



## Bibliometric Analysis of Academic Studies on BREEAM with VOSviewer Software Program

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### Keywords

Bibliometric  
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### Abstract

This study aims to provide a bibliometric analysis of the literature on BREEAM (Building Research Establishment Environmental Assessment Method) to identify research trends, key issues and scientific impacts in this field. BREEAM is a global standard that promotes sustainable building design and construction practices and assesses the environmental performance of buildings. A comprehensive search of the Web of Science database identified 466 academic publications on BREEAM between 1988 and 2024. The main purpose of this study is to determine bibliometric maps by analysing the metadata of "BREEAM" related researches within the scope of variables such as keywords, journals, publications, authors and collaborations of the field. The data were analysed using VOSviewer analysis software and bibliometric indicators such as key concept analysis, publication type, publication language, most active authors, articles, journals, countries and institutions were examined. The results of the analysis show that the majority of BREEAM-related research is written in English language and these studies focus on key topics such as energy efficiency, sustainability and green building. It was also found that international collaborations play an important role in this field and researchers from various countries have contributed. The findings of the study provide an important basis for understanding the current state of research on BREEAM and future research directions. It also aims to contribute to the development of sustainable construction practices by identifying gaps and potential research areas in this field. As a result, it is emphasised that BREEAM is a critical tool for raising sustainability standards in the building sector and minimising environmental impacts.

### Research Article

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## 1. Introduction

In recent years, environmental sustainability and energy efficiency have gained more and more importance in the building sector. In this context, green building assessment systems have been developed to assess the environmental impact of buildings and to encourage sustainable construction practices. One of the most common and effective of these systems is BREEAM (Building Research Establishment Environmental Assessment Method).

Developed in 1988 by the Building Research Establishment (BRE), BREEAM is the first global scale used to assess the environmental performance of buildings and to promote sustainable construction practices. BREEAM assesses and certifies buildings based on various sustainability criteria such as energy consumption, water use, indoor environmental quality, material selection and waste management. This system aims to raise sustainability standards in the building sector by providing a framework for minimising the environmental impact of buildings.

Many academic studies have been conducted on the importance and impact of BREEAM in the building sector. For example, Ding (2008) examined the role of green building assessment systems in sustainable building design and emphasised that BREEAM is a critical tool for projects to achieve sustainability goals [1]. Furthermore, a study

by Reed et al. (2009) showed that BREEAM certified buildings provide significant advantages in terms of energy efficiency and environmental performance. These studies reveal the importance and applicability of BREEAM in the building sector [2].

The aim of this study is to conduct a bibliometric analysis of the literature on BREEAM to identify research trends, key topics and scientific impacts in this field. Bibliometric analysis is a method that helps us understand the development of research fields and their scientific interactions through the examination of publications in the literature with numerical data. For example, a bibliometric analysis by Li et al. (2017) identified key research themes and trends in sustainable construction literature. In this context, various bibliometric indicators such as the distribution of studies on BREEAM by year, most cited articles, keyword analyses and author collaborations will be evaluated [3].

This analysis will provide an important basis for understanding the current state of research on BREEAM and future research directions. It also aims to contribute to the development of sustainable construction practices by identifying gaps and potential research areas in this field. In particular, recent studies (e.g. Darko et al., 2019) have examined the applicability of BREEAM in different geographical regions and its impacts on local construction sectors, which provides important clues for future research [4].

The main purpose of this research is to determine bibliometric maps by analysing the metadata of the research on "BREEAM" within the scope of variables such as keywords, journals, publications, authors and collaborations of the field. BREEAM is a current issue and previous academic studies have been examined. However, it is noteworthy that there is a bibliometric study on this subject in line with the examinations made. The bibliometric study to be prepared on this subject is aimed to pave the way for future studies.

## **2. Material and Method**

In this study, publications on BREEAM were analysed. Bibliometric analysis was performed in the WoS database as a literature search tool. Bibliometric analysis "combines mathematical and statistical methods to quantitatively analyse the number of literature in a particular field and to discover development trends in this scientific field" [5-7]. Bibliometric analysis provides a comprehensive and measurable information evaluation with numerical data and statistics. The results of this analysis aim to provide a more understandable framework for the subject by creating a document containing information about influential publications and general trends in the research area [8-11]. VOSviewer analysis program was used for the study and key concept analysis, publication type, publication language, most influential authors, articles, journals, countries and institutions analyses, co-citation/cited references analysis and co-citation analysis of cited authors and sources were performed with this program.

Bibliometrics is a branch of intersectional science that quantitatively analyses information media and is often used to analyse published information. Bibliometric analysis includes the number of publications and authors, keywords, etc. It can be used to understand the current state of research in the field and to predict trends in related areas of science and technology through analysis [10, 12-14]. Selecting the appropriate visualisation software is of great importance. Current visualisation and analysis software widely used by academics include CiteSpace, HistCite, Gephi, SciTool and VOSviewer. Compared to other software, the VOSviewer analysis software is particularly suitable for this study as it can perform self-occurrence, co-occurrence and cluster analyses of scientific and technical data in specific fields of knowledge, highlight links between research topics and present them clearly [15-19]. Therefore, in this study, VOSviewer software was used to visually analyse the collected literature.

## **3. Results**

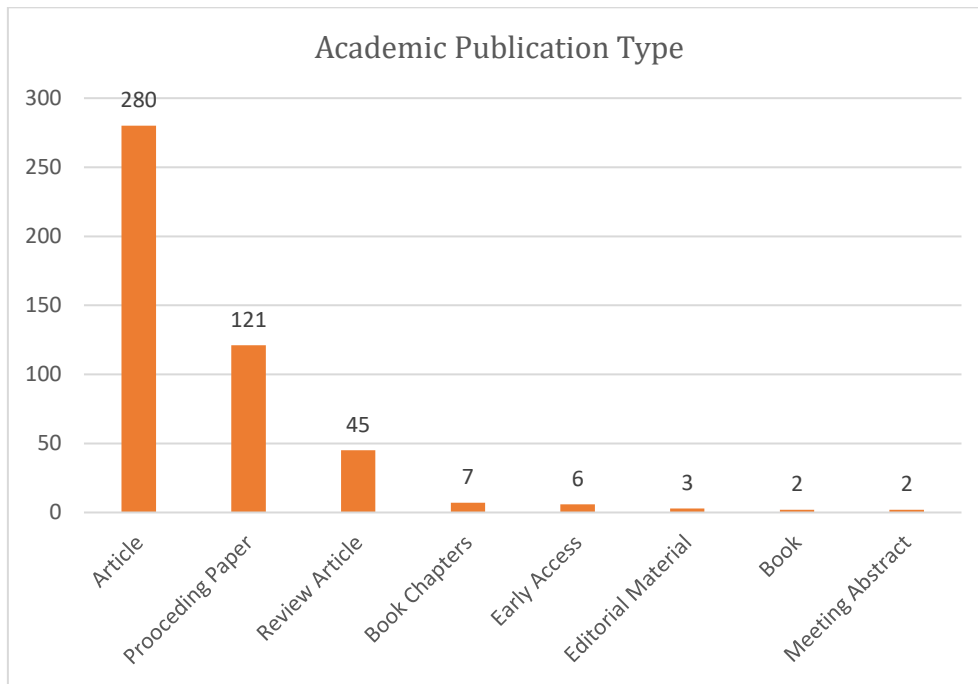
In the study, a literature review on the subject of "BREEAM" was conducted and the results of key concept analysis, publication type, publication language, most active authors, articles, journals, institutions and countries, co-citation / cited references analysis and co-citation analysis of cited sources were obtained by mapping method with VOSviewer analysis program.

