. This gap is critical, as developing countries' socio-economic and cultural contexts can differ markedly from those of developed nations, leading to unique challenges and obstacles not addressed in the current body of research. To fill these research gaps, the following research questions are framed:

- What are the primary barriers to VM implementation in the Jordanian construction industry?
- How can these barriers be categorized and analyzed to understand their underlying structure?
- What are the relationships between these barriers, and how do they impact VM implementation?
- How can the impact of these barriers on VM implementation be predicted?

To fill this gap, the objectives of this study are:

- To identify barriers to VM implementation through a comprehensive literature review.
- To analyze these barriers, Exploratory Factor Analysis (EFA) was used to uncover their underlying structure.
- To examine the relationships between these barriers through Structural Equation Modeling (SEM).
- To predict the impact of these barriers on VM implementation using Artificial Neural Networks (ANN).

This study contributes significantly by comprehensively analyzing the barriers to VM implementation within the Jordanian construction industry, an area underrepresented in existing research primarily focusing on developed countries. Utilizing a multi-method approach involving EFA, SEM, and ANN, this research offers a nuanced understanding of the complex factors impeding VM adoption. The findings enhance theoretical knowledge by uncovering unique challenges in a developing country context and delivering practical insights for stakeholders to devise targeted strategies and policies. By addressing these barriers, the study aims to improve project efficiency, effectiveness, and sustainability in Jordan's construction sector, ultimately advancing construction practices and infrastructure development in similar socio-economic environments. The remainder of this article is organized as follows. Section 2 reviews the relevant literature and develops the research questions. Section 3 describes the methodology, including instrument design, sampling, and data analysis procedures (EFA, PLS-SEM, and ANN). Section 4 reports the empirical results. Section 5 discusses implications for policy and practice, as well as theoretical contributions and limitations. Section 6 concludes and outlines directions for future research.

2. Literature Review

Subjects of sustainability have been stressed by countless studies [35, 36]. Transforming strategic sustainability targets and strategies for projects is a complicated procedure [37]. Balance essentials to be generated among the social sustainability, economic, and environmental aspects [35, 38]. The emergence of sustainability in the building industry has led to a search for practical ways to infuse this concept into existing working environments [20]. The need for sustainable improvement and the innovative corporate social responsibility ethic implemented through companies are drivers that could also encourage VM's massive use at the primary strategic phases [39, 40]. VM is conventionally established as an organized and analytical procedure designed to improve value for money by delivering the required functions with the least cost in line with the quality and sustainability required [41]. Applying VM has attracted increasing interest among most experts, researchers, and building industry practitioners [42-44].

Over the past ten years, VM has evolved using generally accepted tools and approaches into an established method. VM to maximize project efficiency using proprietary, advanced software intended to address issues and a disciplined framework for development [45]. From the project's start to its conclusion, the need for a disciplined methodology, multidisciplinary study, and functional analysis was highlighted [32]. SAVE International defines VM as a cross-disciplinary, systemic endeavor to investigate projects offering the most important benefit at the lowest cost [46]. VM is a sensible strategy that could help to lower life cycle and capital expenses. While consumers often demand cost cuts, Abidin & Pasquire pointed out that VM keeps improving capital investments, quality, profitability, and market image

[20]. Ma & Hao said VM's main concentration is planning structured seminars. These seminars aim mainly to unite several stakeholders' opinions to satisfy the project's needs effectively. SAVE plans these seminars in stages: information, function analysis, creativity, evaluation, and development. These seminars help team members to improve the project and create a reasonably affordable model. VM enhances project performance without sacrificing goals rather than only cost control [47].

Because of the great advantages seen in industrialized nations, VM is common in many of them and attracts interest in developing countries. While earlier studies on VM concentrated on awareness and preparation in underdeveloped nations, more recent studies have examined implementation difficulties. Several obstacles to VM adoption include lack of information, standards, historical data, time, comprehension, and client obligations [48]. Critical elements preventing VM deployment in Malaysia include ignorance, official government backing, and local policies. Stressing resistance to change and contradicting project goals are primary challenges in VM seminars. Similar lack of skilled personnel, problems in workshops, and ignorance of and lack of application records [48]. Kissi et al. [49] looked at 22 VM problems in Ghana and found important elements causing challenges to VM deployment. When Luvara & Mwemezi evaluated VM adoption in Tanzania, they discovered major obstacles, including inadequate information, poor procurement practices, and insufficiently trained staff [50].

Aduze underlined the main hurdles of VM deployment in Nigeria: lack of government legislation, poor client reception, and insufficient VM knowledge [51]. Ezezue discovered that the program's success suffers from adequate attention and orientation toward VM values [52]. Shen pointed out other problems like inadequate government support, VM professionals, and poor implementation dedication. Shen examined VM understanding and application in Hong Kong and discovered that major obstacles were lack of expertise, confidence, and time [53]. Cheah & Ting found that in China, lack of knowledge and technological standards are the biggest challenges to virtual machine implementation [54]. With issues including a lack of standard methods, industry marketing, and knowledge on VM benefits, VM is somewhat new in Sri Lanka [55]. Fard et al. [56] examined VM in Iran and found obstacles to out-dated norms, conventional wisdom, negative attitudes, lack of local direction, and ownership changes. Emphasizing contractual agreements, top management support, team formation, and implementation time, Malla offered recommendations for VM applications in Nepal [30].

Latief & Vincentius Untoro [57] researched VM in the Department of Public Works in Indonesia, noting elements influencing VM preparedness included the number of competent workers, implementation strategy, workforce makeup, technology, management awareness, and training. Examining VM in Western Australia's engineering industry, Whyte & Cammarano [58] discovered that workshop success suffered from time limits, ignorance, and team engagement. According to several studies, lack of expertise, government and management backing, and customer readiness to pay extra expenses are significant obstacles to VM adoption in poor nations. Notwithstanding these obstacles, VM's possible advantages emphasize the necessity of increased knowledge, education, and assistance to enable its acceptance and application.

2.1. Research Gap

Despite the increasing recognition of VM as a pivotal practice for enhancing project efficiency and effectiveness, its implementation within the Jordanian construction industry remains fraught with challenges. Existing literature predominantly addresses VM in broader contexts or other regions, leaving a significant gap in understanding the specific barriers in Jordan. Current research often overlooks the unique socio-economic, cultural, and regulatory factors that impede VM adoption in Jordanian building projects. Furthermore, integrating advanced analytical techniques such as EFA, SEM, and ANN to examine these barriers is limited. This gap underscores the need for comprehensive studies that leverage these methodologies to identify, quantify, and model the complex, interrelated obstacles to VM implementation, thereby providing tailored strategies to foster its adoption in Jordan's construction sector.

3. Research Methodology

This study examines the obstacles to VM deployment in Jordanian construction projects. Three rounds of inquiry were conducted to compile Jordanian experts' data and identify these obstacles. As Figure 1 shows, the investigation was conducted in several stages.

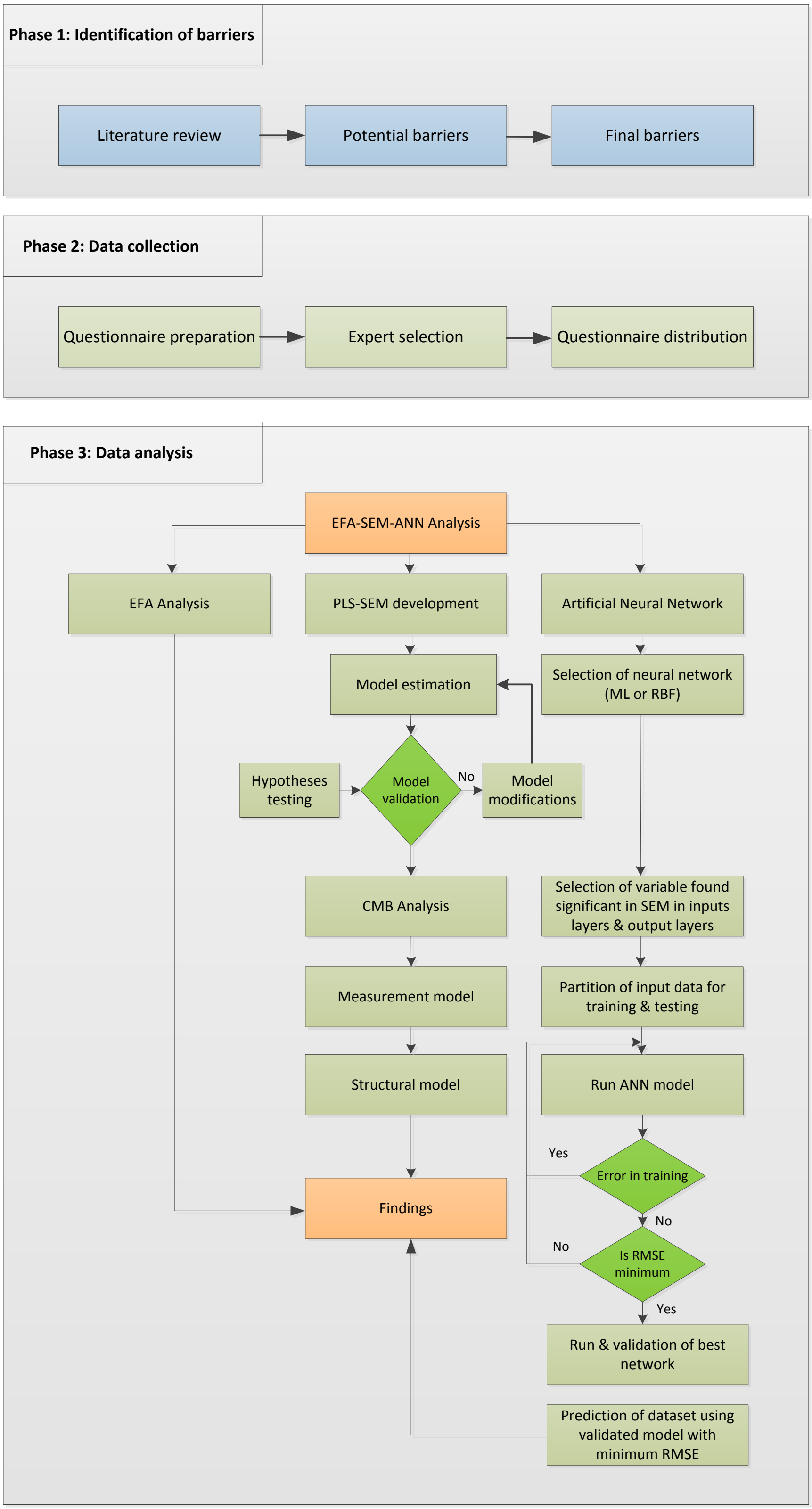

Figure 1. Research Framework

3.1. Identification of Barriers

This work compiled a rapid scoping review. Burnham [59] notes a scoping review as a first evaluation of the current VM research output volume and scope under publication. When a body of research is broad, complicated, varied, or not thoroughly studied, and it would be impractical to offer a more targeted and comprehensive analysis, scoping assessments are advised. This review was deemed essential for this study since it revealed the obstacles to VM implementation in Jordanian building projects. Examining every obstacle's relevance to VM deployment in Jordanian construction projects. The current argument revolves around the variations in the factors influencing success between the two and incentives.

