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Bibliometric Analysis of Post-Occupancy Evaluation (POE): Current Status, Development, and Future Research Directions

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Abstract: The application of post-occupancy evaluation (POE) has increased recently, owing to the methodology's ability to improve building performance. However, the procedures employed vary depending on the building's suitability and category. Therefore, this study aims to provide a comprehensive survey to explore the state-of-the-art POE research. Bibliometric analysis was used to retrieve 381 POE publications from the Scopus database between 1979 and 2020. VOSviewer software was applied for the visualization and scientific mapping of literature. The study helps researchers understand by offering comprehensive data about the most literate nation contributions, publications' significant sources, and devoted authors to POE publications. The findings revealed that the United States, the United Kingdom, and China had rendered the three most literature contributions; Building Research and Information were the top publication's significant source titles, and Hassanain, M.A. is incredibly devoted to POE publication. Research hotspots in the POE focus on building performance, architectural design, and sustainable development. The primary themes in POE concentrate on comfort, sustainability, performance, design and criteria. Future research should emphasize that POE is used on heritage buildings to ensure that these buildings perform well for sustainability. It will significantly value the people involved in the design, construction and also conservation practice.

Keywords: Post-occupancy evaluation, bibliometric analysis, content analysis, Scopus, VOSviewer

1. Introduction

'Post-Occupation Evaluation' or POE has been adopted in various industries, including architecture, engineering, and construction (AEC). Since the 1960s, after nearly 60 years of POE-related studies, researchers have concentrated on connecting human actions to building design and creating a new urban layout (Mustafa 2017).

In the 1980s, POE studies increased in number and complexity. Early POE research included case studies on public and student housing. Problems in the building industry require treatment in facilities such as military barracks, hospitals, government and industrial facilities (El-Darwish and El-Gendy 2018).

Once there, the POE dominated the public and private sectors, emphasizing the working atmosphere (Hassanain et al. 2018) for office and commercial properties. Owners, designers, operators, and users began using POE to close the loop (Candido et al. 2016). POE involves gathering valuable information through surveys, interviews, website visits, and field studies from building occupants, including customers, design team members, and contractors (Preiser et al. 2017). Early identification of potential building performance issues as the primary backup in the evaluation can assist. Solving problems can improve building performance.

A building's evaluation can ensure that it is continually operating at optimum efficiency. This directive accepts POE as a helpful way to provide quality feedback on the building's performance. To achieve the design goal, it seeks to know how long structures are evaluated after design and occupancy (Wongbumru and Dewancker 2016). In addition, service providers use it to analyse and evaluate important building performance issues.

According to Hay et al. (2018), many POE studies have been done in various sectors. It is a result of recognizing the significance of POE in enhancing building performance. Most were in the building sector, covering the residential (Lowe et al. 2018), educational (Muizz O. Sanni-Anibire et al. 2016), commercial (Pastore and Andersen 2019), and health (Oh et al. 2017), including infrastructure projects (Kordestani Ghalenoeei et al. 2018). The studies are generally conceived according to specific needs, including design, energy usage, maintenance costs, and user satisfaction (Roberts et al. 2019).

The POE approach differs from other conventional surveys in that it uses the direct and uninterrupted experience of building users to assess a building's performance. They focus on making users' needs more involved in the evaluation process and construction. Thus, POE can be used to evaluate whether architectural design outcomes meet the expectations of building users (Brown 2018). The potential for performance improvement is enormous when occupants are used as a standard. According to Hashim et al. (2018), building occupants know building knowledge and building performance criteria, promoting occupant satisfaction.

Consequently, POE reports are helpful in all buildings, including education. There is no exception. Business results and expenses are affected by building failure. The relevant POE indicator must be POE-compliant to improve building performance, and the building type must be specified.

The POE method model explains three phases of research: process planning, study conduct, and application (Preiser 1995). Indicative, investigative, and diagnostic are the three stages of POE work. Each POE level process has its methodology that enables future studies.

Considering that POE research has spanned over four decades, a comprehensive overview of the POE field study is required. It is suitable for great diversity and increasing publication rates for bibliometric research. Therefore, this study uses bibliometric analysis to classify the publishing patterns, influential author and publication, lead journals, and cognitive context of POE research. This field provides current information and an overview of the site's evolution and research opportunities.

This study to incorporate better bibliometric analysis and content analysis of the Scopus database publication is solely undertaken for the following purposes: 1) to provide a holistic overview of the main characters such as several articles and citations, document and source types, language categories, and representative source titles, 2) to classify the most influential countries, institutions, and authors, 3) to comprehend research advancements and current researches, 4) to propose POE research directions.

1.1 Previous Review Studies on POE

Researchers also conducted numerous literature reviews with limited studies based on POE studies. Some studies discussed POE instruments, methods, and impacts. Khair et al. (2015) developed occupant-centered review tools for the built environment. Alshibani & Hassanain (2018) investigate POE techniques to expose present methods and models for calculating the maintenance costs. Riley et al. (2015) addressed POE techniques currently available to improve higher education (HE) facilities, while Hong et al. (2018) conducted a functional needs study of users to enhance consumer satisfaction and residential performance. In contrast, M.O. Sanni-Anibire et al. (2016) revised a holistic approach of POE.

There is also a discussion on the application structure and specifications for various building typologies such as public buildings (Agyefi-Mensah et al. 2015), cafeterias and restaurants (Hassanain et al. 2016), museums buildings (Rahim et al. 2017), and offices (Othman & Elsaay 2018). Greater emphasis on sustainability in facility lifecycle development has been discussed by Islam et al. (2019).

Several previous researchers looked into POE's challenges. For instance, Woon (2016) evaluated essential success factors in building performance, while Hassanain et al. (2020) examined significant obstacles to introducing POEs.

Most studies should not use bibliometric analysis despite numerous previous POE literature reviews. Previous researchers such as Roberts et al. (2019) limited their review work to mixed-method systematic review using a Web of Science (WoS) database. Sanchez Leitner et al. (2020) used a comprehensive literature review, whereas Li et al. (2018) limited their survey studies to complete and critical literature reviews. The results of the aspect differences, as illustrated in Table 1, set this study apart from others. Bibliometric analysis reveals origins and context to achieve POE research objectives from 1979 to 2020.