In the Advanced Search section of the Web of Science database on 24.05.2024, the keyword "BREEAM" was entered in the topic tab where the title, abstract and keywords determined by the authors were scanned and online search was performed. As a result of the online search, a total of 466 documents, 280 of which were articles, were found in the relevant keyword groups in the literature. It was determined that the first study indexed in the Web of Science database on the subject was the study "BREEAM New Homes - The Bre Environmental Assessment Method For New Homes" by Raw and Prior (1992) [20].

The data obtained from the Web of Science (WoS) database related to the research topic were analysed by bibliometric mapping method. Bibliometric mapping is defined as a discipline for visualising the structure, relationships and dynamics of studies in the scientific literature in a certain field and aims to reveal the relationships between different fields, different disciplines, journals, scientists, publications, resources and scientific terms [13, 18, 21].

### 3.1. Academic Publication Type Analysis

The types and numbers of academic publications that emerged as a result of a detailed search with the keyword "BREEAM" on 24-05-2024 in the Topic tab in the advanced search section of the Web of Science Core Collections database are shown in Figure 1.



**Figure 1.** Distribution of academic publication types

Although there are 453 academic publications in the WoS database in total, it was determined that there are 466 publications in total in the distribution of academic publication types. 13 of these publications were also indexed in different academic publication types. When the distribution of publication types was analysed, it was seen that 280 of 466 documents were articles and 121 documents were proceeding papers. Articles and papers are followed by review articles with 45 documents. It was observed that the remaining publications consisted of book chapters, early access publications, editorial material, book and meeting abstracts. The different types of publications show that researchers approach the subject of "BREEAM" from a wide perspective. It reveals that academic studies on "BREEAM" are rich in terms of both diversity and depth and that an important accumulation of knowledge has been created in this field.

### 3.2. Distribution of Academic Publication Language

After the search and extraction process in the Web of Science Core Collection database, the publication language distribution of the articles written on the subject of "BREEAM" was analysed and shown in Table 1.

**Table 1.** Distribution of academic publication language

Publications Language	Number
English	438
German	6
Spanish	5
Turkish	2
Croatian	1
Portuguese	1

The publication language distribution of the articles reached after the scanning and sorting process in the Web of Science Core Collection database was analysed and it was determined that a total of 453 articles were published in English (438), German (6), Spanish (5), Turkish (2), Croatian (1) and Portuguese (1).

When the language distribution of the articles is analysed, it is seen that the dominant language of publication in the field is English. The preference of English as the language of publication in the field with 438 articles can be explained as the acceptance of English as the language of academic science in the world and the acceptance of English as the priority language by the journals publishing in the database where the study was conducted. Two studies written in Turkish language are "Evaluation of Mass Housing at the Pre-Design Stage [22]" and "A Pareto Based Genetic Algorithm Model for Sustainable Site Layout Design of Social Housing: SSPM [23]". These results show that academic studies on "BREEAM" are available in German, Spanish, Turkish, Croatian and Portuguese as well as English. The existence of academic studies in different languages is an indication that "BREEAM" is a universal subject and field of study.

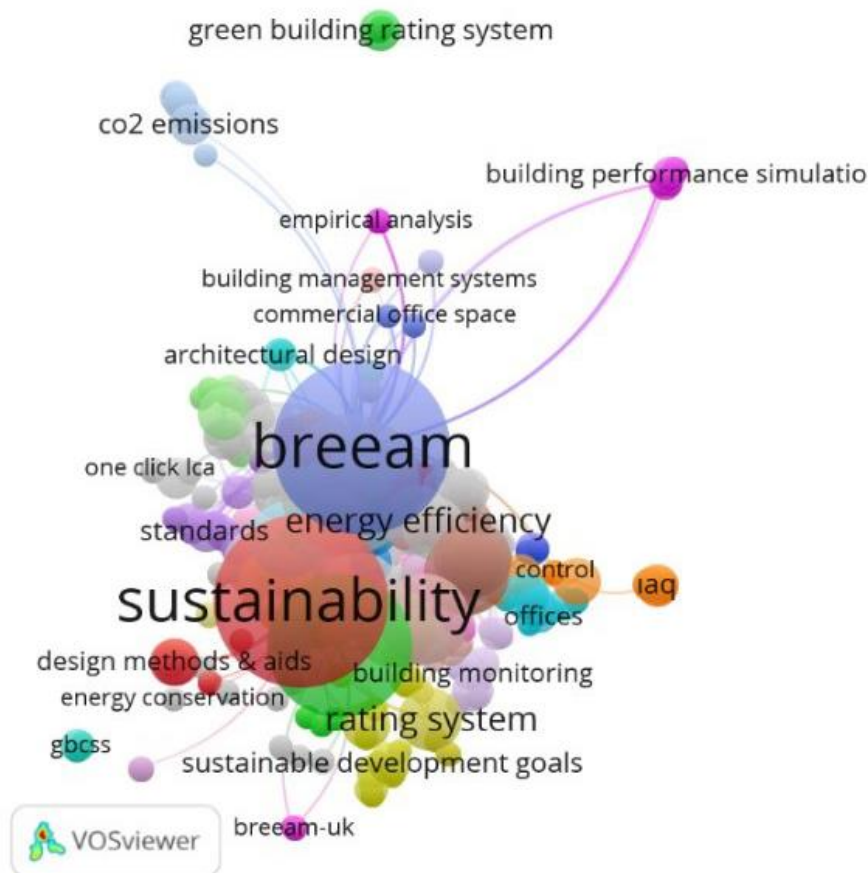
### 3.3. Keyword Analysis

In the VOSviewer analysis programme of the data obtained from the WoS database, co-occurrence/author keywords used by the authors were analysed in order to understand the conceptual structure of the field, to reveal the most effective keywords and to understand where the field has evolved over the years.

The importance of keywords is related to the number of times they appear in the data set. The distance between keywords is an indicator of the relationships between these words. The smaller the distance between two keywords, the greater the relationship between them [24].

