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Status of value management studies in construction projects: A systematic review

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ABSTRACT

The focus of this paper is to examine the status of Value Management (VM) studies in specific construction projects by reviewing 104 relevant articles published from 2001 to 2021. The analysis indicates that the project type, project size, and research theme of VM studies conducted on various construction projects are all significantly correlated. Building projects and large-scale projects are identified as the most favoured subjects of VM studies to date. Meanwhile, researchers are keener on investigating the performance, impacts, and strategy of VM in different construction projects. Based on the status observed, some possible directions for future research are addressed. This paper not only provides evidence to demonstrate VM's broad applicability, but also serves as a favourable reference for researchers to select research issues and topics with greater freedom to develop necessary VM studies in the construction industry.

1. Introduction

Value Management (VM), also known as value engineering in the US, is an effective method for defining and maximising value for money [1]. Value is the balance of what to gain (e.g. benefits) for what to give (e.g. costs) [2]. For a project, VM seeks to maximise its functions at the lowest overall cost without sacrificing quality and performance, in order to provide clients with the optimal benefits and value for money [3]. Evolved from the concept of value analysis from Lawrence Miles in the 1940s, VM was initiated in the context of manufacturing [4]. Subsequently, it was introduced to the construction industry in 1963 to better control the value of construction projects [5]. The approach has achieved great success in the US, and invaded many countries in the last century, such as the UK, Australia, China, Malaysia, Saudi Arabia, etc [6].

Nowadays, broad recognition has been achieved of VM as a well-established approach to attain the best value for money for clients in the construction industry [7]. [8] defined VM as a proactive, creative, problem-solving practice to maximise the functional value of a project with minimum cost by managing its development from concept to operation through structured multidisciplinary team exercises. It is a kind of facilitated team practice that enables good and effective decision-making processes. Optimisation of project functions and costs is one of the optimal outputs of VM. In general, proper VM is capable to bring at least 5–15% total cost saving for a project [9]. The innovative ideas/alternatives generated from multidisciplinary VM team efforts are designed to enhance project functions and value [10]. Such enhancements empower corporation to improve not only clients' satisfaction but also self-competitiveness in order to stay ahead of competition [11]. Furthermore, VM also aids in defining clearer roles and responsibilities for individuals, resolving ambiguities and misperceptions in projects, and improving relationships among stakeholders [12].

The construction industry is one of the vital sectors that significantly impress economic growth [13]. It is often leveraged by developing countries as a platform to stimulate economic transformation towards developed nation status [14]. The widespread adoption of VM has been advocated to lead the industry to consis-

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tently satisfy clients' needs. Despite the fact that VM has a long history in the industry with great track records in project planning, cost control, conflict management, and dispute resolution, its development remains in its infancy in many countries [15]. The levels of its acceptance and application in different construction projects are still unsatisfactory and confined [16].

2. Background

Developed countries, like the US and UK, have already practised VM widely in different construction projects [17]. The US government has mandated VM for all public projects over USD 2 million, while for projects of the transportation sector, the number is even stringent, as low as USD 100,000 [18]. [19] observed that VM has evolved into an established service with commonly understood tools, techniques, and styles for various construction projects in the UK. This may be so in the US and UK, whereas the circumstances in other countries are by no means so splendid. [12] revealed that VM possesses a relatively low usage in Singaporean building projects, and many prefer it to be adopted on smaller projects. In Malaysia, it is farsighted to stipulate VM mandatory enforcement for public projects by the government, while the provision is only limited to large projects with cost over MYR 50 million (≈USD 12 million) [20]. Such costly projects simply account for a relatively small proportion in the industry and can only be undertaken by the highest-grade contractors [16], implying most construction projects in Malaysia with rare exposures to VM. In China, the use of VM sharply declined after the country started the transition from planned economy to market economy [21]. Within the limited use, VM is mostly adopted for Chinese infrastructure projects, while its use in green building projects remains scarce [22]. It was not until this century that many African nations began to aware and embrace this innovative approach [23]. This differentiated situation could be attributed to the lack of awareness of VM's existence and broad applicability, which significantly impedes the approach to obtain a wider and more balanced application in different construction projects [15].

In terms of VM's applicability, VM can be applied to any type of project, irrespective of project size/cost [24]. Costly projects, repetitive projects, complex projects, projects with restricted budgets, and projects with compressed design programmes, were suggested suitable for VM owning to their high potential on the acquisition of greater VM benefits [9]. But VM is not restricted to the above projects and can be applied to any project/asset, or parts of buildings/-subdivisions of the projects [9]. With the increasingly deepening of VM study, the broad applicability that VM possesses has led to a great number of research focuses and potentials. Increasing VM studies are now undertaken by targeting construction projects with specific types. To guide future research, it is important to understand the current status of VM studies in different construction projects, so that future studies can be suitably developed to cater to the needs from present scenario. Until now, literature that provides such information remains absent. This study attempts to supplement this gap.

Herein, a review of literature in relation to VM studies in specific types of construction projects is presented to explore the research status and knowledge gap. Literature review is recognised as an effective method in providing useful information on the current practice [25]. Also, it aids researchers in capturing the trends and inspirations for future studies [26]. This review attempts to reinforce the perception of VM's broad applicability, and provides information for scholars to obtain a thorough picture of past, current, and even future research on the topic. Its recommendations can serve as a favourable reference for future studies with greater freedom in selecting research issues and topics, so as to promote the development of VM studies in the construction industry.

3. Methodology

3.1. Paper retrieval

This review was undertaken through a concentrated comparison of relevant publications on VM domain in different construction projects to understand the research status. A systematic approach was pursued for the retrieval and screening of relevant publications. Papers addressing VM studies for specific construction projects were acquired through the search in major academic databases in engineering and management fields. The method employed herein for selecting appropriate search outputs to review was adapted from [27] and [28] owing to the similarity of research purpose. A three-step framework (see Fig. 1) is structured to illustrate the paper retrieval and selection process.

The first step was an initial comprehensive search of publications. Two academic databases (*Scopus* and *Web of Science*) were chosen for the search due to their influential positions in research community and a great number of publications they own in VM domain [29]. Keywords for searching included *Value Management*, *Value Engineering*, and *Construction Projects*. The terms adopted either contain a unified concept or have a comprehensive lexical category designed to furthest enlarge the emergence of publications in relation to the topic. Time of retrieved publication was limited to the period from *01/01/2001* to *15/02/2021*. Reason for this chosen timeframe is that increasing research awareness was aroused based on VM's applicability in this century, and great efforts were done on VM research to improve its infancy in the academic base [30]. It is considered that the state-of-the-art research on the topic can be clearly depicted by reviewing the literature from this time span [31].

