Exploring the Synergy: A Scientometric Analysis and Bibliometric Review of Value Engineering and Building Information Modeling Integration in Construction Projects

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Abstract: **Construction projects require considerable resources. Optimizing the construction project cost is a crucial task for maximizing the value and ensuring the project success. Value Engineering (VE) has emerged as a key approach to minimize project costs while preserving the essential functions of building components; meanwhile, an innovative technology such as Building Information Modeling (BIM) offers enormous potential to enhance and support the VE process at early stage of the project's life cycle. BIM is a collaborative digital platform that is used in the construction industry to plan, design, construct and manage construction projects. BIM enables the integration of various project elements, such as geometry, relationships, material quantities and schedules. BIM facilitates efficient collaboration among the project stakeholders by saving time and optimizing project outputs.**

limited studies have highlighted the importance of integrating BIM with VE. Furthermore, there remains a significant research gap in the research field regarding a specific framework for practitioners on how to manage construction projects through the BIM-VE integration. To address this gap, this study aims to perform a comprehensive Scientometric Analysis and Bibliometric Review of the available literature on the BIM, VE and BIM-VE integration by utilizing the Scopus database and employing research software VOSviewer.

Keywords: **Value Engineering, Building Information Modeling, BIM, Construction Projects, Scientometric Analysis, Bibliometric Review.**

1. INTRODUCTION

In the construction industry, it is found that projects face enormous challenges such as cost overrun and delays, **[1]** due to the over utilized materials and completion of work that exceed the designed schedule, also low production quality, poor performance and efficiency and lack of coordination, **[2]**. Therefore, one of the techniques used to overcome these difficulties in the construction industry is VE**, [3]**.

VE is a systematic method to improve the value of a project or a product by optimizing the function-cost ratio, aiming to achieve the best possible performance at the lowest possible cost without compromising the quality, reliability, or safety of the project or product, **[4]**. VE can be applied to various stages of the project lifecycle. The utilization of VE process in construction projects is increasing due to the several advantages that it has provided to construction projects. Using The VE process can assist the design team in making decisions during the design phase that can enhance the function and eliminate unnecessary project costs. It utilizes quantitative methods to satisfy stakeholders' requirements and reduce unnecessary costs, **[5]**. Applying VE can save about 5–10% from the construction project cost, **[6]**.VE aims to optimize project outcomes by maximizing value while minimizing the costs. Based on a systematic multidiscipline approach of analyzing design, materials and processes by producing innovative ideas and solutions to enhance project value, **[7]**.

BIM is a digital representation of the building components, which can facilitate the information flow among project disciplines, **[8]**. BIM can also support various processes and functions, such as design, analysis, simulation, visualization, coordination, collaboration and decision making. BIM can be described as a model-based technology that is connected to the project information database which could be used in construction projects as it offers many benefits such as project visualization, digital platform for collaboration, decreasing the rework and minimizing the project cost, enhance design quality and productivity, enhancing sustainability and used in clash detection and minimizing project duration, **[9]**. BIM enables stakeholders to create, share and analyze project information in a coordinated and integrated manner. It supports data-driven decision-making, promotes effective communication and enhances project efficiency throughout its lifecycle. The wide range of applications of BIM includes data management from the design phase to the entire project life cycle **[10]**, **[11]**. Furthermore, The BIM model allows the user to extract geometric data and the required information including procurement, construction, maintenance and all other activities related to the building life cycle, **[12]**. Consequently, the utilization of BIM technology and its advantages could potentially enhance VE practice in many ways, **[13]**. The VE and BIM combination can potentially improve the project value by leveraging the benefits of both methods, such as, BIM can provide accurate and timely information for VE analysis, enable design optimization through parametric modeling and simulation, enhance collaboration among VE team members and other stakeholders and empowers project teams to identify, evaluate and implement cost-effective alternatives that optimize project value, **[14]**.

Limited studies has been conducted regarding VE-BIM integration, **[15]**. However, for practitioners and stakeholders managing construction projects there are no clear or specific frameworks for utilizing this integration. Therefore, this study aims to conduct a scientometric analysis and bibliometric review of the articles published related to BIM and VE integration. Consequently, this study aims to help researchers to analyze the current state of the research and recognize the future developments in BIM-VE integration research.

2. ANALYTICAL METHODS AND TOOLS

In this study, a research tool called the Visualization of Similarities Viewer (VOSviewer) was used for the bibliometric analysis task. VOSviewer was created by Van Eck and Waltman and it is free available software which has been used for knowledge domain visualization (KDV), **[16]**. VOSviewer was utilized for creating and viewing bibliometric maps. It can create several maps and networks such as the source of publications, authors, institutions and countries in terms of simple nodes and links. These networks can be created from the citation, bibliographic coupling, co-citation, or co-authorship relations, **[17]**. In this study, VOSviewer was used to create and display the networks of the retrieved publications. The full counting method was considered in the VOSviewer which implies that each correlation has equal weight.

The following section will be about analyzing the topic of BIM.

3. STUDY RESULTS AND DISCUSSION FOR BIM

In this section, the results are analyzed for co-authorship and co-occurrence networks, as well as the results for co-citations and citations networks for BIM.

3.1 METHODOLOGY OF THE PAPER RETRIEVAL

The papers retrieval selection process was a thorough search of publications by identifying databases, keywords and search constraints. The Scopus database has been considered as a comprehensive resource, covering more journals and scientific publications compared to any other database (such as "Web of Science"), **[18]**. Accordingly, the publications related to BIM were obtained from the Scopus database. In order to conduct our search and extract significant data from the Scopus database, the keywords that were used were with the query string is "(TITLE-ABS-KEY)" ("BIM" OR "Building Information Modeling") AND ("Construction Projects" OR "Construction Industry") AND (LIMIT-TO (LANGUAGE, "English"). In addition, Only English-language documents were included in this study.

The search yielded a large number of publications (5358) documents were displayed. After elimination the non-English language documents. A total of 5344 articles were selected for future content analysis.

3.2 PUBLISHED TIME

The annual distribution of publications over the past two decades is illustrated in Fig. 1. Based on the results exported from Scopus database, the total number of published papers related to BIM was 5344. The annual number of publications demonstrates a rising trend, with the numbers increasing from 3 in 2004 to 516 in 2023 and reaching a peak in 2022 with 757 papers. This trend suggests that the total number of publications at the end of 2023 is likely to be higher than that in 2022, indicating that the publications number on the BIM topic has not reached their peak yet indicating a continuing interest in this topic, **[19]**. A list of publication types is shown in Table 1. The dominant type was Conference Paper followed by journal articles.

Fig. 1: The annual publication Distribution between 2004 and 2023.

Table 1: The retrieved publications type.

Publications Type	Records
Conference Paper	2497
Article	2287
Review	242
Book Chapter	187
Conference Review	91
Book	35
Editorial	5

3.3 DISTRIBUTION OF SUBJECT AREAS

The top 10 subject areas related to BIM according to Scopus are presented in Table 2. "Engineering" is by far the dominant subject area representing 39.38% of total BIM research with 4020 papers, which aligns with BIM's origins and applications in civil, construction and architectural engineering. "Computer science" accounts for 16.40% of publications, highlighting the importance of IT, software and computational techniques in BIM research. "Business, Management and Accounting" and "Environmental Science" have a high share of 6-8%, underlining BIM's application for project management and sustainability. All other subject areas have less than 6% share but that shows the multidisciplinary nature of BIM research extending beyond core technical fields. Further multidisciplinary expansion can be expected with wider industry adoption.