Caponecchia et al. [60] defined a scoping review as usually comprising several phases: timetable establishment, formulation of research questions, identification of sources and search strategies, selection of relevant studies, optional assessment of the selected studies, synthesis of findings, and optional expert consultation. The present work should be underlined as an independent study project rather than a publication compiling past research. Over 21 years, from 2014 to 2023, the literature was searched on the obstacles to using VM in the building sector. Given that the time range provided the required data for their investigation, the researchers took it into account (see Table 1), adopted from Kineber et al. [42]. "What are the barriers to VM implementation in building projects within the Jordanian construction industry?" asked the main question guiding the search for these literary sources. A more comprehensive range of search engines, including Scopus, Emerald Insight, Google Scholar, and similar tools, was consulted to remove the obstacles to VM implementation in Jordanian building projects. The search yielded a few scholarly research articles, reports, books, and other material about VM. The most remarkable ones were decided to be used for this research. The extra pertinent material found throughout the search was divided among numerous areas of the literature review, including Table 1, which summarizes the primary strategies applied in this research adopted from Kineber et al. [42].

Table 1. List of barriers to VM implementation in building projects adopted from Kineber et al. [42]

Categories	Code	Barriers	References								
			1	2	3	4	5	6	7	8	9
Culture and environment	B1	Resistance to accept new innovations	*					*			*
	B2	Lack of active involvement of clients and stakeholders		*		*				*	*
	B3	Difficulty to establish mutual project objectives by stakeholders	*					*			
	B4	Lack of commitment to implement VM		*			*		*		
	B5	Client's inability to communicate requirements and needs to the design team			*					*	
	B6	Self-justifying attitude of the original design team	*			*					*
	B7	Client’s unwillingness to fund VM exercise		*					*		
Workshop dynamics	B8	The procurement and contract strategies are inappropriate for implementing VM			*			*			*
	B9	VM workshop incurs additional cost	*				*			*	
	B10	Difficulty in conducting analysis and evaluation of functions and alternatives		*		*			*		*
	B11	Lack of time to conduct VM studies	*		*		*			*	
	B12	Difficulty in Selecting of an inappropriate approach or method of VM	*			*			*		*
	B13	Problem of technological advancement in employing technology integration in VM approach		*		*		*			*
Standardization	B14	Lack of VM awareness among the clients	*		*			*			*
	B15	Absence of local VM guidelines and legal framework		*		*		*		*	
	B16	Lack of encouragement on the part of government	*			*		*			*
	B17	Lack of legislation which provides VM application in the construction industry.			*		*		*	*	
	B18	Lack of readiness to adopt VM in the industry		*			*		*		*
	B19	Lack of contract provisions for implementation VM between owners	*		*		*		*		

* Note: 1=[32]; 2=[34]; 3=[34]; 4=[61]; 5=[62]; 6=[26]; 7=[48]; 8=[25]; 9=[63].

3.2. Data Collection

A questionnaire can assess behaviour, attitudes, organizational norms, links among several components, and cause-and-effect relationships [64]. The questionnaire was supposed to be an evaluation tool. Fellows & Liu [64] argued for assessing a questionnaire's accuracy, adaptability, and possible power and highlighted numerous circumstances that call for study and surveys. The poll findings mostly reflect assumptions regarding architects, engineers, quantitative auditors, contractor degrees of involvement, and their contributions to building projects. The survey covers every employee working in construction—including managers, general engineers, heavy equipment operators, contractors, subcontractors, construction workers, and supervisors.

A pragmatic sampling approach was used to compile data from the target population with the involvement of multiple stakeholders. Moreover, this paper looks at obstacles to VM deployment in Jordanian construction projects. The study guaranteed an excellent supply of easily accessible samples and allowed every professional in the country a fair opportunity to choose using a random sampling approach [65].

The first utilized to assess the appendix survey samples with a 101-person sample size was exploratory factor analysis (EFA). Reviewing a brief and generally agreed-upon set of responses, the researchers performed the required statistical tests [66]. Using multiple categories, the initial portion of the questionnaire gathered participant demographic data.

Using a 5-point Likert scale, the second component assesses difficulties in VM whereby 5 indicates a very high level and 1 a relatively low one. The following studies have used this measure [66-68]. Table 2 shows the professional demographic data.

Table 2. Demographic details of the experts

Years of experience	Frequency
10 to 15 years	26
15 to 20 years	23
5 to 10 years	23
Less than 5 years	14
More than 20 years	15
Professional field	
Architecture	14
Civil Engineer	36
Construction Manager	24
Design Engineer	1
Electrical	6
Project Manager	2
Quantity surveying	16
Resident Engineer	2
Current position	
Design Engineer	24
Director	9
General Civil Engineer	2
Lead Electrical Engineer	1
Manager	33
Quantity Surveyor	5
Senior Manager	25
Site engineer	2
Organization function	
Client/Developer	16
Consultant	50
Contractor	33
Telecom operator	1
Third party	1
Level of education	
Bachelor's degree	75
Master's degree	20
PhD	6
Level of awareness	
Not Familiar	7
Familiar	54
Moderately Familiar	22
Totally Familiar	18
Perception of VMor Value engineering	
A concept	49
A Technique	37
A profession	15
Training on VM	
No	62
Yes	39
Participated in any VM Workshop or study	
No	23
Yes	78

3.3. Data Analysis

3.3.1. One Sample t-Tests and EFA

Input the questionnaire data using IBM SPSS Statistics 24, a statistical analysis tool. Program SPSS was used for descriptive statistical research, including frequency, mean, and standard deviation (SD) computations and inferential statistical tests like one-sample t-tests and EFA. Using a reliability analysis, the precision of the gathered data was assessed to find any components that had a minimal impact on its general accuracy. Any object needs to be removed from the EFA should it turn unreliable for whatever cause. A Cronbach alpha test helped determine the instrument's trustworthiness. Given a Likert scale questionnaire, as in this study, this test is essential. Tan et al. [69] argue that this method aids in determining the internal consistency of the instrument and the dependability of the acquired data. Inside the interval 0 to 1, one can obtain the Cronbach alpha coefficient. According to Tan et al. [69], a score higher than 0.7 indicates a noticeable degree of data coherence; a value higher than 0.8 implies significant internal consistency. Table 3 displays for the three components the Cronbach's alpha coefficients of 0.932, 0.827, and 0.678 dependability study findings. Table 3 reveals the voter's remarkable internal consistency in their values. These tests reveal rather solid internal consistency.

Table 3. One sample t-test for barriers to implementing VM

Barriers	N	Mean	Rank	Std. Deviation	Std. error	t	df	Sig. (2-tailed)	Sig. (1-tailed)	Mean Difference	95% Confidence Interval of the Difference	
											Lower	Upper
B1	101	4.366	1	0.913	0.091	48.037	100	0	0	4.366	4.186	4.547
B2	101	3.931	15	0.816	0.081	48.436	100	0	0	3.931	3.770	4.092
B3	101	4.208	2	0.898	0.089	47.094	100	0	0	4.208	4.031	4.385
B4	101	3.871	12	0.924	0.092	42.119	100	0	0	3.871	3.689	4.054
B5	101	4.059	6	1.038	0.103	39.321	100	0	0	4.059	3.855	4.264
B6	101	3.980	7	0.980	0.097	40.834	100	0	0	3.980	3.787	4.174
B7	101	4.119	3	1.023	0.102	40.478	100	0	0	4.119	3.917	4.321
B8	101	3.832	14	0.895	0.089	43.016	100	0	0	3.832	3.655	4.008
B9	101	4.079	5	0.880	0.088	46.608	100	0	0	4.079	3.906	4.253
B10	101	4.089	4	0.950	0.095	43.270	100	0	0	4.089	3.902	4.277
B11	101	3.802	16	0.825	0.082	46.322	100	0	0	3.802	3.639	3.965
B12	101	3.931	8	0.840	0.084	47.042	100	0	0	3.931	3.765	4.096
B13	101	3.911	9	0.928	0.092	42.334	100	0	0	3.911	3.728	4.094
B14	101	3.911	9	0.884	0.088	44.447	100	0	0	3.911	3.736	4.085
B15	101	3.525	18	0.955	0.095	37.095	100	0	0	3.525	3.336	3.713
B16	101	3.891	10	0.747	0.074	52.349	100	0	0	3.891	3.744	4.039
B17	101	3.653	17	0.741	0.074	49.567	100	0	0	3.653	3.507	3.800
B18	101	3.861	13	0.708	0.07	54.848	100	0	0	3.861	3.722	4.001
B19	101	3.881	11	0.898	0.089	43.454	100	0	0	3.881	3.704	4.058

Analyzing the sample means that the T-test is a statistical method used in past research [70]. The study assessed the statistical relevance of the sampled population about a given ability using a one-sample t-test. The null hypothesis (H0: U5U0) evaluates the obstacles to VM applications in Jordanian construction projects. Conversely, the alternative theory proposed that these issues are significant (Ha: U>U0), in which case U0, the average population value, was calculated as 3.5 based on the results of Nunkoo & Ramkissoon [71]. The five-point Likert rating system identifies a skill as substantial if its average score is notably over 3.5, demonstrating agreement on the worth of the talent. The vast range of skills required in this study was to apply EFA (Exploratory Factor Analysis) to improve the final analysis. Using exploratory factor analysis (EFA), the main obstacles to VM deployment in Jordanian building projects were discovered. Although the sample size was small—just 101 individuals—the exploratory factor analysis (EFA) was sufficient. According to Field [72], statisticians cannot agree on the suitable sample size for factor analysis. As such, some guidelines—like the 5:1 ratio—have been implemented. According to Bello et al. [66], a primary component analysis calls for a minimum sample size of 100 or five times the number of characteristics.

Pinheiro et al. [73] suggested that, over several criteria, sample size did not affect stability. Still, the importance is in the specific sample dimensions and component saturation level. Gandini et al. [74] suggested that one should consider the whole sample size and the strength of the factor loadings even while assessing the fit of a factor solution. In their study, Waqar et al. [75] demonstrated that even with minor biases present, exploratory factor analysis (EFA) can produce consistent results even in cases of less than 50,000 sample size. Although there have been continuous discussions on the appropriateness of the sample size, the exploratory factor analysis (EFA) performed using the data acquired in this study shows that a sample size of 101 was favourable. Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) sample adequacy [76] helped to assess the appropriateness of the data.

3.3.2. SEM Analysis and Model Development

Combining the viewpoints of econometrics and psychometrics, structural equation modeling (SEM) is a statistical technique [77]. SEM has been extensively applied in several academic fields, including construction management [78], management, organizational behavior [79], etc. SEM deftly integrates multiple regression modeling with factor analysis. Researchers can replicate the relationships between hidden variables (constructs) generated by observable variables (measurement items) using a fundamental approach [78]. SEM is commonly used to find and assess modeling and computational errors and investigate several linked relationships.

As such, the computed measurable variables were acquired, and a thorough assessment of data assumptions concerning methodological and substantive/theoretical problems was performed. SEM lets researchers develop a model, evaluate its applicability, and investigate the several relationships and linkages in the data [79]. A similar term is PLS-SEM for the component-based approach. Mostly employed for the generation of hypotheses and abstract ideas, exploratory research by use of partial least squares (PLS) structural equation modeling (PLS-SEM), one can decrease the necessity to enforce limited assumptions necessary for a thorough evaluation of the most likely hypotheses [80]. The fundamental concepts of sustainability have attracted significant attention [81].

Changing the strategic sustainability targets and the project plan could provide difficulties [82]. There is a need to reach a harmonic and balanced condition between environmental issues, economic viability, and social sustainability. The growing focus of the building industry on sustainability has driven the search for sensible solutions to include it in contemporary workplaces. Companies dedicated to sustainable development and implementing a creative corporate social responsibility approach choose virtual machines even in their planning stages. Dadhich & Hiran [83] contend that the social, financial, and environmental elements of sustainability resemble the part of VM performed in the building process. Expert interviews let us classify six main types of implementation-related challenges. Importantly, these groups align with the ideas and evaluation processes detailed in Perno et al. [84].