A great number of publications were retrieved from the initial search while some appeared to be uncorrelated. Considering the amount of data, processes for filtering out irrelevant publications were necessary. The second step was the filtering process. Criteria to screen out the inappropriate publications were set as follows:

- Only research articles in academic journals were selected to review in consideration of their significant impacts on leading research direction. Book reviews, editorials, review and conference papers were eliminated. This was also to ensure that all retrieved papers could be investigated using an identical analytical construct in terms of research aims and methodologies [27].
- Articles that do not contain the keywords in their titles or abstracts were screened out.
- Articles in languages other than English were excluded.

In the third step, a brief review of the remaining articles' contents was performed to determine their relevancy, so as to select appropriate articles for this review. The papers were examined according to whether the specific type of project studied is explicitly specified. Following the audit of paper relevance, a total of 104 articles were retained as the final output for further in-depth analysis. One limitation was that owing to the inaccessibility of full text of a few articles with potential relevance, the selected publications may not be able to cover all the relevant studies in this domain. However, the overall development of research trends still can be reflected.

3.2. Content analysis

The selected publications covered a wide range of research views on VM studies in various construction projects. Content

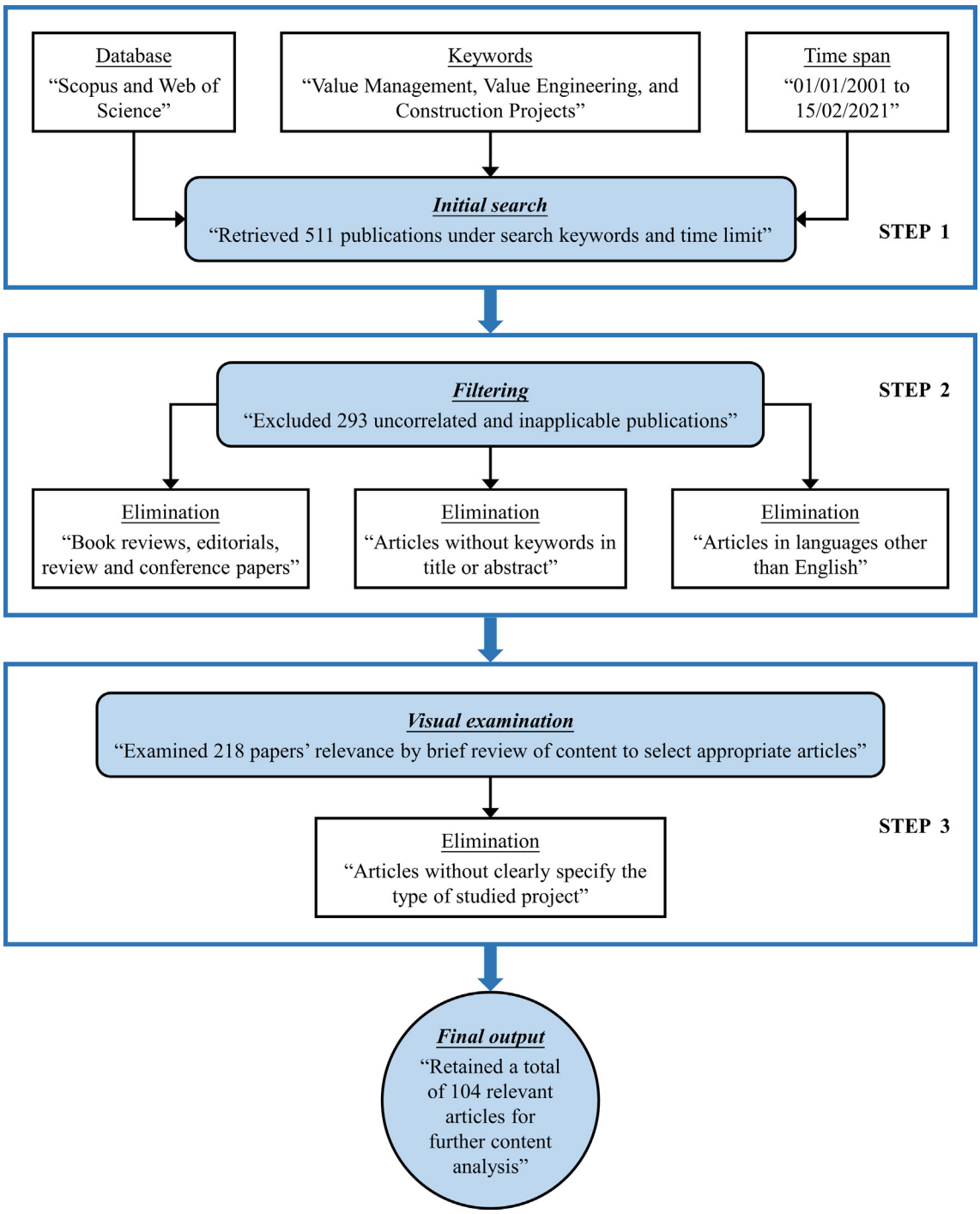

Fig. 1. Framework of publications retrieving and screening.

analysis was used to facilitate an in-depth review. It is a structured and systematic approach to compress numerous words of text into fewer content categories based on explicit rules of coding to identify study components and themes for literature review [32]. The technique empowers scholars to adopt an organised manner to examine large quantities of textual data, to identify the focus of subject matter, and to capture the emerging patterns in literature [33]. Results of content analysis on the selected articles are summarised in **Table A** in the **Appendix** section. Discussion of the results is presented from the views of publication profile and research status.

4. Results and discussion

4.1. Overview of selected publications

4.1.1. Published time

The annual productivity of relevant articles was found to remain at a low level in the early 2000s. This could be explained by the fact that the broad applicability of VM was not widely aware at that time [17], while efforts have been constantly made to raise its recognition. It was not until 2015 that the annual output of pub-

lications began to keep at a relatively high level. Notably, over 60% of the articles were centralised between 2015 and 2021, particularly in 2020 with a maximum of fifteen publications. The overall trend suggests that research interest in the topic is increasing. This could attribute to the rising awareness of VM applicability by previous sustaining endeavours on showing various successful VM applications.