Table 1 - POE previous review studies versus our study

Specific comparison	Li et al. (2018)	Roberts et al. (2019)	Brambilla & Capolongo (2019)	Sanchez Leitner et al. (2020)	Our analysis
Review period in years	2010-2017	1970-2018	1988-2018	2013-2017	No year limit
Source	WoS	WoS	Scopus & PubMed	Google Scholar, Science Direct, CAPES Periodicals Portal, Scopus	Scopus
Research emphasis	POE method statistical analysis	Building's operations and performance of POE	Recent tools of POE	Criteria assessed thru POE using approach 5WH1	All aspects of POE
Method	Comprehensive and critical review	Mixed method systematic review	Systematic literature review	Systematic literature review	Bibliometric analysis and content analysis

2. Research Methodology

2.1 Bibliometric Analysis

The bibliometric analysis commonly includes publication classification, authorship details, country keyword frequency, and citations (h-index). Detailed data obtained via the number and quality of published works helps to explain patterns or trends in research publications (Ahmi and Mohd Nasir 2019).

The VOSviewer software provides a free platform for bibliometric visualization and literature mapping with essential words extracted from scientific literature (www.vosviewer.com). VOSviewer also efficiently performs bibliometric methods like co-authorship and co-word analysis citation (Hu and Milner 2020).

In recent years, bibliometric analyses have gained popularity and combined with their visual representation. Numerous bibliometric studies have recently taken place in fields like healthcare (Bonilla-Aldana et al. 2020) and transportation (Le et al. 2019). The same thing is happening in AEC (Akinlolu et al. 2020). Nonetheless, the lack of bibliometric analysis for POE in a built-in environment research led to a lack of knowledge in this field.

We first clarified the search criteria and identified sources to reach our goal. Second, apply the bibliometric process to examine current research and development patterns. This process used well-known bibliometric measures such as the total number of publications (TP), the percentage of the total number of publications (%), the total number of citations (TC), the average number of citations per publication (C/P), and the H index (h).

Third, it utilises co-citation to visualize cluster divisions, focusing on the degree of academic cooperation and extensive national research intensity. These keywords appeared in hotspot field research, co-occurrences, clustering, and network analysis. Finally, the uniqueness analysis of POE is reported with recommendations and limitations. Fig. 1 shows an overview of the systematic approach to reach the research objective.

2.2 Literature Screening

This study used the Scopus database data to extract POE-related documents as of 28 September 2020. Scopus's more excellent database than WoS makes indexing a specific bibliometric more accessible (Almaliki 2021).
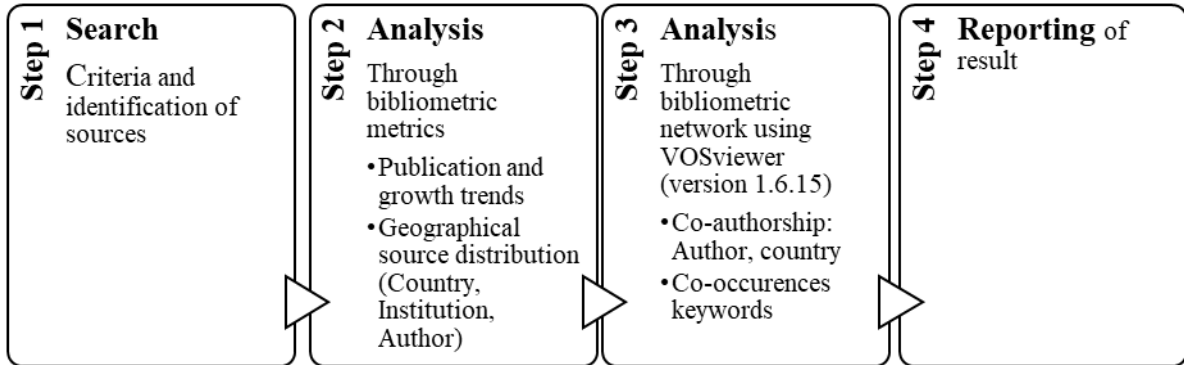

Fig. 1 - Systematic approach to the research objective

The database contains document type and publishing access, language, most potential resource title, subject matter, publishing allocation by regions and lively organisations, authors, title, keywords, and work description using standard bibliometrics. The review took a wide variety of document types. The Scopus exploration does not clarify an initial date, enabling the search feature to identify the oldest documents in the publications. To refine our research study, we confined our quest for POE research findings by title: "post-occupancy evaluation" OR "post occupancy evaluation" OR "POE" OR "postoccupancy evaluation".

This initial query yielded 1,955 publications. However, no inbuilt environment criteria of documents were eliminated after a manual review. The final results of 381 POE publications from 1979 to 2020 were compiled and evaluated for further research using the search strategies shown in Table 2.

Table 2 - Search strategy and retrieval process

Date	Database	Search string
28 September-2020	Scopus	(TITLE ("post-occupancy evaluation" OR "post occupancy evaluation" OR "POE" OR "postoccupancy evaluation"))
First stage screening		
(No initial date/ Document Type/ Subject area have been set)		
Result		1,955 publications for the time from 1979 – 2020 (41 years)
Second stage-Manual screening		
Inclusion document other than focusing on the built environment		
Result		381 publications from the relevant subject area

381 Scopus publication data were exported to Microsoft Excel in comma-separated value and Research Information Systems formats. Excel software is used to generate charts and graphs from published work. In addition, as shown in Figure 2, Harzing's Publishing and Perish software was also used to determine bibliographic measurements and other frequency ranges.

Reference Date	28 September 2020
Publication Year	1979 - 2020
Citation Year	41
Paper	381
Cites Year	96.20
Cites Paper	10.35
Cites Author	1877.4
Paper Authors	189.27
Authors Paper	2.69
h index	29
g index	53

Fig. 1 - Citation metric

3. Analysis and Findings

3.1 Publication Output and Growth Trends

To provide a comprehensive overview of the key characters, we examined the typical publication trends in the fields of POE, such as the number of publications and citations, document and source type, subject area, language, and source title. This first analysis would cover the research productivity based on annual publications. Examining documents through publication year enables researchers to track the evolution and prominence over time (Ahmi and Mohamad 2019). Fig. 3 depicts the total number of POE publications published between 1979 and 2020.