Table 2: Top 10 Records of the retrieved publications according to Scopus subject area

Subject Area	Records	% of Sum
Engineering	4020	39.38
Computer Science	1674	16.40
Business, Management and Accounting	778	7.62
Environmental Science	649	6.36
Social Sciences	551	5.40
Earth and Planetary Sciences	412	4.04
Energy	405	3.97
Mathematics	347	3.40
Materials Science	316	3.10
Decision Sciences	268	2.63

3.4 KEYWORD CO-OCCURRENCE NETWORK

This analysis was adapted in this study to show and map the emerging topics that are related to BIM. All keywords available in the retrieved publications were considered in the analysis and a threshold of 40 was set as the minimum number of keywords. 1269 out of 12600 keywords met the criteria. The network of high frequency keywords along with the keywords evolution over time is represented in Fig. 2 and Fig. 3 respectively. Color-coded nodes indicated different types of clusters; node size indicated the number of occurrences of keywords; and a dense connection line indicated a close relationship between two nodes. According to the results of cluster analysis, six main clusters were created based on keyword cooccurrence labeled as follows, cluster (1) BIM; cluster (2) Project Management; cluster (3) Sustainability; cluster (4) Cost Management; cluster (5) and (6) can be considered under the BIM.

Cluster (1) BIM, has the highest total link strength (52752) and occurrences (7825), indicating it is the largest cluster. It contains core BIM keywords like “Architectural Design”, “3D Modeling”, “Visualization”, “Virtual Reality” and focuses on the technical modeling and visualization capabilities of BIM. The main keywords are linked to the dominant co-occurred keyword “architectural design” which included in cluster (1) BIM, which represents the importance of BIM in collaborating into several topics such as project management and Sustainability. The top 10 occurrences keywords are listed in Table 3 along with the number of occurrences and the total link strength.

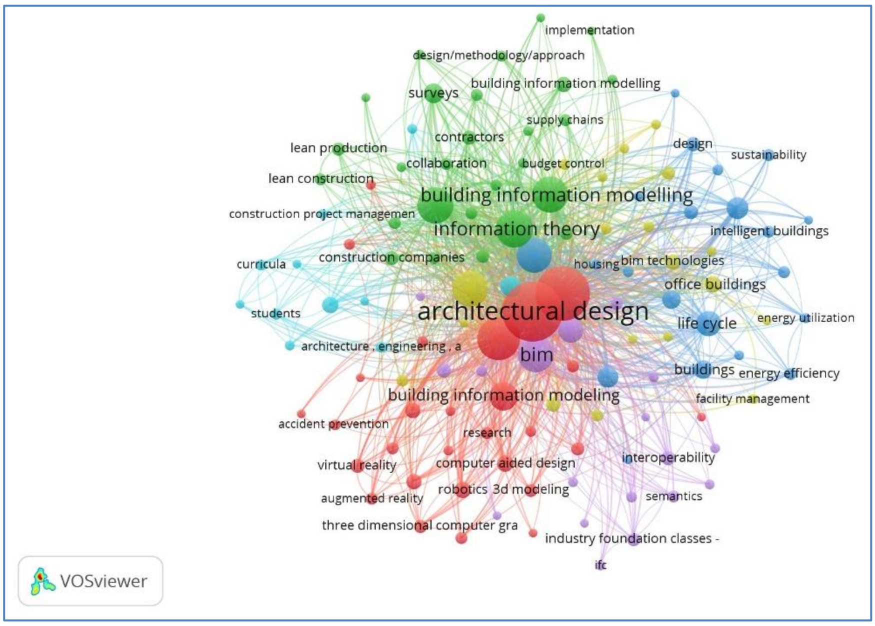

Fig. 2: The network of the keywords Co-occurrence

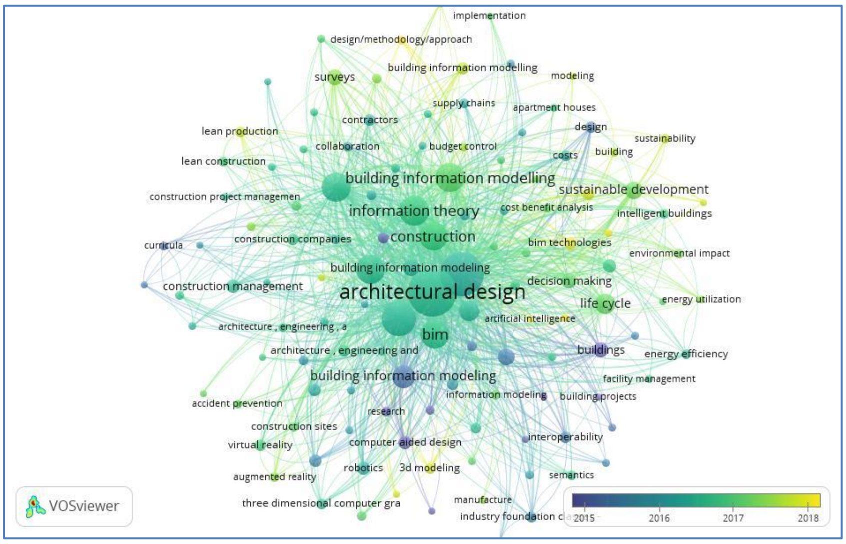

Fig. 3: The evolution of keyword Co-occurrence network

Table 3: List of top 10 co-occurring keywords

Keywords	Occurrences	Total link strength
Architectural design	2394	15774
Construction industry	1920	12323
Building information model - BIM	1119	7960
Information theory	842	6672
BIM	815	4479
Building information modelling	803	5248
Construction projects	780	5184
Project management	775	5621
Construction	723	5562
Building information modeling	482	3001

3.5 CO-AUTHORSHIP NETWORK

Creating and analyzing the knowledge map of co-authorship networks based on prominent authors can serve as a basis for different institutions to establish cooperation between different research groups. This information can also be used by individual researchers seeking cooperation and by publishers to create editorial teams based on the findings of this analysis. The co-authorship network was created based on authors. In Fig. 4 the nodes represent the authors, and the size of the nodes shows how many publications they have. The links between the nodes show how many people have co-authored with them. There are 43 nodes in the network, plus 43 clusters, with zero links. It shows that most authors do not collaborate with each other, and co-authoring is isolated.

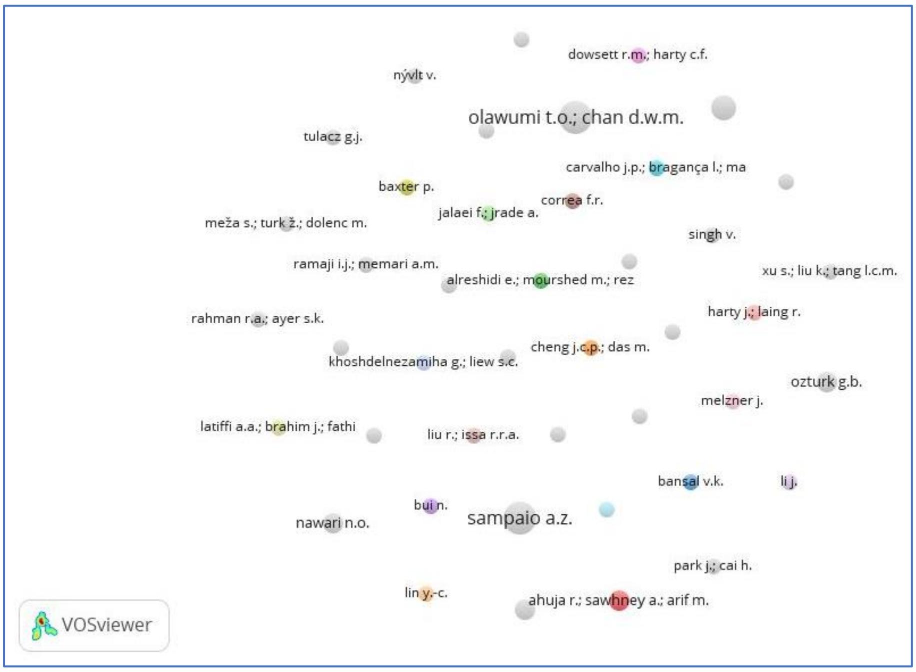

Fig. 4: Co-authorship network - Author.