4.1.2. Published journals

The selected articles are sourced from a total of 72 academic journals. Interestingly, the distribution of journals and articles appears to be relatively balanced. 78% of the journals possess only one relevant article. Only four journals involve articles of more than three, i.e. *International Journal of Technology* (6 articles), *Journal of Construction Engineering and Management* (5 articles), *PCI Journal* (4 articles), and *Ain Shams Engineering Journal* (4 articles).

4.1.3. Geographical jurisdiction

Geographical jurisdiction refers to the country/region from which the data/case was derived in the selected articles. The mainstream markets for specific projects in VM studies were found mostly situated in Asia and the Middle East. The relatively less-flashy performance in the American and European markets could be attributed to where VM has already attained wide and successful applications [34]. Extensive research efforts to drive its various applications may therefore be less demanded. The observed depression in most African markets could be explained by the late introduction of VM to the continent [23], resulting in a weak research awareness based on VM applicability. Notably, over 90% of the articles focused on projects under the circumstance of a single nation. Only a few articles involved cases of multi-country. Most of these articles were found to examine the multinational markets that possess similar economic, social, or cultural environments. VM is the practice that involves activities of multidisciplinary teams, local regimes, and society [19]. The evident variation in geographical jurisdiction seems to indicate that VM studies are more subject to the national or regional contexts of the projects. Also, the generalised findings across national or regional borders might produce potential references while practical implications could be limited.

4.1.4. The adopted research methods

For research articles, it is worthwhile to pay attention to the adopted research methods since their effective applications would result in reliable and practical results for the associated study [25]. Case study was found to be the most favoured method adopted by 54% of the articles on VM in specific construction projects. This could be explained by the fact that case study is designed to investigate why and how a phenomenon is affected by the context of a specific single case or multiple cases [35]. Of the publications that used case study method, 82% were found to present arguments based upon a single case, while the rest examined multiple cases, with a maximum case size of 11 [36] within an individual study. For questionnaire surveys and a mix of qualitative and quantitative methods, the usages account for 11% and 26%, respectively. A category named "others" was assigned, with 9% of articles associated. It relates to the approaches like observation, group discussion, and conceptual methods that were less commonly used in the selected publications. The less utilisation of these methods could be attributed to the need for more convincing results or actual application on the topic, or in considering sole conceptual analysis, without empirical studies to draw practical conclusions.

4.2. Research status

4.2.1. Research status based on project type

This review is based on an examination of how current research supports the broad applicability of VM, which is applicable to any type of project. The specific construction projects targeted by the selected publications were identified and found to be diverse. In order to facilitate better analysis, a common classification rule [37] based on project application area was used to categorise the studied projects into three major types, namely building projects, infrastructure projects, and industrial projects. The description of each type of project can be found in Table 1.

Table 2 summarises the number of articles connected to each type of project by period, in order to understand the status of VM studies based on project type. **Eq. (1)** was used to obtain the corresponding percentage of relevant articles under the same period.

$$P(\%) = (N/T) \times 100\% \quad (1)$$

Where N is the number of articles related to a type of project in a period, and T is the total number of articles related to all types of projects in a period. The equation was correspondingly adapted for the calculation of percentage in Tables 3 and 4.

It is noted that some articles focused on more than one type of construction project. Multiple calculations on these articles

Table 1
Description of the three major types of construction projects.

Project type	Designed by	Characteristics and scopes
Building	Architects	• Spaces involved are typically developed for people's living, working, and social interaction.
		• The building and its system generally comprise the majority of project costs [38].
		• Scope of application areas commonly involves residential, offices, schools, institutions, medicals, commercials, warehouses, etc.
Infrastructure	Civil engineers	• Primarily perform a function that is integral to the effective operation of a system.
		• Provide capacities such as transportation, transmission, distribution, collection, and the interaction of goods, services, or people [39].
		• Mostly span a wide geographical region, affect multiple jurisdictions and stakeholder groups.
		• Application areas include railways, roads, highways, bridges, tunnels, canals, pipelines, electrical transmission or distribution, fibre optic networks, etc.
Industrial	Process engineers (namely mechanical, industrial, chemical engineers)	• Usually require large capital investment for the use of extensive piping and mechanical equipment.
		• Scope of this designation contains projects associated with power plants, manufacturing plants, refineries, steel mills, ocean construction, etc. [40].

Table 2
Distribution of articles by period and project types.

Project type	Period								Total	P(%)
	2001–2005		2006–2010		2011–2015		2016–2021			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)		
Building	2	33	7	32	13	59	35	65	57	55
Infrastructure	4	67	14	64	9	41	16	30	43	41
Industrial	1	17	2	9	0	0	4	7	7	7

Note: the total percentage of a period may exceed 100% due to some articles examined more than one type of project.

Table 3
Distribution of relevant articles by period and project sizes.

Project size	Period								Total	P(%)
	2001–2005		2006–2010		2011–2015		2016–2021			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)		
Large	1	50	13	93	10	100	24	83	48	87
Small	1	50	5	36	1	10	6	21	13	24

Note: the total percentage of a period may exceed 100% due to some articles examined more than one size of project.

Table 4
Distribution of relevant articles by period and identified research themes.

Research theme	Period								Total	P(%)
	2001–2005		2006–2010		2011–2015		2016–2021			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)		
VM performance and impacts	4	67	11	50	18	82	32	59	65	63
VM strategy	3	50	12	55	8	36	28	52	51	49
VM influencing factors	2	33	2	9	3	14	14	26	21	20
VM application status	0	0	1	5	4	18	7	13	12	12

Note: the total percentage of a period may exceed 100% due to some articles examined more than one research theme.

were executed in the corresponding section when applicable. The total percentage of some periods would hence exceed 100%. The percentage can reflect the extent of research attention and efforts being paid to studying VM for each type of project during a period. Meanwhile, comparing the corresponding percentages can reveal the extent's tendency to change over different periods.

In an overall view, 55% of the articles were related to VM in building projects, making this type of project the most favoured in VM studies over the last two decades. This was followed by infrastructure projects as another major subject of VM studies, with 41% of articles associated. By contrast, the scenario of VM studies in industrial projects appears to be relatively depressed, with only 7% of articles involved. This generates a significant gap that VM studies in industrial projects are often neglected. Such negligence could be attributed to their lack of attention, awareness, or reference in the field of construction [147]. It is laudable that efforts to incorporate building projects into VM studies have expanded over time. While continuing such efforts, it is recommended to place additional emphasis on VM studies for industrial projects.

