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AN OVERVIEW OF THE SIGNIFICANCE AND APPLICATION OF CONSTRUCTABILITY IN VALUE ENGINEERING

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ABSTRACT

Value Engineering (VE) and constructability are not distinct; instead, they are complementary work processes that may be used as vital elements in achieving total quality. Constructability is a value management (VM) tool developed as an attempt to integrate design and construction activities. VE is often implemented when there is a limited chance to influence the cost and time of the project effectively. Thus, project contractors and owners conduct VE analysis before construction by applying the constructability process. The activities of these two processes somehow complement each other in achieving their goals. Considering the output of existing VE approaches, it seems that despite the significance of constructability, it does not have an appropriate significance in VE projects. This study aims to evaluate the importance of constructability in VE and provide some suggestions for facilitating and improving it with VE. A type of systematic review in the related literature and conducted pattern coding called overview was utilized to obtain the study's aim. The research found that a large part of the proposed VE solutions that cover the principles and concepts of constructability focused on the pre-study and the main study phases of VE and the management subgroup. Significant areas related to the supplementary studies phase or environmental solutions, including cultural and legal issues, have been neglected. Therefore, addressing them provides an appropriate context to improve constructability by using the VE process.

Keywords: Value Engineering (VE); Constructability; Systematic review, Construction Industry

1. INTRODUCTION

The distinction between design and construction phases and the increasing growth of these issues lead the construction industry to implement Value Engineering (VE) services and consider constructability issues. VE provides a tool to reduce project lifecycle costs, while constructability services benefit constructive participation during the planning and design stages. Although VE may save money, a project cannot be succeeded just by relying on it. Integrating the process with all the stakeholders is the best way to bring together a qualified team, collaboration, design, and construction, as well as implement constructability and value improvement. Further, constructability that uses knowledgeable and experienced professionals to make better decisions can maximize the profit for the owner because it influences the whole project. It is so mainly when the constructability is done at the early stages of planning and design before creating a particular scope.

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Nowadays, the industry's knowledge and experience can be involved with design decisions to influence the project output significantly (Al-Fadhli, 2020). Unfortunately, while some concepts of constructability are considered in implementing the usual VE process, they are often conducted after essential design decisions have been made. Not only is this too late, but it can also no longer make changes that maximize profits. Probably, it reinforces the notion that, at this time, it is just a critique of the designer or favor to the owner. Under such conditions, VE implementation may be too late and useless.

The significance of constructability in the VE implementation was first mentioned four decades ago in the Texas Highway guide by Hugo et al. (1990). However, the issue was still not taken seriously until 1994, when the impact of using VE and constructability concepts to enhance total quality management was evaluated by Russell et al. (1994). They concluded that VE and constructability are complementary processes that may be used as vital elements in achieving total quality.

Despite the abundance of existing research in implementing VE and constructability techniques and how the plans and models were developed, some question remains unanswered. For instance, scholars are still wondering how much the literature addresses these two concepts and how much the VE solutions focus on constructability. Can the place of constructability be improved with the help of VE? The answer to these questions will determine the current state of focus on constructability issues and their position in VE implementation. It can also improve awareness of the current situation and the extent to which the mission of VE has improved constructability. Moreover, how much the proposed value solutions overlap with the principles and concepts of constructability provides suggestions regarding strengthening these areas can also be determined. To answer these questions, this research begins by introducing constructability and VE. Following that, using the overview method, it analyzes and evaluates the current focus of VE solutions on constructability, recent improvements, and neglected issues in the existing literature.

2. LITERATURE STUDY

2.1. Constructability

Increased competition and the introduction of product concepts in the construction industry have triggered the industry to become very specialized. Such specialization in the construction industry has separated design and construction activities. These changes consequently bring designers gradually to move away from the construction process. It has been observed in many cases that their plans show a less understanding of the construction process. This lack of comprehension due to the designers' ignorance and inexperience has often led to increased construction costs.

Sometimes, it leads to unconstructive designs (Russell, Swiggum, et al., 1994). Constructability is one of the concepts that help develop integrated designs. The concept of constructability, which first appeared in the United States as buildability and later in the United Kingdom in the late 1970s, refers to how productivity and quality in the construction industry can be improved by linking the design and construction sectors to each other (Trigunarsyah, 2007). Accordingly, when the project ideas are formed before construction, the most significant constructability issues should be considered in the designs (Mathern, 2019). However, ignoring constructability by designers and contractors has become almost commonplace during the project phases. Thus, the obstacles to implementing these activities are essential for achieving the projects' general goals that must be addressed in developed and developing countries (Saghatforoush et al., 2009). Some of the advantages of constructability include: 1) timely completion and following the initial planning; in some cases, the projects can be accomplished earlier than scheduled, 2) saving project costs, 3) reducing costs due to design changes, 4) improving the quality of the project, 5) achieving an acceptable level of productivity, 6) improving team performance, 7) reducing adverse risks of the project, remarkably, those related to unpredicted problems, 8) improving communication between key stakeholders, and 9) increasing the satisfaction of customers and project stakeholders (Eldin, 1999; Elgohary et al., 2003; Francis et al., 1999; Jadidoleslami et al., 2018; Jergeas & Put, 2001; Pheng & Abeyegoonasekera, 2001; Trigunarsyah, 2004). In short, constructability tries to minimize the gap between what the designers do and what the contractors implement on the project site.