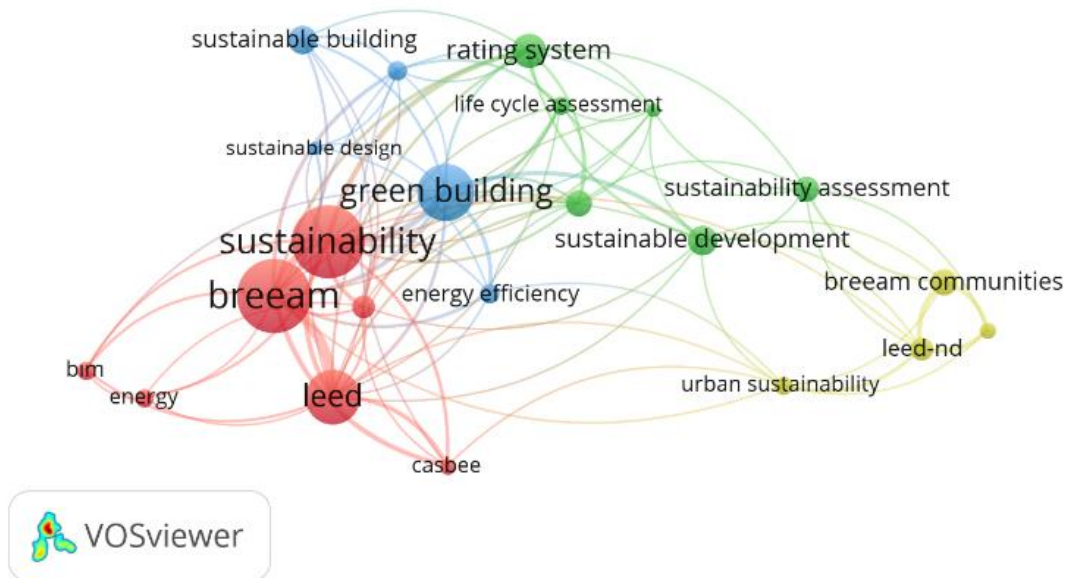
The use of common word analysis allows researchers to provide detailed information on the content of each cluster. In addition, common word analysis can be used to predict future research in the field, which can be achieved when the inferences drawn from the detailed analysis of the publication and the keywords carefully selected from future research directions are used in the analysis. In this context, co-word analysis is suitable for researchers who wish to diversify their interpretations of co-citation analysis (past tense) or bibliographic matching (present tense) and predict the future state of the field. For this reason, common word analysis can provide researchers with a perspective on the future of the field [25].

A total of 919 different keywords were used in the study and the network visualisation map for 762 keywords that interact with each other is shown in Figure 2.



**Figure 2.** Keyword analysis network map

In order to identify the most active and most effective topics in the field from the 163 keywords used in the research, the 22 most effective keywords that meet the criteria of "use together in at least 5 publications" were identified and visualised in Figure 3.



**Figure 3.** Network map of the most effective keywords

The network map created by VOSviewer software with the criterion of "use in at least 5 publications" was visualised as a total of 21 keywords (items) in 4 clusters.

The first cluster, shown in red colour, consists of 6 items as BIM-Building Information Modeling, CASBEE-Comprehensive Assessment System for Built Environment Efficiency, Energy, LEED-Leadership in Energy and Environmental Design, BREEAM- Building Research Establishment Environmental Assessment Method, Sustainability. It was observed that the dominant keyword of the word group (cluster) was "BREEAM".

The second cluster, shown in green, consists of 6 components: Building Performance, Life Cycle Assessment, Sustainability Assessment, Sustainable Construction, Rating Systems, Sustainable Development. It is seen that the dominant keyword of the word group (cluster) is "Rating Systems".

The third cluster, which is shown in blue colour, consists of 5 components: Green Building, Sustainable Building, Sustainable Design, Energy Efficiency and Environmental Assessment. It was observed that the dominant keyword of the word group (cluster) was "Green Building".

The fourth cluster, shown in yellow, consists of 4 elements: BREEAM Communities, LEED-ND Leadership in Energy and Environmental Design - Neighbourhood Development and Urban Sustainability and CASBEE-UD / CASBEE for Urban Development. It was observed that the dominant keyword of the word group (cluster) was "BREEAM Communities".

According to the common word analysis, it was seen that the keywords were gathered in 4 different coloured clusters. The words in these clusters provide information related to the relevant topics studied in the field. When the clusters are examined, important keywords such as "BREEAM" in the largest cluster in red, "Rating Systems" in the second cluster in green, "Green Building" in the third cluster in blue, and "BREEAM Communities" in the fourth cluster in yellow attract attention.

The time-based keyword layer network map created in order to better understand the change and transformation of the research topics related to the field in different years, to reveal the trend of the field that changes according to different time periods and to identify trend study topics is visualised and presented in Figure 4.

When the keyword analysis layer visualisation map of the study is examined; the key concepts dominating the field in 2014-2024 are; "BREEAM- Building Research Establishment Environmental Assessment Method, Energy, LEED-Leadership in Energy and Environmental Design, CASBEE- Comprehensive Assessment System for Built Environment Efficiency, BIM-Building information modelling, sustainable building, energy efficiency, Sustainability, building performance, sustainability assessment, sustainable construction, sustainable development, sustainable design, environmental assessment, life cycle assessment, green building, BREEAM communities, rating systems, LEED-ND Leadership in Energy and Environmental Design- Neighbourhood Development, urban sustainability, CASBEE-UD / CASBEE for Urban Development".

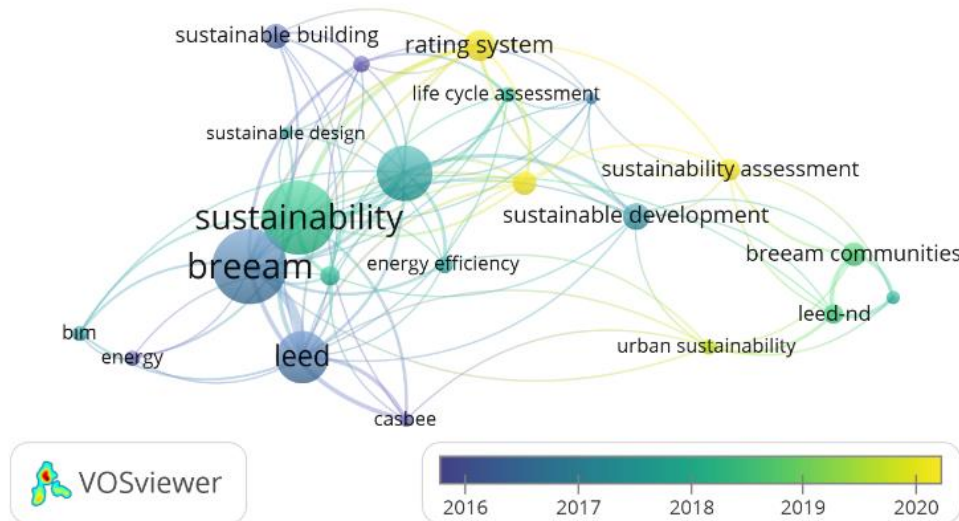


Figure 4. Keyword layer analysis

Within the scope of the research, the 10 most effective keywords of the field according to the co-occurrence power are presented in Table 2.

According to the co-occurrence power, the most effective keyword in the field is BREEAM keyword with 51 co-occurrence and 70 total link power, second is LEED keyword with 50 co-occurrence and 50 total link power, third is Green Building keyword with 35 co-occurrence and 41 total link power.

In the analysis, "bioharmological buildings", "carbon foodprint", "climate change", "neighbourhood assessment tools" and "CityGML", which have been studied less in recent years and are considered as a gap in the field, were determined as keywords.

Table 2. The most effective keywords

Key Concept	Co-occurrence	Total Link Power
BREEAM	51	70
Sustainability	50	50
Green building	35	41
LEED	33	58
Rating System	27	42
Sustainable development	14	15
Sustainable building	13	9
BREEAM communities	12	16
Sustainable construction	12	15
Sustainability assessment	11	9

### 3.4. Most Efficient Authors Analysis

As a result of the citation analysis, 43 authors who have at least one publication among 741 authors publishing in the field and who meet the criteria as a result of bibliometric analysis performed in WOSviewer analysis software with the criterion of receiving at least 100 citations were taken into consideration. The visual map of the citation analysis of the first 43 authors is presented in Figure 5.

In order to present the visual network of the citations received by the authors more clearly and to better understand the connection between the authors, the first author among the authors with co-authorship links was included in the analysis and the data on the other authors were not included in the analysis. The visual network map created in this direction is presented in Figure 6.