VM has the ability to be applied to any type of project to exploit its favourable role. This can be demonstrated by various projects targeted by the selected studies. Except for generic buildings [12,36,41–56], the investigated buildings' specific roles included residential/housing [57–70], commercial [60,71,72], medical [73,74], institute [75,76], art [77,78], parking [79], office [60,75], building service [80–82], as well as multiple use [83–85]. The form of building covered high-rise [69,70] and multi-story complexes [76,86]. In addition to conventional buildings, emerging holistic/-conceptual buildings like green buildings [22,68,87–89], sustainable buildings [16,62,90–93], were also appeared in the selected articles. The majority of studies on merging VM and sustainable/-green building concepts were published over these years, suggesting increasing interest in this regard. Such growing interest could be attributed to VM's great potential in improving building design, construction, and operation in order to achieve the requirements of sustainability [3].

Apart from generalised infrastructure [47,94–101], projects associated with the transportation sector [10,102,103], particularly highway/road [104–115], bridge [116–120], railway [121–124], and tunnel [125,126] were found to be the most frequently studied among the selected articles. Projects related to water transmission (e.g. water supply and transport [127,128], sewage discharge [129], underground water retention [130]) were also included. Other areas of infrastructure that have been covered but less studied were bay [131], dam [132], pipelines [133], and exploration construction [134]. It was found that most infrastructure-related VM studies in the recent decade were conducted on road and railway projects, indicating a growing interest in these projects. Despite fewer VM studies in industrial projects [45,46,135–139], cases were still found diverse, such as power plants, chemical plants, gas-oil plants, etc.

VM's broad applicability is demonstrated by the various types of projects studied by the selected articles. The differentiated research efforts observed, on the other hand, revealed that a clear gap still exists in VM studies conducted on construction projects of different types. VM is also recommended for projects of any size. It is worthwhile to explore whether project size shows any pattern that influences VM studies in construction projects.

4.2.2. Research status based on project size

Of the total 104 articles reviewed, 55 were found to explicitly state the scale/cost of the projects studied. They were extracted for the analysis of status of VM studies based on project size. To date, global consensus on the particular definitions of projects of different sizes has yet been achieved [140]. The categorisation of project size herein was based on either the article's specification or the collective cluster of project costs. Meanwhile, other information (if stated, e.g. project duration, project complexity, workload, firm size, etc.) would provide a reference for further clarifying the size of the project. Previous studies [140,141] suggested that the cut-off cost for demarcating smaller construction projects should not exceed USD 10 million. Thus, small construction projects with costs indicated were all clustered under USD 10 million in this study. The majority of them were found for a cost below USD 5 million, with a few for even lower than USD 1 million [69,71,83]. Many large-scale projects were identified with a cost between USD 10 million and 100 million, as well as including some mega projects over USD 1000 million [48,55,63,94,103,114,119,121–123]. One element that attracts mega projects to embrace VM is the tangible cost reduction. According to [121], millions of dollars could be saved as the result of VM conducted on mega railway-station construction work. This was also the case for Hong Kong's greatest rail project, where the use of VM saved billion of Hong Kong dollars while maintaining project performance [122]. Furthermore, the feasibility of an IDR 36 Trillion (≈USD 2500 million) High-Speed Train project in Indonesia was facilitated by the optimisation of function and cost through VM [123]. Most mega projects studied were found connected to infrastructure, while other types of mega projects remain a lack in VM studies.

The frequency of different sizes of construction projects studied by the relevant articles is summarised in Table 3 by period. Calculated by the adapted **Eq. (1)**, the percentage of articles within the same period is also presented. It is noted that some articles focused on more than one size of project within a study. Thus, the total proportion of a period could be higher than 100%.

0.87% of the articles that stated the size/cost of the studied project were found to examine construction projects of larger sizes. Such a high proportion makes large-scale projects the most favoured subjects of VM studies in this century. The number of VM studies conducted on large projects has been trending upward in recent years, indicating a growing study interest in this size of projects. It could be due to large projects having greater potential in achieving more evident benefits from VM implementation, such as higher visible budget reduction, clearer cost-effectiveness, etc [9]. Another explanation could be that in countries like Malaysia [20], South Korea [56], and others, VM is a mandatory task in managing large projects due to legislation. It might therefore drive scholars to be more inclined to conduct VM studies for projects of larger sizes. Additionally, the percentage of VM studies in large construction projects has maintained relatively high under each period. This further indicates that VM studies for large construction projects have steadily maintained a high degree of research awareness in this century.

Regarding construction projects of smaller sizes, however, the status of VM studies is not so splendid. The total number of VM studies relating to small projects is less than a third of that relating to large ones. This results in a considerable gap in which VM research on smaller construction projects is overlooked. The intensity of studying VM for small projects was observed still not strong enough. One prominent challenge that small projects commonly face is their successful completions and deliveries within restricted budgets [140]. As an effective method for cost control, VM appears much imperative to be used in small projects, making the implication of obtaining maximum value for the least amount of money more pronounced [9]. Besides, small projects are commonly contracted by Small and Medium Enterprises (SMEs) [140]. Project function optimisation and deliverable enhancement through VM would aid SMEs in better handling the challenges of high competition and low profitability of small projects [142]. However, the innate characteristics of small projects like short duration and fewer people involved seem to impede these projects from widely embracing VM, as the approach requires time and expertise [18]. Therefore, a call is aroused for more research to aid smaller construction projects in better using VM and achieving its benefits.

In addition, the VM research pattern between project type and size was examined. Both small and large sizes were found to be involved in the three types of projects. Such scenario effectively supports the broad applicability of VM to be applicable to any construction project without consideration of project type and size.

4.2.3. Research status based on study theme

By content analysis, the themes of VM studies in specific construction projects were examined. Four major categories of study themes were identified, namely (1) VM performance and impacts, (2) VM strategy, (3) VM influencing factors, and (4) VM application status. Table 4 provides the number of articles related to each identified theme by period, as well as the calculated percentage of articles under the same period. Notably, some articles contain more than one research theme. Multiple calculations of the related papers to the corresponding theme were allocated. Hence, the total percentage of a period could be greater than 100%.