Based on the reports of the construction phase and results, implementing construction criteria at all project stages requires much information. However, in the initial phase of designing construction projects, there is a possibility of reducing the adverse effects and increasing the positive impacts of applying the concepts of constructability. One of the strategies is to use performance-based requirements. Indeed, it requires design processes and methods that support informed design selections (Mathern, 2019; Mendelsohn, 1997). The Construction Industry Institute of Australia (CIIA), a leading institution that studies constructability in Australia, has presented 12 principles in a 25-to-30-year effort. The CIIA has considered the most appropriate time for applying these principles in the project lifecycle. These principles are suitable for the objectives of this study, covering:

1. Integration: constructability should be implemented in the project's design phase in an integrated form.
2. Knowledge of construction: project design should include simultaneous application of knowledge and experience.
3. Team skills: the composition of the project team and their capabilities, experiences, and skills should be compatible with the project definition.
4. Common goals: defining and understanding common goals will increase the project's level of completion.
5. Available resources: applied technologies in the design sector should be compatible with the existing resources and capabilities.
6. External factors: these factors affect the project’s cost and time.
7. Plan: the detailed project plan should be implementable, and the project team should be committed to its implementation.
8. Construction methodology: the construction method should be thoroughly considered in designing the project.
9. Accessibility: considering the accessibility of the construction phase in the design phase will increase the project’s level of completion.
10. Specifications: constructability should be considered in developing and expanding the project specifications.
11. Technology: using innovations and new methods and technologies will improve the project implementation.
12. Feedback: it is helpful to evaluate and analyze the project after its construction by an experienced team to improve the constructability of similar projects in the future.

The principles of constructability and their role in the project lifecycle are presented in Table 1.

Table 1 The principles of constructability (CIIA, 1993)

PROJECT LIFE					**PRINCIPLES OF CONSTRUCTABILITY**	
After construction	**Construction**	**Design development**		**Planning / Feasibility**		
		Detailed design	**Conceptual design**			
MR	MR	MR	VR	VR	Integration	P1
IR	MR	MR	VR	MR	Knowledge of construction	P2
IR	IR	VR	VR	R	Team skills	P3
MR	IR	IR	VR	VR	Common goals	P4
IR	IR	R	R	VR	Available resources	P5
IR	IR	MR	R	VR	External factors	P6
IR	R	R	VR	MR	Program	P7
IR	IR	VR	VR	MR	Construction methodology	P8
IR	R	VR	VR	IR	accessibility	P9
IR	IR	VR	IR	IR	Specifications	P10
IR	VR	IR	IR	IR	Technology	P11
VR	IR	IR	IR	IR	Feedback	P12
LEGEND: VERY RELEVANT (VR) MEDIUM RELEVANT (MR)				RELEVANT (R) USUALLY IRRELEVANT (IR)		

As provided in Table 1, constructability is not limited to the design phase. Instead, it should be processed throughout the project lifecycle. As the project progresses, the impact of design errors on the overall cost of the project increases. Therefore, to achieve a higher impact, it is better to use constructability in the project initial phases, such as the design phase (Zolfagharian et al., 2012).

Nima et al. (2001) proposed 23 concepts to improve and facilitate constructability at different stages of the project lifecycle. In addition to the 12 constructability principles, these concepts have been considered a basis for evaluating the significance of constructability in VE and other relevant review studies, shown in more detail in Table 2.

Table 2 The concepts of facilitating constructability in the project lifecycle (Nima et al., 2001)

The concepts of improving constructability in the conceptual planning phase	
C1	The constructability plan of the project should be discussed and documented through the participation of all project team members in the execution plan.
C2	A project team consisting of the owner representatives, the engineer, and the contractor, should be formed and maintained to address the construction issue from the beginning to the end of the project.
C3	Knowledgeable and experienced people in the construction field should have access to the project's initial planning to avoid interferences and conflicts between designs and construction phases.
C4	Construction methods should be considered in selecting the type and number of contracts required for the project implementation.
C5	The main construction project schedule should be implementable in the construction and should be determined as soon as possible

C6	To conduct field operations quickly and efficiently, the main construction methods should be reviewed and analyzed as soon as possible to guide the design according to these methods. It can include recovery and improvement methods as well as sustainable planning.
C7	The site layout should be carefully considered to ensure that construction, operation, and maintenance are performed efficiently. In addition, it aims to avoid interferences between activities performed during these steps
The concepts of improving constructability in the preparation and implementation phase	
C8	Design and preparation plans should be compatible with the construction sequence. Therefore, the implementation plan should be addressed before the design and preparation.
C9	Advanced information technologies are essential for any field, including the construction industry. Therefore, using those technologies overcomes the problem of assigning specialized roles in this field and strengthens the structure.
C10	The designs should be configured by simplifying and reviewing the design by qualified personnel of construction and implementation. By so doing, the construction can be more efficient.
C11	Project elements should be standardized to the extent that they never adversely affect the project cost.
C12	Technical specifications of the project should be simplified and configured to achieve efficient construction without reducing the performance level or efficiency of the project
C13	The modulation and pre-installation of the project elements should be considered and carefully studied. Transportation installation, prefabricated modularity, and design should be among the desired options to facilitate construction.
C14	Project design should consider the access to human resources, materials, and equipment required at the site.
C15	The design should strive to facilitate construction in unfavorable weather conditions. They should plan for project construction in favorable weather conditions. Under changing climate conditions, the designer should increase the project elements used in the workshops in the form of prefabricated structures
The concepts of improving constructability in the operation phase	
C16	The sequence of field tasks should be adjusted to minimize the damage to the efficiency of some project elements. Additionally, the adjustment can reduce the need for scaffolding, the applied format, or the density of human resources, materials, and equipment
C17	Innovation in temporary construction materials or systems and innovative implementation of existing construction materials or systems that are not limited by design maps and technical specifications will improve the constructability.
C18	Innovation in new methods of using tools and technology, modification of existing tools and technologies, or introduction of new tools and technologies that will reduce labor intensity, and increase mobility, safety, or access, will improve constructability in the implementation phase.
C19	Introducing innovative methods to use existing equipment or modifying existing equipment to increase productivity will improve constructability.
C20	Encouraging the builders to use prefabrication to increase productivity, reduce scaffolding, and improve the project’s constructability under unfavorable weather conditions.
C21	Encouraging builders to innovate using temporary facilities will increase constructability.
C22	The good contractors' list should be documented based on quality and time. By so doing, contracts for future construction work should be determined not only based on low bids but also on other features of the project, such as quality and time.
C23	Evaluation, documentation, and feedback on issues related to constructability concepts should be maintained throughout the project to be used as the lessons learned in future projects.