The total link strength (TLS) score for documents indicates the total strength of a given researcher's co-authorship relationships with other researchers. In the citation analysis of VOSviewer, the frequency of cited works of an author who appears as the first author in the articles is examined [26]. In other words, in the author analysis, the total number of citations received by the researcher over all his/her works is determined. According to the number of citations received from the authors, the first 5 authors with the highest number of citations are presented in Table 3.

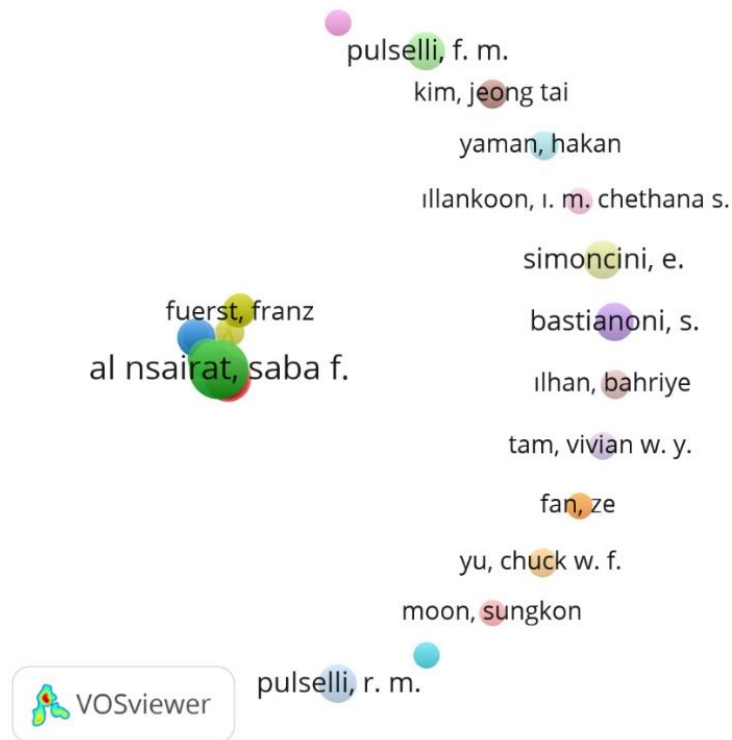


Figure 5. Author network analysis with the most citations

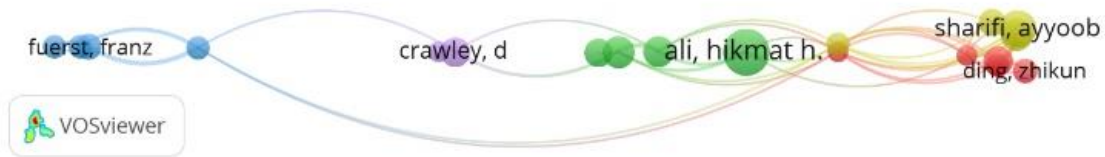


Figure 6. Most effective author network analysis

Table 3. Most influential authors

Nu.	Author Name	Number of Article	Number of Citation	TLS
1	Hikmat H. Ali	1	340	10
2	Ayyoob, Sharifi	4	244	16
3	Akito, Murayama	2	203	15
4	Saleh H. Alyami	4	199	18
5	Yacine Rezgui	2	188	15

In the analysis of the authors, Hikmat H. Ali ranks first with 1 publication, 340 citations and 10 link strength, while Ayyoob Sharifi ranks second with 4 publications, 244 citations and 16 link strength. The third most influential author is Murayama Akito with 2 publications, 203 citations and 15 link strengths, the fourth is Saleh H. Alyami with 4 publications, 199 citations and 18 link strengths and the fifth is Yacine Rezgui with 2 publications, 188 citations and 15 link strengths.

### 3.5. Most Effective Articles Analysis

With the restriction of 280 publications, articles with at least 50 citations, 35 articles with the highest number of citations in the field were identified through the VOSviewer analysis programme, and the 29 most influential articles among them were included in the analysis and visualised in Figure 7 and presented below.

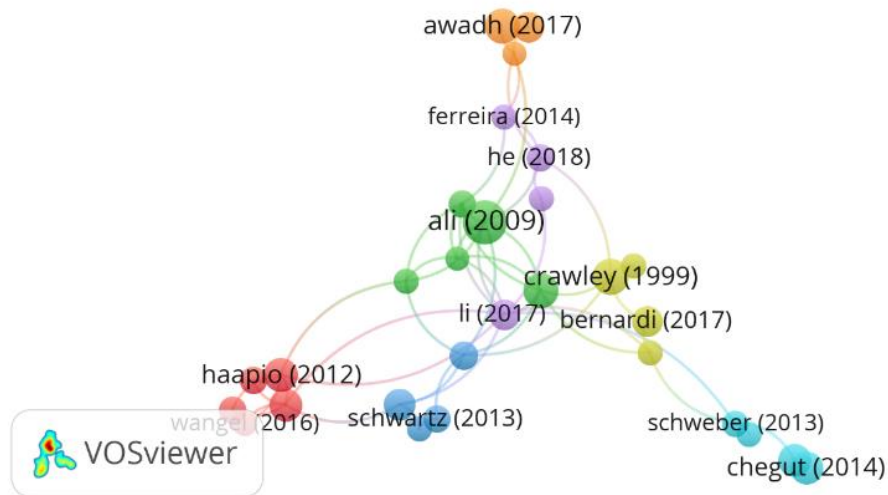


Figure 7. Network visualisation of the articles with the most citations

As a result of the analysis, the first 5 articles with the highest number of citations were analysed and presented in Table 4.

When the first five articles are analysed; "Developing a Green Building Assessment Tool For Developing Countries- Case of Jordan" written by Hikmat H. Ali and Saba F. Al Nsairat in 2009 is the most influential article with 340 citations. The aim of the article is to contribute to a better understanding of the concept of green building assessment tool and its role in achieving sustainable development by developing an effective green building rating system based on the dimensions of sustainable development tools for housing units in Jordan. In the research, international green building rating tools such as LEED, CASBEE, BREEAM, GBTool and others were analysed. Then, new assessment items were defined in accordance with Jordan's local conditions and these items were discussed with various stakeholders, 50% of whom are sustainable development experts. As a result of the research, SABA (Green Building Rating System) was recommended as the most effective green building rating tool that is environmentally, socially and economically appropriate for the Jordanian context.

Table 4. Analysis of the most effective articles

Author(s)	Article Name	Journal Name	Keyword(s)	Citation	Reference
Hikmat H. Ali & Saba F. Al Nsairat (2009)	Developing a green building assessment tool for developing countries - Case of Jordan	Building and Environment	achieving sustainable development, sustainable development, LEED, CASBEE, BREEAM, GBTool	340	[27]
Drury Crawley & Ilari Aho (1999)	Building environmental assessment methods: applications and development trends	Building Research & Information	Environmental Assessment, Green Buildings, Life Cycle Assessment, Building Performance, Green Building Challenge	188	[28]
R.M. Pulselli et al. (2007)	Emergy analysis of building manufacturing, maintenance and use: Em-building indices to evaluate housing sustainability	Energy and Buildings	building design LEED BREEAM emergy	181	[29]
Omar Awadh (2017)	Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis	Journal of Building Engineering	LEED, BREEAM climate change environmental assessment	167	[30]
H. Alyami & Yacine Rezgui (2012)	Sustainable building assessment tool development approach	Sustainable Cities and Society	environmental assessment methods LEED BREEAM CASBEE	162	[31]

In the analysis, the second most influential article with 181 citations was the 1999 study by Drury Crawley and Ilari Aho, "Building Environmental Assessment Methods: Applications And Development Trends". In the article; it



is mentioned that the construction and property sector has developed a series of methods to assess the 'greenness' of buildings in the 1990s, both for new designs and for existing buildings. It reveals that these range from very detailed life cycle assessment methods that take into account all the tangible and operational environmental impacts of building materials, to higher level environmental impact assessment methods that assess the wider implications of a building's impact on the environment, and in between these two are environmental assessment methods such as BREEAM, BEPAC, LEED and GBA. In this paper, the potential market applications of these systems are discussed and recommendations are made by comparing a few of the major environmental assessment methods.