The co-authorship network based on the country of the co-author is created. The threshold was set to 5 documents per country; the results show that only 62 of 121 countries met the criteria as illustrated in Fig. 5. In general, there is an established network of collaboration between countries. The magnitude of the collaboration is determined by the size of the node and the font. The United States, China, the United Kingdom and Australia have been identified as the most influential countries in the field of BIM. The United States has the highest number of publications (552) with 16,000 citations, while China has 495 publications (8,239 citations).

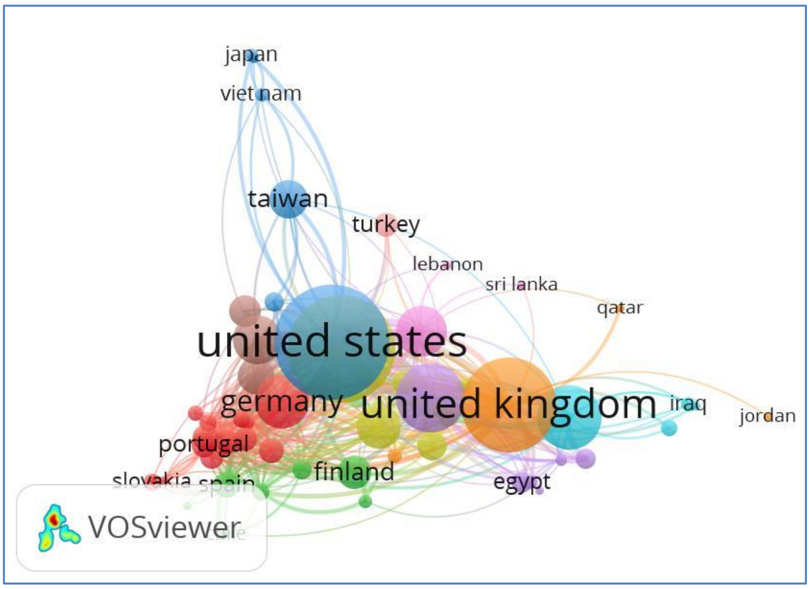

Fig. 5: Co-authorship network – Country

3.6 CITATION NETWORK

The purpose of the citation analysis was to determine the primary research documents and sources, as well as the countries associated with them. The identification of document citations and citation groups facilitates the analysis of the highly cited documents to highlight the critical research areas.

For the citation analysis based on the document, the citation number was set to 100, only 173 of 3358 publications met the criteria. The most cited document had 791 citations and the analysis showed 173 clusters were found with no links. Fig. 6 presents the citation analysis network and the larger the circle, the higher the citation rate. Listed in Table 4 are the top 10 citations articles along with their related citations.

Fig. 6: Document as a unit of citation analysis

Table 4: Top 10 cited publications.

Publication title and reference	Year	Citations
The project benefits of Building Information Modelling (BIM) **[20]**	2013	791
Application Areas and Data Requirements for BIM-Enabled Facilities Management, **[21]**	2012	617
Understanding and facilitating BIM adoption in the AEC industry, **[22]**	2010	590
A critical review of the use of 3-D printing in the construction industry, **[23]**	2016	534
BIM implementation throughout the UK construction project lifecycle: An analysis, **[24]**	2013	466

A theoretical framework of a BIM-based multi-disciplinary collaboration platform, **[25]**	2011	448
Interaction of Lean and Building Information Modeling in Construction, **[26]**	2010	423
Towards a semantic Construction Digital Twin: Directions for future research, **[27]**	2020	377
A Critical Review of the Use of Virtual Reality in Construction Engineering Education and Training, **[28]**	2018	373
Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges, **[29]**	2017	369

The following section will be about analyzing the topic of VE.

4. STUDY RESULTS AND DISCUSSION FOR VE

In this section, the results are analyzed for co-authorship and co-occurrence networks, as well as the results for co-citations and citations networks for VE.

4.1 METHODOLOGY OF THE PAPER RETRIEVAL

The keywords that were used were with the query string is "(TITLE-ABS-KEY)" ("VE" OR "Value Engineering") AND ("Construction Projects" OR "Construction Industry") AND LIMIT-TO (LANGUAGE, "English"). In addition, Only English-language documents were included in this study.

The initial search yielded a vast number of publications (660) documents were displayed. After elimination the non-English language documents. A total of 608 articles were selected for future content analysis.

4.2 PUBLISHED TIME

The annual distribution of publications over time is presented in Figure 7. Based on the results exported from Scopus database, the total number of published papers related to VE was 608. Research interest in value engineering was low in the 1970s with only 1-2 papers per year. This aligns with VE still being an emerging concept, the Publications production grew in the 1980s with a maximum of 9 papers in 1990 as VE gained traction. But output was still limited. The pace quickened in the 1990s with 5-24 papers annually. VE was getting established as a recognized methodology. The 2000s saw a steady climb in publications from 14 to 21 per year. The rapid growth phase was from 2008-2012 with 26-27 papers per year. This coincides with the increasing industry adoption of VE. Since 2016 the publications had increased from 21 to a peak of 36 in 2020. The trend in the last decade indicates VE research has entered a productive, progressive phase with growing industry relevance. VE publication trends reflect its evolution from an emerging concept in the 1980s to an established methodology in 2000s to an expanding research domain currently being integrated with innovative technologies and processes. A list of the publication types is shown in Table 5. The dominant type was journal articles followed by Conference Paper.

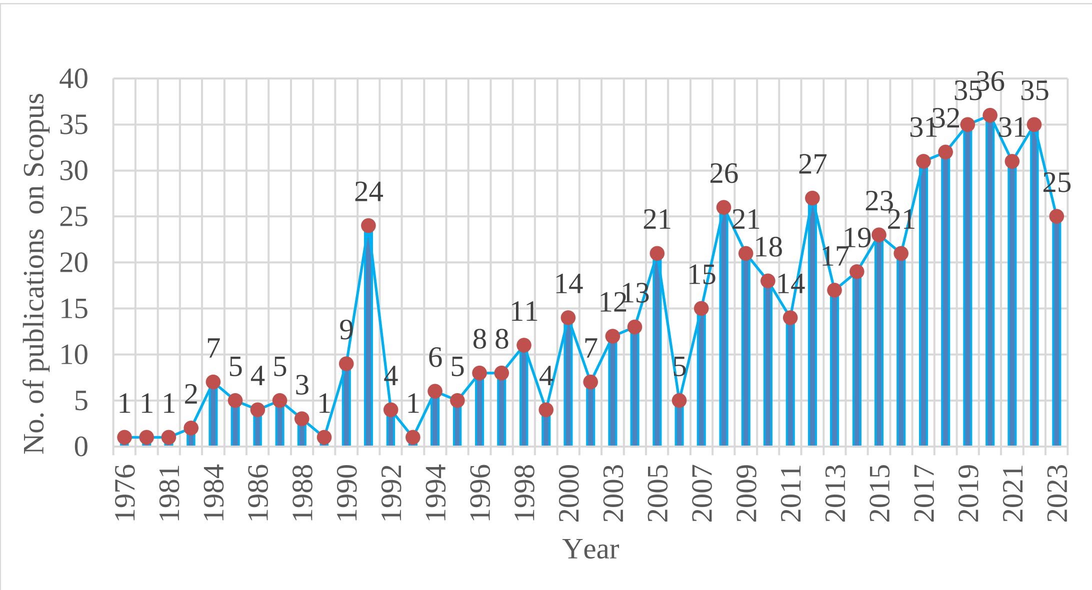

Figure 7: The annual publication Distribution between 1986 and 2023.