2.2. Value Engineering

The Society of American Value Engineers (SAVE) defines VE as a set of systematic and applied techniques used to evaluate the function of a product or service. Further, the method ensures that the function is used at a minimum cost. The main difference between VE and other project optimization tools is in solving the problem and focusing on teamwork along with cost-benefit analysis of possible solutions. VE is about achieving the specified functions, at the lowest cost (or total cost of project lifecycle), without compromising quality, and with the reliability of performance or delivery (Pulaski et al., 2006). In large-scale projects, VE studies are usually conducted at 30 to 90 percent of the design stage. In such studies, technical requirements are considered, and significant savings are achieved in most projects. However, there are cases in which some reliable VE recommendations are not accepted. One of the reasons for losing such opportunities is that the proposed changes recommend modifying the underlying criteria of the project. From the employers' view, such modifications are considered a violation of the underlying criteria. In some cases, key decision makers may consider the significant changes at this level as an opportunity to unravel the ambiguities of the project. To provide logical and defensible answers to these questions and reduce the potential of losing such opportunities, a value planning approach has been considered to help the project clients to take maximum advantage of applying VE (Hammersley, 2002)

Systematic VE is reflected in the work plan, an applied formula that guides the team in the VE implementation throughout the process. VE's work plan is aligned with the step-by-step and creative problem-solving framework. There are various standard work plans for VE according to the country's laws or the executive organization. SAVE proposed a work plan that many researchers have used as the basis of their study. It consists of three main stages: pre-study, main study, and supplementary study (Al-Yafei et al., 2017). The stages and steps of the work plan are put into several classifications, as presented in Figure 1.

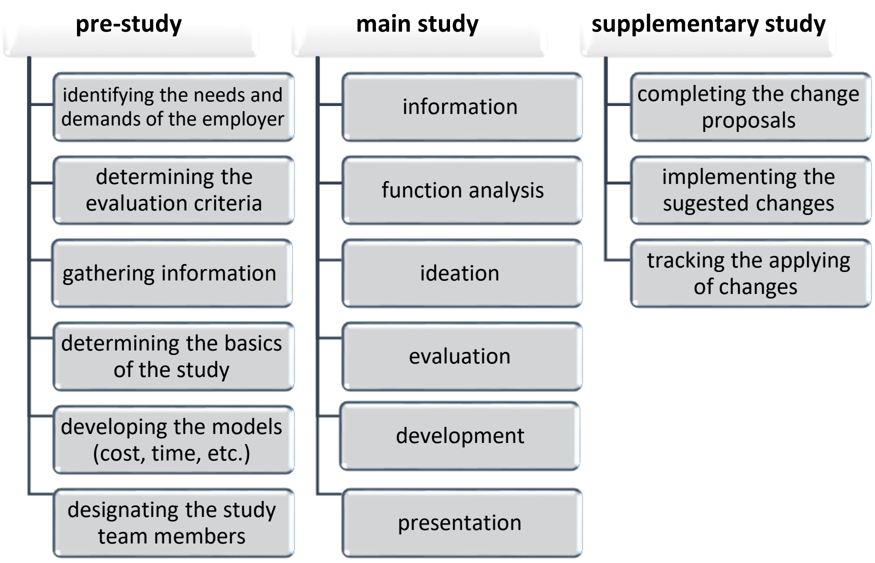

Figure 1 VE Work plan (Al-Yafei et al., 2017)

Despite a slight difference, most existing literature agrees with this classification. Sometimes, two or more stages is presented in one step. These stages focus primarily on three stages, that incluwhich

1. Pre-study stage: The activities done at this stage should fulfill the prerequisites and requirements of the main study phase, which involve identifying the needs and demands of the employer/customer, determining the evaluation criteria, gathering specific information, defining the basics of the study, developing the models, designating the study team members, and planning for holding study sessions. Furthermore, the activities also include collecting and compiling information as a pre-study report for the information phase in the main workshop.
2. The main study stage includes the main steps of implementing value methodology. The most crucial stage of this classification is the main workshop, including six-phases information, function analysis, creativity (ideation), evaluation (judgment), development, and presentation.
3. Supplementary study stage: The purpose of the supplemental study is to ensure the implementation and application of the recommended changes at the end of the value study. As long as the ideas of the study are not implemented, the study will not be practical. The most important task of the experts of the VE team or other experts approved by the management is to complete the changes recommended by the VE team. Moreover, they need to develop, complete, and present an implementable plan. It is one of the reasons why one of the project managers should be a member of the value team. While the value team leader may track the implementation progress, the project consultant (designer or planner) is responsible for the project implementation.

2.3. The Position of Constructability and Value Engineering in the Project Lifecycle

VE can be implemented at any project lifecycle stage to significantly impact the project results. However, it is evident that if it is implemented at the early stages of the project, less effort will be needed at the later stages (Al-Yafei et al., 2017). During the construction phase, value analysis may be performed by the designers or the contractors. As the project progresses, it is impossible to change the technical specifications without making changes to the project cost. The number and periods of the VE analysis are determined by the project's technical and financial conditions. In costly and complex projects, some supplementary intermediate studies may be conducted.

Meanwhile, small and uncomplicated projects may only require one analysis. The best time to start VE in a project is when the design is completed for approximately 25 to 35 percent, where primary systems have been determined, and the VE suggestions can be implemented based on the schedule without interruption. If the VE workshop is set up at this stage, it will achieve its highest efficiency since all design sections operate under VE supervision. Subsequently, about 60 to 70 percent of the design progress is suitable for performing VE because many details of the design and the selection of suggestions are done. The VE team allows the items to be correctly matched as it is an efficient help to the project team. In other cases, a VE workshop may be needed at the end of the construction phase. It is so when the project requires too much budget or focuses on the final design's effectiveness (Shariatmadar & Astaneh, 2013). Accordingly, due to this fact, there is various time conducting VE analysis or studies during the project lifecycle. Thus, different methods for using these services may be applied depending on the study's time.