Furthermore, this study revealed that the adoption of VM in the building sector was evaluated using the SEM technique in order of influence. SEM studies the interactions of several elements fully. The results show that every hypothesis corresponds with the given measures. According to Ye et al. [85], the approach comprises adjustable components and constraints connected to the structure [86] and is grounded on mathematical equations [87]. Claim that Structural Equation Modelling (SEM) is becoming increasingly appreciated for non-experimental research.

Moreover, they noticed that the approaches of hypothesis analysis lacked consistent and strict oversight. One looked at the relationship between elements and mitigating problems in virtual machine environments. This was accomplished using the formative and reflecting qualities of the Partial Least Squares (PLS) model. Still, this work conducted the PLS-SEM analysis using three important evaluations: the common method variance, the structural model, and the measurement model. PLS-SEM is commonly used for structural equation modeling, which helps build links between dependent and independent components [87].

- **Sample Size**

It is recommended that the determination of sample size be grounded on objective methodological and statistical analysis [64]. Chandio [88] concurred that the magnitude of the sample size needed increases with the complexity of the statistical analysis. The relationship between the sample size and the selected statistical methodology is a crucial consideration for any given research study [64]. As a result, the determination of sample size requirements was based on the selected statistical analysis methodology for the creation of the VM implementation model.

As with other statistical methods, the acquisition of consistent estimations in SEM necessitates a suitable sample size [89]. According to Gorsuch [90], it is recommended a sample size of at least 100 individuals for any data analysis whereas Ali et al. [91] recommended a sample size of at least 100.

Given the utilization of a PLS-SEM methodology for model development in this study, the survey was distributed to 150 individuals. From this distribution, 101 responses were received, resulting in a response rate of approximately 73.85%. This rate of return was deemed suitable for the specific aims of this research endeavor [92, 93].

- **Common Methods Variance (CMV)/ Measurement Model**

Derived from the radiation known as the CMV [94]. The CMB aims to clear the error analysis results since the data collecting techniques could provide challenges [94]. Complete awareness of these problems and difficulties depends on CMV. Thus, a methodical and thorough study of a particular ingredient was conducted [87]. The measuring model helps one to grasp the relationship between the measures and their underlying idea. One might consider the validation process of the measurement model as the inspection and evaluation [86]. PLS keeps an ongoing database of related ideas and evaluates the appropriateness of specific sets of policies. Examining the reflective model (first order) by assessing composite reliability (c-r), average variance extracted (AVV), and discriminant validity would help one to evaluate the dependability of indicators [95]. Often referred to as the coefficient of consistency or dependability [96], Cronbach's alpha measures the degree to which a series of questions fairly evaluates a single, unidimensional idea. The mathematical formula for Cronbach's alpha (α) is given in Kaewkungwal [97].

$$\alpha = \frac{\mathrm{N}-\bar{\mathrm{r}}}{1+(\mathrm{N}-1)-\bar{\mathrm{r}}} \tag{1}$$

Whereas "N" denotes the overall count of objects, the variable "r" shows the average correlation between the items. Considering the known differences in Cronbach's alpha's precision, measuring dependability calls for a confirmatory strategy [95]. Alhamami et al. [98] indicated that composite dependability (ρ_c) is a more accurate assessment. Whereas 0.6 is considered a suitable threshold for exploratory studies, Chambers et al. [99] argue that a minimum value of 0.7 for ρ_c is required for all kinds of research. Chambers et al. [99] calculate composite reliability using the following equation:

$$\rho_c = \frac{(\sum\lambda_i)^2}{(\sum\lambda_i)^2+\sum\mathrm{var}(\varepsilon_i)} \tag{2}$$

In this case, 1 less the square of lambda (λ_2) corresponds to the variance of the error term ε_i. Whereas ρ_c indicates the general dependability score of a composite, λ_i represents the loading of every item on a latent component. Cronbach's alpha is computed ignoring the factor loadings of individual items. Composite dependability exceeds Cronbach's alpha using the item loadings recorded in the theoretical model [100].

Moreover, latent variable convergent validity [101] was assessed using the average found in AVE. With the universally used AVE metric, one might demonstrate the convergent validity of the many elements of the model. AVE follows a formula like this:

$$\mathrm{AVE} = \frac{\sum\lambda_i^2}{\sum\lambda_i^2+\sum\mathrm{var}(\varepsilon_i)} \tag{3}$$

The average variance extracted is shortened as AVE. The equation var(ε_i) = $1 - \lambda_2$ reflects the variance of the error term while I am reflecting the loading of every item onto a latent construct. Moreover, research has been carried out to confirm the discriminant's validity. Every construction is studied theoretically [101]. The goal is to verify if the investigated idea is empirically unique.

- **Model Structural**

The structural model was first proposed as a basic approach for concurrently analyzing complex links between objects. Similarly, Aibinu & Al-Lawati [102] built a structural model evaluating VM problems. Two primary approaches form the foundation of the structural model used in this work:

According to Chambers et al. [99], the primary goal of a collinearity analysis is to ascertain the extent to which other variables could forecast or account for the changes of a given variable. The main concern is that collinearity can cause the significant indicator weight measurements to be shown slanted. Furthermore, collinearity can significantly raise the error probability when bootstrapping standard errors. The measure of the degree to which several indicators of the same construct contribute to the variance of a single indicator is the variance in inflation factor (VIF). It is often used to evaluate the collinearity present. According to Durdyev et al. [6], the Variance Inflation Factor (VIF) should not exceed the designated level of 5.0 to produce the test report for the Partial Least Squares (PLS) method in Smart PLS 4.0 software.

Unlike reliance on parametric assumptions, the bootstrapping method generates the variability of data points inside sub-samples. A resampling analysis is sometimes achieved using bootstrapping. Usually presented as structural or regression coefficients, the method divides an extensive dataset into smaller groups and evaluates a limited number of statistical variables. This study revealed a causal relationship between factors influencing VM in the building industry acceptability. Consequently, the internal relationship in this case—more significantly, the link between the variables $, µ, and €1 in the structural model—may be stated as a linear equation as shown below [103]:

$$\mu = \beta £ + €1 \tag{4}$$

Residual variance (€1) and path coefficient (β) are noteworthy. Standardized and multiple regression studies have the same weight then.

3.3.3. ANN Analysis

Using learning mechanisms and providing a helpful perspective on the synapse and neuron functioning of the brain, artificial neural network analysis improves knowledge acquisition [103]. ANN analysis, among other machine learning methods, lets researchers forecast the significance of antecedents [104]. Furthermore, helping researchers validate and improve Partial Least Squares Structural Equation Modelling (PLS-SEM) data is ANN. Dadhich & Hiran [83] provide a method to address construct non-linearity and linearity. The authors propose a grading system based on sensitivity assessments [105] and a hierarchical arrangement of the constructions. The mathematical forms of activation functions are shown here:

$$\text{Distinctiveness (Linear) } (x) = x \tag{5}$$

$$\text{Hyperbolic Tangent } \tanh(x) f_x = \frac{2}{1+e^{-2x}} - 1 \tag{6}$$

$$\text{Sigmoid factor } f_x = \frac{2}{1+e^{-x}} \tag{7}$$

Moreover, studies have revealed that ANNs beat multi-step regressions or structural equation models (SEMs) on the accuracy and dependability of the outputs. Thus, it is reasonable to conclude that completing research using PLS-SEM and ANN advantages both techniques [105]. Furthermore, there have been ideas that ANNs replicate human brain information transmission. ANNs comprise three constituents: the learning technique, network architecture, and transfer function [106]. Apart from subcategories comprising feed-forward multilayer perceptrons, recurrent networks, and radial basis networks [107], these features also cover Combining three-layer structure—which includes inputs, outputs, and hidden neurons—with feed-forward multilayer perceptrons (MLPs)—allows researchers to independent variables usually coincide with the input layer. These components compile unprocessed data and transfer it as synaptic weights to hidden neurons. An output neuron provides a model depending on representing other variables' parameters.

Furthermore, thorough research has been done on the activation and sigmoid functions [108]. Moreover, multilayer neural network models are highly praised for their dependability and durability since they can effectively manage complex problems in higher-order models—the selected method used multilayer perceptron neural networks for training and testing.

4. Results

4.1. One sample Test Analysis

Using a value of 3.5, a one-sample t-test was conducted to find whether the respondents considered a given ability or performance at least "important." This would mean one can consider abilities and competences scoring higher than 3.5 noteworthy. Based on the results (p = 1-tailed), the one-sample t-test analysis reveals variations in the perceived contributing factors to cloud-based computing adoption in the Saudi Arabian construction sector. See Table 3 for the three objects with the highest mean ratings: B1, B3, and B7. Over the course of the study, these scores have been relatively consistent. The results show that specific barriers caught out clearly among the multiple elements evaluated. With a mean score of 4.366, for example, "Resistance to accepting innovations" (B1) rated highest, closely followed by "Difficulty to establish mutual project objectives by stakeholders" (B3), with a mean score of 4.208. Each scored notably above 3.8 on average; other noteworthy hurdles included "Client's unwillingness to fund VM exercise" (B7), "Difficulty in conducting analysis and evaluation of functions and alternatives" (B10), and "Lack of VM awareness among the clients" (B14). These results highlight the widespread nature of cultural, financial, and procedural difficulties impeding the efficient application of VM in the Jordanian building industry.

4.2. Exploratory Factor Analysis (EFA)

Applying EFA aimed to find the factors that might fairly evaluate different components of the same occurrence and establish the relationships between others. This study sought to remove obstacles to adopting VM in the building sector. Table 4 shows the results of the EFA exploratory factor analysis. With a significance level of 0.000, Bartlett's test of sphericity yielded a value for the given data of 304.744. Based on the facts, the correlation matrix appears to be not an identity matrix [108]. The sample is suitable for factor [109] since the KMO value 0.734 exceeds the required level of 0.50 for factor analysis. These two results show that one can classify the elements entirely using factor analysis.

Table 4. EFA results

Communalities			Initial Eigenvalues			Extraction Sums of Squared Loadings			Component		
Barriers	Initial	Extraction	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	1	2	3
B1	1	0.786	11.393	59.961	59.961	11.393	59.961	59.961	0.66	-0.233	0.543
B2	1	0.595	1.459	7.681	67.643	1.459	7.681	67.643	0.744	-0.198	0.036
B3	1	0.851	1.005	5.288	72.931	1.005	5.288	72.931	0.821	-0.246	0.343
B4	1	0.761	0.842	4.43	77.361				0.831	-0.221	-0.148
B5	1	0.8	0.765	4.025	81.386				0.837	-0.214	-0.233
B6	1	0.842	0.616	3.244	84.630				0.851	-0.261	-0.225
B7	1	0.774	0.505	2.657	87.287				0.786	-0.35	0.181
B8	1	0.777	0.454	2.388	89.675				0.776	-0.245	-0.339
B9	1	0.645	0.378	1.988	91.663				0.774	-0.216	0.009
B10	1	0.688	0.341	1.796	93.459				0.819	0.059	0.118
B11	1	0.666	0.249	1.309	94.769				0.772	0.109	-0.24
B12	1	0.74	0.207	1.088	95.856				0.785	0.222	0.272
B13	1	0.798	0.202	1.061	96.917				0.645	0.564	0.253
B14	1	0.638	0.151	0.793	97.711				0.762	0.218	0.099
B15	1	0.778	0.126	0.661	98.372				0.713	0.491	-0.168
B16	1	0.745	0.117	0.616	98.989				0.83	0.232	0.053
B17	1	0.581	0.089	0.467	99.455				0.62	0.421	-0.14
B18	1	0.733	0.068	0.358	99.813				0.845	-0.006	-0.139
B19	1	0.658	0.036	0.187	100.000				0.788	0.108	-0.162

The factor analysis produced some critical new understanding of the obstacles in the way Jordan's building sector may apply VM. His study revealed three separate elements that explain the variation in barrier perception. The first component prominently influenced by barriers such as "Resistance to accept new innovations" (B1), "Difficulty to establish mutual project objectives by stakeholders" (B3), and "Client's unwillingness to fund VM exercise" (B7), accounted for 59.961% of the variance. The second component, characterized by barriers like "Lack of commitment to implement VM" (B4) and "Client's inability to communicate requirements and needs to the design team" (B5), explained an additional 7.681% of the variance. The third component included barriers such as "Difficulty in conducting analysis and evaluation of functions and alternatives" (B10) and "Lack of readiness to adopt VM in the industry" (B18), contributing 5.288% to the total variance.