These publications can be divided into four phases, considering the research domain's annual distribution and history engraved. The analysis showed a significant increase from the earliest in 1979 to 33 articles in 2019, the highest number of POE publications. The first POE publication entitled "Postoccupancy evaluation of a surgical suite" by Fitzgerald H and Beck WC was published in 1979, describes a successful design that should include user analysis at all levels.

Publishing growth in the first 30 years (before 2010) was slightly sluggish. During this period, POE publications had less than 15 documents issued annually. It is important to note that the number of articles tended to fluctuate throughout the year up to 2017. There was a significant increase in 2001, 2005, 2009, 2010 and 2013, respectively with (n = 7, n = 11, n = 16, n = 18, n = 27) publication. Since 2014, there has been an increase in POE-related publications, except in 2017 and 2019, which reported a slight decline. Based on the number of publications on POE, this topic is less popular with academics for research.

The bibliometric analysis results show the amount of POE articles published over the last decade has increased significantly, from 26 in 1979–1989 to 260 in 2011–2020, almost ten times (see Fig. 3). Naturally, 68.24% of the publications have been published in the past decade, indicating that POE is a new field of growing interest, especially in the last decade. This condition can be attributed to POE's understanding of building evaluations' significance, and some scholars are devoted to POE studies.
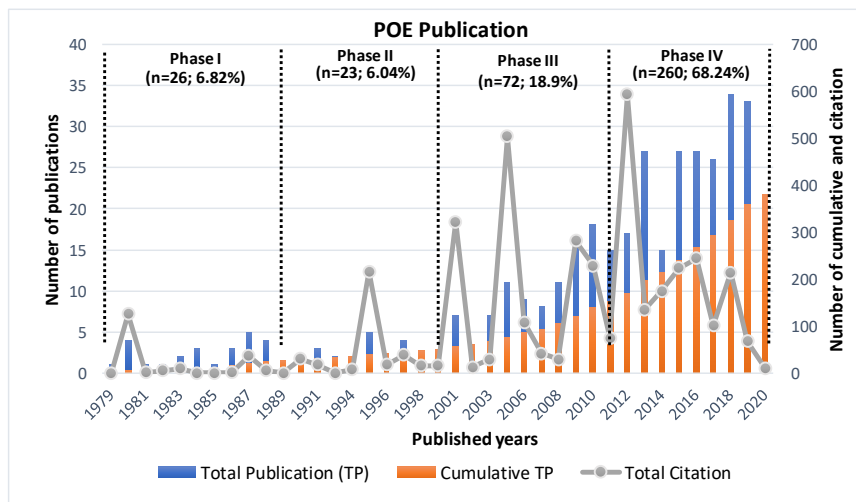

Fig. 3 - Annual growth of POE publications, total citations, and cumulative number of publications, Scopus1979–2020 (n=381)

Documents from published data sets were also determined by document and source type and language used in POE articles. Document types are unique papers such as conference proceedings, journal articles, or book chapters. On the other hand, a source document is a journal, conference, book chapter, series of books, or trade journal (Sweileh et al. 2017). Document and source type publication by language is shown in Fig. 4. Fig. 4a shows nine POE document types. Notes, book, editorial, erratum, and letter are limited document types (less than five).

Meanwhile, in Fig. 4b, publications are classified into five source types, with journals (n=242; 63.52%) ranking first and conference proceedings (n=92; 24.15%) second. Fig. 4c shows that the documents were primarily published in English (n=369, 96.34 %) based on the publications taken (more than 90%). Two publications are bilingual.
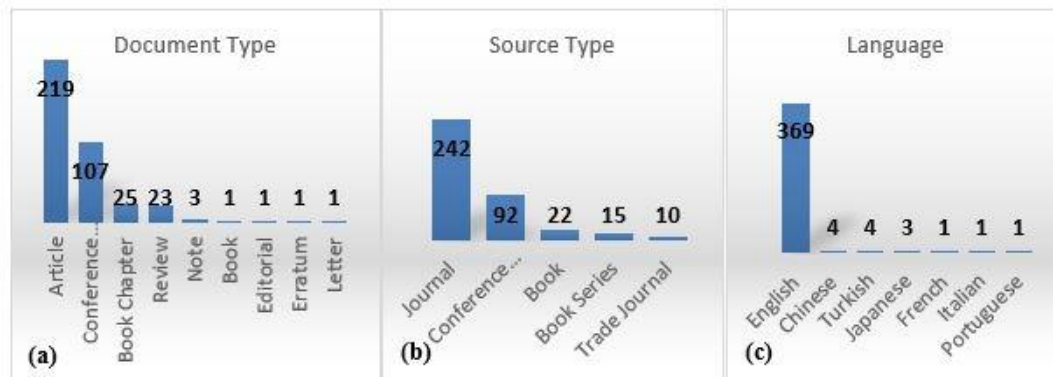

Fig. 2 - POE publication by (a) Document Type (b) Source Type (c) Language

Each Scopus source title has a subject representing a specific field of study. Table 3 depicts the top 10 of the overall distribution of 638 total publications in the subject area based on four phases, with POE and Scopus index divisions appearing the most frequently. This distribution enables us to see the degree of research conducted on a particular subject over time and identify problems that have become more focused. It covers 24 POE-related issues and involves multidisciplinary nature, including computer science, medicine, economics, physics, and psychology.

In the last decade, articles on 'Engineering', 'Social Sciences', and 'Environmental Science', show significant increases. The number of publications on POE in 'Engineering' and 'Environmental Science' is almost three times and six times that of other fields. POE publications have quadrupled in the last decade in 'Social Science.' The subject covered is ranked-highest because POE is more centered on engineering studies (see Table 3). Of those 24 subject areas, three (0.47%) were for one publication, three (0.94%) were for two publications, and two (0.94%) were for three publications. While one subject area (0.63%) contained four publications, two subject areas (1.88%) included six publications, one subject area (1.10%) contained seven publications, and one subject area (1.41%) had nine publications. The other 11 subject areas (92.63%) had at least ten publications and above.