Therefore, VE can be done either actively or reactively. The active approach uses VE to gather ideas from the beginning of design. Thus, different design options are considered, and the most cost-effective option is conducted continuously at the design stage. The reactive method gathers cost-effective possibilities by reviewing the design of other project personnel, such as builders and other design engineers. This task is carried out after completing the design or a specific component. Therefore, the reactive approach suggestions must be redesigned to improve the desired areas.

VE and constructability are complementary work processes that may be used as vital elements in achieving total quality. Constructability is a value management tool developed as an attempt to integrate design and construction activities. Figure 3 shows the ideal feedback channels associated with these two approaches in the facility life cycle (Morro, 1991), where VE is a feedback loop that is limited to the design phase, suggesting it to be performed at the early stages of the project to maximize the results. If VE is applied at later stages, it may increase the investment required for implementation and resistance to change (Al-Fadhli, 2020).

As the VE implementation is usually done when there is a limited chance for effective influence on the project cost or time, applying the constructability process allows the contractor or the owner to analyze the VE before the beginning of construction. This issue shows the significance of ongoing feedback or the availability of the lessons learned and experiences. The constructability includes all the feedback loops from the implementation phase shown in Figure 2, where the entry of executive experts at all stages of the facility cycle is desirable. Therefore, studying process constructability is valuable and can be considered a subset of the VE process.

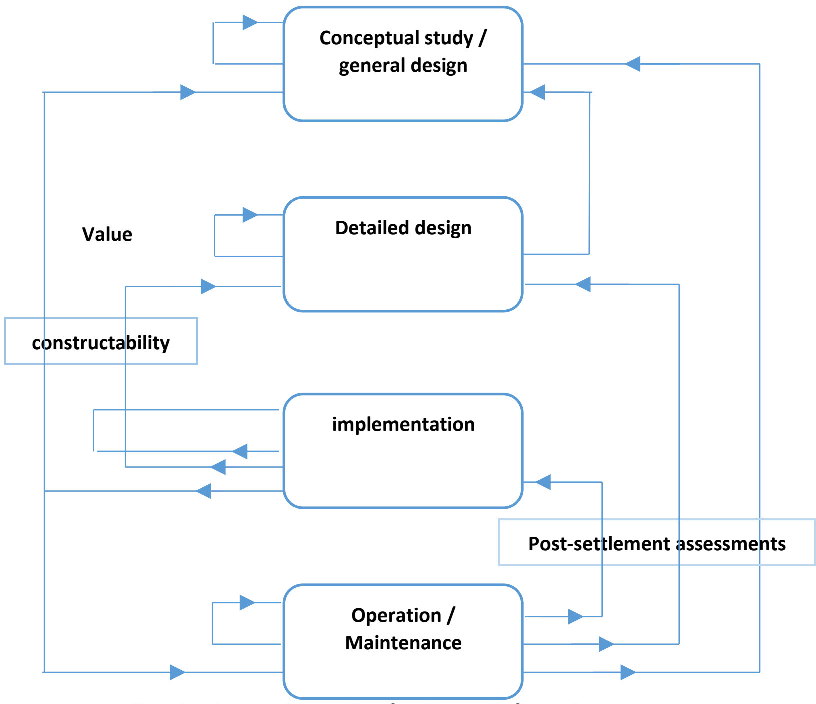

Figure 2 Feedback channels in the facilities lifecycle (Morro, 1991)

3. METHODS

3.1. The Basics of the Overview Method

The first review of research on a particular topic should be carried out as an overview (Higgins & Kanaroglou, 2016). The overview research methodology is appropriate for this study since the aim of this study is to provide a general view of the concepts and principles of constructability in the VE approach. Moreover, it is one of the studies that has not been discussed yet through systematic reviews. An overview is a term for different techniques of presenting a general view of an issue. This review can have various levels of structuring. Some researchers have equated an overview with a qualitative and narrative review. However, it seems more appropriate to consider it a semi-systematic study group (Tsagris & Fragkos, 2016), considering its purpose to review the texts and describe their features. In this method, there is no limitation on database selection. Therefore, after selecting keywords and search strategy, the approach focuses on selecting articles and studies with a higher combination of keywords. The selection criteria for screening articles are done according to the article's coherence degree with the objectives of this study. The research steps are shown in Figure 3.

Figure 3 The research steps

3.2. The Overview Steps

As this method is close to the narrative review approach, no systematic steps or stages are defined. According to the existing valid articles conducted using this method, the steps of the review are determined as follows (Banerjee & Ghose, 2016; de Bakker et al., 2010; Fischer & Onyango, 2012):

Step 1: Developing the screening criteria for eligible studies

The main research question was about finding the current position of constructability in the VE approach. This research determined some acceptance criteria to select articles, covering:

a. Language of the articles: English
b. Release time: 1990 was selected as the basis of the search limitation, given the start of the constructability concept expansion
c. Type of studies: books, articles, and dissertations published in valid scientific journals or conferences

Step 2: Search for studies

In this study, five databases in English were searched without a time limit. The searched keywords were *"Value Engineering" AND' (Constructability; OR buildability)'.*

Step 3: Selection of studies and data collection

Step three is selecting the appropriate articles. In this step, the articles found in the previous step were evaluated and screened step by step. To achieve this aim, the found papers were reviewed several times, and several of them were deleted. After searching and studying the mentioned databases and evaluating their compliance with the acceptance criteria defined in the first step, some articles related to VE and constructability were found. These articles were found based on the keywords. The details of the search and delete processes are presented in Table 3.

Table 3 The name of databases searched in the present study

Database name	Initial search	After the first screen	After the second screen	After the final screen
Science Direct (Elsevier)	43	22	0	0
Google Scholar	63	41	32	17
ASCE	34	6	6	5

Database name	Initial search	After the first screen	After the second screen	After the final screen
Springer	97	49	27	7
ProQuest	2	2	2	1
Total	239	120	67	30

According to Table 3, the process of selecting articles is as follows:

a. A total of 239 selected articles were reviewed. During this stage, titles unrelated to the research question were removed (119 articles were removed, and 120 remained).
b. Subsequently, the abstracts of the remaining articles were reviewed, and the abstracts unrelated to the research question were removed (53 articles were deleted, and 67 remained).
c. Then, the results of the remaining articles were studied, and the articles that did not answer the research question were removed (37 articles were deleted, while the rest remained).

