Mapping the knowledge domains of value management: A bibliometric approach

Abstract

Purpose: This paper aims to review the state-of-the-art of literature of Value Management (VM) and to map the VM domain to provide a launch pad for further knowledge development and dissemination.

Design/methodology/approach: This study employed Citespace bibliometric analysis software to systematically, comprehensively, and accurately review the VM-related literature and; to map the VM knowledge domain.

Findings: The results reveal the current VM knowledge base, clusters, research hotspots, and the evolutionary trajectory while contributing to the development of VM knowledge by providing a dynamic platform for integrating future developments in research.

Originality/value: The contribution of this article to scientific VM knowledge is, therefore, a quantitative and accurate VM knowledge map based on a bibliometric analysis of data from the VM knowledge base, domains, and evolution. The findings can be generalised and used as an effective knowledge mapping tool in a specific field of study that could complement and add significant value to the often adopted more traditional literature reviews. This study further recommends that the proposed knowledge map be frequently updated by similar future studies to fill gaps that arise with changing needs, priorities, and contexts, as well as to identify corresponding future demands in the VM research domain.

Keywords: Value Management (VM), Citespace, Literature Review, Bibliometric Analysis

Introduction

Although firms engage in a variety of practices to manage their performance as well as those of their supply chains (Jacobs et al., 2017), an increasingly frequent strategy among stakeholders is to pay more attention to value creation (Tantalo and Priem, 2016). Value

Management (VM) is a multidisciplinary process that seeks to achieve the best value in the project processes and to meet the client's needs. It is a team-oriented, structured, analytical process that targets the systematic analysis of function (Tahir et al., 2016). VM has been widely adopted in engineering and manufacturing processes (Shen and Yu, 2012) and it has been extensively practised in developed countries (Ncube and Rwelamila, 2017) due to its potential benefits in optimising project performance (Tohidi, 2011) and creating value for firms. It can be successfully applied worldwide in all types of construction including buildings, offshore oil/gas platforms (Perera et al., 2006) and also in product manufacturing industries (Leber et al., 2014). The applications of this technique in the construction industry have expanded rapidly (Shen and Yu, 2012) and VM is currently in high demand (Mousakhani et al., 2017). This is not surprising, given the higher demands for better 'value for money' that accompany increasing aspirations of clients and end-users. Therefore, it is an integral part in the formulation and development of many civil infrastructure projects targeting 'best' value for money.

There are many VM related multidisciplinary studies in the scientific literature. However, only a few studies have been undertaken to review the historical development of the VM knowledge base; Jay and Bowen (2015) reviewed the literature on VM and innovation from an evidenced-based historical perspective. However, these reviews were typically qualitative, based on manual assessments, and they were limited in number.

In recent years, various structured tools have been developed for overcoming the above limitations when analysing literature (Wei et al., 2015). These tools focus on unveiling hidden connections between the literature i.e. cited references and co-cited references of various knowledge domains that cannot be easily interpreted by manual methods (Li et al., 2017). Visualising tools such as Citespace have therefore been developed to create informative conceptualisations of literature (Cobo et al., 2011). For instance, He et al. (2017) used

Citespace to map BIM knowledge, whereas Wei et al. (2015) used Citespace to map GIS knowledge. However, there could be shortcomings in Citespace software too i.e. completeness of database accessed and glitches in the software itself. Although the bibliometric analysis technique facilitates objective, quantitative and accurate reviews of literature without replacing the manual reviewing process, manual review is still valuable for understanding and interpreting a complex subject and identifying any critical factors. However, there is a dearth of literature based on such a systematic review of the VM knowledge base.

This study tracks the development and implementation of VM throughout the past few decades and explores the demand for VM in time to come. It identifies (a) a VM knowledge base; (b) knowledge domains (clusters); (c) key contributors to the knowledge domain (highly cited articles); (d) research hotspots (through keywords); (e) knowledge evolution (through citation bursts) and proposes a VM knowledge map based on the consolidated findings. Therefore, the paper primarily presents a state-of-the-art quantitative summary of VM knowledge.

Background

Although many researchers have attempted to map scientific literature over the years, few attempts have been made to map knowledge in the VM research domain although Ncube and Rwelamila (2017) have provided evidence to show that this is needed.

The origin of VM can be traced back to World War II when there was a material shortage in the manufacturing sector due to an amplified consumption of materials for war purposes (Cheah and Ting, 2005). VM evolved from Value Analysis (VA) (Shen and Liu, 2004), which was first developed by Lawrence D. Miles, an electrical engineer who was assigned to the purchasing department of General Electric (GE), to alleviate the material shortage in GEs production during that period (Al-Yami and Price, 2005). Miles suggested alternatives for the scarce materials that delivered similar or even better performance and the same functions

without compromising quality (Shen and Yu, 2012).Cost reductions were also achieved as a by-product of this approach (Cheah and Ting, 2005).