According to the results, researchers' most favoured theme was investigating the performance and impacts of using VM in various construction projects, which accounted for 63% of the articles. Meanwhile, the extent of research attention and efforts on the theme within each period has been maintained at a relatively high level. It was followed by 49% of articles focusing on another major theme that is VM strategy for different construction projects. By contrast, not much attention was paid to the influencing factors and application status of VM in specific construction projects. Research efforts on these two themes are deemed at an inadequate level. Notably, the quantity of studies related to all themes has increased over time. Particularly in 2016–2021, substantial growth has been demonstrated. This indicates a rising interest in VM studies on all identified themes over these years. It is expected to continue expanding in the future. Further descriptions of each theme and its status are provided as follows.

"*VM performance and impacts*" refers to the outcomes and benefits that VM produces for various construction projects after its adoption. Studies related to this theme unanimously praised that the prominent output of VM is the effective control and reduction in project cost. Findings drawn in most articles stated that VM implementation would result in around 5–15% cost saving for construction projects, regardless of project type and size. Several studies revealed that such a cost-cutting range can be greatly exceeded. Two alternatives proposed by [64] through VM's study considerations were clarified to reach 15–40% cost saving for a residential project. This also occurred in a dam project, when VM deployment resulted in a cost reduction of 30–40% [132]. In addition, [128] proved that a rigorous and methodical VM process can save as much as 41% of the overall cost in infrastructure construction. The approach managed to reduce 20% of the design cost for an airport pipeline building project, as well as 40% of the life cycle cost under the assumption of ten-year operation [133]. However, cost savings of such magnitude were only found in large building and infrastructure projects. Ambiguity remains in whether VM can accomplish that for industrial and smaller projects. Aside from cost reduction, publications on this theme also suggested a slew of other VM benefits that can be expressed in different construction projects. Time-saving, function optimisation, quality/performance improvement, productivity/efficiency enhancement, energy-

saving, uncertainty mitigation, project feasibility promotion, interpersonal advancement, conflict resolution, clients satisfaction fulfilment, and minimisation of waste and environmental damages are some of them. Some studies examined the performance and impacts of integrating VM with other management methods for various-sized building and infrastructure projects. Risk Management (RM) [63,80,132,135], Building Information Modelling (BIM) [41,67,70,71], Analytical Hierarchy Process (AHP) [58,83], lean construction methods [76], and Quality Management (QM) [52] are some of the managerial systems that VM is frequently combined with. The majority of these approaches were discovered to possess distinct phases as VM does, which can aid them in a good integration with VM. It was believed that project management processes could attain optimum efficiency with the smallest inputs by combining rather than adopting multiple managerial approaches independently [143]. Also, such a combination could magnify the performance of VM in cost reduction, risk control, time optimisation, and efficiency improvement. However, studies on the integration performance and impacts for industrial projects are still rare. Awareness of related research could be raised.

"*VM strategy*" is the theme to examine proper methods, processes, and guidelines for implementing VM in different construction projects. Articles in this theme included proposing conceptual frameworks/models as guidelines for VM in construction projects of various types and sizes. The step-by-step or phase-by-phase VM processes were favoured by researchers as they are unambiguous and consistent with the distinct phases of VM job plan [68,73,95,117,121,134]. However, studies involving such kinds of processes were found mostly for large projects, resulting in a lack of relevant research in smaller projects. [144] suggested that the level of professionalisation of VM practise should be adjusted and determined according to the size of the project, and that for smaller projects, a clear, concise, and streamlined VM strategy could be more acceptable. The specific construction projects were generally employed in the studies on this theme to illustrate or validate the proposed strategy's feasibility and performance. In addition, this theme also featured the concept of integrating VM with other management methods. The integrated implementation framework/process were proposed to aid practitioners in incorporating VM in different construction projects alongside other methods, such as BIM [70,91], AHP [103,110,136], RM [80,132], Knowledge Management (KM) [10], Context-Sensitive Solutions (CSSs) [102], etc. Studies of such integration were found mostly for large projects, regardless of project type. However, implementing multiple approaches simultaneously could aid small projects in overcoming the disparity between management inputs and constrained resources, which is a major issue in these projects [140]. Hence, future research is commended to examine proper strategies to integrate VM with other management systems for smaller projects. Furthermore, several studies [101,106,131] presented criteria or methods for better analysis and evaluation of project value and functions, in order to facilitate effective VM processes in construction projects. The proposed evaluation strategies were found mostly emphasised for infrastructure projects. Such studies in building and industrial projects appear to be lacking.

"*VM influencing factors*" delegates the factors that influence VM in specific construction projects from internal or external perspectives with positive or negative impacts, such as barriers, drivers, challenges, success factors, risk factors, etc. Within studies on this theme, the majority were found to examine critical success factors and barriers of VM implementation in construction projects, with projects of all three types and two sizes covered. It was also found that these factors were diverse and commonly varied depending on the context of the specific project. Understanding these factors would aid different construction projects in better customising VM decisions and strategies to their own conditions [145]. There were a few articles [12,60,89] that looked into the risk factors encountered during VM process for both large and small building projects. However, such studies conducted on infrastructure and industrial projects were absent among the selected articles. Relevant research is encouraged in the future, as bearing associated risks during VM process can cause inefficiencies and impede the progress of VM [146]. The integration of VM with other management systems was also presented in publications within this theme. Such study was only shown in VM combined with BIM in small building projects, with both triggering and hindering factors investigated [71]. This is commendable as the study confirmed that efficiency and performance improvements are the primary motivator for small building projects to integrate VM with other management methods, despite the fact that small project characteristics like tight schedule would make such integration challengeable. For projects of other types and sizes, factors influencing the integration of VM with different management approaches remain hazy, needing more research to clarify. It is worth mentioning that [92] adopted SWOT (strengths, weaknesses, opportunities and threats) analysis as a tool to investigate the advantages, barriers, and potentials of incorporating sustainability into VM process. Such tool can clearly scan the internal strengths and weaknesses of using VM for construction projects, and highlight the opportunities and threats presented by the external environment [92]. Nonetheless, the use of SWOT analysis in VM studies for different construction projects is still uncommon and worth promoting.