Finally, 30 articles remained and proceeded to the next step. In qualitative studies, there is a possibility of confirming samples with limited numbers, such as this research. If so, it is emphasized that if the resulting piece is selected following the qualitative and systematic principles, it will cover all the information that the researcher is looking for (Lincoln & Guba, 1984; Tsagris & Fragkos, 2016). The specifications and frequency of the selected articles are presented in Table 4. It includes their release time, type and nature of studies, and research methodology.

Table 4 The name of databases searched in the present study

	Year of publication			Type of review studies				The research method of selected articles				
Group	1990-2000	2000-2010	2010-2020	Book	Article	Thesis	Government reports and documents	Case study	Survey	benchmarking	Book	Without mentioning the method
Total	10	8	12	2	25	1	2	8	12	6	2	2

According to Table 4, most studies in this review were conducted from 2010 to 2020. The data indicates the increased awareness of the significance of the place of constructability in value studies in the last decade. Most of these studies were conducted through survey methods. In addition, about 83 percent of them were published in Scientific databases, whereas the rest took the form of books, dissertations, or government reports.

Step 4: Bias risk evaluation in studies

The methodological quality or bias risk evaluation in the preliminary studies is necessary for a systematic review. The first qualitative validation of articles is to ensure the search process described in the previous steps. It means that if the selection of the articles in terms of the searched database were made correctly in the last step, the reviewer could then start extracting and evaluating the information from articles that meet the input criteria. The type of extracted data focused on the purpose of the review. At this stage, the data to be extracted and the data extraction process should be documented. The mentioned process has been observed in this research.

Step 5: Data analysis

In this study, a code was first assigned to all VE solutions. The code that covered the principles and concepts of constructability was screened in joint studies related to the purpose of the research. After that, the code was analyzed.

Step 6: Presenting the results and "summary findings" tables

The analysis results were presented in the format of tables.

Step 7: Results interpretation

In step seven, the details of the review results were interpreted.

4. RESULTS AND DISCUSSION

Citavi 5 software was used for taking notes. Table 5 shows a part of the approach related to this review step.

Table 5 A Part of the extracted codes related to the place of constructability in VE studies

NO.	VE solutions enhancing constructability	Cover-related constructability principles	Cover the concepts of improved constructability	The implementation phase of the proposed solution in VE	Source
1	Knowledge management	P12	C23	Pre-study/data collection	(Al-Fadhli, 2020)
	Strengthen communication between partners, and take advantage of the experience of contractors and subcontractors	P1,P2,P3	C1, C2, C3, C4, C5	Pre-study/data collection	
	Focus on the design phase	P2, P5	C8, C14 ,C21, C22	Main study/function analysis	
	Improve relationships between different parties in the project	P4	C2,1	Pre-study/identifying the needs of the owner	
	Use the suggestions and experience of contractors in practical options	P1, P2, P3	C1, C2, C3, C4, C5	Pre-study/data collection	
2	Risk identification	P6	C7, C8, C10, C15	Main study/function analysis	(Charles et al., 2017)
	Assessing the ability to build a project with the entry of the main stakeholders of the project (including design and construction personnel)	P1, P2, P3	C1, C2, C3, C4, C5	Pre-study/data collection	
	Structural study of design using building information modeling (BIM)	P11	C9, C18	Pre-study/preparation of models	
	Gathering evidence and lessons learned	P12	C23	supplementary studies	
3	Builder interaction between building owner, building designers, and builder	P1	C2	Pre-study/data collection	(Omigbodun, 2001)
	Provide extensive knowledge of the design team in providing appropriate options	P5, P8, P2	C10, C11, C13	Pre-study/data collection	
	Simplification	P5, P8, P2	C10, C11, C13	Main study/function analysis	
	Simultaneous engineering	P1, P2, P3	C1, C2, C3, C4, C5	Pre-study/data collection	
	Assemble a multidisciplinary team at the beginning of the project	P1, P3	C1, C2	Pre-study/Determining team members	
	Conduct audits and reviews	P12	C23	supplementary studies	
	Modular constructions	P8, P9, P10, P11	C13	Main study/development	
	Planning	P7	C1, C5, C8	Pre-study/data collection	

The focus of studies in the project lifecycle was investigated by considering the frequency of extracted codes related to the constructability principles in this step, the resultso of which is shown in Figure 4.