Table 3 - Top-10 subject areas on POE publication based on four phases

Subject area	Year				TP* (%)
	1979-1989	1990-1999	2000-2009	2010-2020	
Engineering	**15**	10	**44**	173	242 (37.93%)
Social Sciences	7	**11**	14	64	96 (15.05%)
Environmental Science	7	4	7	48	66 (10.34%)
Energy	0	0	17	29	46 (7.21%)
Computer Science	2	0	2	27	31 (4.86%)
Business, Management and Accounting	0	1	2	22	25 (3.92%)
Medicine	3	1	2	17	23 (3.61%)
Arts and Humanities	2	3	7	9	21 (3.29%)
Earth and Planetary Sciences	3	1	1	12	17 (2.66%)
Materials Science	0	0	0	15	15 (2.35%)

*Some of the source titles have been categorized into several subject areas

The last characteristic analysis for publication trend will examine research productivity utilising POE source titles and Cite Score. Table 4 shows the ten most active POE research source titles. We highlighted each indicator's maximum value in bold.

The 381 selected articles on POE analysed in this paper appeared in 154 source titles. From these sources, 105

titles (27.82%) published only one publication, 36 titles (24.41%) published two to four publications, and 16 titles (36.48%) published five or more publications on POE. Building Research and Information, Facilities, Building and Environment, and Intelligent Buildings International were lead source titles with (n=17; 4.46%), (n=17; 4.46%), (n=14; 3.67%) and (n=12; 3.15%) publications and percentages on the topic, respectively.

The 'Building Research and Information' journal covers 100% engineering disciplines. Engineering and social sciences are two closely related subject areas in the Journal of Facilities. In the top 15 most productive source titles, the 'Energy and Buildings' journal is the most influential in POE research terms of Cite Score (9.9), followed by the 'Environment and Behavior' journal (8.8) and 'Building and Environment' journal (8.4).

Table 4 - Most productive source title

No	Source Title/ Publisher	TP (%)	TC	Cite Score	SJR 2019	SNIP 2019	Subject area of source title
1	Building Research and Information /Taylor & Francis	**17 (4.46%)**	**832**	6.8	1.175	2.167	Engineering
2	Facilities/ Emerald	17 (4.46%)	444	2.1	0.399	0.933	Engineering & Social Sciences
3	Building and Environment / Elsevier	14 (3.67%)	363	8.4	1.871	**2.604**	Engineering, Social Sciences & Environmental Science
4	Intelligent Buildings International / Taylor & Francis	12 (3.15%)	107	2.4	0.297	0.723	Engineering & Computer Science
5	Health Environments Research and Design Journal / SAGE	9 (2.36%)	59	2.7	0.59	1.887	Medicine
6	Procedia Engineering/ N/A	9 (2.36%)	61	2.7	0.316	1.333	Engineering
7	Building Performance Evaluation from Delivery Process to Life Cycle Phases/ Springer International Publishing	8 (2.10%)	6	N/A	N/A	N/A	Engineering, Material Science, Business Management and Accounting and Economics, Econometric and Finance
8	Architectural Engineering and Design Management / Taylor & Francis	7 (1.84%)	69	3.9	0.693	1.264	Engineering and Business Management and Accounting
9	Environment and Behavior/ SAGE	7 (1.84%)	163	**8.8**	**1.538**	2.206	Environmental Science
10	IOP Conference Series: Earth and Environmental Science / IOP Publishing Ltd	7 (1.84%)	0	N/A	N/A	N/A	Environmental Science and Earth and Planetary Science

3.2 Geographical Source Distribution and Cooperation by Country, Institution and Author

Every 381 publication was assigned a country and an institution based on Scopus data. The document contained 29 undefined countries, no ambiguous institution, and one unclear author. Consequently, 93.36% of the publications could be attributed to a country/territory, 100% to an institution, and 99.74% to an author.

3.2.1 Most Influential Countries

This section examines evaluation indicators such as TP, %, TC, C/P, and h-index to identify influential countries, institutions, and authors in the POE domain.

Generally, our dataset defines 51 distinct countries. The maximum number of countries was 437 (one author may live in multiple countries, or multiple writers from different countries may collaborate). The worldwide distribution of participating countries is shown in Fig. 5. Geographical inequality can also be seen by looking at continents by extending the data regarding countries. Asia was leading the publications (n=119; 27.23%), followed by Europe (n=116; 26.54%), North America (n=108; 24.71%), Oceania (n=27; 6.18%), Africa (n=20; 4.58%), and South America (n=18; 4.12%).
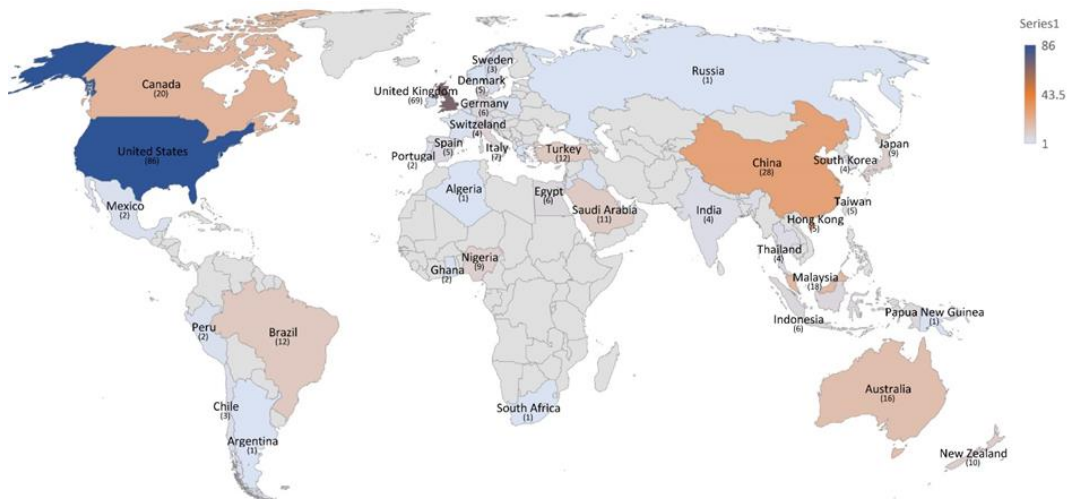
Fig. 3 - Distribution of POE publications by country (Scopus database)

Table 5 shows the top 10 contributing to POE research. The 15 countries account for approximately 73% of the publication. Out of 51 regions, 35 countries (18.99%) produced five or fewer publications. Seven countries (12.13%) produced between six to ten publications, and nine countries (62.24%) have produced more than ten. Based on TP and %, most publications are in the United States (n=86; 19.68%). The United Kingdom had the second-highest number of publications (n=69; 15.79%), followed by China (n=28; 6.41%), Canada (n=20; 4.58%) and Malaysia (n=18; 4.12%).