4.3. SEM analysis

4.3.1. Common Method Bias

A single-component analysis of the proposed model revealed the variance of the traditional method [110]. Studies have shown that if the overall variance of the variables is less than fifty percent [111]. The averages process bias does not affect the acquired results. The common method variance is below 50% [112]. The initial components explained that 38.43% of the variance cannot be modified.

4.3.2. Measurement Model Assessment

4.3.2.1. Convergent Validity Analysis

The measuring model evaluates the degree of consistency and agreement among several (barriers) of the same concept [69]. To evaluate concept validity, one applies the measurement model. Using the following tests in parallel with PLS-SEM, Cruz-Jesus et al. [95] suggest assessing the convergent validity of the proposed constructs: "composite reliability scores (ρ_c), Cronbach's Alpha (α), and Average Variance Extracted (AVE)", Table 5, based on Kin et al. [113], revealed elements influencing VM had's acceptance had a composite reliability of > 0.60, thereby showing acceptance. Table 5 reports a Cronbach Alpha value of 0.60.

Table 5. Measurement model of barriers to implementing VM

Categories	Code	Outer loading	Cronbach's Alpha α	Composite Reliability	AVE
Culture and environment	B1	0.774	0.93	0.943	0.71
	B2	0.853			
	B3	0.866			
	B4	0.84			
	B5	0.714			
	B6	0.793			
	B7	0.781			
Workshop dynamics	B8	0.874	0.886	0.913	0.64
	B9	0.723			
	B10	0.856			
	B11	0.866			
	B12	0.771			
	B13	0.885			
Standardization	B14	0.841	0.902	0.923	0.668
	B15	0.862			
	B16	0.865			
	B17	0.872			
	B18	0.744			
	B19	0.757			

El Barachi et al. [114] show a modest to high degree of dependability in their results. With the AVE, the convergent validity of the idea variables was assessed. Suprapto et al. [115]. Table 5 demonstrates that each research component's expected AVE values exceed 50%. The measuring model was revealed to be convergent as well as internally stable.

Moreover, this implies that the measuring elements completely overlooked any other construct and evaluated the construct in the study model. According to Lei et al. [79], the perfect external load score is 0.70. Still, if the study provides a strong case, scores of 0.50 or above are appropriate. The outside loads from the SEM model are shown in Table 5 and Figure 2.

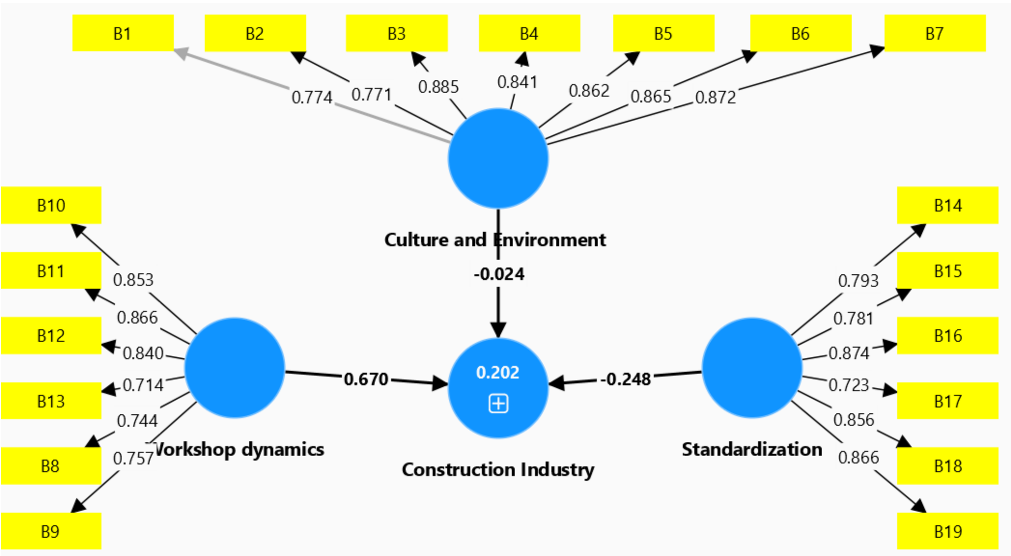

Figure 2. SEM Model

4.3.3. Discriminant Validity Assessment

Research applying SEM [87] makes growing use of discriminant validity assessment. This seeks to identify the singularity or pragmatic distinction of the notion [95]. This study used the Hetrotrait-Monotrait Criterion Ratio (HTMT), cross-loadings, and the Fornell-Larcker criteria to assess discriminant validity. The data in Table 4 reveals how the

Fornell and Larcker method is applied to establish and validate the discriminant validity of the elements influencing the acceptance of VM [116]. Construct indicators and variable correlation must be more than the square root of the AVE. A third method for evaluating discriminant validity in variance-based SEM is the HTMT criteria ratio.

Under proper measurement, the HTMT method links two constructions. Fu et al. [81] assessed distinctive validity with variance-based SEM employing. They applied the HTMT approach for this purpose. The two theories differ when the score falls between 0.85 and 0.90. Should there be similar ideas, the score should be less than 0.90; it should not be less than 0.85. Table 6 presents the under-study component HTMT values. The statistics suggest that discriminant validity exists. A cross-loading method was used to assess the discriminant validity of the factors influencing VM acceptability. This approach is utilized by El Barachi et al. [114] to determine whether a variable has a larger cross-loading than any other variable on a latent construct created from many thoughts. Table 7 presents the design with loadings higher than the different buildings.

Table 6. Discriminant validity (HTMT)

Constructs	Construction Industry	Culture and environment	Workshop dynamics	Standardization
Construction Industry				
Culture and environment	0.337			
Workshop dynamics	0.319	0.847		
Standardization	0.442	0.870	0.890	

Table 7. Cross loadings results

Items	Construction Industry	Culture and environment	Standardization	Workshop dynamics
B1	0.365	0.774	0.525	0.579
B2	0.372	0.745	0.746	0.853
B3	0.45	0.649	0.718	0.866
B4	0.387	0.685	0.751	0.84
B5	0.262	0.462	0.681	0.714
B6	0.279	0.642	0.793	0.74
B7	0.205	0.516	0.781	0.713
B8	0.272	0.717	0.874	0.771
B9	0.116	0.478	0.723	0.53
B10	0.302	0.76	0.856	0.764
B11	0.317	0.655	0.866	0.734
B12	0.188	0.771	0.656	0.627
B13	0.26	0.885	0.69	0.725
B14	0.259	0.841	0.682	0.796
B15	0.273	0.862	0.732	0.736
B16	0.249	0.865	0.76	0.738
B17	0.319	0.872	0.634	0.701
B18	0.28	0.724	0.683	0.744
B19	0.244	0.741	0.645	0.757

4.3.4. Structural Model Assessment

4.3.4.1. Collinearity Analysis

Although ‘workshop dynamics’ and ‘standardization’ are related, they capture different levels of practice: workshop-level facilitation/participation versus organization-level procedures/guidelines. Measurement checks support distinctiveness: each indicator loads highest on its intended construct with no cross-loading exceeding its primary loading; the square roots of AVE exceed inter-construct correlations; and all HTMT values remain below conventional thresholds (≤0.85). These results indicate adequate discriminant validity between the two constructs. Although the concepts of the VM-based challenges were similarly formative, the formative assessment models reveal an astonishingly high correlation between measures. Every VIF value came out less than 3.5. Each of these theories was reasoned as the cause of VM's issues. Table 8 lists the main route coefficient β for VM subscales: Culture and environment, Standardization, and Workshop dynamics.

Table 8. Formative constructs analysis

Paths	β	SD	P-Values	VIF
Culture and Environment → Construction Industry	-0.007	0.148	0	1.791
Standardization → Construction Industry	-0.184	0.222	0	1.731
Workshop dynamics → Construction Industry	0.612	0.293	0	1.893

4.3.4.2. Bootstrap Analysis Evaluation

Validating the planned research hypothesis was one of the fascinating aspects of the project. Bootstrapping lets one assess [115]. The model hypothesis's relevance denoted by the value of every road [95], the route coefficient measures the degree of influence one road has on another. To calculate the coefficient errors for Confirmatory Factor Analysis (CFA), the most recent SmartPLS program, 4.0.9.9, has included a bootstrapping method. Examining the proposal, the t-statistics [95] were computed using 5000 subsamples. In the PLS Model, a single structural equation—equation 1—explores the fundamental connections among the constructions. Moreover, this equation provides a way to overcome VM-related problems.

Consequently, considerable focus was placed on the standardized p-values for the endogenous idea and the importance of grasping the bootstrapping analysis results [86]. Refer to Table 9 to find that the results revealed significant and positive influence ($\beta = 0.169$, $p = 0.000$) on obstacles to implementing virtual machines. The paper centers on the major challenges to virtual machine implementation.

Table 9. Path analysis

Paths	β	SD	P-Values	VIF
Barriers to implementing VM → Construction Industry	0.169	0.093	0	1.464

4.3.4.3. The Structural Model's Explanatory Power (R2)

In PLS-SEM, a critical assessment is performed to determine the R2 for the virtual machine [117]. Being the dependent variable, the study found that the exogenous construct explained 19.8% of the variance in barriers to deploying the VM. This is shown by the R2 and corrected R2 values of 0.017. These results indicate that the degree of issues in VM is judged appropriate and has a minimal impact [114].

4.4. ANN Analysis

Following a similar approach as Lo et al. [105], this work used the SEM-PLS route analysis's basic components as the ANN model's input neurons. ANNs allow one to extract extensive information, including complex nonlinear correlations, efficiently. Before adding ANNs, one must minimize the data and identify necessary variables using linear techniques. Artificial neural networks (ANNs) improve prediction and classification accuracy by spotting trends that linear approaches could overlook. In the early stages of data processing, pertinent variables must first be found using a linear approach before ANNs are applied. ANNs were investigated in challenging interactions following essential element recognition. ANNs can be used in nonlinear interactions between the exogenous and endogenous variables in absent, non-regular data distribution cases.

Great opposition against ANNs exists due to short sample sizes, noise, and outliers. The model might control non-compensatory models, which mimic compensatory models because they do not depend on one element to offset a decrease in another. Specially designed with IBM's SPSS neural network module, we utilized an artificial neural network (ANN). Unlike their conformability to a normal distribution, artificial neural networks (ANNs) let one identify and explore linear and nonlinear interactions. Although the feed-forward-backward-propagation (FFBP) approach uses training to forecast errors in the reverse direction, concurrently dispersing inputs in the forward direction helps estimate the completion of an investigation. Both hidden and input layers were constructed using a multilayer perceptron with a sigmoid activation function. Many learning runs help to increase forecast accuracy and reduce mistakes. Two groups were formed from the surviving samples: one for training and another with 90% set for testing. The researchers calculated the root mean square error (RMSE) through ten-fold cross-valuation, reducing overfitting [117]. To assess the projection accuracy of the model, we looked at the root mean square error (RMSE) of the training and testing datasets together with the mean and standard deviation. For further details, kindly find Figure 3. The ANN model was evaluated using 10-fold cross-validation. For each fold, we trained the network on 90% of the data and tested on the remaining 10%. We report the root-mean-square error (RMSE) for training and test sets, averaged over all folds (with SD). In addition, the coefficient of determination R^2 for the ANN predictions was calculated [107] to quantify variance explained.