The final theme, "*VM application status*" refers to the current development and status of VM application in different construction projects, such as VM's usage/frequency, practitioners' acceptability, awareness, perception, or familiarity towards VM, etc. Understanding the current application status aids in reflecting the shorts of VM deployment in different construction projects, so as to arouse the needed attention. Yet relevant studies on this theme account for a minimal frequency. More than 90% of the articles on this theme were published between 2011 and 2021. This implies that research awareness on this theme has significantly grown over the last decade. Many studies have indicated that the use of VM in different construction projects is still relatively low [12,16,82,93,139], and practitioners' awareness, experience, and strong familiarity with the approach are diverse and unsatisfactory [41,44,51,53,62]. However, practitioners' acceptance and perceptions of VM as an effective method for achieving the best value for money for projects of any type/size were found to be positive [41,51,60,65]. Common perception believed that large projects do more VM, as they have more extra budget for VM workshops and visible cost savings and effectiveness can be detected after VM [9]. [12] countered such perception, revealing that VM usage in Singapore was more than three times higher in small building projects than in large ones. [12] also revealed the reason for that can be the cost of implementing VM in smaller building projects is typically lower and the benefits VM yields tend to be more tangible and perceivable. However, it remains blurry if this is the scenario for other types of small projects. Among the limited studies on this theme, the majority were found to be dedicated to building projects (see Fig. 2). Thereby, negligence was revealed in studying this theme for infrastructure and industrial projects.

Figs. 2 and 3 depict the distribution of different types and sizes of construction projects being examined within each theme, in order to understand how project characteristics influence VM study preference. Some articles contain more than one theme and/or feature more than one type/size of project. Thus, multiple counts of the relevant article would be performed according to the corresponding sections.

In terms of the themes "VM performance and impacts" and "VM strategy", VM studies in three types of projects possess a similar scenario, as shown in Fig. 2. Regardless of research themes, build-

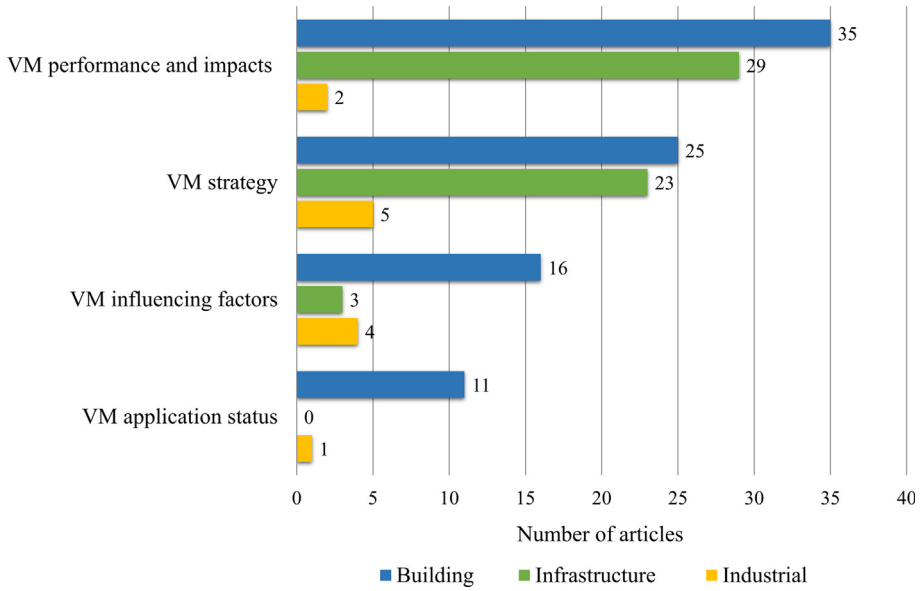

Fig. 2. Distribution of relevant articles by project type and research theme.

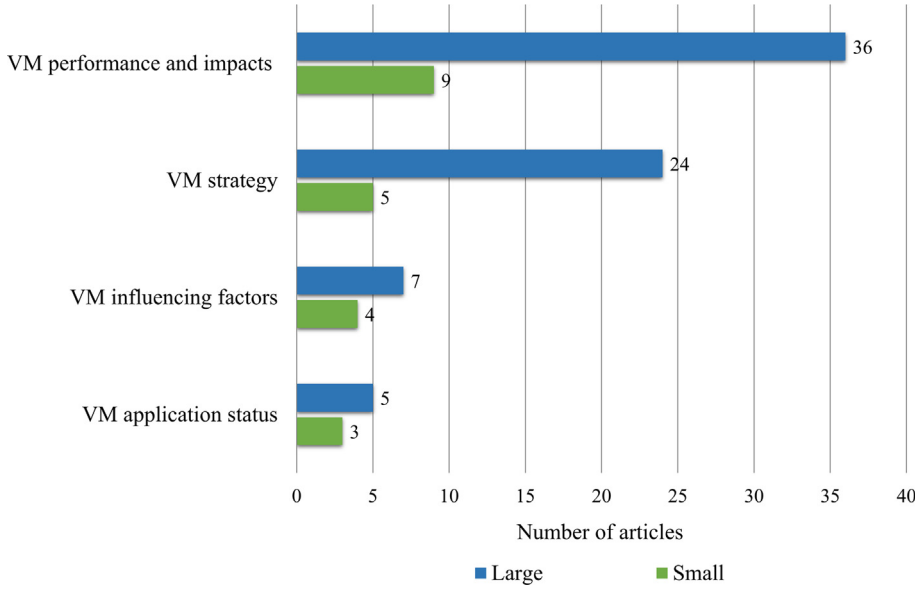

Fig. 3. Distribution of relevant articles by project size and research theme.

ing projects have consistently been the most favoured subject for VM studies in this century. Interestingly, "VM strategy" was found to be the most studied theme for industrial projects, instead of the one with the greatest overall attention. Research on the "VM implementation status" in infrastructure projects was absent from the selected articles. This omission encourages more corresponding concern and action from scholars in a global context. Referring to Fig. 3, a similar circumstance was demonstrated in terms of all themes in both sizes of projects. Large construction projects were found to be favoured for all VM research themes. The negligence of VM studies in small projects was observed to be not affected by the differences in research themes.

On the whole, VM studies have become increasingly diversified over these years. This review has revealed clear preferences for VM studies in specific construction projects, which is linked to project type, project size, and research theme. The observed status based on research themes can provide a reference for scholars with greater freedom in selecting research issues and topics for future VM studies.

5. Directions for future study

Over the years, increasing VM studies in specific construction projects were found. This indicates that research interest in this topic is growing. More studies are expected in the future. Some possible directions for future study are proposed based on the status observed from this review.

It is suggested that subjects of future VM studies could focus more on those overlooked projects, such as industrial projects and smaller projects. Identifying the status and issues of VM in these projects, as well as suggesting proper strategies to facilitate their better application of VM, are highly laudable. It is also commended to study how different construction projects can achieve

the requirements of green/sustainable construction through VM. Regardless of any project, research into integrating VM with other management methods for simultaneous application in the project is always advocated. Management approaches like RM and BIM can be good options for integrating with VM, as they are deemed proactive and feature evident phases like VM that can facilitate a good combination. Directions could be focused on investigating the factors that drive and hinder the success of such integration, as well as formulating appropriate strategies to assure simultaneous implementation and amplify the capabilities and performance of VM.