The third most cited paper in the analysis with 181 citations is the 2007 paper by R.M. Pulselli, E. Simoncini, F.M. Pulselli, S. Bastianoni entitled "Emergy Analysis of Building Manufacturing, Maintenance and Use: Em-Building Indices to Evaluate Housing Sustainability" by F.M. Pulselli, F.M. Simonini, F.M. Pulselli, F.M. Simonini, F.M. Pulselli, S. Bastianoni, 2007, an emergy (with "m") analysis was applied to a building to take into account the main energy and material flows into the building's manufacturing, maintenance and utilisation processes. Building materials, technologies and building elements are measured and compared with each other to provide a baseline calculation that can be used for impact assessment and selection. A comprehensive assessment of the construction sector was then made through a series of synthetic indices.

The fourth ranked index, with 167 citations, is the 2017 paper by Omair Awadh, "Sustainability and Green Building Rating Systems: LEED, BREEAM, GSAS and Estidama Critical Analysis" by Omair Awadh in 2017, provides an objective analysis between two internationally applied GBRSSs; LEED and BREEAM, and two developed specifically for the Gulf region; Estidama and GSAS. These four systems are analysed in a way that addresses and prioritises sustainability fundamentals. The study also focuses on energy and water criteria and quantitatively discusses the credit weights given by these systems.

The article titled "Sustainable Building Assessment Tool Development Approach" written by Saleh H. Alyami and Yacine Rezgui in 2012, which ranks fifth in the analysis with 162 citations, examines the most important and common environmental assessment methods worldwide: BREEAM, LEED, SBTool and CASBEE. It identifies areas of convergence and divergence to enable the incorporation of environmental criteria into new potential schemes. In addition to being considered as a starting point for the consensus-based process procedure, it also provides a general model for the development of an effective environmental assessment methodology for the establishment of an environmental assessment methodology suitable for Saudi Arabia.

### 3.6. Most Effective Journals Analysis

In the Web of Science database, out of 113 journals publishing in the field of research, the 19 most active journals in the field were reached by performing citations-sources analysis in the VOSviewer bibliometric analysis mapping tool with the restriction of publishing at least 3 documents and at least 10 citations. The status of the journals is mapped and presented in Figure 8.

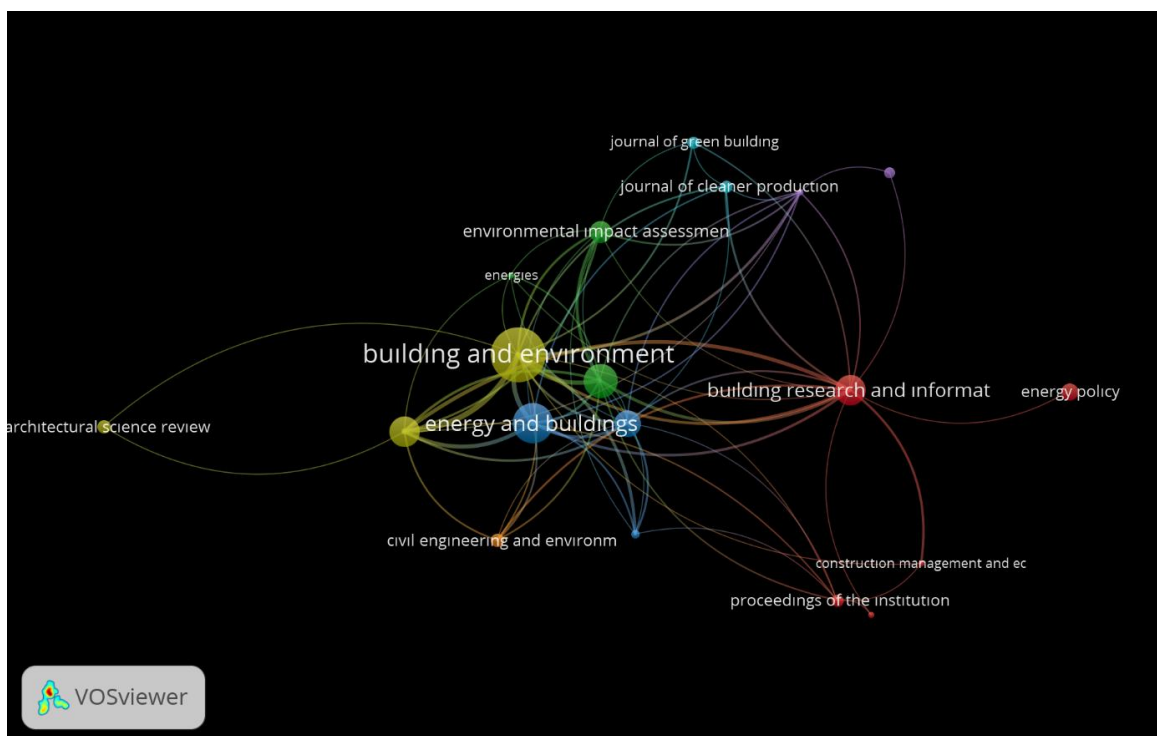


Figure 8. Network map of the most efficient journals

As a result of the analysis, it was determined that the most effective 19 journals were gathered in 7 clusters. In the first cluster; Applied Sciences-Basel, Building Research and Information, Construction Management and Economics, Energy Policy, Proceedings of the Institution of Civil Engineers-Engineering. In the second cluster; Energies, Environmental Impact Assessment Review, Sustainable Cities and Society journals are included. In the third cluster; Buildings, Energy and Buildings, Journal of Building Engineering journals; in the fourth cluster; Architectural Science Review, Building and Environment, Sustainability journals. In the fifth cluster; Architectural Engineering and Design Manager, Environment Development and Sustainability journals; in the sixth cluster, Journal of Cleaner Production, Journal of Green Building journals and finally in the seventh cluster, Civil and Engineering and Environmental Systems journals. Information on the most cited journals is shown in Table 5.

**Table 5.** The most effective journals

<b>Journal Name</b>	<b>Number of Articles</b>	<b>Number of Citations</b>	<b>Total Link Power</b>
Building and Environment	17	1,150	101
Energy and Buildings	13	699	60
Sustainable Cities and Society	10	541	52
Building Research and Information	9	444	58
Sustainability	34	439	73
Journal of Building Engineering	6	347	32
Environmental Impact Assessment Review	6	253	25
Energy Policy	3	169	1
Civil and Engineering and Environmental Systems	3	122	16
Architectural Science Review	6	122	2

When the most cited journals were analysed, it was found that "Building and Environment" ranked first as the most active journal in the field with 17 publications, 1,150 citations and 101 link strength. "Building and Environment" is an international journal that publishes original research articles, comprehensive review articles, editorials and short communications on building science, urban physics and human interaction with the indoor and outdoor built environment. The journal is focused on innovative, state-of-the-art technologies and knowledge, rigorously validated by measurement and analyses. The journal publishes articles on the environmental performance of the built environment across a wide range of spatial scales, from cities, communities, buildings, building systems and assemblies, as well as other built environments related to transport and industrial environments (URL-1, 2024).