The number of TC by country was led by the United Kingdom, with 1480 citations and an h-index of 18, exceeding any other country. The United States comes in second with 1022 citations and an h-index of 16, followed by Canada and Australia, which have 292 and 253 citations, respectively, and an h-index of 8. These findings indicate that developed countries have taken prominent roles in POE research compared to developing countries. Although developed countries contribute to publications, developing-country institutions remain the most active in POE-related publications, particularly in assuring long-term evaluation for building performance improvement.

Table 5 - Top-10 most active countries contributed to the publications

Countries	TP	%	TC	C/P	*h*
The United States/ North America	**86**	**19.68**	1022	11.88	16
The United Kingdom/ Europe	69	15.79	**1480**	**21.45**	**18**
China/ Asia	28	6.41	74	2.64	4
Canada/ North America	20	4.58	292	14.60	8
Malaysia/ Asia	18	4.12	57	3.17	4
Australia/ Oceania	16	3.66	253	15.81	8
Brazil/ South America	12	2.75	62	5.17	4
Turkey/ Asia	12	2.75	135	11.25	5
Saudi Arabia/ Asia	11	2.52	107	9.73	6
New Zealand	10	2.29	121	12.10	6

3.2.2 Most Influential Institutions

The POE domain's most influential organisations were identified by analysing documents from various institutions. The findings show 160 institutions are publishing POE studies. The top 10 organizations contributing to POE research are shown in Table 6. Concerning TP and %, the POE study is led by King Fahd University of Petroleum and Minerals, followed by Reading University and MARA University of Technology. Fourth and fifth place went to Georgia Institute of Technology and Victoria University of Wellington. Furthermore, three of the top ten productive institutions are from the United States and the United Kingdom, two from Malaysia. 23.15 % of the institutions had only a single publication, whereas 3.09 % of the contributing institutions had at least ten articles on the issue of POE.

Table 6 - Top-10 most active institutions published articles

Institutions	TP	%	TC	C/P	h
King Fahd University of Petroleum and Minerals, Saudi Arabia	**10**	**3.09**	104	10.40	**6**
University of Reading, United Kingdom	8	2.47	53	6.63	3
Universiti Teknologi MARA, Malaysia	8	2.47	27	3.38	2
Georgia Institute of Technology, The United States	6	1.85	156	26.00	4
Victoria University of Wellington, New Zealand	6	1.85	69	11.50	4
Carnegie Mellon University, The United States	5	1.54	132	26.40	4
Oxford Brookes University, The United Kingdom	5	1.5	127	25.40	2
Cornell University, The United State	5	1.54	88	17.60	5
Universiti Teknologi Malaysia, Malaysia	5	1.54	16	3.20	2
Loughborough University, The United Kingdom	4	1.23%	**383**	**95.75**	2

3.2.3 Author Influence and Co-Authorship Analysis

Table 7 gives the top 10 authors from 160 who contributed the most documents to POE. The active authors are Hassanain from King Fahd University of Petroleum and Sanni-Anibire from Damman Community College. Those ranks first and second with (n=10; 2.62%) and (n=5; 1.31%) publications respectively. The third is Ahmad from International Islamic University Malaysia (n=4; 1.05%).

Among ten publications by Hassanain, five were co-authored with Sanni-Anibire. The average number of authors was 2.4 per publication. Bouchlaghem. D (127), Bordass (61.75), and Leaman (50.00) have the highest TC and h-index contributions to the POE domain. The average number of citations is clearly expressed from 127 to 0.25 per publication.

Table 7 - Top-10 most active authors' contributions

Author (Country/ Institution)	TP	%	TC	C/P	h
Hassanain, M.A (Saudi Arabia/ King Fahd University of Petroleum and Minerals)	**10**	**2.62**	104	10.4	**6**
Sanni-Anibire, M.O. (Saudi Arabia/ Dammam Community College)	5	1.31	55	11	3
Ahmad, N. (Malaysia/ International Islamic University Malaysia)	4	1.05	1	0.25	1
Aziz, A. (United States/ Carnegie Mellon University)	4	1.05	247	61.75	4
Bordass, B (the United Kingdom/ William Bordass Associates)	4	1.05	134	33.5	4
Choi, J.H. (the United States/ University of Southern California)	4	1.05	132	33	4
Loftness, V. (United State/ Carnegie Mellon University)	4	1.05	132	33	4
Yaman, R (Malaysia/ Universiti Teknologi MARA)	4	1.05	1	0.25	1
Al-Hammad, A.M. (Saudi Arabia/ King Fahd University of Petroleum and Minerals)	3	0.79	32	10.67	2
Bouchlaghem, D. (the United Kingdom/ Loughborough University)	3	0.79	**381**	**127**	2

Fig. 6 represents the number of articles depending on the number of writers per article. A sum of 80 documents are sole authorship articles (n=80; 121.0%). Multi-authored publications account for approximately 78.73 % of all publications in the POE domain. Two authors co-authored most POE articles. In many cases, co-authors have close relationships with other authors in the same field.
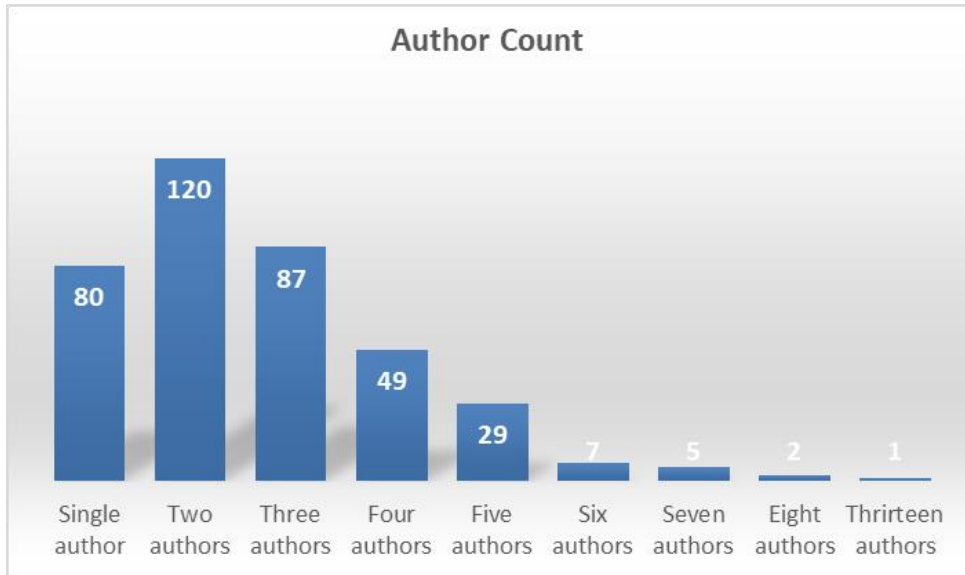
Fig. 4 - Author(s) per publication