The development of VM in different construction projects was asserted to remain in its infancy in many countries. This should be interpreted by more studies on the current use and deficiency of VM in different construction projects, particularly in infrastructure and industrial projects. In addition, more research is encouraged to identify and evaluate factors that have a significant impact on VM in various construction projects, such as the risk factors encountered during VM. As little VM research was conducted on specific construction projects in most parts of Africa, more studies are recommended in order to facilitate the widespread use of VM in the continent. Besides, future studies using proper and multiple research methods to yield reliable findings are highly advocated. Research outputs are hoped to appear in more diverse journals to better publicise and promote the approach in different construction projects.

6. Conclusion

This paper provides an overall status of VM studies in specific types of construction projects by reviewing 104 relevant articles published from 2001 to 2021. The bibliometric result indicates that research interest in the topic is increasing over these years. Clear preferences were found in the VM studies conducted on specific construction projects. Majority of the research efforts have been focused on VM in building and large-scale projects, suggesting these projects to be the most favoured subjects of VM studies in this century. The research trend observed indicates that interests in these projects are expected to continue growing in the future. Negligence is therefore aroused to VM studies in projects of other types and sizes, craving for more attention. Four topics have been identified as the key research themes of VM studies in relation to specific construction projects, namely (1) VM performance and impacts, (2) VM strategy, (3) VM influencing factors, and (4) VM application status. It was found that researchers are keener on studying the performance, impacts, and strategy of VM in various construction projects, while a significant gap is generated in terms of other themes.

This review provides evidence to support the broad applicability of VM. Its recommendations aid researchers in flexibly selecting research issues and topics to develop necessary VM studies in the future. Also, it can serve as a reference for reviewing studies of other management methods in specific construction projects. Such kind of review based on the applicability of management approaches appears to be less to date. Understanding the current research status and trends would be beneficial in guiding future studies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A Summarisation of content analysis of the selected articles.

No.	Article	Year	Journal	Geographical jurisdiction	Methodology	Project type*			Project size**		Research theme***			
						PT1	PT2	PT3	PZ1	PZ2	RT1	RT2	RT3	RT4
1	[49]	2001	J Archit Eng	West Africa & Middle East	Others	√					√			
2	[134]	2001	Netherlands J Geosci	Netherlands	Others		√				√	√	√	
3	[120]	2002	PCI J	US	Case study		√			√	√			
4	[45]	2005	J Constr Eng Manag	US	Mixed methods	√		√	√			√	√	
5	[116]	2005	PCI J	US	Case study		√				√			
6	[101]	2005	J Manag Eng	Unspecified	Mixed methods		√					√		
7	[139]	2006	J Manag Eng	US & Saudi Arabia	Mixed methods			√	√	√		√	√	√
8	[79]	2006	PCI J	US	Case study	√			√		√			
9	[75]	2006	J Green Build	US	Mixed methods	√			√	√	√			
10	[77]	2007	Build. Res. Inf.	UK	Mixed methods	√			√	√	√			
11	[102]	2007	Transp Res Rec	Canada	Case study		√					√		

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(*continued*)

No.	Article	Year	Journal	Geographical jurisdiction	Methodology	Project type*			Project size**		Research theme***			
						PT1	PT2	PT3	PZ1	PZ2	RT1	RT2	RT3	RT4
12	[118]	2007	PCI J	US	Case study		√				√			
13	[135]	2008	World Acad Sci Eng Technol	Iran	Case study			√			√			
14	[125]	2008	Constr Manag Econ	Iran	Case study		√		√			√		
15	[73]	2009	IEEE Trans Eng Manag	South Korea	Case study	√			√			√		
16	[127]	2009	Civ Eng Environ Syst	South Korea	Mixed methods		√			√		√		
17	[129]	2009	J Constr Eng Manag	Canada	Case study		√					√		
18	[111]	2009	Transp Res Rec	US	Case study		√				√			
19	[74]	2009	JONA J Nurs Adm	US	Others	√							√	
20	[10]	2009	Autom Constr	Canada	Case study		√					√		
21	[121]	2010	J Chinese Inst Eng	Taiwan	Mixed methods		√		√			√		
22	[103]	2010	Int J Proj Manag	Taiwan	Mixed methods		√		√			√		
23	[90]	2010	J Build Apprais	Egypt	Case study	√			√			√		
24	[47]	2010	Proc Inst Civ Eng Eng	UK	Case study	√	√		√	√	√			
25	[112]	2010	J Appl Sci	Iran	Mixed methods		√				√			
26	[122]	2010	Proc Inst Mech Eng	Hong Kong	Case study		√		√		√	√		
27	[104]	2010	KSCE J Civ Eng	South Korea	Case study		√		√		√			
28	[131]	2010	Renew Energy	China	Case study		√		√		√	√		
29	[113]	2011	Aust J Basic Appl Sci	Iran	Questionnaire survey		√				√	√		
30	[50]	2011	Lean Constr J	Finland	Case study	√					√	√		
31	[105]	2011	Transp Res Rec	US	Case study		√		√		√	√		
32	[51]	2011	J Financ Manag Prop Constr	Northern Ireland	Mixed methods	√			√		√			√
33	[76]	2012	Int J Technol	Indonesia	Case study	√					√			
34	[80]	2013	Life Sci J	Iran	Mixed methods	√					√	√		
35	[52]	2013	Int J Technol	Indonesia	Questionnaire survey	√					√			
36	[132]	2013	J Civ Eng Manag	Iran	Case study		√		√		√	√		
37	[94]	2014	Procedia Technol	Indonesia	Mixed methods		√		√		√			
38	[59]	2014	Built Environ Proj Asset Manag	Brazil	Case study	√			√		√	√		
39	[88]	2014	Int J Appl Eng Res	Malaysia	Others	√					√			
40	[78]	2014	Museum Manag Curatorsh	UK	Case study	√			√		√			
41	[117]	2014	Pract Period Struct Des Constr	US	Case study		√					√		
42	[61]	2015	J Teknol	Malaysia	Case study	√					√			
43	[108]	2015	Can Geotech J	Canada	Case study		√				√			
44	[114]	2015	Int J Technol	Indonesia	Others		√		√		√			
45	[123]	2015	Int J Technol	Indonesia	Mixed methods		√		√		√			
46	[81]	2015	J Teknol	Malaysia	Questionnaire survey	√							√	
47	[82]	2015	J Teknol	Malaysia	Questionnaire survey	√					√	√	√	√
48	[119]	2015	Int J Technol	Indonesia	Case study		√		√		√			
49	[12]	2015	J Manag Eng	Singapore	Questionnaire	√			√	√			√	√