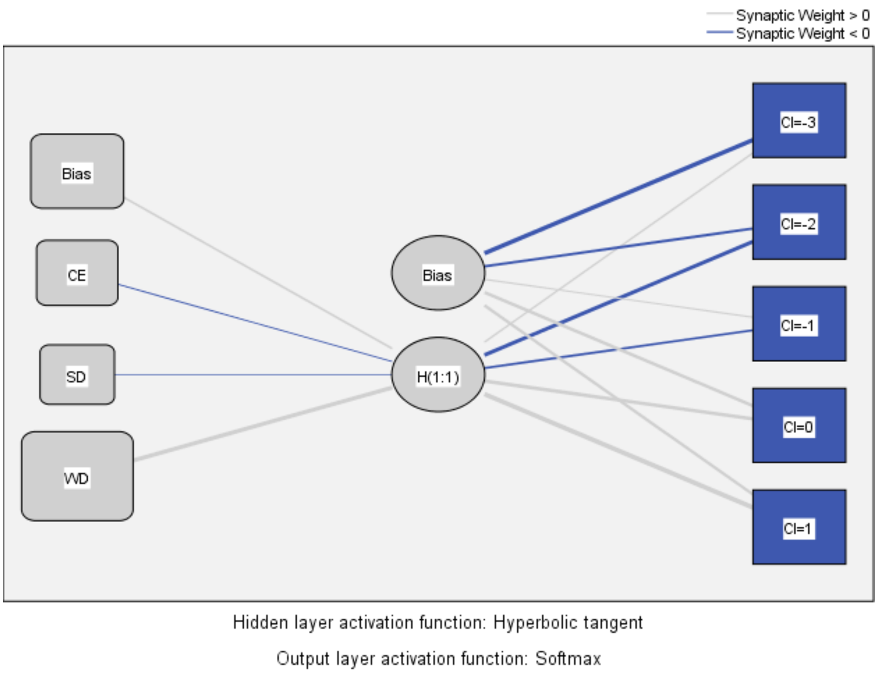

Figure 3. Model Prediction

The training and testing procedures produce root mean square error (RMSE) values of 0.764 and 0.768. Table 10 shows fairly little numbers. We have shown that the model fits reality. Using the method of Singh et al. [107] to evaluate the R2 value of the artificial neural network (ANN) model, the investigation of this research resulted with a 100% accuracy rate and revealed that the model precisely predicted factors affecting the acceptance of VM.

Table 10. RMSE values of the training and testing

Neural network	Model Input: barriers to implementing VM; Output: Construction Industry	
	Training	Testing
	RMSE	RMSE
ANN1	0.760	0.689
ANN2	0.732	0.689
ANN3	0.732	0.734
ANN4	0.716	0.738
ANN5	0.750	0.666
ANN6	0.689	0.747
ANN7	0.764	0.717
ANN8	0.725	0.679
ANN9	0.688	0.768
ANN10	0.723	0.670
Mean	0.727	0.709
SD	0.046	0.058

Analyzing every input neuron's capacity to forecast events helped to evaluate them. We ascertain the normalized significance of each input neuron by dividing their relative relevance by the maximal value [115]. About all the predictors, VM-related issues have a normalized relevance score of 100%.

5. Discussion

5.1. Findings

Using a combination of EFA, SEM, and ANN, this study delves into the barriers to implementing VM in the Jordanian construction sector. The analysis identifies three primary categories of barriers: culture and environment, workshop dynamics, and standardization, each significantly impacting VM adoption.

Categories 1: Culture and Environment

Cultural and environmental factors emerged as substantial barriers, with outer loadings ranging from 0.714 to 0.866. The highest loadings were associated with difficulties creating mutual project objectives among stakeholders (0.866) and a lack of active involvement from clients and stakeholders (0.853). These findings are consistent with prior research by Othman et al. [34] and Kineber et al. [42], which identified cultural resistance and environmental constraints as critical challenges to implementing innovative management practices in the MENA region. Additional factors, such as resistance to accepting new innovations (0.774), lack of commitment to VM implementation (0.840), and the client's inability to effectively communicate requirements to the design team (0.714), further underscore the pervasive nature of these barriers. The reluctance of clients to fund VM exercises (0.781) and the self-justifying attitude of the original design team (0.793) highlight entrenched cultural norms that hinder VM adoption, aligning with global findings by [42, 43, 70].

The findings align with those of Tanko et al. [100], which pointed out that participants in value management (VM) recognize and categorize the sustainability and functions of construction projects through a structured, team-oriented approach that focuses on problem-solving within the 'environment' factor. This method has significantly improved value practices in the construction industry [118].

However, the Malaysian construction sector has identified cultural resistance to change as a major hurdle to adopting VM [119]. To move forward, those involved in this strategy should be open to new ideas and improvements [118]. This perspective is supported by Othman et al. [34], who found that cultural barriers to implementing VM were notably greater than the average score of 3 on their scale, highlighting the importance of addressing these cultural challenges.

Categories 2: Workshop Dynamics

Workshop dynamics also present significant challenges, with outer loadings ranging from 0.723 to 0.885. The highest loading was observed for the problem of technological advancement and integrating technology into the VM approach (0.885), emphasizing the need for practical VM workshops. The importance of well-organized and interactive workshops is further highlighted by high loadings for factors such as improper procurement and contract methods (0.874) and the lack of time allocated for VM studies (0.866). These findings align with the work [61, 120], emphasizing the need for structured and engaging workshops to achieve successful VM outcomes. Poor workshop management often leads to inadequate communication and reduced stakeholder engagement, which are critical for the successful implementation of VM. Additional barriers within this category include the added costs of conducting VM workshops (0.723), difficulties in analyzing and assessing functions and alternatives (0.856), and challenges in selecting the correct VM strategy or method (0.711), which are consistent with findings [46, 68].

This finding aligns with the work of Mohamad Ramly et al. [121], who highlighted that the work plan and structured process reflect the core principles of value management (VM), setting them apart from other management approaches. Tanko et al. [122] recommended that regular VM workshops be introduced in the construction sector as a way to build capacity and clearly demonstrate the importance of VM to construction professionals and stakeholders involved in its application. Similarly, another study [123] emphasized that implementing VM in construction should be based on formal workshops.

Additionally, the creativity phase is crucial within the VM workshop [118]. This phase enhances projects by introducing new ideas, as creativity involves reimagining existing concepts in innovative and sustainable ways [124]. It has also been suggested that technological advancements should be integrated into VM activities, as digital tools can enhance accessibility and connectivity [125]. To ensure the success of VM workshops, it’s essential to implement a technological approach to counteract valuation analysis [126].

Categories 3: Standardization

Barriers related to standardization are also significant, with outer loadings ranging from 0.744 to 0.872. The absence of laws supporting VM application in the construction industry (0.872) and the lack of governmental encouragement (0.865) were the most critical barriers identified, underscoring the importance of consistent policies for VM adoption. These findings align with research by [34, 62], which noted that the lack of standardized policies is a primary obstacle to VM's consistent and effective use. The need for standardized VM processes is further emphasized by barriers such as the lack of VM awareness among clients (0.841), the absence of local VM guidelines and legislative frameworks (0.862), and the reluctance within the industry to embrace VM (0.744). The lack of contract provisions for VM implementation between owners (0.757) further highlights the challenges in ensuring consistency and coherence across projects, a point stressed [68, 120, 127].

Based on past studies, the obstacles found in the Jordanian construction sector are part of more general worldwide problems. However, given other socioeconomic and political elements, the degree and influence of these obstacles could be more noticeable in developing nations. For instance, the results on cultural resistance and environmental problems match [26, 128], while the critical function of well-run seminars reflects the conclusions of [48, 129]. Likewise, the value of standardizing VM processes is well known; [33, 63] stress the requirement of consistent policies to overcome discrepancies and inefficiencies.

The findings align with those of Tanko et al. [100], which highlighted that awareness of relevant information and experience is essential for effectively implementing the value management (VM) approach. Consequently, construction workers need training on the various aspects of VM. It's unrealistic to expect clients to adopt VM in their projects if they collaborate with professionals who lack the necessary facilitation skills [34]. Efficient resource allocation has been identified as a crucial factor influencing the success of a project and the implementation of the program, which also applies to VM. Sufficient resources must be allocated to ensure the successful execution of the VM program. The project's outputs and resources should be considered together, as each variable directly impacts the other [130]. Therefore, active involvement and support from the client in adopting VM practices in modern construction are vital [122]. Client support can provide essential assistance, such as financial incentives and necessary guidelines to meet sustainability requirements [118]. As a result, progress will be documented throughout the VM implementation process [118]. Additionally, it is important to educate clients and policymakers about the benefits and potential of using VM in construction projects [34].

5.2. Implications

This research has ramifications for the barriers to VM application in the Jordanian construction sector regarding several theoretical, practical, and policy implications.

5.2.1. Theoretical Implications

By offering a sophisticated knowledge of the particular barriers to VM implementation within the framework of the Jordanian construction sector, this study adds excellent value to the body of current knowledge. Previous studies mainly concentrated on VM techniques in rich countries, hence lacking knowledge of the difficulties experienced in underdeveloped nations like Jordan. Through identifying and analyzing these obstacles, this study broadens the focus of VM research to include developing countries, where cultural and socioeconomic elements greatly influence the acceptance of management techniques. Furthermore, the combination of EFA, SEM, and ANN provides a thorough methodological framework that may be used in the subsequent investigations to investigate intricate interactions and project results in VM and other management approaches. This multi-method approach improves the analytical rigour and offers a solid basis for more theoretical advancement in construction management.

5.2.2. Practical Implications

This study underlines how urgently improved stakeholder involvement and communication are needed to remove environmental and cultural obstacles impeding virtual machine adoption. Building companies should prioritize creating a cooperative environment whereby every participant—including clients, designers, and contractors—is actively engaged in the VM process. Structured training courses and digital tools enabling efficient communication and teamwork will help accomplish this. Furthermore, the paper underlines the need to optimize VM seminars' dynamics. Companies can thus invest in the training of facilitators who can more successfully run seminars, guaranteeing that they are well-organized, participatory, and focused on addressing critical issues such as procurement challenges, time restrictions, and technology integration. Using cutting-edge technology such as VM (VR) and simulation tools can help these seminars be more exciting and compelling, producing improved results. Moreover, the research emphasizes implementing uniform virtual machine tools throughout projects. This covers the creation of templates, rules, and established processes guaranteeing consistency and coherence in virtual machine applications, improving project productivity, lowering variability, and enabling more seamless implementation over several projects.

5.2.3. Policy Implications

This research emphasizes how urgently supportive regulations and legal frameworks that enable the general acceptance of VM machines in the building sector must be developed. Legislators should consider passing laws requiring VM in public and private sector projects so that its advantages are acknowledged and included in accepted building techniques. Policies could consist of the creation of legal requirements for VM application in project planning and execution as well as incentives for companies who embrace VM methods, including tax breaks or money for VM training and implementation. Furthermore, government-led campaigns are significant and are meant to increase awareness among industry players of the benefits of virtual machines. Public campaigns, seminars, and instructional programs intended to raise knowledge and respect for VM's ability to improve project efficiency, lower costs, and raise general quality could be part of these activities. Targeted policies and laws addressing the highlighted obstacles in this study have great potential to change the Jordanian building sector, thereby increasing its competitiveness, efficiency, and sustainability. This strategy helps local businesses establish standards for other developing nations dealing with similar issues, supporting more general attempts to enhance world-building standards and infrastructure development.