Table 5: The retrieved publications type.

Publications Type	Records
Article	295
Conference Paper	271
Conference Review	20
Review	12
Book Chapter	10

4.3 DISTRIBUTION OF SUBJECT AREAS

The top 10 subject areas related to VE according to Scopus are presented in Table 6. “Engineering” accounts for most publications with 492 papers, which is expected given the origins of VE and applications in industrial/manufacturing engineering. “Business and management” are a distant second with 163 publications, highlighting the increasing use of VE in construction project management. “Computer science” and “decision sciences” have a moderate contribution with 84 and 44 papers respectively, pointing to VE's integration with IT. Environmental science's share of 44 papers which highlights VE's linkages with sustainability evaluation and decision making. “Social sciences” and “materials science” also have 35 and 34 publications respectively, indicating VE's expanding interdisciplinary nature. While engineering still dominates, the subject area spread indicates VE research and adoption has expanded beyond technical branches into management, sustainability and IT applications in recent times. Further multidisciplinary focus can be expected as VE integrates with emerging fields.

Table 6: Top 10 Records of the retrieved publications according to Scopus subject area.

Subject Area	Records	% of Sum
Engineering	492	47.91
Business, Management and Accounting	163	15.87
Computer Science	84	8.18
Decision Sciences	44	4.28
Environmental Science	44	4.28
Materials Science	35	3.41
Social Sciences	34	3.31
Energy	31	3.02
Earth and Planetary Sciences	28	2.73
Mathematics	21	2.04

4.4 KEYWORD -OCCURRENCE NETWORK

This analysis was adapted in this study to show and map the emerging topics that are related to VE. All the keywords available in the retrieved publications were considered in the analysis and a threshold of 5 was set as the minimum number of keywords. 220 out of 3795 keywords met the criteria. The network of high frequency keywords along with the keywords evolution over time is represented in Fig. 8 and Fig. 9 respectively. According to the results of cluster analysis, nine main clusters were created based on keyword co-occurrence. Cluster (1) value engineering, has the highest total link strength (1248) and occurrences (154), indicating it is the largest cluster. Contains key terms like “value engineering”, “construction projects”, “decision making”, “engineering workshops” and “cost saving” etc. Represents foundational VE research on principles, processes and applications in construction. The top 10 occurrences keywords are listed in Table 7 along with the number of occurrences and the total link strength.

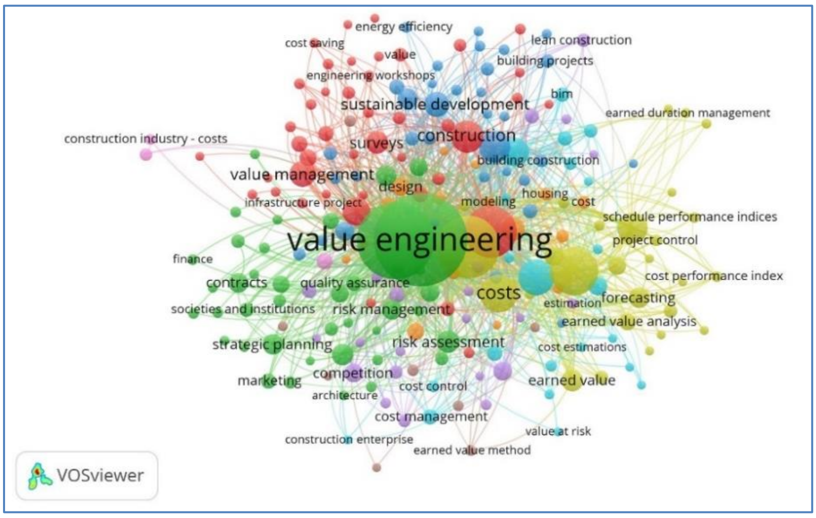

Fig. 8: The network of the keywords Co-occurrence

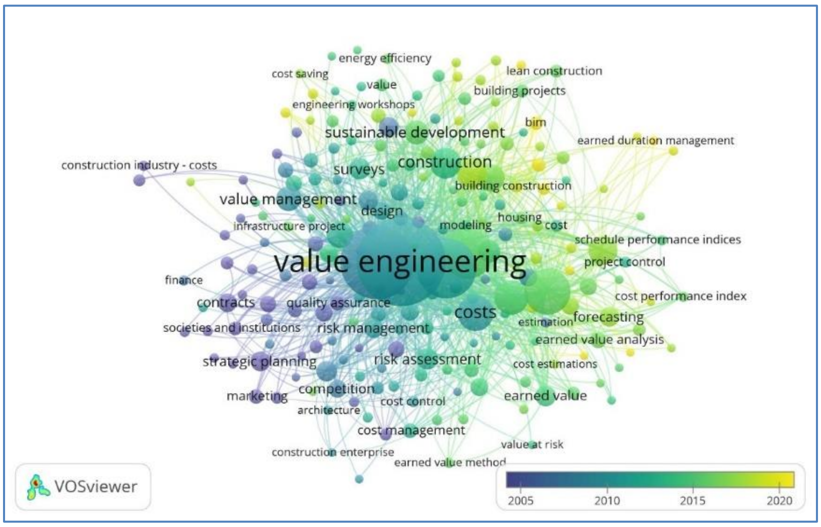

Fig. 9: The evolution of keyword Co-occurrence network

Table 7: List of top 10 co-occurring keywords

keywords	Occurrences	Total link strength
Value engineering	480	3081
Construction industry	334	2063
Project management	222	1717
Construction projects	154	1248
Budget control	136	1146
Costs	83	701
Cost benefit analysis	74	695
Construction	61	531
Cost engineering	57	496
Earned value management	56	501

4.5 CO-AUTHORSHIP NETWORK

The co-authorship network was created based on authors. In Fig. 10. There are 15 nodes in the network, plus 15 clusters, with zero links. It shows that most authors do not collaborate with each other, and co-authoring is isolated.

Fig. 10: Co-authorship network - Author.

The co-authorship network based on the country of the co-author is created. The threshold was set to 5 documents per country, the results show that only 27 out of 74 countries met the criteria as illustrated in Figure 11. In general, there is an established network of collaboration between countries. The United States leads with 126 documents and 840 citations, indicating substantial research output and impact in this field. Followed by China that ranks second with 58 documents and 380 citations, showing increasing focus from this rapidly developing country. Established research nations like UK, South Korea, Canada feature next with high output. Among developing countries, Malaysia, India and Egypt show notable research activity with more than 20 papers each. Australia has lower output at 21 documents but high impact with 682 citations. Sign of influential quality research. Bibliometric analysis reveals active VE research across both developed and developing economies.