In POE studies, VOSviewer also generates co-authorship analysis of authors. The authors' relationship power is illustrated by the hue, circle, font dimension, and line thickness. In this network visualisation map, 885 authors were identified by a minimum of two documents with two citations using the entire counting method. Fig. 7 presents the detail with 79 items, 44 clusters, 51 links, and 107 link strengths. Leading authors are co-authors who have an excellent relationship and have produced more papers.

Fig. 7a shows 22 major author networks. This diagram is dominated by a closed circle of POE research authors. Authors with similar hues represent collaboration clusters. For example, Fig. shows that Aziz A., Choi J.-H., Loftness V., and Park J. collaborated and researched (red). Twenty-two single authors are portrayed as network nodes working individually, without any co-authorship links to certain other POE scholars. Fig. 7b shows that the leading network researchers are Hassanain M.A., Sanni-Anibire M.O., Al-Hammad A.M, Aziz A., Choi J.-H, and Loftness V. Another researcher is linked to one of these top researchers. Therefore, the authors' publication should be boosted within the POE domain, especially from authors outside the identified circle. Some researchers should not dominate the desire to interact loose clusters into large centralised research networks.
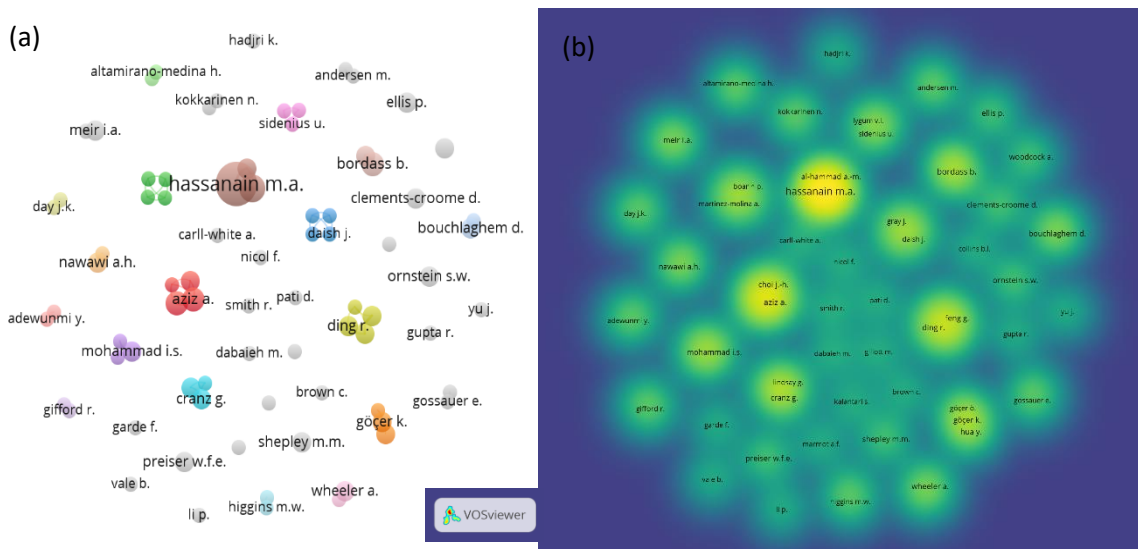

Fig. 5 - Author co-authorship map. Note (a) Network visualization map based on document-weights; (b) density visualization map based on document-weights

The entire counting method identified a co-authorship among 22 countries based on a minimum of two documents with two citations. Non-networked countries are excluded. Fig. 8 illustrates 22 items, six clusters, 33 links, and 49 link strengths. The number of documents represented by the circles is depicted in Fig. 8a. Larger circles represent more

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documents. Six colours are used in the POE study to distinguish six clusters. For example, the USA (n=86), Switzerland, Germany, and Canada co-authored many. Also shown is the United Kingdom (n=69), Sweden, and Australia are deeply linked in cooperation with POE research. The line thickness can represent the co-authorship frequency with each country. Malaysia, Brazil, and Egypt have no interconnection with other countries; therefore, they are not shown in Fig. 8a.

There is also a considerable geographical clustering of countries cooperating, like Switzerland, Belgium, Spain, and Peru in Europe. New Zealand, Saudi Arabia, and Japan all indicated limited co-authorship participation. The POE research collaboration is led by the United States and Saudi Arabia (Fig. 8b).
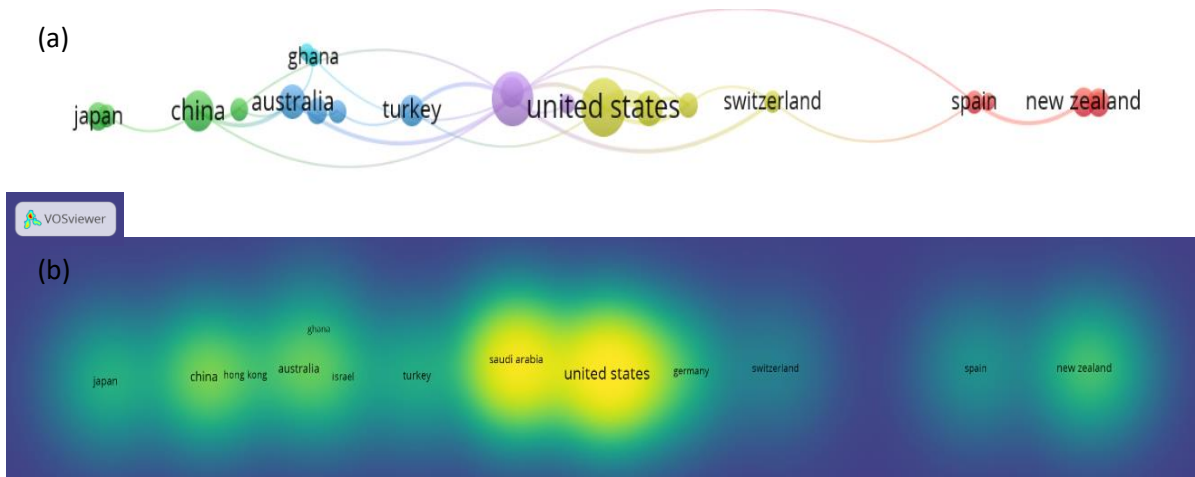