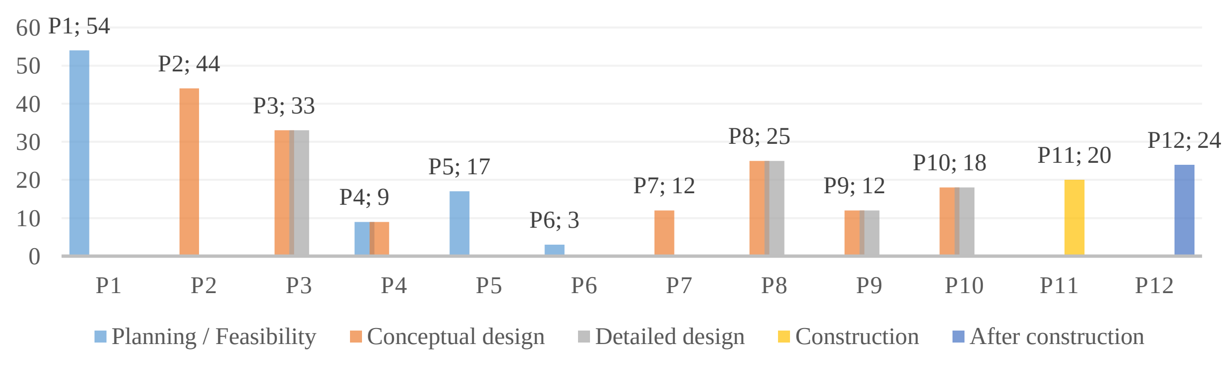

Figure 4 Extracted codes related to the place of constructability in VE studies

As argued earlier, Table 1 reveals that the best time to use the 12 principles of constructability in the project lifecycle varies and is not restricted to one phase. Thus, Figure 5 describes that some principles corresponding to the related phases will cover more than one column. For instance, the P3 principle stated that the best time to use it was both in the conceptual and detailed design phases. Its corresponding column in the diagram covered both phases, hence, the two columns. In contrast, other principles were shown in single columns, such as P1, whose best usage time was only in the planning and feasibility phase, and P2, whose appropriate phase was only in the conceptual design phase. Figure 5 shows the extracted codes related to the concepts of improving constructability, presented separately according to the degree of focus of studies in the project lifecycle.

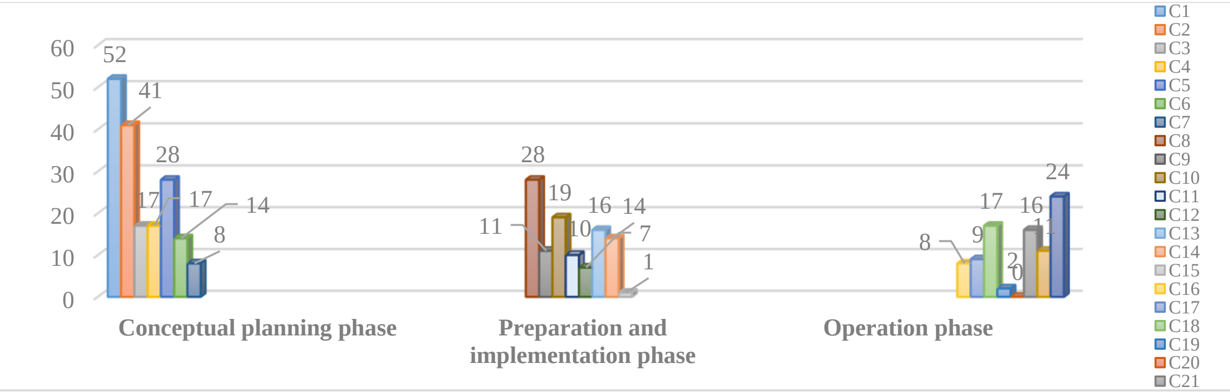

Figure 5 Extracted codes related to the place of constructability in VE studies

According to Figure 1, concepts C1-7 were defined in the conceptual planning phase. Meanwhile, concepts C8-15 were put in the preparation and implementation phase, and concepts C16-23 were carried out in the operation phase. Figure 5 shows that the concepts related to the solutions presented in the mentioned phases are shown separately based on their frequency. According to both diagrams, VE studies cover the principles and concepts of constructability at all project lifecycle stages. However, it is interesting that constructability as one of the functions of VE has received particular attention in the design phase. The majority of the existing studies in the initial phases confirm this issue. Based on this fact, however, as the project progresses, the impact of not paying attention to the design implementation and accuracy will affect the project's overall costs. Thus, constructability should be noted at the early stages of the project, such as the design stage, to achieve a higher impact.

In the continuation of the review, considering the scope of implementing the solutions presented in VE, codes listed in Table 5 were grouped in a similar concept. New codes were assigned to thus with similar concepts in a subgroup. These three groups of management, engineering, and environment were under the scope of implementing the solutions presented in VE (see Figure 6).