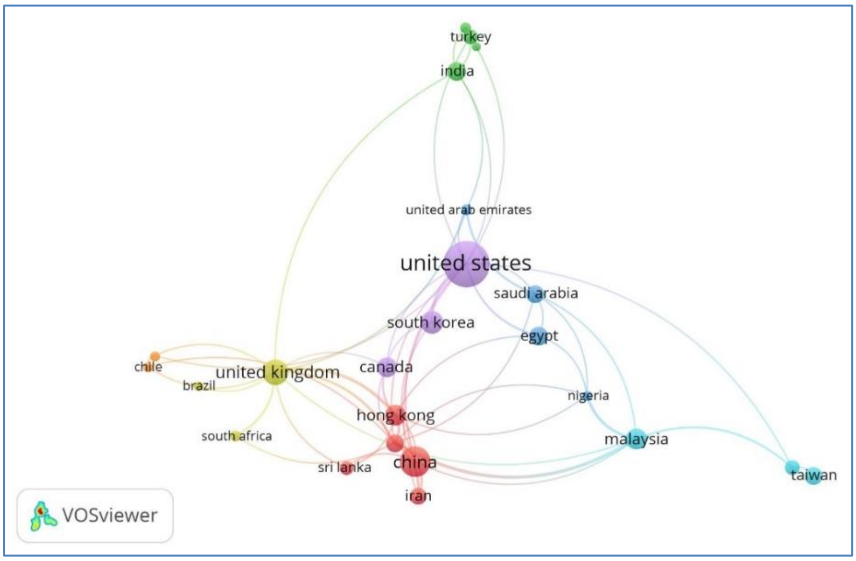

Figure 11: Co-authorship network - Country.

4.6 CITATION NETWORK

For the citation analysis based on the document, the citations number was set to 5, only 204 of 608 publications met the criteria. The most cited document had 247 citations and the analysis showed 204 clusters were found with no links. Figure 12 presents the citation analysis network and the larger the circle the higher the citation rate. Listed in Table 8 the top 10 cites articles along with their related citations.

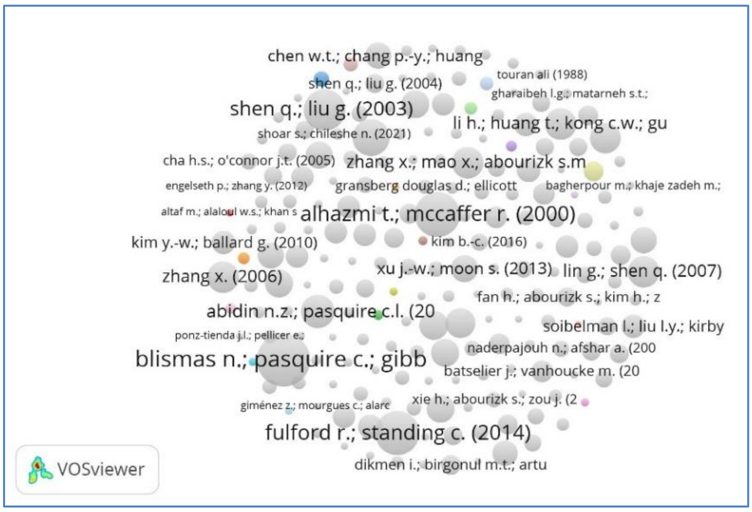

Figure 12: Document as a unit of citation analysis.

Table 8: Top 10 cited publications.

Publication title and reference	Year	Citations
Benefit evaluation for off-site production in construction, **[35]**	2006	247
Project procurement system selection model, **[36]**	2000	176
Construction industry productivity and the potential for collaborative practice, **[37]**	2014	170
Critical success factors for value management studies in construction, **[38]**	2003	150
Trends in productivity improvement in the US construction industry, **[39]**	2000	120
Revolutionize value management: A mode towards sustainability,, **[40]**	2007	98
Integrating design and construction through virtual prototyping, **[41]**	2008	90
Measuring the performance of value management studies in construction critical review, **[42]**	2007	88
Developing a knowledge management system for improved value engineering practices in the construction industry, **[6]**	2009	87
Managing value as a management style for projects, **[43]**	2007	83

The following section will be about analyzing the topic of VE-BIM integration.

5. STUDY RESULTS AND DISCUSSION FOR VE-BIM INTEGRATION

In this section, the results are analyzed for co-authorship and co-occurrence networks, as well as the results for co-citations and citations networks for VE-BIM integration.

5.1 METHODOLOGY OF THE PAPER RETRIEVAL

This literature review adopted a systematic approach to search and evaluate relevant publications. On BIM and VE integration. Fig.13 represents the framework for paper retrieval selection process that comprises of four steps.

The initial step was a thorough search of publications by identifying databases, keywords and search constraints. The publications related to the integration of BIM and VE were obtained from the Scopus database. In order to conduct our search and extract significant data from the Scopus database, the keywords that were used were with the query string is "(TITLE-ABS-KEY)" ("VE" OR "Value Engineering" AND "BIM" OR "Building Information Modeling"). In addition, the time span for extracting the publications was set from 2007 to 2023. Furthermore, Only English-language documents were included in this study.

The initial search yielded a few publications while some appeared to be unrelated to the study scope. Considering the amount of data, it was necessary to filter out unrelated documents. Therefore, the second step was the filtering process ,in this step, the data was filtered and evaluated by reviewing the document titles and abstracts. In the third stage, a full-text review was conducted to the remaining articles' contents to determine their eligibility and publications that did not meet the study scope were eliminated. Finally, in the last step, the final output of the remaining articles was taken for further in-depth analysis. Applying the previous framework, 95 documents were displayed. The initial list was examined and 5 irrelevant titles articles to be eliminated and 90 publications were remained. After reviewing the abstract and conclusion of the remaining publications, 20 were found irrelevant and removed. Finally, A total of 70 articles were selected for future content analysis.

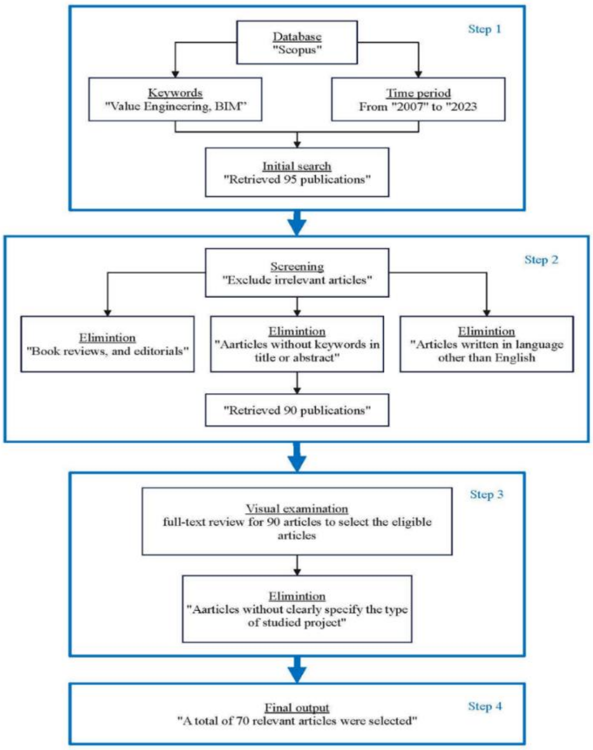

Fig. 13: Framework of publications retrieving and screening.

5.2 PUBLISHED TIME

Fig. 14 shows the annual productivity of each relevant publication over time. The first publication was published in 2007. The number of publications has increased exponentially since then, reaching a peak of 13 publications in 2022. This trend indicates that there is more research interest in this topic. This shows that the topic has only recently gained attention. Therefore, the number of studies related to BIM-VE integration is expected to grow in the coming years. Fig. 15 shows the citations summary for each publication per year. The total number of citations was 801 with the highest being 195 citations in 2019. Table 9 illustrates the distribution of the retrieved publications according to its document type. Among all publications, journal articles showed the highest record of 43 documents followed by conference papers of 38 documents. Hence, considering these numbers it is crucial to focus on the conference publications in addition to the journal articles. Also, regarding the classification of the retrieved publications listed by the subject area according to Scopus, approximately 40% of the all documents were Engineering-based, as shown in Table 10.