6. Conclusion

This study investigated the obstacles to Value Management (VM) adoption in Jordan's building sector using a multi-method design that integrated EFA, PLS-SEM, and ANN. Findings identify three barrier clusters—standardization and organizational practices, workshop design and participation, and culture and industry environment—with workshop dynamics exerting the strongest adverse effect on adoption. Convergence between SEM paths and ANN importance ranks supports the conclusion that improving workshop structure and participation, alongside the formalization of organizational procedures, provides a high-leverage route to near-term gains. Methodologically, the study contributes an evidence-triangulation framework that couples measurement validity with predictive assessment, strengthening external relevance for decision-makers.

Several limitations should be acknowledged. The data are cross-sectional and self-reported, which may affect causal interpretation and introduce common-method bias; the sampling frame centers on building projects, limiting generalizability to other subsectors. Future work should employ longitudinal designs, broaden sectoral coverage, and evaluate the barrier taxonomy across different MENA contexts. Additional predictive experiments (e.g., gradient boosting, SHAP-based explanations) could complement ANN results and provide richer sensitivity analysis. For practice, the results motivate three priorities: institutionalize standardized VM processes; enhance workshop facilitation, attendance, and timing within project decision gates; and support culture-aware capability building through training and guidance. Taken together, these steps offer a pragmatic roadmap for accelerating VM adoption and realizing value outcomes in the region.

6.1. Future Research

Subsequent work should incorporate contextual moderators to clarify when and where the identified levers are most effective. In particular, indicators of government procurement systems (e.g., tendering rigidity, prequalification rules, approval cycles, payment timelines) and economic constraints (e.g., budget volatility, inflationary pressure, financing terms) can be measured and tested as moderators of the relationships between standardization/organizational practices, workshop design and participation, and VM adoption. Moderation can be assessed within PLS-SEM using the product-indicator or two-stage approach, and—where regimes are distinct—through multi-group analysis after establishing measurement invariance (MICOM). Given the sample size requirements for interaction effects, future studies should plan for larger samples and consider multi-wave or longitudinal designs to strengthen causal interpretation and track the impact of policy or market shifts on adoption dynamics. Collecting minimal procurement descriptors (e.g., public vs private, procurement method, average approval time) and basic economic strain indicators (e.g., cost overrun pressure) would enable a systematic test of these contextual influences and help tailor policy and managerial sequencing—for example, pairing guideline roll-outs with culture-aware training in rigid procurement environments, or prioritizing workshop improvements where economic pressure constrains extensive standardization.

7. Declarations

7.1. Author Contributions

Conceptualization, A.M.Z. and M.A.; methodology, A.M.Z., M.A., and A.A.; software, A.M.Z. and M.A.; validation, A.M.Z. and M.A.; formal analysis, A.M.Z. and A.A.; investigation, A.M.Z., M.A., and A.A; resources, A.M.Z. and M.A.; data curation, A.M.Z. and M.A.; writing—original draft preparation, A.M.Z., M.A., and A.A.; writing—review and editing, A.M.Z., M.A., and A.A.; visualization, A.M.Z., M.A., and A.A.; supervision, A.M.Z. and M.A.; project administration, A.M.Z. and M.A.; funding acquisition, A.M.Z. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available in the article.

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7.4. Conflicts of Interest

The authors declare no conflict of interest.

8. References

[1] Kineber, A. F., Othman, I., Oke, A. E., Chileshe, N., & Buniya, M. K. (2020). Identifying and assessing sustainable value management implementation activities in developing countries: The case of Egypt. Sustainability (Switzerland), 12(21), 9143. doi:10.3390/su12219143.

[2] Kineber, A. F., Oke, A. E., Alyanbaawi, A., Abubakar, A. S., & Hamed, M. M. (2022). Exploring the Cloud Computing Implementation Drivers for Sustainable Construction Projects—A Structural Equation Modeling Approach. Sustainability (Switzerland), 14(22). doi:10.3390/su142214789.

[3] UNEP. (2009). Buildings and climate change: summary for decision-makers. Sustainable Buildings and Climate Initiative, Sustainable Buildings and Climate Initiative (UNEP), Nairobi, Kenya.

[4] U.S. Department of Energy. (2008). Energy Efficiency Trends in Residential and Commercial Buildings. U.S. Department of Energy, Washington, United States.

[5] Boermans, T., Hermelink, A., Schimschar, S., Grözinger, J., Offermann, M., Engelund Thomsen, K., ... & Aggerholm, S. O. (2011). Principles for Nearly Zero-energy Buildings. Paving the way for effective implementation of policy requirements. Buildings Performance Institute Europe BPIE, Brussels, Belgium.

[6] Durdyev, S., Ismail, S., Ihtiyar, A., Abu Bakar, N. F. S., & Darko, A. (2018). A partial least squares structural equation modeling (PLS-SEM) of barriers to sustainable construction in Malaysia. Journal of Cleaner Production, 204, 564–572. doi:10.1016/j.jclepro.2018.08.304.

[7] Yaseen, Z. M., Ali, Z. H., Salih, S. Q., & Al-Ansari, N. (2020). Prediction of risk delay in construction projects using a hybrid artificial intelligence model. Sustainability (Switzerland), 12(4), 1514. doi:10.3390/su12041514.

[8] Mousa, A. (2015). A Business approach for transformation to sustainable construction: An implementation on a developing country. Resources, Conservation and Recycling, 101, 9–19. doi:10.1016/j.resconrec.2015.05.007.

[9] Fang, Z., Gao, X., & Sun, C. (2020). Do financial development, urbanization and trade affect environmental quality? Evidence from China. Journal of Cleaner Production, 259. doi:10.1016/j.jclepro.2020.120892.

[10] Kissi, E., Boateng, E., & Adjei-Kumi, T. (2015). Strategies for implementing value management in the construction industry of Ghana. Proceedings of the DII-2015 conference on infrastructure development and investment strategies for Africa, 16-18 September, 2015, Livingstone, Zambia.

[11] Adeyemi, L. A., & Idoko, M. (2008). Developing local capacity for project management--Key to social and business transformation in developing countries. Project Management Institute (PIM), Pennsylvania, United States.

[12] Maceika, A., Bugajev, A., & Šostak, O. R. (2020). The modelling of roof installation projects using decision trees and the AHP method. Sustainability (Switzerland), 12(1), 59. doi:10.3390/SU12010059.

[13] Oke, A. E., Kineber, A. F., Albukhari, I., & Dada, A. J. (2024). Modeling the robotics implementation barriers for construction projects in developing countries. International Journal of Building Pathology and Adaptation, 42(3), 386–409. doi:10.1108/IJBPA-06-2021-0093.

[14] Morshed, A., & Khrais, L. T. (2025). Cybersecurity in Digital Accounting Systems: Challenges and Solutions in the Arab Gulf Region. Journal of Risk and Financial Management, 18(1), 41. doi:10.3390/jrfm18010041.

[15] Jekale, W. (2004). Performance for public construction projects in developing countries: Federal road and educational building projects in Ethiopia. Norwegian University of Science & Technology: Trondheim, Norway.

[16] Lewis, E., Chamel, O., Mohsenin, M., Ots, E., & White, E. T. (2018). Our Common Future. Sustainaspeak, 195–196, Routledge, Milton Park, United Kingdom. doi:10.4324/9781315270326-140.

[17] Kibert, C.J. (1994). Final Session of the First International Conference of CIB TG 16. The First International Conference of CIB TG 16, Florida, United States.

[18] Hill, R. C., & Bowen, P. A. (1997). Sustainable construction: Principles and a framework for attainment. Construction Management and Economics, 15(3), 223–239. doi:10.1080/014461997372971.

[19] Wolstenholme, A., Austin, S., Bairstow, M., Blumenthal, A., Lorimer, J., McGuckin, S., ... & Davies, R. (2009). Never waste a good crisis: a review of progress since Rethinking Construction and thoughts for our future. Loughborough University, Loughborough, United Kingdom.

[20] Abidin, N. Z., & Pasquire, C. L. (2007). Revolutionize value management: A mode towards sustainability. International Journal of Project Management, 25(3), 275–282. doi:10.1016/j.ijproman.2006.10.005.

[21] SAVE International. (2007). Value Methodology Standard and Body of Knowledge. SAVE International, Mount Royal, United States.

[22] Kineber, A. F., Mohandes, S. R., ElBehairy, H., Chileshe, N., Zayed, T., & Fathy, U. (2022). Towards smart and sustainable urban management: A novel value engineering decision-making model for sewer projects. Journal of Cleaner Production, 375. doi:10.1016/j.jclepro.2022.134069.

[23] Li, C. Z., Tam, V. W., Hu, M., & Zhou, Y. (2024). Lean construction management: A catalyst for evaluating and enhancing prefabricated building project performance in China. Journal of Building Engineering, 94(May), 109930. doi:10.1016/j.jobe.2024.109930.

[24] Rabnawaz Ahmed, R., & Zhang, X. (2021). Multi-layer value stream assessment of the reverse logistics network for inert construction waste management. Resources, Conservation and Recycling, 170. doi:10.1016/j.resconrec.2021.105574.

[25] Kim, J., Koo, C., Kim, C. J., Hong, T., & Park, H. S. (2015). Integrated CO2, cost, and schedule management system for building construction projects using the earned value management theory. Journal of Cleaner Production, 103, 275–285. doi:10.1016/j.jclepro.2014.05.031.

[26] 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. doi:10.1016/j.ijproman.2010.11.003.

[27] Khodeir, L. M., & El Ghandour, A. (2019). Examining the role of value management in controlling cost overrun [application on residential construction projects in Egypt]. Ain Shams Engineering Journal, 10(3), 471–479. doi:10.1016/j.asej.2018.11.008.

[28] Althoey, F., Waqar, A., Hamed Alsulamy, S., Khan, A. M., Alshehri, A., Idris Falqi, I., Abuhussain, M., & Awad Abuhussain, M. (2024). Influence of IoT implementation on Resource management in construction. Heliyon, 10(15), 32193. doi:10.1016/j.heliyon.2024.e32193.

[29] Chilakamarri, S. (2023). 'Show, don't tell!' – Popular films for discussion of individual values in construction project management. Project Leadership and Society, 4. doi:10.1016/j.plas.2023.100082.

[30] Malla, S. (2013). Application of Value Engineering in Nepalese Building Construction Industry. Professional Project Management Education, Thailand.

[31] Alhusban, M. (2018). Conceptual procurement framework for building information modelling uptake to enhance buildings' sustainability performance in the Jordanian public sector. Ph.D. Thesis, University of Portsmouth, Portsmouth, United Kingdom.

[32] Lin, X., Mazlan, A. N., & Ismail, S. (2022). Barriers to the implementation of value management in small construction projects. Journal of Building Engineering, 54. doi:10.1016/j.jobe.2022.104639.

[33] Srikar, T., Sesha Sai Ratnamala, B., & Sree Lakshmi, V. (2022). Evaluation and development of management model for sustainable value chain in Indian construction industry. Materials Today: Proceedings, 60, 1623–1628. doi:10.1016/j.matpr.2021.12.186.

[34] Othman, I., Kineber, A. F., Oke, A. E., Zayed, T., & Buniya, M. K. (2021). Barriers of value management implementation for building projects in Egyptian construction industry. Ain Shams Engineering Journal, 12(1), 21–30. doi:10.1016/j.asej.2020.08.004.

[35] Emmanuel Oke, A., Omoregie Aghimien, D., & Olusola Olatunji, S. (2015). Implementation of Value Management as an Economic Sustainability Tool for Building Construction in Nigeria. International Journal of Managing Value and Supply Chains, 6(4), 55–64. doi:10.5121/ijmvsc.2015.6405.

[36] Oke, A. E., Kineber, A. F., Elshaboury, N., Elseknidy, M., Abunada, Z., & Ilori, S. A. (2025). Decision-making model for benefits of agile project management in residential buildings. Proceedings of the Institution of Civil Engineers - Engineering Sustainability, 6. doi:10.1680/jensu.25.00006.