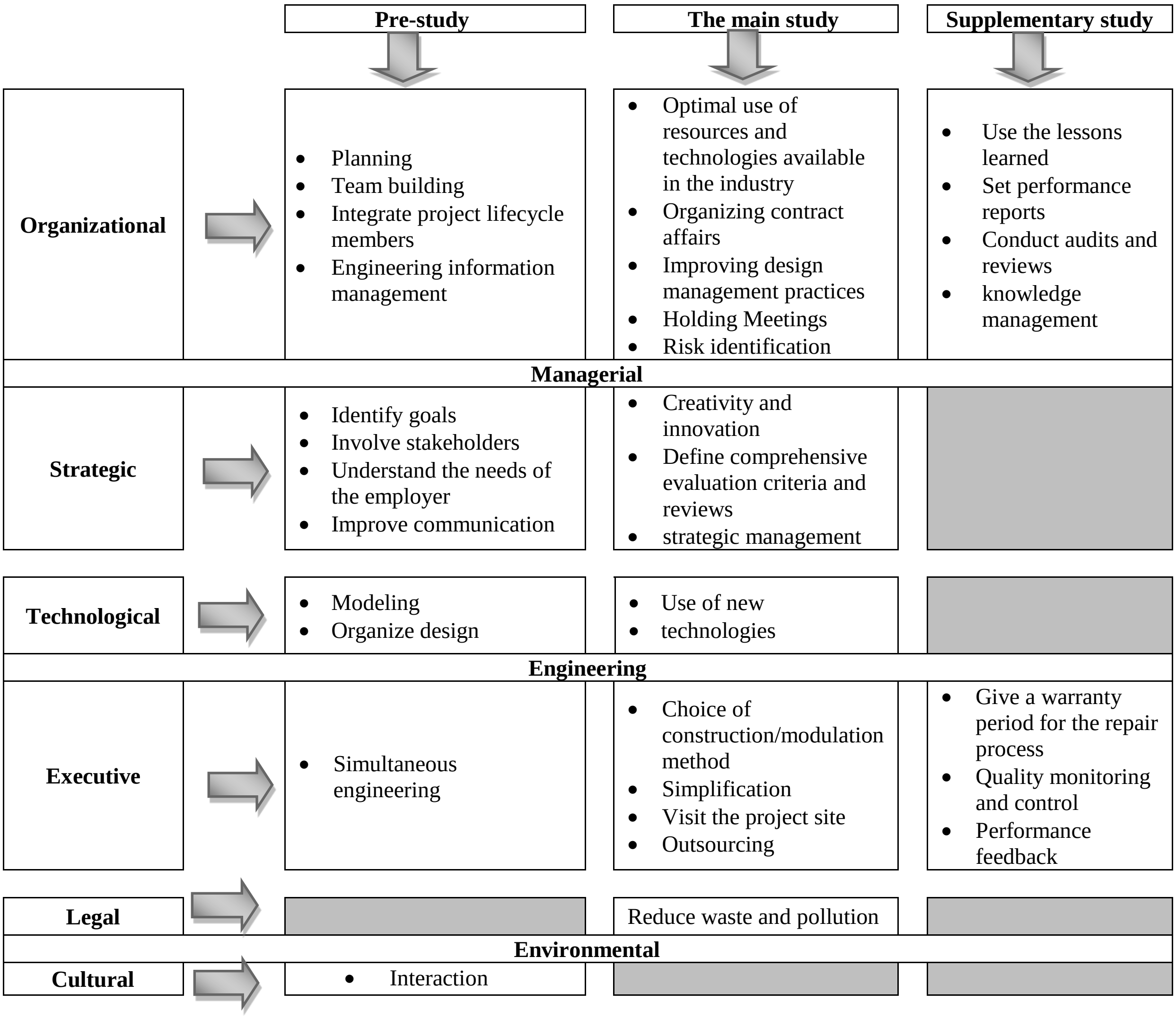

Figure 6 Coding pattern of the solutions presented in VE to improve constructability

In the vertical axis of Figure 6, three groups were defined, i.e., management with strategic and organizational subgroups, engineering with executive and technological subgroups, and the environment with cultural and legal subgroups. Then, the solutions with a nature appropriate to these groups and subgroups were included in the desired category. Despite being applicable to the nature of groups in the vertical axis, it is necessary to explain that these solutions were also classified according to the implementation phase of the solution presented in VE in the corresponding horizontal axis. For example, the team building solution is under the management solutions' organizational subgroup according to the vertical axis. This solution is significant in the VE pre-study phase considering the horizontal axis. In Figure 6, cases where a corresponding solution was not found in the defined phase, such as they were neglected or not studied, are shown with an empty box.

The results of Figure 6 are summarized in the following three items:

1. The majority of previous studies related to the place of constructability in VE focused on management solutions in the organizational and strategic fields, as well as the VE's pre-study phase main study.
2. The study gap in the legal aspects of environmental solutions is evident in the pre-study phase and needs more attention.
3. Despite their significance and positive effect on improving the place of constructability, environmental solutions (cultural and legal) had a small role in existing studies in all three phases of VE.

As mentioned earlier, it is necessary to ensure the implementation of value studies in the supplementary studies phase. However, various sections have been completely neglected in the studies related to the place of constructability in VE. These sections include an evaluation of the performance of management (strategic), engineering (technological), and environmental(cultural and legal) solutions.

The results of pattern coding extracted from the review in Figure 6 show that the most significant focus of studies on the place of constructability in VE was management principles and concepts. For instance, Al-Fadhli (2020) challenged this issue in a two-stage field study. In the first stage, the study identified the reasons for the failure of VE and constructability implementation in infrastructure projects. The obstacles to implementing these two techniques were identified by selecting several designs and construction experts in Iraq as the research's statistical population, and a questionnaire was distributed among them. The questionnaire analysis provided an integrated model for implementing VE and constructability in infrastructure projects. The proposed model was validated using the same statistical population in the second stage. The study found that the significance of constructability should be considered at all stages of the project lifecycle. However, it is emphasized that if there is a need to deepen the constructability technique as one of the functions of VE, it is better to pay special attention to it in the design phase. One of the reasons is that it can have the most impact. In this study, some management-organizational solutions were presented, among which we can refer to the "improving knowledge management" solution in the supplementary studies phase of VE. This solution implies constructability's P12 principle (the need for feedback). It improves the C23 concept (the need to document and record the lessons learned from the project) to enhance the constructability of the operation phase. In many articles reviewed in this study, the need to address this solution, which is one of the few studies focused on the supplementary studies phase of VE, has been repeatedly emphasized (Atabay & Galipogullari, 2013; Cha & O'Connor, 2005; Churcher, 2017; J. Mccuish & Kaufman, 2002; Miladi Rad & Aminoroayaie Yamini, 2016).

Presenting solutions such as "strengthening the relationship between partners", "possibility to use the experience of subcontractors," and "emphasis on improving the relationships between different parties" in this study and related to the pre-study phase of VE includes principles p1 (integration), p2 (construction knowledge), and P3 (team skills) related to constructability. It also covers five basic concepts for improving constructability in the conceptual planning phase (C1-5). This study refers to the solution of involving stakeholders in all phases of the project based on the p4 principle (defining the common goals) and concepts C1 and C2. They all emphasize the significance of the management-strategic dimension of the solutions presented in VE to improve constructability in the pre-study phase.

Similarly, addressing the solutions show the significance of different dimensions of the management group solutions in improving the place of constructability in VE. Some examples include the solutions focusing on "realistic planning" (Cha & O'Connor, 2005; Fong, 1996; Gambatese et al., 2007; Kusumi, 1989; Mccuish, 2010; Miladi Rad & Aminoroayaie Yamini, 2016); Omigbodun (2001) that covered P7 principle (plan) and concepts C1 and C5 and C8, or "strengthening team building" the studies that include principles P1 (integration) and P3 (team skills) and concepts C1 and C2 (Cha & O'Connor, 2005; Gambaese et al., 2007; Kusumi, 1989; Mccuish, 2010; Miladi Rad & Aminoroayaie Yamini, 2016) , as well as the solution of "improving engineering information management" (Austin & Thomson, 1999; Cha & O'Connor, 2005; Kusumi, 1989; J. Mccuish & Kaufman, 2002; Omigbodun, 2001) that includes principles P1 (integration) and P10 (project specifications) and concepts C6, C8, C10, and C12.