Over the last few decades, the VM research field has been enriched with numerous findings in the scientific literature (Ismail et al., 2010), such as VM as a tool for project briefing and design process management (Yu et al., 2005); performance measures (Lin and Shen, 2007); client value systems (Kelly, 2007); and hard versus soft VM (Green and Liu, 2007, Behncke et al., 2014). These studies either provide fundamental building blocks or may simply illustrate some practical applications of VM.

Apart from these publications, some other literature findings separately support some new trends in VM, i.e., integrated solutions (integrated with: (a) lean concept - (Ekanayake and Sandanayake, 2017), (b) sustainability - (Rachwan et al., 2016), (c) risk management - (Kalani and Kamrani, 2017)) that enhance the performance of VM applications (Oke and Aigbavboa, 2017). Despite the importance of identifying these fundamental findings, very few studies have reviewed the historical development of VM knowledge. Furthermore, all these studies were based on a manual review process, which could be distorted by some unavoidable subjectivity, lack of time and resources to to cover the entire spectrum, and lack of quantitative analysis. Also, there has been no attempt to integrate the fast-developing 'new knowledge' of VM with 'past knowledge' of VM.

Therefore, bibliometric analysis techniques such as Citespace have been developed to address the shortcomings of the manual review process (Cobo et al., 2011). Researchers can discover hidden connections and trends in the literature with the use of such advanced software. These tools combine quantitative analysis and visualisation to improve the users' understanding of a specific knowledge domain, especially the dynamics of underlying themes (Chen et al., 2010a).

Research methodology

This study therefore used Citespace software to map the existing knowledge base of VM to fill the current research gaps. In this context, systematic exploration of the VM knowledge base using bibliometric analysis was seen to be beneficial in establishing a scientific theory of VM by identifying and consolidating relevant knowledge from the key publications on which VM is based.

Fang et al. (2017) identified CiteSpace as a bibliometric software that facilitates visualisation of knowledge domains and enriched with clarity and interpretability of visualizations with diverse visual analytic functions (Chen, 2006). Compared to the other existing visualisation tools, Citespace is more balanced and powerful (Wei et al., 2015). Citespace is especially useful in identifying an intellectual base, emerging trends of topics, hotspots, and landmarks allied with various publications in a group of publications, and subsequently generating different visualisation graphs or illustrations to represent the patterns of scientific literature in a specific domain.

Data Collection

This study collected a core dataset comprising of 1139 publications including 412 journal articles, 8 review papers, and 719 conference proceedings from 1990 to 2017 from the Web of Science (WoS), which is a reputable bibliographic database that facilitates access to high-quality publications. This was achieved by searching the topic 'Value Management,' 'Value Planning', 'Value Analysis' and 'Value Engineering' while excluding the topic 'Earned Value Management' which is different. Furthermore, articles that included these topics in their title, abstract, or keywords were selected for the study.

The data was used in identifying the knowledge domains, knowledge base, citation bursts, and the evolution patterns of VM. Each dataset contains the bibliographic record of a published article, the list of authors, title of the publication, the abstract, keywords and the set of

references cited in the article. All the references included the first author's details, type and the year of publication and, volume/issue details, which were effectively used for data analysis.

Data analysis

The data retrieved from Web of Science (WoS) was analysed using Citespace by conducting document co-citation analysis. The findings were then used to develop a bibliographic map of VM that represents a network of collaboration towards the knowledge domain including cited references, and co-occurring keywords. Compared to the conventional technique, this method facilitates a more extensive review and provides a diverse range of related topic investigations (Li et al., 2017). Furthermore, the bibliometric technique provides the flexibility of reviewing literature at any time during a study since frequent and rapid analysis is possible and convenient with such software, unlike with conventional manual methods.

Links in document co-citation networks convey the frequency of citing two articles together in another article in a dataset (Li et al., 2017). Each dot in the visualisation symbolises a node in the network that is a cited reference. The merged network with nodes and links shows the development of a knowledge domain over a specific time by highlighting significant publications with labels. These significant publications are the highly cited references that can be considered as landmark papers in the knowledge domain.

Moreover, Citespace analysis facilitates more precise ways to identify some prominent groups in a data set, known as clusters. Each cluster distinguishes a different domain (Li et al., 2017). Modularity and the mean silhouette scores indicate the properties of each cluster. If the modularity is relatively high, the network is divided into loosely coupled clusters. Further, a higher silhouette score suggests that the homogeneity of the cluster is high (Chen, 2013). This study also used document co-citation analysis to visualise the network of VM, identify the landmark publications, nodes, links, clusters, and citation bursts. Citation bursts indicate the

milestones of the evolution of the VM knowledge base by identifying a sharp increase of citation counts related to a specific article. The results generated from these co-citation analysis techniques are presented in the next section of this article.