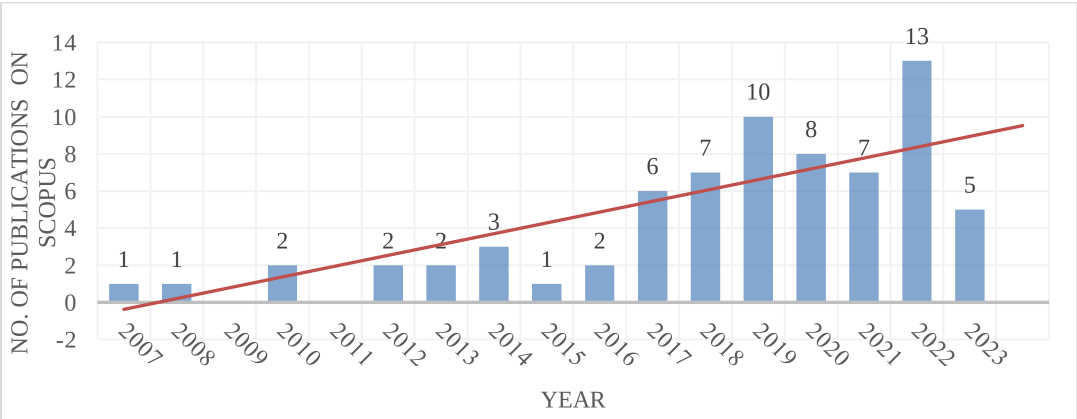

Fig. 14: The publications trend.

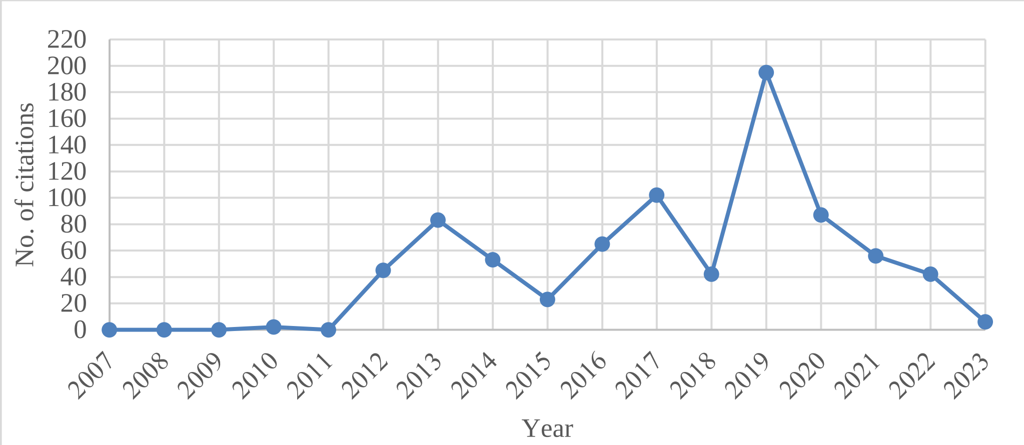

Fig. 15: Citations summary by year

Table 9: The retrieved publications type.

Publications Type	**Records**
Article	43
Conference Paper	38
Conference Review	7
Review	2

Table 10: Records of the retrieved publications according to Scopus subject area.

Subject Area	**Records**	**% of Sum**
Engineering	67	39.64
Computer Science	22	13.02
Environmental Science	16	9.47
Business, Management and Accounting	13	7.69
Energy	11	6.51
Social Sciences	11	6.51
Decision Sciences	5	2.96
Mathematics	5	2.96
Chemical Engineering	4	2.37
Earth and Planetary Sciences	3	1.78
Materials Science	3	1.78
Physics and Astronomy	3	1.78
Arts and Humanities	2	1.18

5.3 KEYWORD CO-OCCURRENCE NETWORK

The keyword co-occurrence analysis is one of the best approaches to show the investigated areas within specific topics and represent the main content of current research, also help the researchers realize the emerging scientific topics and trends over time, **[49]**. This analysis was adapted in this study to show and map the emerging topics that are related to VE-BIM integration. All the keywords available in the retrieved publications were considered in the analysis and a threshold of 5 was set as the minimum number of keywords. 26 out of 587 keywords met the criteria. The network of high frequency keywords along with the keywords evolution over time is shown in Figure 16 and Figure 17 respectively.

The network shows that "Value Engineering" keyword is the largest node in the network and the keyword "Building Information Modeling" with its different spelling such as "BIM" or "building information model" have a lot of Occurrences which make them the core of this domain. The connected keywords with Value Engineering and Building Information Modeling such as "Architectural Design", "Construction Projects", "Project Management", "Cost Engineering" and

"Budget Control" indicating that VE and BIM with those keywords are largely used in these fields. Therefore, the VE and BIM integration can have the potential to assess several strategies in optimizing and controlling the construction project's cost. The top 10 keywords listed by Occurrences are presented in Table 11.

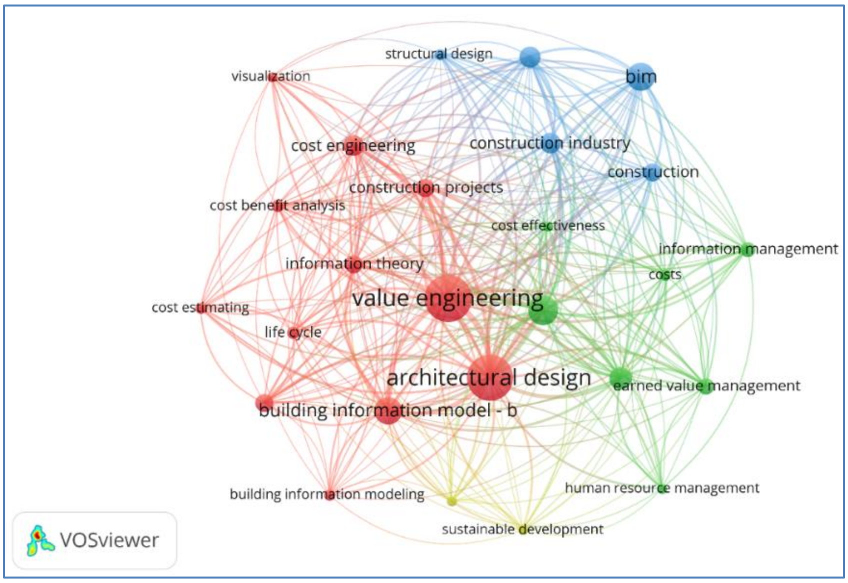

Figure 16: The network of the keywords Co-occurrence.

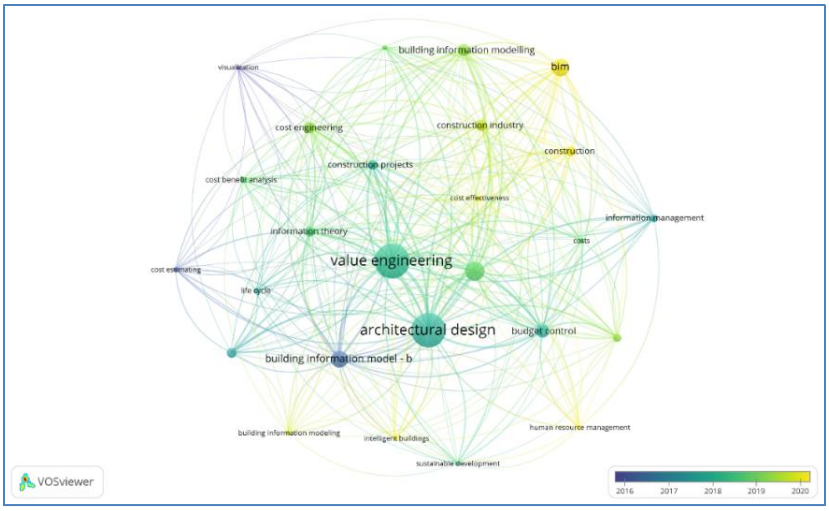

Figure 17: The evolution of keyword Co-occurrence network.