"Energy and Buildings" ranks second among the journals in the field with 13 publications, 699 citations and 60 link strength. "Energy and Buildings;" an international journal dedicated to research on energy use and efficiency in buildings, is an international journal that publishes articles with clear links to energy use in buildings. Its aim is to present new research results and proven new practices aimed at reducing a building's energy needs and improving indoor environmental quality. Energy and Buildings considers and publishes papers that significantly advance building science. It favours practical and experimental research papers that report important innovations. It accepts papers reporting advances in theoretical and simulation methods after the results have been fully validated using appropriate experimental data; papers reporting the application of numerical or theoretical methods for the analysis of new technology, materials and innovative designs are likewise accepted (URL-2, 2024). The journal "Sustainable Cities and Society" is the third most active journal in the field with 10 publications, 541 citations and 52 link strengths. "Sustainable Cities and Society" is an international journal focusing on basic and applied research that aims to design, understand and promote environmentally sustainable and socially resilient cities. Supporting a wide range of methodological and technical approaches including experimental, observational, monitoring and management studies and policy analysis, the journal publishes review articles on key developments as well as basic and applied articles (URL-3, 2024).

### **3.7. Most Effective Countries Analysis**

A co-authorship/countries analysis was conducted in the WoS database to identify the countries that contributed the most to the literature with article publications containing the research topic and the studies conducted together between countries. The 64 countries in which the relevant studies were identified were reduced to 24 dominant countries in the field with the restrictions of publishing 5 studies and receiving 25 citations and presented in Figure 9.

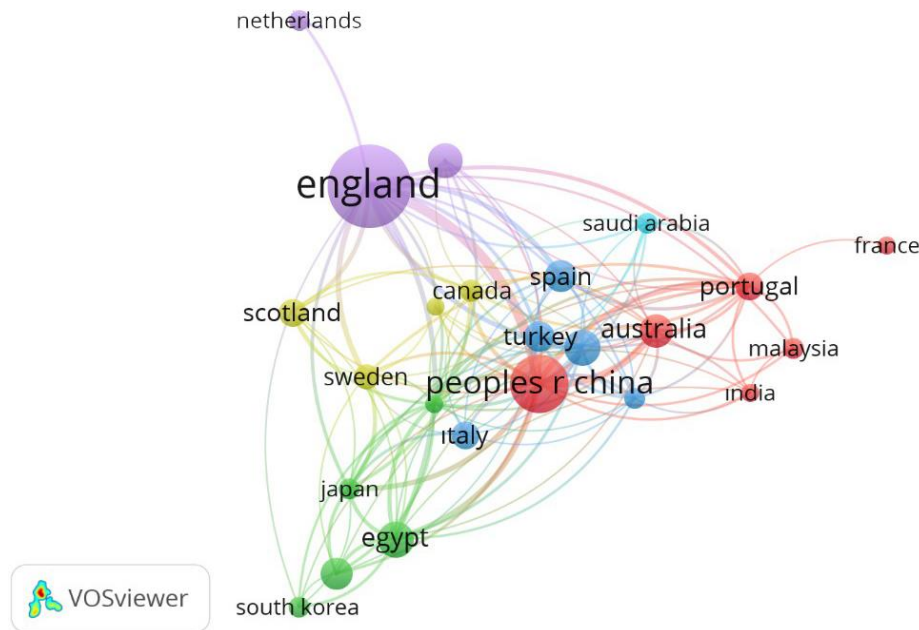


Figure 9. Most efficient countries network map

The network map created with the constraints determined through the VOSviewer programme was mapped as 24 countries (items) and 6 clusters. The first cluster includes the People's Republic of China, France, India, Portugal and Malaysia; the second cluster includes Egypt, Finland, Germany, Japan and South Korea; the third cluster includes Iran, Italy, Spain, Turkey and the USA. The fourth cluster includes Brazil, Canada, Scotland and Sweden; the fifth cluster includes England, the Netherlands and Poland; and the sixth cluster includes Saudi Arabia. The 10 most efficient countries determined as a result of the findings obtained in the study are presented in Table 6.

Table 6. Most active countries according to the number of documents

Country Name	Number of Documents	Number of Citation
United Kingdom	60	1.168
People's Republic of China	33	904
United States of America	15	472
Egypt	15	235
Poland	14	94
Australia	13	349
Spain	12	159
Germany	12	74
Turkey	11	324
Italy	10	378

When the studies conducted by the countries on the subject of study were evaluated according to the data obtained from the WoS database; it was seen that the United Kingdom ranked first with 60 documents and 1,168 citations, and the People's Republic of China ranked second with 33 documents and 904 citations. The United States of America ranked third with 15 documents and 472 citations. The United States of America was followed by Egypt with 15 documents and 235 citations, Poland with 14 documents and 94 citations, Australia with 13 documents and 349 citations, Spain with 12 documents and 159 citations, Germany with 12 documents and 74 citations, Turkey with 11 documents and 324 citations, Italy with 10 documents and 378 citations.

### 3.8. Most Active Institutions Analysis

Coauthorship / organisations analysis was performed to determine the most active and most publishing organisations on the subject based on the data obtained from the WoS database with search words and certain constraints. In the visualisation made with the help of the Vosviewer program, in the visual map obtained, the size of the nodes indicates the number of studies covering the subject studied in the relevant institution and the colour clusters indicate the cooperation between the institutions [32].

In the research, it was determined that there were 371 institutions working on the subject researched in the relevant database, the number of institutions was reduced to 34 institutions with the conditions of having at least 2 articles and 50 citations through the WOSviewer program, and 7 interconnected institutions within these institutions were visualised and presented in Figure 10.



Figure 10. Network map of the most influential organisations

The 7 institutions (items) are visualised as 3 clusters with the WoSviewer program. The red cluster shows the relationships between the institutions of Norwegian University of Science and Technology, University of Cambridge, University of Reading. Between Norwegian University of Science and Technology and University of Cambridge, Pritchard and Kelly (2017), "Realising Operational Energy Performance in Non-Domestic Buildings: Lessons Learnt from Initiatives Applied in Cambridge" was carried out jointly[33].

The green cluster shows the relationship between Chongqing University and The University of Melbourne. He et al., (2022) "How green building rating systems affect indoor thermal comfort environments design" was written in collaboration between two universities [34].

The blue cluster shows the relationship between Shenzhen University and Western Sydney University. Ding et al. (2018), "Green building evaluation system implementation" study is presented as an example of the studies carried out in cooperation with two institutions [35].

The 10 most active institutions according to the number of citations working on the subject are presented in Table 7.