Findings

Results generated from document co-citation analysis

The study conducted a document co-citation analysis using the core data set of VM from 1990 to 2017 since it is the development era of the knowledge domain. According to the analysis, Citespace divided the timeline into a series of time slices where each slice equals a year. The top fifty (50) citations within each time slice were used for the analysis. Figure 1 shows the detailed outcome of document co-citation analysis of Citespace, i.e. co-citation network including 205 nodes and 433 links. Modularity Q of the findings is equal to 0.8787 denoting that the network is reasonably divided into tightly coupled clusters. The mean silhouette value 0.5039 indicates that the homogeneity of the clusters is fair.

(Insert Figure 1 here)

In Figure 1, citations with large nodes represent the frequently cited publications and suggest that these papers contribute substantially to the VM knowledge base. Therefore, Kelly (2004) is one of the frequently cited publications important for constructing the VM knowledge base.

(Insert Table 1 here)

Details of the top ten most cited publications are presented in Table 1. The most cited publication is the book 'Value Management of Construction Projects', authored by Kelly, Male, and Graham. The book describes the background and structure of VM, the theoretical framework within which value resides, the service and its attendant professionalism and ethical issues, and the future of VM (Kelly, 2004). The book is therefore a significant publication in this field. The sixth highly cited publication is also a book authored by Steven Male but without

the collaboration of the other author. The book is called 'Value Management: The Value Management Benchmark' (Male, 1998) and it has become a benchmark publication in the VM knowledge domain that explores the new era of VM. Although there are other books published on VM (Gomez, 1999), the highly cited book publications are on VM in the construction industry. The findings further support the argument made in the literature i.e. VM has received a higher demand in the construction industry compared to the other industries to achieve the best value for the client (Mousakhani et al., 2017). Apart from these two publications, all the other eight publications are review oriented articles related to VM in different projects.

Chen et al. (2010c) developed a model for assessing the performance of Value Engineering (VE; section of VM) workshops. According to Kelly et al. (2002), VM is an umbrella term that refers to the process as a whole and covers all the methodologies whether they entail Value Planning, VE or Value Analysis (VA).

However, the VE workshop performance assessment model proposed by Chen et al. (2010) can be used to assess two VE workshops of a construction project to demonstrate its usefulness in performance assessment to enhance the performance of the workshops. Ibusuki and Kaminski (2007) proposed a methodology that integrates VE and target-costing concepts together to enhance product performance, which is a new input into the knowledge base. Zhang et al. (2009) established a VE knowledge management system to enhance the creative power of the VE team beyond their collective capability and subsequently enhance the efficiency and effectiveness of the VE process, which has been noted as a significant publication. Also, the findings of Stoker (2006) reveal another application of VM; providing a new narrative for networked governance. The findings of Shen and Chung (2002) highlight the importance of a Group Support System (GSS), i.e., a set of techniques, software, and technology designed to focus and enhance the communication, deliberations and decision-making of groups for improving VM studies in construction.

Furthermore, Male et al. (2007) conducted a study to identify the series of styles for conducting VM in projects. The findings provide the potential to take VM to its next stage of development, and therefore this publication has become the eighth most highly cited article. The ninth highly cited article reveals the awareness of VM and the nature of its practice by professional civil, electrical and mechanical engineers in the South African construction industry and provides evidence of a gap between theory and practice (Bowen et al., 2010). In summary, all ten publications consider VM to be a systematic value achieving strategy that can be used to pursue specific research objectives in physical or social environments regardless of the specific area of research.

Identification and interpretation of clusters

As the second step of the analysis, this study investigated the clusters of VM publications to identify outliers in the body of knowledge. Cluster labels are selected from the noun phrases of each cluster, and the noun phrases are extracted from titles, keywords and the abstracts of the publications. Top-ranked noun phrases have been selected as the cluster labels. Three specialised metrics: Log Likelihood Ratio(LLR), Mutual Information (MI) test and the Latent Semantic Index (LSI), are used to identify the most significant clusters of VM and their most significant terms. LLR test identifies the uniqueness of a term to a specific cluster whereas LSI and MI tests respectively recognise the most representative words in each dimension and the most salient aspect of the clusters (Chen et al., 2010b).

(Insert Figure 2 here)

Figure 2 shows the clusters generated in this study with their cluster labels. The cluster label size is generated based on the total number of publications in a cluster and the labels were created using abstract terms and their relative importance by conducting the LSI test. Moreover,

the largest cluster is numbered as #0 whereas the smallest cluster is numbered as #9. The value of silhouette for each cluster is greater than 0.85, indicating robust and meaningful results.

It is interesting to find that the clusters of clients, implementation and the function are well connected and linked by the publications (nodes). The most significant cluster is the client (#0), which includes 28 articles and a silhouette value of 0.92. The articles are related to VM in public projects and awareness and practise of VM in different countries in construction projects. The most active citer to the cluster is (0.29) Jaapar et al. (2012) implementation of value management in public projects. Since all the articles within the cluster are about the real-time practice and application, the articles review the benefits for the clients allied with VM in construction projects. Hence, the cluster name 'client' is linked with the VM knowledge domain to a greater extent.