Table 11: Top 10 co-occurred keywords.

Keyword	Occurrences	Total link strength
Architectural design	44	269
BIM	22	99
Budget control	16	117
Building information model - BIM	21	128
Building information modeling	12	59
Building information modeling (BIM)	6	29
Building information modelling	15	98
Construction	12	88
Construction industry	14	79
Construction projects	12	95

5.4 CO-AUTHORSHIP NETWORK

Creating and analyzing the knowledge map of co-authorship networks based on prominent authors can serve as a basis for different institutions to establish cooperation between different research groups. This information can also be used by individual researchers seeking cooperation and by publishers to create editorial teams based on the findings of this analysis. The co-authorship network was created based on authors. In Figure 18, the nodes represent authors and the size of the nodes shows how many publications they have. The links between the nodes show how many people have co-authored with them. There are 69 nodes in the network, plus 69 clusters, with zero links. It shows that most authors do not collaborate with each other, and co-authoring is isolated.

The co-authorship network based on the country of the co-author is created. The threshold was set to 5 documents per country, the results show that only 7 out of 27 countries met the criteria. Figure 19 illustrates that the nodes are composed of three items: Canada, the United Kingdom and South Korea.

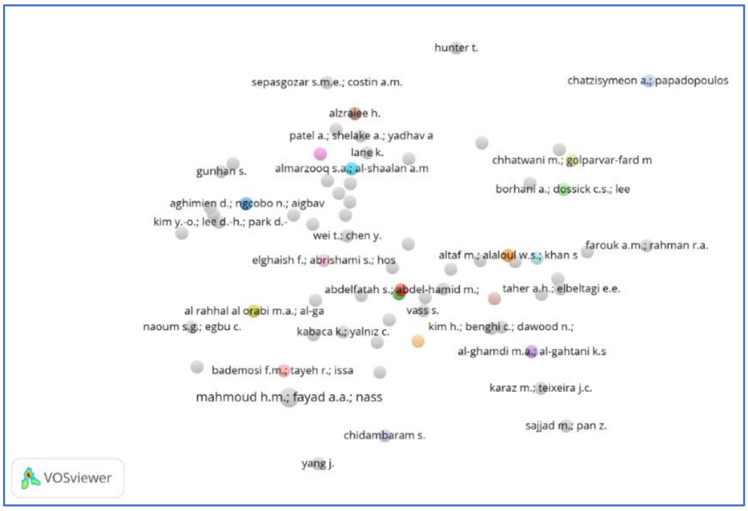

Figure 18: Co-authorship network - Author.

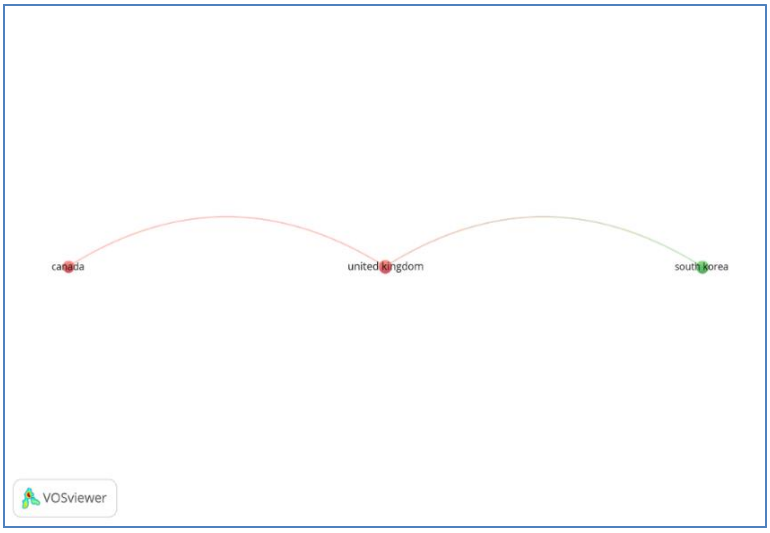

Figure 19: Co-authorship network - Country.

5.5 CITATION NETWORK

The purpose of the citation analysis was to determine the primary research documents and sources, as well as the countries associated with them. The identification of document citations and citation groups facilitates the analysis of the highly cited documents to highlight the critical research areas.

For the citation analysis based on the document, the citations number was set to 5, only 32 publications met the criteria. The most cited document had 83 citations and the analysis showed 32 clusters were found with no links. Figure 20Figure 20 presents the citation analysis network and the larger the circle the higher the citation rate.

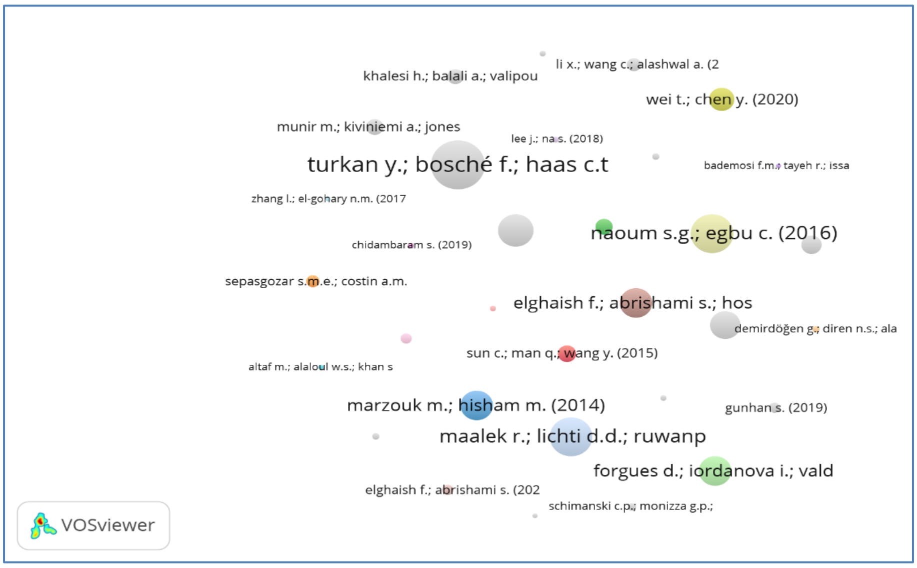

Figure 20: Document as a unit of citation analysis.

6. THE INTEGRATION OF VE AND BIM

Several Research has been conducted on the utilization of VE to manage and control the construction project costs, **[50]** however, there has been a lack of research into the BIM-VE integration to enhance cost management and optimization. The study examines the potential use of BIM to capture and visualize stakeholders' requirements during the design phase of low-income housing projects **[51]**. BIM enabled the visualization and analysis of various client requirement options. This enables the design solutions chosen for the stakeholders to be made accessible, monitored, monitored and validated. Adopting to the needs and expectations of the end-users, requirements modelling can help to generate value for social housing projects. Capturing client requirements in a structured way is an important first step in value engineering to understand project objectives.