Table 7. Most cited institutions

Name of Institution	Number of Documents	Number of Citation	Total Power	Link
University of Reading	10	344	3	
The Hong Kong Polytechnic University	5	280	2	
University of Cambridge	5	209	3	
Nagoya University	2	203	2	
National Institute for Environmental Studies	2	203	2	
Cardiff University	3	188	0	
Shenzhen University	3	145	2	
National Taiwan University	3	132	1	
İstanbul Teknik Üniversitesi	2	124	0	
Norwegian University of Science and Technology	2	121	1	

In the study on BREEAM, it was seen that University of Reading was the most effective institution according to the number of citations with 344 citations. The Hong Kong Polytechnic University ranked 2nd with 280 citations and University of Cambridge ranked 3rd with 209 citations.

### 3.9. Co-Citation/Citation References Analysis

The references related to the references in the bibliography of 280 articles were analysed and co-citation / cited references (co-citation / cited references) analysis, in which the links between the references are presented visually, was performed. 10.480 references in 280 articles were visualised as 16 items and 3 clusters, provided that they were repeated at least 20 times, and presented in Figure 11.

In the first cluster shown in red colour; "Developing a green building assessment tool for developing countries-Case of Jordan" published by Hikmat H. Ali and Saba F. Al Nsairat in 2009 [27]; "Sustainable building assessment tool development approach" published by Saleh H. Alyami and Yacine Rezgui in 2012 [31]; "Building environmental assessment methods: redefining intentions and roles [36]" published by Raymond J. Cole in 2005; "Sustainable construction-The role of environmental assessment tools" published by Grace K.C. Ding in 2008, "Sustainable construction-The role of environmental assessment tools" [1]; Appu Haapio and Pertti Viitaniemi in 2008, "A critical review of building environmental assessment tools" [37]; Libby Schweber in 2013, "The effect of

BREEAM on clients and construction professionals" [38] and Libby Schweber and Hasan Haroglu in 2014, "Comparing the fit between BREEAM assessment and design processes" [39].

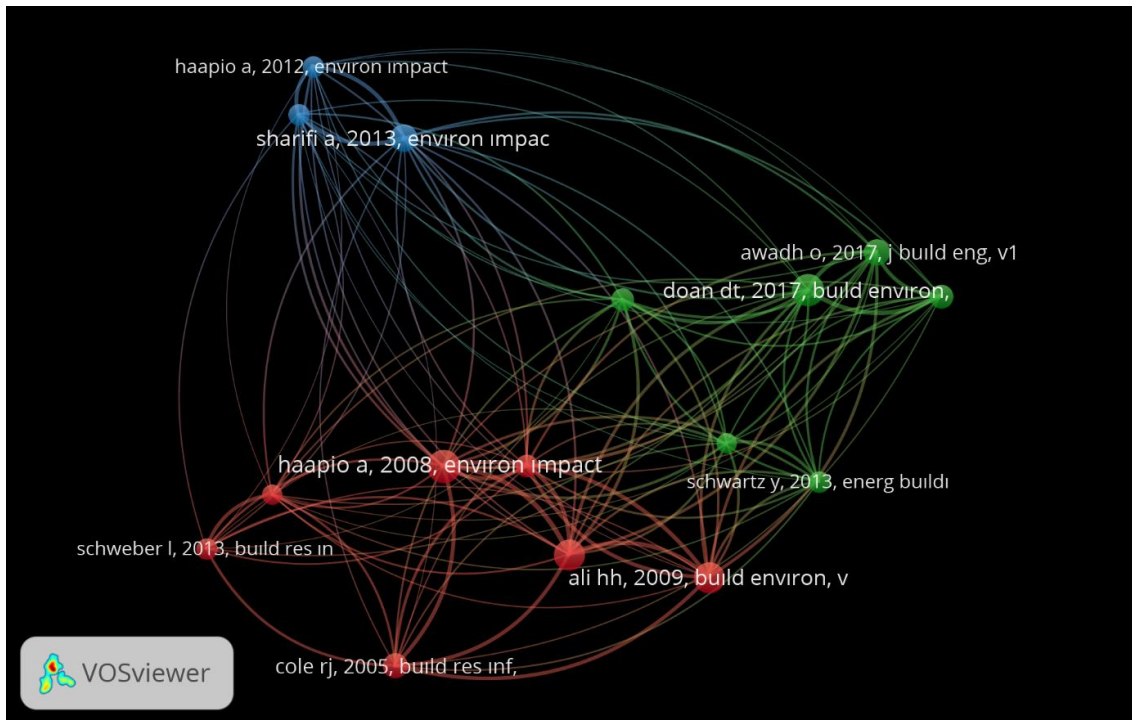


Figure 11. Cited references network map

In the second cluster shown in green colour; "Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis" [30]; "A critical comparison of green building rating systems" published by Dat Tien Doan et al. in 2017 [40]; "Benchmarking energy use assessment of HK-BEAM, BREEAM and LEED" published by W.L. Lee and J. Burnett in 2008 [41]; "Critical review and methodological approach to evaluate the differences among international green building rating tools" published by B. Mattoni et al. "Critical review and methodological approach to evaluate the differences among international green building rating tools" [42]; "Comparative Review of Five Sustainable Rating Systems" by Binh K. Nguyen and Haşim Altan in 2011 [43] and "Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study" [44].

The third cluster in blue contains the articles "Towards sustainable urban communities" published by Appu Haapio in 2012 [45]; "A critical review of seven selected neighbourhood sustainability assessment tools" published by Ayyoob Sharifi and Akito Murayama in 2013 [46] and "Neighbourhood sustainability assessment in action: Cross-evaluation of three assessment systems and their cases from the US, the UK, and Japan" published by Ayyoob Sharifi and Akito Murayama in 2014 [47].

According to the analysis, the 5 most cited references are presented in Table 8.

Table 8. Most cited references

Author(s)	Article Name	Number of Citation	Total Link Power	Reference
Appu Haapio and Pertti Viitaniemi (2008)	A critical review of building environmental assessment tools	45	137	[37]
Dat Tien Doan et al. (2017)	A critical comparison of green building rating systems	42	107	[40]
Grace K.C. Ding (2008)	Sustainable construction-The role of environmental assessment tools	41	142	[1]
Hikmat H. Ali and Saba F. Al Nsairat (2009)	Developing a green building assessment tool for developing countries-Case of Jordan	41	124	[27]
Ayyoob Sharifi and Akito Murayama (2013)	A critical review of seven selected neighborhood sustainability assessment tools	34	86	[46]

### 3.10. Co-Citation Analysis of Cited Authors

In the VOSviewer analysis programme, co-citation/cited authors analysis was performed to reveal the authors cited together in different articles and their collaborations. The 7326 authors in the bibliographies of the articles constituting the sample of the study were reduced to 13 authors (items) with the condition of at least 30 citations and visualised as 3 clusters and shown in Figure 12.

In cluster 1 (red), Ali, H.H., Alyami, S.H., Awadh. O., Ding, G.K.C., Doan, D.T., Lee, W.L., Suzer. O., while the most cited author of the cluster is Lee, W.L. with 65 citations.

In cluster 2 (green); Berardi, U., Haapio. A., Sharifi, A., were observed. The most cited author is Sharifi, A., with 90 citations.

Cluster 3 (blue); Cole, R.J., Schweber, L., and the most influential author of the cluster was Cole, R.J., with 116 citations.

The 5 most frequently cited authors on BREEAM are presented in Table 9.