The second most important cluster is about implementation (#1). The articles within this cluster present details about implementing VM in projects. The article by Jay and Bowen (2011) that contributes most to this cluster suggests that VM should provide a VA methodology for designing housing. These findings confirm that VA is also a subsection of VM as suggested by Kelly et al. (2002). Luo et al. (2011), have developed a group decision support system for implementing VM studies in construction briefings that has become one of the turning points of VM implementation. The article is the third 'highly contributing' article to the cluster with 0.18 value.

The third-ranked (#2) cluster is cost management. Significantly the cluster comprises 15 articles published in the years 2015 and 2016. Therefore, the cluster reflects the current trend of VM. Maisenbacher et al. (2015) introduced the term integrated VE to the VM knowledge domain and it has become a new initiative. Integrated VE facilitates matrices to combine the two concepts of target costing and VE in a structural model to deduce value optimization

potentials (Sadi et al., 2015, Behncke et al., 2014, Maisenbacher et al., 2016b). Therefore, the new method targets value optimization by a combination of either increasing the functionality of the customer or reducing the product's costs (Maisenbacher et al., 2016a). To support the findings above, it is important to highlight that the ultimate goal of VE is not to reduce cost but to ensure value for money (Perera et al., 2011) while improving functionality (Kelly, 2004). Hence, the integration of VE and target costing will effectively address both the functional and cost targets of a project and generate robust project outcomes. Moreover, the cluster identifies innovative solutions in cost management in relation to VM.

In fact, all the other major clusters also link the significant areas related to the VM knowledge base; e.g., functional requirements of a project (Jin-wen and Xiao-ying, 2009) and achieving value for money (Zhang et al., 2009), to name a few.

Keyword co-occurrence network analysis

Analysis of keyword co-occurrence network is meaningful and valuable in exploring the evolution of research topics in a specific knowledge domain (Zhang et al., 2017). Further, this network can reveal the collective interconnection of keywords as well as the research hotspots. This study developed a keyword co-occurrence network using Citespace as shown in Figure 3.

(Insert Figure 3 here)

The outcome is generated from the core dataset with 165 nodes. Each node represents a keywordidentified from the publications, and the size of each node reflects the frequency of co-occurrence of the keywords.

According to Figure 3, the mostly cited keyword is VE with a frequency of 253. "VE is a systematic approach which seeks to achieve value for money by providing all necessary functions at the lowest total cost" (Male et al., 2007). Although VE is a subset of VM (Shen and Yu, 2012), where the convergence is on developing value in the detailed design and

construction stages of a technical project (Pasquire and Mauro, 2001), there are many independent publications on VE as well. These separate publications on VE have made a significant contribution to the VM domain too. The second largest frequency of keyword co-citation is 142 for VM which is the major research domain in this study.

The third largest hotspot in the VM knowledge domain is management. It has been previously argued to distinguish VM from other management styles. Although function analysis is a distinguishing characteristic of VM that differentiates it from other management styles, the availability of numerous tools and methodologies used by value managers prolonged this debate. However, Kelly and Male have proven VM to be a methodological value enhancing management style from their international benchmarking study between 1996 and 1998 that aimed to understand the tools, techniques, and styles of VM (Male et al., 2007), which in turn opened the path for further research.

Design is the fourth largest hotspot with 39 occurrences since the VM process involves design optimisation by eliminating unnecessary costs associated with designs without reducing the functional quality (Perera et al., 2011). However, VE is the most active area for investigating design problems, recognising the design objectives explicitly (Behncke et al., 2014), and proposing design solutions in the field of VM.

As stated throughout the paper, the ultimate objective of VM is to ensure value for money (Green, 1994, Perera et al., 2011). Hence, the keyword value has become a key area of research in this study. In contrast, Tohidi (2011) identified VM as a methodology that can be used to escalate the performance of projects. The highest performance is achievable only when the purpose is mainly increasing the value rather than merely reducing the costs, and hence VM is utilised to determine the best design alternatives for projects (El-Nashar and Elyamany, 2017).

The keyword ‘system’ is also ranked within the top 10, since VM is a professionally applied

systematic approach used to solve problems (Witschey and Wulff, 1998, Alaa-El-Dean, 2010, Al-Yami and Price, 2005).

Evolution of VM knowledge – analysis of citation bursts

Citation bursts reflect the dynamics of a field by referring to articles that have received sharp increases in citations. Figure 4 shows the top 11 references with the strongest citation bursts. The earliest citation burst started in 1998 and was consistent with the rapid development of VM throughout the period 2003 to 2006. From 2005 to 2010, researchers were mostly focusing on enhancing VM studies related to the construction industry (Shen and Liu, 2003, Lin and Shen, 2007, Shen and Chung, 2002). Also, the focus was to broaden the VM approach into other industries for process assessment and improvement (Ojala, 2006).