Fig. 6 - Country co-authorship map. Note (a) Network visualization map based on document-weights; (b) density visualization map based on document-weights

Finally, Fig. 9 depicts the institutional collaboration network on POE. Six hundred six institutions were identified as collaborating using the entire counting method, each with two documents and two citations. Fig. 9a shows the institutional co-authorship network with 17 items, 13 clusters, four links, and five total link strengths. The top three influential institutions in POE publication are the Architectural Engineering Department at King Fahd University of Petroleum and Minerals in Saudi Arabia, the Department of Construction Management and Engineering at University Reading in the United Kingdom, and the Center for Building Performance and Diagnostic at Carnegie Mellon University in the United States. The density visual representation in Fig. 9b shows that the Architectural Engineering Department, King Fahd University of Petroleum and Minerals in Saudi Arabia, prompted the collaborative efforts in POE research. Previous findings on countries' co-authorship and institutional collaboration networks show research with institutions outside their clusters. More cross-institutional collaborations are required to connect existing clusters to an extensive research network.
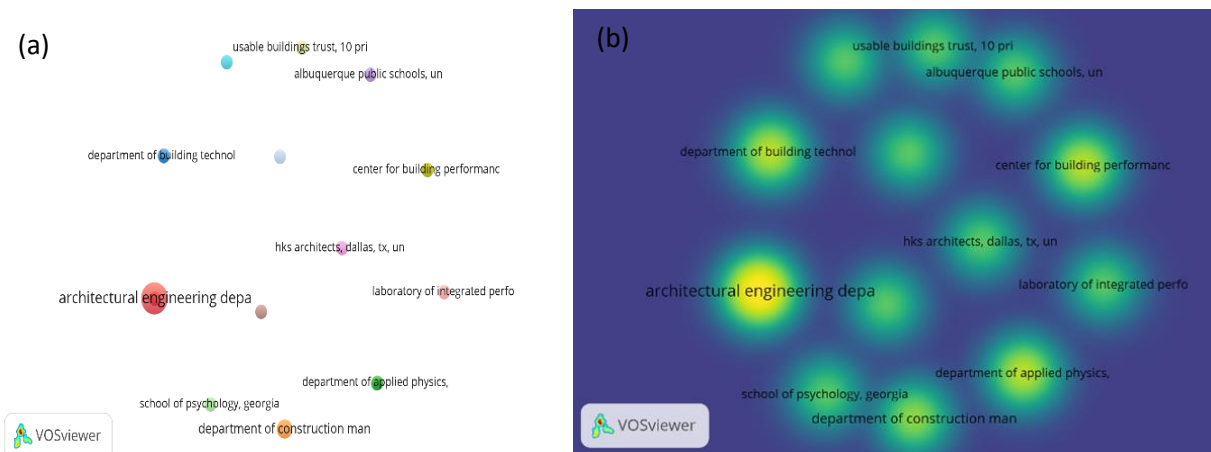

Fig. 7 - Institutional co-authorship map. Note (a) Network visualization map based on document-weights; (b) density visualization map based on document-weights

3.3 Keyword Co-Occurrence

VOSviewer mapped keywords reflecting the author's intentions and interests. Vilutiene et al. (2019) mentioned keyword frequency analysis for evaluating hot topics and advances in a field. Therefore, co-occurring keyword analysis was used to scientifically quantify this region's main POE research hotspots and identify emerging research trends and gaps

Fig. 10 depicts a network view of author keywords used to address connections with other keywords based on colour, circular size, text size, and connecting line thickness. Every node in the image is a keyword; larger nodes reflect a higher frequency. Similarly, a thicker link indicates that two keywords co-occur more frequently. The overall spacing of terms shows relationships. The more substantial the overlap between keywords, the closer they are related.

VOSviewer found 786 keywords from the initial collection of 381 publications. The minimum number of occurrences of a term was used three times, yielding 160 keywords. The network map also uses a thesaurus file to combine similar keywords. For instance, 'sustainability' for 'sustainable design' and 'sustainable development'. As a result, 54 co-occurrence keywords were identified and grouped into five clusters indicated by different colours.

Colored keywords, for example, could be used to highlight POE research themes. Themes were divided into clusters based on POE studies as follows:

Cluster (1):   POE for comfort (red) contains keywords like 'thermal comfort', 'housing', 'occupant satisfaction', 'indoor air', 'satisfaction', 'workplace', etc.

Cluster (2):   POE for sustainability (green) contains keywords like 'sustainable development', 'green building', 'productivity', 'energy', 'environment', 'schools', etc.

Cluster (3)   POE for performance (blue) contains keywords like 'building performance', 'feedback', 'education', 'facility management', 'innovation', 'quality control', etc.

Cluster (4)   POE for design (yellow) contains keywords like 'post-occupancy evaluation', 'architectural design', 'indoor environment quality', 'questionnaire', 'benchmarking', etc.