[37] Aarseth, W., Ahola, T., Aaltonen, K., Økland, A., & Andersen, B. (2017). Project sustainability strategies: A systematic literature review. International Journal of Project Management, 35(6), 1071–1083. doi:10.1016/j.ijproman.2016.11.006.

[38] Martens, M. L., & Carvalho, M. M. (2017). Key factors of sustainability in project management context: A survey exploring the project managers' perspective. International Journal of Project Management, 35(6), 1084–1102. doi:10.1016/j.ijproman.2016.04.004.

[39] Fewings, P., & Henjewele, C. (2019). Construction project management: an integrated approach. Routledge, London, United Kingdom. doi:10.4324/9780203831199.

[40] Massoud, M., Kineber, A., Elshaboury, N., Abunada, Z., Arashpour, M., Alatroush, M., Mostafa, S., & Alhusban, M. (2026). Identifying and assessing the internet of things implementation barriers for sustainable building projects: SEM-ANN approach. KSCE Journal of Civil Engineering, 30(1). doi:10.1016/j.kscej.2025.100310.

[41] AS 418-2007. (2007). Australian Standard: Value Management. Australian Standards, Sydney, Australia.

[42] Kineber, A. F., Othman, I., Oke, A. E., Chileshe, N., & Zayed, T. (2023). Value management implementation barriers for sustainable building: a bibliometric analysis and partial least square structural equation modeling. Construction Innovation, 23(1), 38–73. doi:10.1108/CI-05-2021-0103.

[43] Mum, N., Atabay, Ş., Tekin, H., & Akkaya, D. (2025). Addressing the Value Management Approach in Public Construction Works: Barriers, Critical Success Factors, and Potential Risks. Sustainability, 17(12), 5247. doi:10.3390/su17125247.

[44] M.Zamil, A., Alhusban, M., & Abdulrahman, A. (2025). Investigating the challenges of value management adoption for sustainable construction projects: a PLS-SEM approach. Discover Applied Sciences, 7(10), 1098. doi:10.1007/s42452-025-07715-6.

[45] Zimmermann, J., & Eber, W. (2017). Criteria on the Value of Expert's Opinions for Analyzing Complex Structures in Construction and Real Estate Management. Procedia Engineering, 196, 335–342. doi:10.1016/j.proeng.2017.07.208.

[46] Thneibat, M., Thneibat, M., Al-Shattarat, B., & Al-kroom, H. (2022). Development of an agent-based model to understand the diffusion of value management in construction projects as a sustainability tool. Alexandria Engineering Journal, 61(1), 747–761. doi:10.1016/j.aej.2021.05.005.

[47] Ma, W., & Hao, J. L. (2024). Enhancing a circular economy for construction and demolition waste management in China: A stakeholder engagement and key strategy approach. Journal of Cleaner Production, 450. doi:10.1016/j.jclepro.2024.141763.

[48] Jaapar, A., Zawawi, M., Bari, N. A. A., & Ahmad, N. (2012). Value Management in the Malaysian Construction Industry: Addressing a Theory and Practice Gap. Procedia - Social and Behavioral Sciences, 35, 757–763. doi:10.1016/j.sbspro.2012.02.146.

[49] Kissi, E., Boateng, E. B., Adjei-Kumi, T., & Badu, E. (2017). 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. doi:10.1080/15623599.2016.1233088.

[50] Luvara, V. G. M., & Mwemezi, B. (2017). Obstacles against Value Management Practice in Building Projects of Dar es Salaam Tanzania. International Journal of Construction Engineering and Management, 6(1), 13–21. doi:10.5923/j.ijcem.20170601.02.

[51] Aduze, O. C. (2014). A study of the prospects and challenges of value engineering in construction projects in Delta and Edo States of Nigeria. Master Thesis, Nnamdi Azikiwe University, Awka, Nigeria.

[52] Ezezue, B. (2015). Value management in Nigerian manufacturing companies: challenges and prospects. 11th International Business and Social Research Conference, 8-9 January, 2015, Dubai, United Arab Emirates.

[53] Shen, Q. (1997). Value management in Hong Kong's construction industry: Lessons learned: International conference proceeding, Hong Kong.

[54] Cheah, C. Y. J., & Ting, S. K. (2005). Appraisal of value engineering in construction in Southeast Asia. International Journal of Project Management, 23(2), 151–158. doi:10.1016/j.ijproman.2004.07.008.

[55] Perera, S., & Karunasena, G. (2004). Application of value management in the construction industry of Sri Lanka. The Value Manager, 10(2), 4-8.

[56] Fard, A. B., Rad, K. G., Sabet, P. G. P., & Aadal, H. (2013). Evaluating effective factors on value engineering implementation in the context of Iran. Journal of Basic and Applied Scientific Research, 3(10), 430-436.

[57] Latief, Y., & Vincentius Untoro, K. (2009). Implementation of value engineering in the infrastructure services of Indonesia's public works department. Value World, 32(3), 10-14.

[58] Whyte, A., & Cammarano, C. (2012). Value management in infrastructure projects in Western Australia: Techniques and staging. Proceedings of the 28th annual ARCOM Conference, 3-5 September, 2012, Reading, United Kingdom.

[59] Burnham, J. F. (2006). Scopus database: A review. Biomedical Digital Libraries, 3. doi:10.1186/1742-5581-3-1.

[60] Caponecchia, C., Coman, R. L., Gopaldasani, V., Mayland, E. C., & Campbell, L. (2020). Musculoskeletal disorders in aged care workers: a systematic review of contributing factors and interventions. International Journal of Nursing Studies, 110. doi:10.1016/j.ijnurstu.2020.103715.

[61] Lin, X., Mazlan, A. N., Ismail, S., Hu, L., Kasiman, E. H. Bin, & Yahya, K. (2023). Status of value management studies in construction projects: A systematic review. Ain Shams Engineering Journal, 14(1), 101820. doi:10.1016/j.asej.2022.101820.

[62] Shen, Q., Chung, J. K. H., Li, H., & Shen, L. (2004). A Group Support System for improving value management studies in construction. Automation in Construction, 13(2), 209–224. doi:10.1016/j.autcon.2003.07.001.

[63] 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. doi:10.1016/j.autcon.2009.03.004.

[64] Fellows, R. F., & Liu, A. M. (2021). Research methods for construction. John Wiley & Son, Hoboken, United States.

[65] Liu, Y., Eckert, C. M., & Earl, C. (2020). A review of fuzzy AHP methods for decision-making with subjective judgements. Expert Systems with Applications, 161. doi:10.1016/j.eswa.2020.113738.

[66] Bello, A. O., Eje, D. O., Idris, A., Semiu, M. A., & Khan, A. A. (2024). Drivers for the implementation of modular construction systems in the AEC industry of developing countries. Journal of Engineering, Design and Technology, 22(6), 2043–2062. doi:10.1108/JEDT-11-2022-0571.

[67] Tafesse, S., Girma, Y. E., & Dessalegn, E. (2022). Analysis of the socio-economic and environmental impacts of construction waste and management practices. Heliyon, 8(3), e09169. doi:10.1016/j.heliyon.2022.e09169.

[68] Kineber, A. F., Othman, I., Oke, A. E., Chileshe, N., & Zayed, T. (2021). Exploring the value management critical success factors for sustainable residential building – A structural equation modelling approach. Journal of Cleaner Production, 293. doi:10.1016/j.jclepro.2021.126115.

[69] Tan, C. C., Sayampanathan, A. A., Kwan, Y. H., YEO, W., & Yeo, N. E. M. (2023). Validity and Reliability of the European Foot and Ankle Society (EFAS) Score in Patients with Hallux Valgus in Singapore. Journal of Foot and Ankle Surgery, 62(2), 295–299. doi:10.1053/j.jfas.2022.08.003.

[70] Kineber, A. F., Ali, A. H., Elshaboury, N., Oke, A. E., & Arashpour, M. (2024). A multi-criteria evaluation and stationary analysis of value management implementation barriers for sustainable residential building projects. International Journal of Construction Management, 24(2), 199–212. doi:10.1080/15623599.2023.2267870.

[71] Nunkoo, R., & Ramkissoon, H. (2012). Structural equation modelling and regression analysis in tourism research. Current Issues in Tourism, 15(8), 777–802. doi:10.1080/13683500.2011.641947.

[72] Field, A. (2024). Discovering statistics using IBM SPSS statistics. Sage publications limited, London, United Kingdom.

[73] Pinheiro, A. B., Panza, G. B., Berhorst, N. L., Toaldo, A. M. M., & Segatto, A. P. (2024). Exploring the relationship among ESG, innovation, and economic and financial performance: evidence from the energy sector. International Journal of Energy Sector Management, 18(3), 500–516. doi:10.1108/IJESM-02-2023-0008.

[74] Gandini, A., Quesada, L., Prieto, I., & Garmendia, L. (2021). Climate change risk assessment: A holistic multi-stakeholder methodology for the sustainable development of cities. Sustainable Cities and Society, 65. doi:10.1016/j.scs.2020.102641.

[75] Waqar, A., Qureshi, A. H., & Alaloul, W. S. (2023). Barriers to Building Information Modeling (BIM) Deployment in Small Construction Projects: Malaysian Construction Industry. Sustainability (Switzerland), 15(3), 2477. doi:10.3390/su15032477.

[76] Olanrewaju, A. L., & Woon, T. C. (2017). An exploration of determinants of affordable housing choice. International Journal of Housing Markets and Analysis, 10(5), 703–723. doi:10.1108/IJHMA-11-2016-0074.

[77] Wong, K. K. K. (2013). Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. Marketing bulletin, 24(1), 1-32.

[78] Tabatabaee, S., Mahdiyar, A., Durdyev, S., Mohandes, S. R., & Ismail, S. (2019). An assessment model of benefits, opportunities, costs, and risks of green roof installation: A multi criteria decision making approach. Journal of Cleaner Production, 238. doi:10.1016/j.jclepro.2019.117956.

[79] Lei, C. F., Ngai, E. W. T., Lo, C. W. H., & See-To, E. W. K. (2023). Green IT/IS adoption and environmental performance: The synergistic roles of IT–business strategic alignment and environmental motivation. Information and Management, 60(8), 103886. doi:10.1016/j.im.2023.103886.

[80] Nureen, N., Xin, Y., Irfan, M., & Fahad, S. (2023). Going green: how do green supply chain management and green training influence firm performance? Evidence from a developing country. Environmental Science and Pollution Research, 30(20), 57448–57459. doi:10.1007/s11356-023-26609-x.

[81] Fu, C., Liu, Y. Q., & Shan, M. (2023). Drivers of low-carbon practices in green supply chain management in construction industry: An empirical study in China. Journal of Cleaner Production, 428. doi:10.1016/j.jclepro.2023.139497.

[82] Celik, Y., Petri, I., & Rezgui, Y. (2023). Integrating BIM and Blockchain across construction lifecycle and supply chains. Computers in Industry, 148. doi:10.1016/j.compind.2023.103886.

[83] Dadhich, M., & Hiran, K. K. (2022). Empirical investigation of extended TOE model on Corporate Environment Sustainability and dimensions of operating performance of SMEs: A high order PLS-ANN approach. Journal of Cleaner Production, 363. doi:10.1016/j.jclepro.2022.132309.

[84] Perno, M., Hvam, L., & Haug, A. (2022). Implementation of digital twins in the process industry: A systematic literature review of enablers and barriers. Computers in Industry, 134. doi:10.1016/j.compind.2021.103558.

[85] Ye, H., Li, D., Ye, X., Zheng, Y., Zhang, Z., Zhang, H., & Chen, Z. (2019). An adjustable permeation membrane up to the separation for multicomponent gas mixture. Scientific Reports, 9(1), 7380. doi:10.1038/s41598-019-43751-0.