(Insert Figure 4 here)

After 2010, the trend was towards public VM (Stoker, 2006, Bryson et al., 2014) where VM was established as a management style. Integrated VM was another significant area of research which began in 2014 and is still a new direction of VM. Therefore, developing an extended model for integrated VM (Behncke et al., 2014) has been counted as the second strongest citation burst. In 2016, the scientific community paid special attention to VE, and the paper which aimed at assessing the overall performance of value engineering workshops for construction projects (Chen et al., 2010c) has been added to the strongest citation bursts list. Furthermore, integrated VE (Ekanayake and Sandanayake, 2017) has also appeared in the construction industry by expanding the horizons of the VM research domain.

Discussion and implications

The needs for a systematic and comprehensive review of VM literature and for developing a VM knowledge map have been identified by many studies. However, published descriptions of the evolution of VM are incomplete and fragmented (Jay and Bowen, 2015). The

methodology is widely practiced in many countries around the world (Kim et al., 2016), and such wide coverage highlights the necessity for a VM framework to organise domain knowledge further. Although Jay and Bowen (2015) conducted a review of VM, their study was limited to a manual review based on a desk study and did not identify the VM knowledge domains, hotspots and citation bursts of knowledge evolution. Therefore, this study developed a VM knowledge map to fill the existing gap in this research domain by integrating bibliometric analysis findings on the VM knowledge base, domains, hotspots and citation bursts of knowledge evolution.

As shown in Figure 5, the VM knowledge map comprises six major components, namely knowledge base, highly contributing publications, the body of knowledge, research hotspots, knowledge evolution patterns, and the future. The VM knowledge base includes all the publications (1128) related to VM from 1990 to 2017, retrieved from the WOS database. The study considered that these publications are directly linked with the VM research field and took them to be the core contributors.

(Insert Figure 5 here)

Key pillars supporting the success of VM knowledge development are the highly contributing publications since the knowledge development mostly relies on them. The pillars indicate the information shown in Table 1, including two book publications and eight review-oriented articles related to VM in different projects as the highly contributing publications.

The knowledge domains are the structured sub-divisions of the VM body of knowledge, i.e., clusters which can promote the understanding and implementation of VM. Ten clusters including Clients, Implementation, Cost Management, Function, Case Study, Value, Relationship, Triz, Decision, and Model are identified and considered as the façade of the

knowledge map which divides the entire body of knowledge into meaningful subsets and ties them together in an integrated knowledge domain.

Keywords are the meaningful representative indicators that connect and track the threads in the evolutionary trajectory of research topics and indicate the research hotspots within the VM field of knowledge as derived from this study. Hence, the keywords facilitate insights into the knowledge domain and open the window for research highlights as denoted in Figure 5 research hotspots. Value Engineering, Value Management, Management, Design, Value, Performance, System, Construction, Model and Value Analysis are the significant hotspots derived in this study, which indicate the major objectives of VM, i.e., achieving value for money (Perera et al., 2006), performance enhancement (Tohidi, 2011) to name a few. The objectives targeted by the various VM studies throughout the evolution of VM are structured under the hotspots above.

Knowledge evolution is symbolized at the level of the upper roof tie-beam in the VM knowledge map. A step-wise evolution is reflected in the citation bursts, that emerge from the dynamics of the VM research field, i.e., reflecting articles in a sub-domain that have received sharp increases in citations. Applications of VM in the construction industry received major consideration in the early part of the 21st century, which followed an earlier trend in other industries such as automation. There are many publications related to VM in the construction industry, which also highlights the importance of its implementation in the construction sector (Maznan et al., 2012, Ismail et al., 2010, Thiry, 2002).

The application of VM in the public-sector construction industry expanded quickly as it became a mandatory requirement in many public projects in USA, Hong Kong, and Australia (Shen and Yu, 2012). Indeed, it has been practised in both public-sector projects and some private-sector companies, e.g. in UK by companies such as BNFL, BAA, Railtrack, BA and the water

companies, particularly Yorkshire Water and Southern Water (Male, 1998). Similarly, it has been practised in Australian multinational companies such as Hawker Siddley. However, compared to the public sector, the application of VM in the private sector is relatively low. The reason behind that is less awareness and less support from the client (Fong et al., 2001) since they play a vital role in ensuring the success in implementing VM (Kelly, 2004).

At the beginning of 2010 the focus was on public VM, which is another different area of research and a social concept. However, the emergence of integrated VM shifted focus to the construction industry again after 2010. Integrated solutions of VE appeared as a research hotspot recently by expanding the limits. Hussin et al. (2013) highlighted the necessity of integrating sustainability and VE, whereas Karunasena et al. (2016) attempted to integrate both the concepts together in relation to the construction industry resulting in a hybrid approach harnessing two benefits from one process.