In other studies, Charles et al. (2017) conducted a case study and SWOT analysis in Nigeria to evaluate the impact of constructability and VE on construction projects. First, about 300 questionnaires were distributed among project managers, architects, engineers, consultants, and contractors. This questionnaire had two parts. The first part was intended to analyze the industry and identify the weaknesses, opportunities, and threats in the country's construction industry. In the second part, the questionnaire examined constructability and VE in the construction industry of Nigeria. The findings of this study showed a lack of serious focus on constructability in implementing VE in the construction industry in Nigeria. Thus, a framework indicates how integrating these two concepts can enhance knowledge and facilitate implementation. This study has stated other solutions, such as "identifying risks". These solutions are based on principle P6 of constructability (external factors affecting the project) and concepts C15, C10, C8, and C7. Again, in these cases, the significance of management group solutions was evident. This article referred to other solutions, such as examining the constructability of the presented designs using Building Information Modeling (BIM). In addition, it emphasized design modeling and organization, covering principles P11 (using technology) and concepts C18 and C9 related to improving constructability, which highlight the significance of engineering-technological solutions.

Other review studies (Gambatese et al., 2007; A. A. E. Othman, 2011) have referred to the significance and role of new technologies in VE studies to improve constructability. Solutions based on the implementation of simultaneous engineering and reducing the gap between the design and construction phases have been proposed, which emphasize the improvement of engineering-implementation solutions (Al-Fadhli, 2020; Chasey & Schexnayder, 2000; Pocock et al., 2006). Industrialization methods, such as assembly in construction and modularization (Cha & O'Connor, 2005; Hanlon & Sanvido, 1995; Mccuish, 2002; Omigbodun, 2001; Russell, Gugel, et al., 1994), and field visits and site management (Atabay & Galipogullari, 2013; En Mao et al., 2018; Miladi Rad & Aminoroayaie Yamini, 2016a) are among the other solutions related to the engineering-implementation group. These solutions focused on the main study phase of VE.

Another study by Omigbodun et al. (2001) examine dhow value engineering helps achieve an optimal solution to a design problem in the construction industry through an analytic comparison between several projects in the Middle East and West Africa. In that study, "constructive interaction between construction owners, designers, and builders" was introduced as a solution to improve constructability through VE. It is one of the few cultural solutions presented in the environmental group. As mentioned earlier, despite the significance of environmental issues from legal and cultural aspects, which have a significant impact on enhancing the place of constructability in VE, the existing studies have not addressed them in depth. It can be assumed that perhaps focusing on this field and strengthening various aspects of environmental dimensions will significantly affect other areas.

For example, improving the cultural growth of the organization and the flexibility of traditional thinking governing various aspects such as team building and improving communication will also be effective. In addition, concerning legal solutions, removing the obstacles related to law, such as competitive restrictions in tenders, will provide the context for more principled selections.

Therefore, it is helpful to conduct more studies in these neglected areas. This review covered various managerial-organizational aspects in the engineering-implementation group relatively well. These include the use of "recording the lessons learned", "preparing regular reports" (Churcher, 2017; DOT, 2015), "conducting audits and reviews" and "performance feedback" (O'Connor & Miller, 1995; Omigbodun, 2001; A. A. E. Othman, 2011), and covered solutions such as "guaranteeing the repair process" (Atabay & Galipogullari, 2013), and "monitoring, and quality control" (DOT, 2015; A. A. E. Othman, 2011). However, given the purpose of the supplementary studies phase, which is to ensure the implementation and application of the changes recommended at the end of the value study, this phase requires more attention. The focus on this VE phase was low, and attention to the issues related to monitoring and evaluating the performance of management-strategic solutions as well as environmental solutions in both cultural and legal subgroups was neglected in this phase.

5. CONCLUSION

VE workshops are expected to identify and improve alternative methods to meet the project needs that save the capital or operating costs for the project sponsor. Constructability is one of the techniques used to prevent problems and increase costs due to factors related to the efficient ability of the contractor to improve the project. This study aimed to evaluate the place of constructability in VE and to provide suggestions for its improvement. Thirty documents were selected, studied, and assessed using the overview method by applying the defined criteria for the review to achieve these goals. In this process, the position of constructability in VE was initially evaluated. It was determined which VE solutions include the principles and concepts of constructability. The density of existing studies on this topic primarily covers which stages of the project lifecycle. These solutions were classified into management, engineering, and environment. The reviewed articles summarized to what extent they are focused on these principles and concepts, in which VE phase these solutions are implementable. Yet, it was examined what solutions have been neglected and whether addressing them can create an appropriate context for improving the place of constructability in VE. Then, it was considered that each of these overlooked solutions requires more attention in which VE phase. In addition, given the neglected sections, some solutions such as trying to improve the cultural growth of the organization and the flexibility of traditional thinking governing it, or resolving legal obstacles such as competitive limitations in tenders, and the need to monitor and evaluate the performance of management-strategic solutions as well as environmental solutions were suggested in two cultural and legal subgroups. The purpose was to create a place of constructability in VE.

Prior to this research, the position of constructability in VE had not been evaluated in a focused and separate manner. It was unclear which VE solutions were implementable in which phase of the value project to improve constructability. The findings of this study indicated that a large part of the proposed VE solutions that cover the principles and concepts of constructability is focused on the pre-study and the main study phases of VE and the management subgroup. Significant areas related to the supplementary studies phase or environmental solutions, including cultural and legal issues, have been neglected. Hence, addressing them provides an appropriate context to improve the place of constructability in VE. Moreover, identifying and implementing them can pave the road for leading studies. Given the gap in existing studies and the lack of addressing the environmental solutions related to cultural and legal issues, it is suggested that future studies consider the output of the model analysis of this study as a basis for designing a framework to examine the degree of constructability in the VE project. Moreover, the present study suggests future research to identify the obstacles and enablers to facilitate their implementation while identifying the neglected environmental solutions through field research.

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