VE is often used in construction projects to eliminate the unnecessary cost without affecting the functional requirements of the constructed facilities' components. Studies have been conducted to automate this process, however, they have not provided adequate components visualization. A framework for VE based on a four-dimensional BIM model was provided ,**[52]**, allowing designers and VE team members to assess and compare various design alternatives for the project components. This model integrates with the BIM model to automate data extraction and visualization, RSmeans to provide cost estimation data and the Analytical Hierarchy Process (AHP) to create a multi-attribute criterion to assist users in the evaluation process and then ranking alternatives. Overall, combining 4D simulation and VE extends the traditional VE methodology to better assess construction-related benefits, supporting more informed decision making.

VE technique is used for enhancing the project's value and minimizing the waste. Generating Ideas during VE workshop is time-consuming and often rely on the experience of VE participants. The idea generation process is recognized as an area to be further improved. A VE idea bank is presented based on a BIM model, **[53]**. This model is designed to store, retrieve and reuse VE data in a systematic manner, as well as to generate new ideas efficiently. The proposed system comprises of 1) Data model based on the VE Idea Bank; 2) creating BIM objects; and 3) integrating BIM and VE Idea Bank. The model was developed using C# programing language within the Autodesk API platform. Further research should be conducted to determine how to link the proposed VE Idea Bank in the creativity phase with the previous phase (information phase) and the succeeding phase (evaluation phase) within BIM environments. Additionally, how BIM could allow users to automatically evaluate the costs of new VE ideas and alternatives during the evaluation phase.

VE has become a well-established cost-reduction technique in the construction industry. A study was conducted using the implementation of VE and BIM combination to evaluate the potential of combining VE and BIM to achieve cost-reduction in the construction industry, **[54]**. The case study conducted on a shop lot units project needs to be renovated to become a student center. The results of the study indicate that approximately 27% of the project cost was reduced and that the project's value increased. Additionally, the study revealed that the major barriers of implementing BIM in the construction industry were due to lack of awareness.

A case study was conducted to demonstrate the effectiveness of the utilization of BIM to support VE workshops to reduce the costs associated with the construction project in 2013 for the Greater Cairo Metro (Line 3-Phase 3), **[55]**. The study resulted in the reduction of cost by 23% of the total price of the typical slabs and 1.7% of the whole contract amount while maintaining the basic function of the structural elements. Furthermore, using BIM has great advantages for the construction industry. Such as the visual retrieving of project data, allows for clash resolves, help in schedule the construction project procedure. In the case study, the measured cost information is based on direct costs. However, in future studies, the life cycle cost should be considered instead. BIM and VE play a significant role in the performance and cost optimization of construction projects. However, there is limited research on integrating BIM with VE for a stronger synergy in the AEC industry.

Selecting the appropriate finishing materials for a building flooring project can be a challenging task for decision makers due to the complexity of the process. A framework for choosing the optimal finishing materials for the construction of building flooring was developed using the BIM-VE approach, **[56]**. The floor finishing materials can significantly influence the cost, appearance and quality of a construction project. The proposed framework seeks to formalize the selection process by conducting a weighted criteria analysis of materials against project requirements. Criteria comprise of functional, aesthetic, environmental and economic needs. Weightings are assigned based on user survey inputs. BIM is used to model alternative materials with parameterized properties and visualize options. Overall, this study offers a structured approach to BIM-driven material selection based on data, which will enhance the user's decision-making process when selecting flooring finishing materials during the design phase, considering the sustainability impact.

Cost control is an important process during the construction phase. This involves monitoring and controlling costs as the project progresses. A case study was presented in which BIM and VE were integrated to be utilized for cost control in construction projects, **[13]**. The BIM, AHP and Entropy method were used to calculate weight and coefficient and the proposed framework was confirmed by a case study conducted on a high-rise building project in China. The study resulted in a 10% reduction in project cost and duration, as well as an improvement in overall project performance and quality. The benefits of this integration can be applied throughout the entire construction project stages.

VE and BIM are utilized to achieve a green building envelope that considers both energy savings and life cycle costs. A proposed framework for optimizing green building envelope based on BIM-VE that includes a BIM model, **[57]**, an energy-saving analysis model, a life cycle cost analysis model and a value analysis model. For building energy simulation BIM technology was used. In the scheme decision-making sub-model, VE integrating energy saving with life cycle cost is used to evaluate the envelope schemes and select the optimal one. A significant result is that the value tends to increase with the increase of the energy-saving rate, while the life cycle cost tends to change irregularly with the increase of the energy-saving rate. This implies that to achieve higher energy saving for a green building, the increase in the life-cycle costs is not a sufficient condition. The results of this study will help the designers to optimize their design from the energy saving point of view and life cycle perspective.

A framework was developed utilizes the VE-BIM combination to select the optimum design alternative for sustainable buildings that will enhance sustainable design, **[58]**. This framework includes the development of a five-dimension model (5D) that integrates time and cost for design alternatives. For the energy efficiency study of the building, Design Builder and BIM model are used to extract thermal files and the associated quantities. Additionally, SimaPro 8.3.0.was used to evaluate the environmental emission analysis for different design alternatives. The LEED rating is then used to assess the performance of the alternatives. The evaluation starts after the creation of the required criteria for the study is complete. The (AHP) approach was used to select the best alternative. Only the direct costs were considered in the developed model.

The advancements in BIM technology highlighted the efficient use of time for the construction project phases. Especially, the various capabilities of plugins provide an opportunity to create tailored and customized solutions for BIM applications., that can be done using coding and scripting interfaces such as Dynamo and Python. Due to the inadequacy of the generic BIM platforms to meet specific purposes, developing customizable plugins tailored to precise requirements is essential. A plug-in system was presented to integrate BIM and VE for enhanced quantity takeoff and management , **[59]**. The plug-in known as a Roombook has three features: family's creation, copying parameters values and a creation list. Many advantages could be gained from using the plugins such as: time saving; design automation; repetitive facilitating tasks; workflow customizing; improving productivity; easing BOQ tasks.

A survey was Conducted to collect insights a practitioner from design companies and construction firms located in South Korea on the advantages and challenges of using BIM and Value Analysis VA, **[60]**. The results showed that 87%

respondents have already acknowledged BIM and the practicability of BIM in the architecture, engineering and contractors (AEC) industry. Furthermore, about 70% of respondents who have acknowledged BIM have utilized BIM in their projects. The respondents were also asked their perception of the usefulness of the BIM based value analysis software. About 67% of the survey participants replied that the add-on for BIM will be used to analyze the value of their project. The study concluded that utilizing the VA in construction projects will be beneficial for the practitioners and professionals in the construction industry.

7. CONCLUSION

A comprehensive evaluation of the publications, including research articles and conference papers, is being conducted using data from the Scopus database in the fields of BIM, VE and their integration in the construction projects. Through a scientometric analysis and bibliometric review, the study has explored the trends and research gaps in these fields. The findings suggest that while there is a significant publication on BIM and VE separately, there is a noticeable lack of research on the synergy between VE and BIM in managing construction projects.

Limited studies focused on how building costs may be managed through VE. However, there is little research on BIM and VE integration for improved cost management and optimization is underway. Although BIM based cost estimating tools have existed for a while, only a few major construction companies could use their full capabilities. Moreover, most studies are only considering direct costs in the measured cost information, therefore, future studies should consider life cycle costs (LCC) in their studies. It is also important to develop a framework that could help manage the construction projects through the BIM and VE integration. Therefore, this study has highlighted the research gap in the integration of VE and BIM and emphasized the need for future studies to focus on the synergy between VE and BIM for improved cost management and optimization in construction projects. The researchers are also encouraged to put more efforts into this field to achieve the full potential of BIM. By filling this research gap, the construction industry can significantly enhance its efficiency and reduce costs.

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