As a new initiative Park et al. (2017) presented a BIM-based idea bank for managing value engineering ideas, where BIM and VE concepts are integrated together. Lean integrated VE (Ekanayake and Sandanayake, 2017) is also a revolutionised research trend under 'integrated VE': it targets waste reduction while enhancing the project functionality. VE could also be combined with other managerial tactics like risk management and, it could facilitate a pathway to the diagnosis of the problems in the procedure of VE (Kalani and Kamrani, 2017). Therefore, the research direction has shifted towards integrated solutions and hence the future of the VM research domain would be on identifying and formulating innovative integrated solutions of VM for achieving the best value for products or projects in keeping with current priorities, which is shown as the highest or roof level objective of this study as shown in Figure 5 on the VM knowledge map.

Moreover, the knowledge map represents the state-of-the-art of VM knowledge and facilitates a dynamic platform which can integrate future changes. The bibliometric approach has made a significant contribution to the relevant body of knowledge compared to the manual review technique, which relies mostly on the opinion of experts using the content analysis technique. For instance, compared to the manual review conducted by Jay and Bowen (2015), this study provides a comprehensive review of the literature, as well as opens the door for frequent reviews of the emerging literature and updating both the knowledge base and the knowledge map.

Conclusion

The discipline of VM has received growing attention within the construction industry since enlightened clients have increasingly transcended a 'lowest price' mindset and have insisted on the application of VM to ensure value for money. This study selected the bibliographic analysis technique to review literature in the VM knowledge domain and used the software Citespace due to the marked advantages of this technique over the manual reviewing process. 1128 publications related to VM were retrieved from WoS and analysed using Citespace. Accordingly, this enabled identification of publications that have 'contributed highly' to the VM knowledge base. A total of ten key research hotspots were identified in this study. Specifically, a few key milestones in VM knowledge evolution were noted, including integrated VM and integrated VE in the construction industry.

Finally, future VM is projected to rely upon innovative integrated solutions of VM for achieving the best value for products and projects. The scientific contribution of this article to VM knowledge is therefore a quantitative and accurate VM knowledge map based on a bibliometric analysis of data from the VM knowledge base, domains, and evolution. The methodology and findings can be generalised and used as an effective knowledge mapping tool

in a specific field of study. The proposed VM knowledge map should frequently be updated by injecting findings from (a) relevant future studies to fill new gaps that arise with changing needs, priorities, and contexts, as well as the related (b) feedback from industry practitioners, following the implementation of recommendations developed based on the new knowledge gained. After all, the 'proof of the pudding' is in the value of knowledge advances in a practical/ applied field like VM would arise from improved performance in practice by those adopting recommendations based on the new knowledge. This will therefore, in turn help to identify corresponding future demands in the VM research domain.

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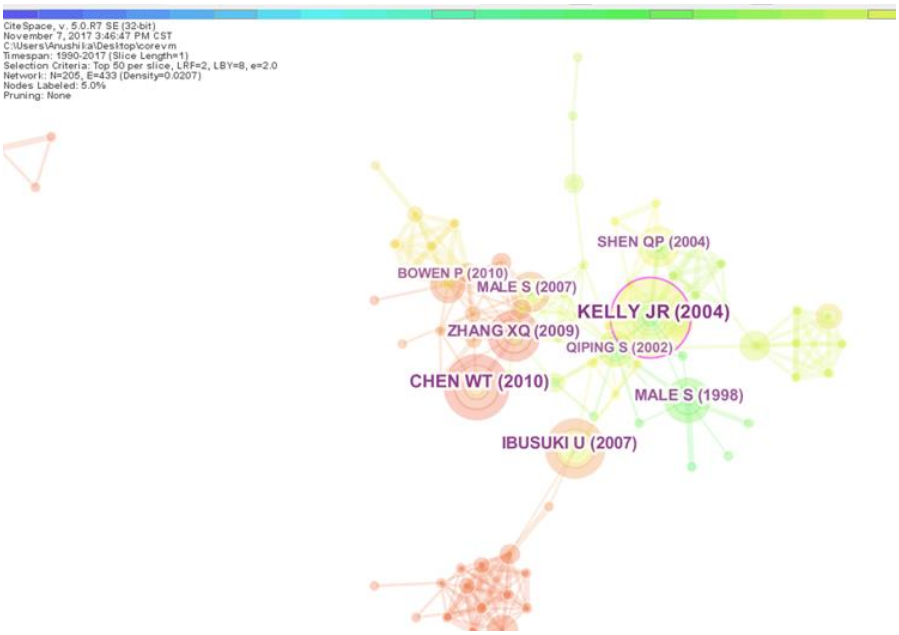