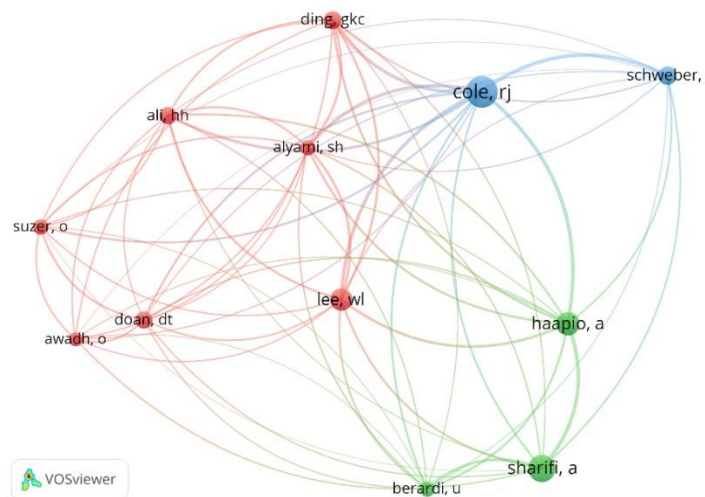


Figure 12. Co-citation network analysis map of cited authors

Table 9. Most cited authors

Author Name	Number of Citations	Total Link Power
Cole, R.J	116	493
Sharifi, A.	90	280
Haapio, A.	73	349
Lee, W.L.	65	294
Schweber, L.	48	165

The 3 most cited authors are Cole, R.J. with 116 citations, Sharifi, A. with 90 citations and Haapio, A. with 73 citations.

### 3.11. Co-Citation Analysis of Cited Sources

In the study on the Green Building Certificate BREEAM, co-citation / cited sources analysis was conducted to identify the most frequently cited sources and their relationships with each other. 6042 sources were mapped as 20 items and 4 clusters with the condition of being cited at least 50 times and shown in Figure 13.

Cluster 1 (red) consisted of Automation in Construction, Energy and Buildings, Energy Policy, Energy, Energy Procedia, Journal of Building Engineering, Procedia Engineering, Renewable and Sustainable Energy Reviews. The most effective source in the red cluster was found to be the Energy and Buildings journal with 467 citations.

Cluster 2 (green) consisted of Ecological Indicators, Environmental Impact Assessment, Habitat International, Journal of Cleaner Production, Sustainable Cities and Society, Sustainability - University of Basel. The most cited source in the green cluster was Journal of Cleaner with 325 citations.

Cluster 3 (blue) consisted of Building Research and Information, Construction Management and Economics, Journal of Environmental Management, Thesis- Journal. The dominant source in the blue cluster was identified as Building Research and Journal with 424 citations.

Cluster 4 (yellow) consisted of Building and Environment, Indoor and Built Environment and Building and Environment journal was found to be the dominant source of the cluster with 679 citations.

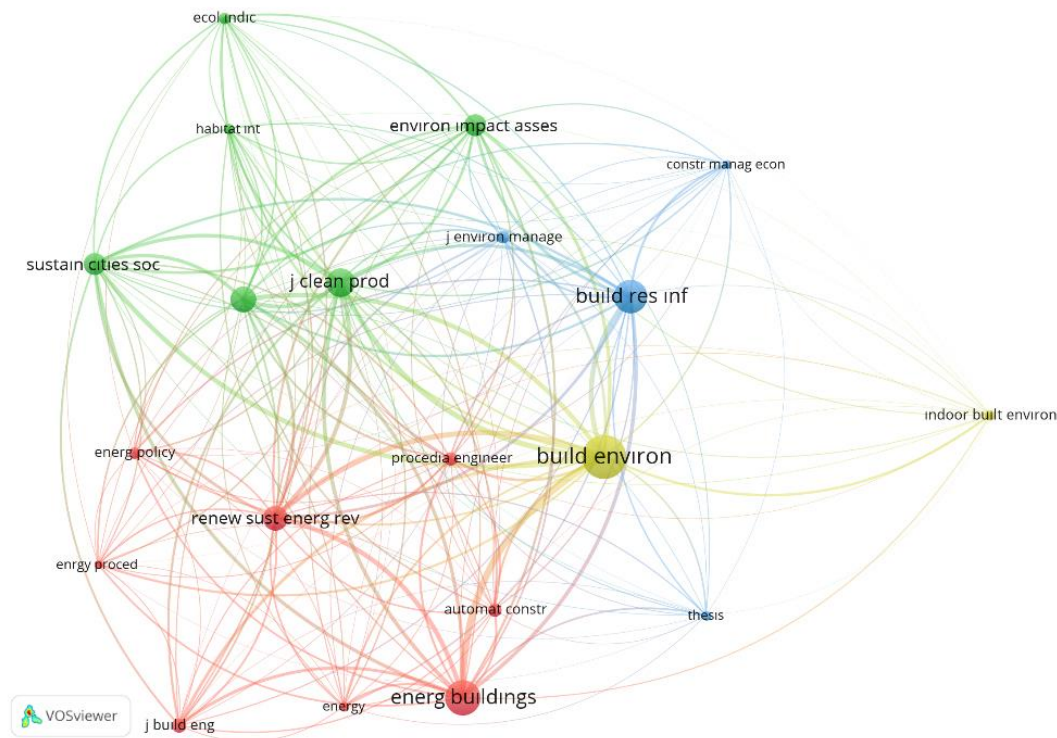


Figure 13. Cited sources network map

The 5 most cited references of the study on BREEAM are presented in Table 10.

Table 10. The most cited sources

Source Name	Number of Citations	Total Link Power
Building and Environment	679	12179
Energy and Buildings	467	8592
Building Research and Information	424	5408
Journal of Cleaner Production	325	7251
Sustainability – University of Basel	281	5581

Building and Environment ranks first with 679 citations and 12179 total link strength. Building and Environment is followed by Energy and Buildings with 467 citations and 8592 total link strength and Building Research and Information with 424 citations and 5408 link strength.

#### 4. Conclusion

In this study, a bibliometric analysis of the literature on BREEAM (Building Research Establishment Environmental Assessment Method) was carried out. The data obtained revealed research trends, key topics and scientific impacts in this field. The main findings of the study are as follows:

**Distribution and Types of Publications:** The majority of publications on BREEAM are in the form of articles, followed by papers and review articles. This shows that the subject of BREEAM has attracted a wide interest in the academic field and that a significant body of knowledge has been accumulated in this field.

**Publication Language:** The majority of the publications are written in English. This is due to the fact that English is the dominant language in the academic field. There are also a small number of publications in Turkish, German, Spanish and other languages.

**Keyword Analysis:** The results of the analysis show that BREEAM is associated with key topics such as sustainability, energy efficiency, green building and life cycle assessment. In addition, it has been identified how research on BREEAM has evolved over the years and what topics it has focussed on.

**Academic Collaborations and Active Authors:** International collaborations and contributions of researchers from various countries have been found to be important in studies on BREEAM. Active authors and collaborations reveal the existence of studies examining the applicability of BREEAM in different geographical regions and its effects on local construction sectors.

**Future Research Areas:** As a result of the analysis, potential areas that have been less studied in relation to BREEAM and could be investigated in the future have been identified. These areas include "bioharmological buildings", "carbon footprint", "climate change", "neighbourhood assessment tools" and "CityGML".

This study provides an important basis for understanding the current state of research on BREEAM and future research directions. It also aims to contribute to the development of sustainable construction practices by identifying gaps and potential research areas in this field. The impact and importance of BREEAM in raising sustainability standards in the building sector demonstrates the need for continued research in this area.

#### Author contributions:

The authors contributed equally to the study.

#### Conflicts of interest

The authors declare no conflicts of interest.

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