(*continued*)

No.	Article	Year	Journal	Geographical jurisdiction	Methodology	Project type*			Project size**		Research theme***			
						PT1	PT2	PT3	PZ1	PZ2	RT1	RT2	RT3	RT4
					survey									
50	[53]	2015	J Civ Eng Manag	Denmark	Questionnaire survey	√								√
51	[109]	2016	Procedia Eng	Czech Republic	Others		√				√			
52	[106]	2016	J Constr Eng Manag	South Korea	Case study		√		√		√	√		
53	[130]	2016	J Constr Eng Manag	South Korea	Case study		√					√		
54	[36]	2016	J Facil Manag	Norway	Case study	√			√		√			
55	[57]	2016	Procedia Environ Sci	Egypt	Case study	√			√		√			
56	[46]	2016	J Civ Eng Manag	Serbia, Montenegro, Croatia & Macedonia	Mixed methods	√		√				√	√	
57	[54]	2016	Int J Supply Chain Manag	Malaysia	Others	√					√			
58	[55]	2016	Proc Inst Civ Eng Eng	China	Case study	√			√		√			
59	[22]	2016	Front Eng Manag	China	Case study	√			√		√	√	√	
60	[16]	2017	J Des Built Environ	Malaysia	Questionnaire survey	√			√		√			√
61	[58]	2017	Turkish Online J Des Art Commun	Unspecified	Mixed methods	√			√		√			
62	[48]	2017	Bus Syst Res	US & Norway	Mixed methods	√			√			√	√	
63	[60]	2017	J Financ Manag Prop Constr	Sri Lanka	Case study	√			√	√		√	√	√
64	[115]	2017	J Eng Des Technol	Iran	Case study		√		√		√	√		
65	[91]	2017	Information	Unspecified	Others	√						√		
66	[138]	2017	Proc Inst Civ Eng-Munic Eng	Saudi Arabia	Case study			√	√		√	√		
67	[83]	2018	Alexandria Eng J	Egypt	Case study	√				√	√			
68	[63]	2018	Int J Procure Manag	Iran	Case study	√			√		√			
69	[68]	2018	Int J Civ Eng Technol	India	Mixed methods	√					√	√		
70	[56]	2018	Math Probl Eng	South Korea	Case study	√						√		
71	[41]	2018	Int J Civ Eng Technol	South Korea	Questionnaire survey	√					√			√
72	[107]	2018	Int J Ecosyst Ecol Sci	Iran	Case study		√		√		√	√		
73	[128]	2018	Int J Constr Manag	Iran	Case study		√		√		√	√		
74	[71]	2018	Int J Eng Technol	Malaysia	Case study	√				√	√		√	
75	[92]	2018	Eng Constr Archit Manag	Hong Kong	Mixed methods	√					√	√	√	
76	[87]	2019	Sustainability	Saudi Arabia	Questionnaire survey	√							√	
77	[95]	2019	Proj Manag J	Australia	Others		√					√		
78	[126]	2019	SN Appl Sci	Iraq	Case study		√		√		√	√		
79	[69]	2019	ARPN J Eng Appl Sci	Indonesia	Case study	√				√	√	√		
80	[96]	2019	Int J Proj Manag	UK	Case study		√		√				√	
81	[64]	2019	Ain Shams Eng J	Egypt	Mixed methods	√			√		√			
82	[133]	2019	Int J Sci Technol Res	Indonesia	Case study		√			√	√			
83	[124]	2020	Int J Eng Res	Egypt	Case study		√		√		√			

(*continued on next page*)

(*continued*)

No.	Article	Year	Journal	Geographical jurisdiction	Methodology	Project type*			Project size**		Research theme***			
						PT1	PT2	PT3	PZ1	PZ2	RT1	RT2	RT3	RT4
			Technol											
84	[89]	2020	Appl Sci	Saudi Arabia	Questionnaire survey	√							√	
85	[72]	2020	J Eng Appl Sci	Egypt	Mixed methods	√						√		
86	[86]	2020	Constr Innov	Egypt	Mixed methods	√						√	√	
87	[137]	2020	Proc Inst Civ Eng Procure Law	Iran	Mixed methods			√					√	
88	[93]	2020	Sustainability	Egypt	Mixed methods	√								√
89	[65]	2020	Buildings	Egypt	Questionnaire survey	√						√		√
90	[97]	2020	Procedia CIRP	France	Case study		√				√			
91	[100]	2020	Proc Inst Civ Eng Procure Law	South Africa	Case study		√		√		√			
92	[42]	2020	Int J Sustain Dev Plan	Malaysia	Case study	√				√	√	√		
93	[110]	2020	Ain Shams Eng J	Egypt	Case study		√					√		
94	[66]	2020	Sustainability	Unspecified	Case study	√			√			√		
95	[67]	2020	J. Ambient Intell. Humaniz. Comput.	China	Case study	√					√			
96	[98]	2020	Int J Technol	Unspecified	Case study		√		√		√			
97	[84]	2020	Build Environ	Australia	Case study	√			√		√			
98	[136]	2021	Ain Shams Eng J	Egypt	Case study			√				√		
99	[62]	2021	J Clean Prod	Egypt	Mixed methods	√						√	√	√
100	[43]	2021	J Constr Eng Manag	Egypt	Mixed methods	√						√		
101	[70]	2021	Adv Civ Eng	China	Mixed methods	√			√		√	√		
102	[44]	2021	Ain Shams Eng J	Egypt	Questionnaire survey	√							√	√
103	[85]	2021	Build Environ	Australia	Case study	√			√		√	√		
104	[99]	2021	Int J Constr Manag	Indonesia	Mixed methods		√						√	

Notes: *PT1–Building, PT2–Infrastructure, PT3–Industrial;

**PZ1–Large, PZ2–Small;

***RT1–VM performance and impacts, RT2–VM strategy, RT3–VM influencing factors, RT4–VM application status;

"√" means this article is related to the information in the corresponding section.

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