Figure 1: Document co-citation network of Value Management studies

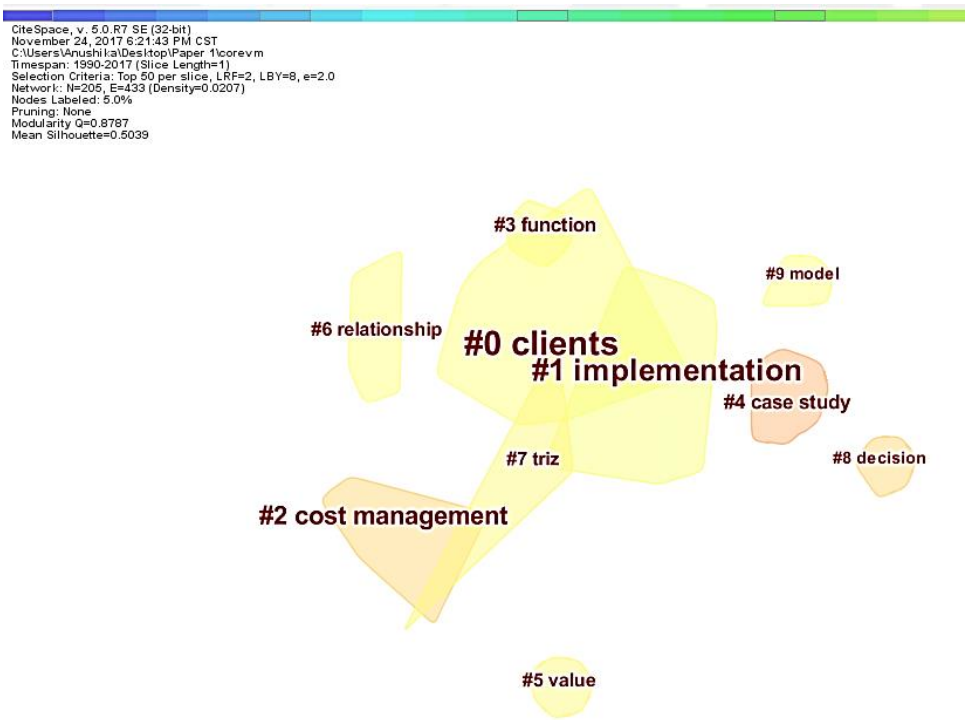

Figure 2: Clusters of knowledge domains within the VM discipline

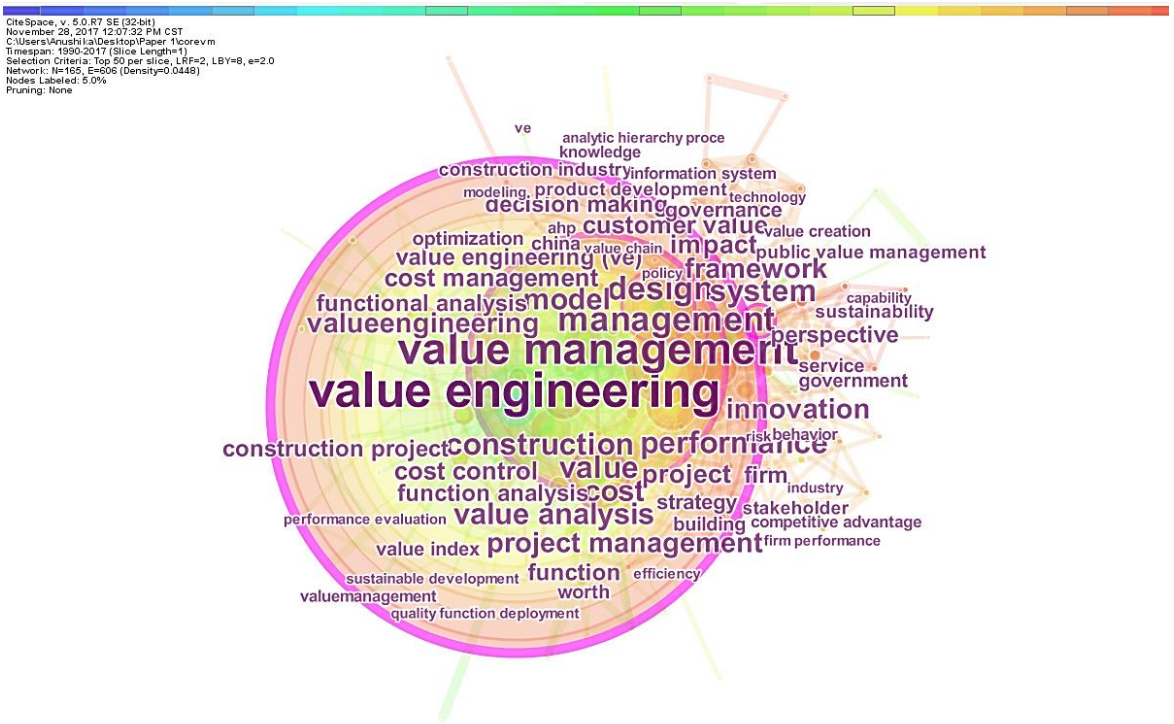

Figure 3: Keywords co-occurrence network

Top 11 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2000 - 2017
MALE S, 1998, VALUE MANAGEMENT BEN, V, P	1998	6.9021	**2003**	2006	
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OJALA P, 2006, THESIS U OULU, V, P	2006	3.9181	**2007**	2009	
OJALA P, 2000, ENHANCING SOFTWARE B, V, P	2000	3.1057	**2007**	2008	
SHEN QP, 2003, J CONSTR ENG M ASCE, V129, P485, DOI	2003	3.0812	**2009**	2010	
KELLY JR, 2004, VALUE MANAGEMENT CON, V, P	2004	3.7227	**2010**	2011	
LIN GB, 2007, J MANAGE ENG, V23, P2	2007	2.9786	**2010**	2012	
STOKER G, 2006, AM REV PUBLIC ADM, V36, P41, DOI	2006	3.2683	**2011**	2014	
BEHNCKE FGH, 2014, PROCEDIA COMPUT SCI, V28, P781, DOI	2014	4.1985	**2016**	2017	
BRYSON JM, 2014, PUBLIC ADMIN REV, V74, P445, DOI	2014	3.0309	**2016**	2017	
CHEN WT, 2010, INT J PROJ MANAG, V28, P514, DOI	2010	3.5161	**2016**	2017	

Figure 4: Top 11 references with strong citation bursts

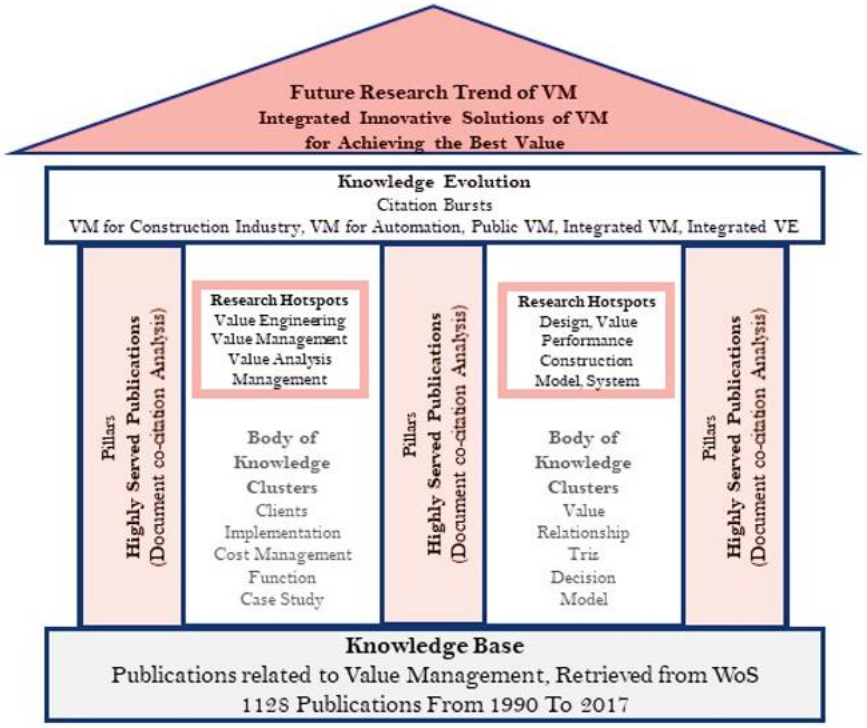

Figure 5: VM Knowledge Map

Table 1: The ten most cited publications in the discipline of Value Management

Author	Title	Year	Published in:
Kelly JR, Male S, Graham D	Value management of construction projects	2014	Book
Chen WT, Chang Po-Yi, Huang Ying-Hua	Assessing the overall performance of value engineering workshops for construction projects	2010	International Journal of Project Management
Ibusuki U, Kaminski P	Product Development Process with Focus on Value Engineering and Target-Costing: A Case Study in an Automotive Company	2007	International Journal of Production Economics
Zhang X, Mao X, Abourizk S	Developing a knowledge management system for improved value engineering practices in the construction industry	2009	Automation in Construction
Stoker G	Public Value Management: A New Narrative for Networked Governance	2006	The American Review of Public Administration
Male S	Value Management: The Value Management Benchmark	1998	Book
Shen G, Chung J, Li H, Shen L	A Group Support System for improving value management studies in construction	2004	Automation in Construction

Male S, Kelly J, Gronqvist M, Graham D	Managing value as a management style for projects	2007	International Journal of Project Management
Bowen P, Edwards P, Cattell K, Jay I	The awareness and practice of value management by South African consulting engineers: Preliminary research survey findings	2010	International Journal of Project Management
Shen Q**,** Chung JKH	A group decision support system for value management studies in the construction industry	2002	International Journal of Project Management

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