[86] Khalil, M., Khawaja, K. F., & Sarfraz, M. (2022). The adoption of blockchain technology in the financial sector during the era of fourth industrial revolution: a moderated mediated model. Quality and Quantity, 56(4), 2435–2452. doi:10.1007/s11135-021-01229-0.

[87] Kineber, A. F., Oke, A. E., Hamed, M. M., Rached, E. F., & Elmansoury, A. (2023). Modeling the Impact of Overcoming the Green Walls Implementation Barriers on Sustainable Building Projects: A Novel Mathematical Partial Least Squares—SEM Method. Mathematics, 11(3), 504. doi:10.3390/math11030504.

[88] Chandio, F. H. (2011). Studying acceptance of online banking information system: A structural equation model. Ph.D. Thesis, Brunel Business School, Uxbridge, United Kingdom.

[89] Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). Multivariate Data Analysis. Cengage Learning, Boston, United States.

[90] Gorsuch, R. L. (2013). Factor Analysis. Psychology Press, New York, United States. doi:10.4324/9780203781098.

[91] Ali, A. H., Elyamany, A., Ibrahim, A. H., Kineber, A. F., & Daoud, A. O. (2024). Modelling the relationship between modular construction adoption and critical success factors for residential projects in developing countries. International Journal of Construction Management, 24(12), 1314–1325. doi:10.1080/15623599.2023.2185940.

[92] Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International, New Delhi, India.

[93] Wahyuni, D. (2012). The research design maze: understanding paradigms, cases, methods and methodologies: discovery service for UNIV of South Carolina. Journal of Applied Management and Accounting Research, 10(1), 69–80.

[94] Chen, C.-F., & Ding, C. G. (2025). An improvement in the detection of common method biases. Quality & Quantity. doi:10.1007/s11135-025-02167-x.

[95] Cruz-Jesus, F., Pinheiro, A., & Oliveira, T. (2019). Understanding CRM adoption stages: empirical analysis building on the TOE framework. Computers in Industry, 109, 1–13. doi:10.1016/j.compind.2019.03.007.

[96] Owusu, E. K., Chan, A. P. C., & Ameyaw, E. (2019). Toward a cleaner project procurement: Evaluation of construction projects' vulnerability to corruption in developing countries. Journal of Cleaner Production, 216, 394-407. doi:10.1016/j.jclepro.2019.01.124.

[97] Kaewkungwal, J. (2023). The Grammar of Science: How "Good" is Your Instrument? Outbreak, Surveillance, Investigation & Response (OSIR) Journal, 16(1), 40–45. doi:10.59096/osir.v16i1.262097.

[98] Alhamami, M., Alduais, A., Alasmari, M., & Qasem, F. (2024). Development and validation of the Arabic children's strong communication scale: a pilot study. Frontiers in Psychology, 15. doi:10.3389/fpsyg.2024.1380296.

[99] Chambers, E. C., Pichardo, M. S., & Rosenbaum, E. (2016). Sleep and the Housing and Neighborhood Environment of Urban Latino Adults Living in Low-Income Housing: The AHOME Study. Behavioral Sleep Medicine, 14(2), 169–184. doi:10.1080/15402002.2014.974180.

[100] Tanko, B. L., Abdullah, F., Mohamad Ramly, Z., & Enegbuma, W. I. (2018). An implementation framework of value management in the Nigerian construction industry. Built Environment Project and Asset Management, 8(3), 305–319. doi:10.1108/BEPAM-09-2017-0078.

[101] Benligiray, S., Güngör, A. Y., & Akbaş, İ. (2024). Measuring remote working skills: Scale development and validation study. PLoS ONE, 19(4 April), 1. doi:10.1371/journal.pone.0299074.

[102] Aibinu, A. A., & Al-Lawati, A. M. (2010). Using PLS-SEM technique to model construction organizations' willingness to participate in e-bidding. Automation in Construction, 19(6), 714–724. doi:10.1016/j.autcon.2010.02.016.

[103] Kineber, A. F., Oke, A., Hamed, M. M., Alyanbaawi, A., Elmansoury, A., & Daoud, A. O. (2023). Decision Making Model for Identifying the Cyber Technology Implementation Benefits for Sustainable Residential Building: A Mathematical PLS-SEM Approach. Sustainability (Switzerland), 15(3), 2458. doi:10.3390/su15032458.

[104] Akour, I. A., Al-Maroof, R. S., Alfaisal, R., & Salloum, S. A. (2022). A conceptual framework for determining metaverse adoption in higher institutions of gulf area: An empirical study using hybrid SEM-ANN approach. Computers and Education: Artificial Intelligence, 3. doi:10.1016/j.caeai.2022.100052.

[105] Lo, P. S., Dwivedi, Y. K., Wei-Han Tan, G., Ooi, K. B., Cheng-Xi Aw, E., & Metri, B. (2022). Why do consumers buy impulsively during live streaming? A deep learning-based dual-stage SEM-ANN analysis. Journal of Business Research, 147, 325–337. doi:10.1016/j.jbusres.2022.04.013.

[106] Arpaci, I., Karatas, K., Kusci, I., & Al-Emran, M. (2022). Understanding the social sustainability of the Metaverse by integrating UTAUT2 and big five personality traits: A hybrid SEM-ANN approach. Technology in Society, 71. doi:10.1016/j.techsoc.2022.102120.

[107] Singh, A. K., Kumar, V. R. P., Shoaib, M., Adebayo, T. S., & Irfan, M. (2023). A strategic roadmap to overcome blockchain technology barriers for sustainable construction: A deep learning-based dual-stage SEM-ANN approach. Technological Forecasting and Social Change, 194. doi:10.1016/j.techfore.2023.122716.

[108] Loh, X. M., Lee, V. H., & Leong, L. Y. (2022). Mobile-lizing continuance intention with the mobile expectation-confirmation model: An SEM-ANN-NCA approach. Expert Systems with Applications, 205. doi:10.1016/j.eswa.2022.117659.

[109] Oke, A. E., Kineber, A. F., Olanrewaju, O. I., Omole, O., Jamir Singh, P. S., Samsurijan, M. S., & Ramli, R. A. (2023). Exploring the 4IR Drivers for Sustainable Residential Building Delivery from Social Work Residential Perspective—A Structural Equation Modelling Approach. Sustainability (Switzerland), 15(1), 468. doi:10.3390/su15010468.

[110] Waqar, A., Alharbi, L. A., Abdullah Alotaibi, F., Othman, I., & Almujibah, H. (2023). Impediment to implementation of Internet of Things (IOT) for oil and gas construction project Safety: Structural equation modeling approach. Structures, 57. doi:10.1016/j.istruc.2023.105324.

[111] Dubey, R., Bryde, D. J., Dwivedi, Y. K., Graham, G., Foropon, C., & Papadopoulos, T. (2023). Dynamic digital capabilities and supply chain resilience: The role of government effectiveness. International Journal of Production Economics, 258. doi:10.1016/j.ijpe.2023.108790.

[112] Benzidia, S., Makaoui, N., & Subramanian, N. (2021). Impact of ambidexterity of blockchain technology and social factors on new product development: A supply chain and Industry 4.0 perspective. Technological Forecasting and Social Change, 169. doi:10.1016/j.techfore.2021.120819.

[113] Kin, T. M., Abdull Kareem, O., Nordin, M. S., & Wai Bing, K. (2015). Teacher change beliefs: Validating a scale with structural equation modelling. School Leadership and Management, 35(3), 266–299. doi:10.1080/13632434.2014.962503.

[114] El Barachi, M., Salim, T. A., Nyadzayo, M. W., Mathew, S., Badewi, A., & Amankwah-Amoah, J. (2022). The relationship between citizen readiness and the intention to continuously use smart city services: Mediating effects of satisfaction and discomfort. Technology in Society, 71. doi:10.1016/j.techsoc.2022.102115.

[115] Suprapto, M., Bakker, H. L. M., Mooi, H. G., & Hertogh, M. J. C. M. (2016). How do contract types and incentives matter to project performance? International Journal of Project Management, 34(6), 1071–1087. doi:10.1016/j.ijproman.2015.08.003.

[116] Hsu, C. L., & Lin, J. C. C. (2015). What drives purchase intention for paid mobile apps?-An expectation confirmation model with perceived value. Electronic Commerce Research and Applications, 14(1), 46–57. doi:10.1016/j.elerap.2014.11.003.

[117] Elseufy, S. M., Hussein, A., & Badawy, M. (2022). A hybrid SEM-ANN model for predicting overall rework impact on the performance of bridge construction projects. Structures, 46, 713–724. doi:10.1016/j.istruc.2022.10.100.

[118] Kineber, A. F., Siddharth, S., Chileshe, N., Alsolami, B., & Hamed, M. M. (2022). Addressing of Value Management Implementation Barriers within the Indian Construction Industry: A PLS-SEM Approach. Sustainability (Switzerland), 14(24), 16602. doi:10.3390/su142416602.

[119] Jaapar, A., Endut, I. R., Ahmad Bari, N. A., & Takim, R. (2009). The Impact of Value Management Implementation in Malaysia. Journal of Sustainable Development, 2(2), 210. doi:10.5539/jsd.v2n2p210.

[120] Aghimien, D., Ngcobo, N., Aigbavboa, C., Dixit, S., Vatin, N. I., Kampani, S., & Khera, G. S. (2022). Barriers to Digital Technology Deployment in Value Management Practice. Buildings, 12(6), 731. doi:10.3390/buildings12060731.

[121] Mohamad Ramly, Z., Shen, G. Q., & Yu, A. T. W. (2015). Critical Success Factors for Value Management Workshops in Malaysia. Journal of Management in Engineering, 31(2), 05014015. doi:10.1061/(asce)me.1943-5479.0000288.

[122] Tanko, B. L., Abdullah, F., Ramly, Z. M., & Enegbuma, W. I. (2017). Confirmatory Factor Analysis of Value Management Current Practice in the Nigerian Construction Industry. Journal of Advanced Research in Applied Sciences and Engineering Technology, 9(1), 32–41.

[123] Kineber, A. F., Othman, I., Oke, A. E., Chileshe, N., & Alsolami, B. (2020). Critical value management activities in building projects: A case of Egypt. Buildings, 10(12), 239. doi:10.3390/buildings10120239.

[124] Lee, S., Hyun, C., & Hong, T. (2009). RETRIEVE: REmembering Tool for Reusing the Ideas Evolved in Value Engineering. Automation in Construction, 18(8), 1123–1134. doi:10.1016/j.autcon.2009.07.004.

[125] Coetzee, C. E. L. (2010). Value management in the construction industry: what does it entail and is it a worthwhile practice? Bachelor Thesis, Pretoria, South Africa.

[126] Gregori, P., & Holzmann, P. (2020). Digital sustainable entrepreneurship: A business model perspective on embedding digital technologies for social and environmental value creation. Journal of Cleaner Production, 272. doi:10.1016/j.jclepro.2020.122817.

[127] Bröchner, J. (2021). Construction project management fiction: Individual values. International Journal of Project Management, 39(6), 594–604. doi:10.1016/j.ijproman.2021.04.005.

[128] Naderpour, A., & Mofid, M. (2011). Improving construction management of an educational center by applying Earned Value technique. Procedia Engineering, 14, 1945–1952. doi:10.1016/j.proeng.2011.07.244.

[129] Shen, Q., & Chung, J. K. H. (2002). A group decision support system for value management studies in the construction industry. International Journal of Project Management, 20(3), 247–252. doi:10.1016/S0263-7863(01)00076-X.

[130] Wernerfelt, B. (1984). A resource-based view of the firm. Strategic Management Journal, 5(2), 171-180. doi:10.1002/smj.4250050207.