Cluster (5)   Criteria POE (purple) contains keywords like 'buildings', 'Nigeria', 'facilities', 'school buildings', 'China', 'higher education', etc.
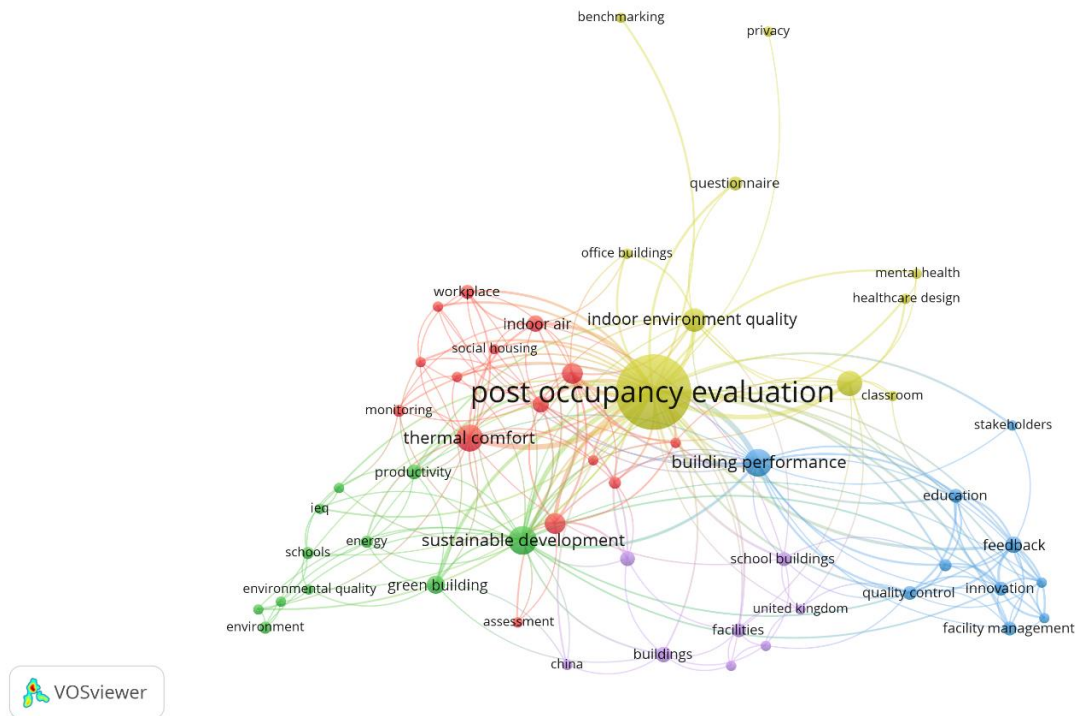

Fig. 10 - Author keywords network map

To understand the POE field's evolution, we divide POE research into four phases: (a) 1979–1989, (b) 1990–1999, (c) 2000–2009, and (d) 2010–2020. Table 8 lists the top 10 best keywords during four phases. During the four phases, the terms related to POE research grew, as did the research focus. Due to its complete release, the minimum occurrence of terms for VOSviewer software was set at one for 1979–1989 and 1990–1999. Whereas for the 2000–2009 and 2010–2020 phases, the minimum occurrence of terms was assessed as three.

Table 8 - Four-phase keyword analysis

No	Keyword 1979-1989	F	Keyword 1990-1989	F	Keyword 2000-2009	F	Keyword 2010-2020	F
1	Evaluation	2	Assessment Process	1	Post Occupancy Evaluation	32	Post Occupancy Evaluation	159
2	Architectural design	1	Data collection	1	Sustainable Development	8	Building performance	18
3	Habitats	1	Environment	1	Thermal Comfort	7	Architectural Design	16
4	Research	1	Occupational Therapy	1	Feedback	6	Sustainable Development	16
5	User	1	Physical	1	Building Performance	5	Indoor Environment Quality	15
6					Education	5	Thermal Comfort	15
7					Indoor Air	5	Occupant Satisfaction	11
8					Innovation	5	Housing	10
9					Customer Focus	3	Green Building	9
10					Probe	3	Satisfaction	6

F=Frequency

The co-occurrences networks of four different phases are illustrated in Fig. 11. Fig. 11a shows that most studies on the 1979–1989 phase emphasis on post-occupancy evaluation, architectural design, habitats, and so on. As a result, the first POE domain study subject centered on the foundational POE evaluation on the residents of the completed structure via a survey to obtain input in design (Bechtel et al. 1980), housing (Lawrence 1981), solar homes (Pickett 1984), and zoo setting (Maple and Finlay 1987). The evaluation findings help ensure that future buildings' design, construction, and operation will be improved by systematic evaluation (Smeallie 1988).

During 1990-1999, prominent POE-related research topics included building projects and amenities and more oriented study on physical environmental exposures such as a hospital setting building (see Fig. 11b). Occupant and physical environmental conditions were also conducted covering women's medical centre (Shepley et al. 1995), psycho-social needs (Cannon 1997), and improving wayfinding processes in a new paediatric hospital (Brown et al. 1997). Carpenter and Oloufa (1995) stated a well-designed POE system continuously improves all aspects and phases of building projects

The next phase of POE development, from 2000 to 2009, was committed to sustainable development, indoor thermal, innovation, feedback, and education. (See Fig. 11c.) A post-occupancy assessment was used to determine the implications of user participation in the building process. Sustainability, thermal comfort, feedback, and building performance are inextricably linked. Thermal comfort indirectly improves building performance by increasing client satisfaction. Building performance parameters are positively correlated to customer satisfaction (Nawawi and Khalil 2008). According to Gossauer & Wagner (2007), occupants can provide valuable information about a building's efficiency and comfort.

During this phase, academics became interested in POE assessments upon achieving educational building such as schools (Mumovic et al. 2009) and universities (Elmualim and Awbi 2003; Hassanain and Mudhei 2006). In addition, the researchers might well focus on indoor environmental quality, advancement, service orientation, probing, and quality assurance. As a consequence of this phase, it is clear that POE research is pervasive, with a renewed emphasis on the following phases.

Throughout the 2010–2020 phase, a few new POE directions were initiated, including design and architecture, indoor environmental, accommodation, green architecture, and so on (see Fig. 11d). Building performance, sustainability, and thermal comfort remained significant from the previous phase. The 'architectural design' phrase occupies the second largest hotspot, with 16 occurrences in this phase. POE is often used in architectural design to evaluate a finished building's qualities. Thus, facilities such as housing and residences (Aigbavboa and Thwala 2012; Adekunle and Nikolopoulou 2020), offices (Bae et al. 2020), and hospitals (Adamy and Abu Bakar 2018) are among those studied in this phase.

In addition, studies on green buildings are gaining popularity among POE researchers, such as Gupta et al. (2019) studies on green buildings, while Raouf and Al-Ghamdi (2020) examined the quality of the green building. The apparent strong links between indoor and refitted green environments will boost productivity and occupant satisfaction.
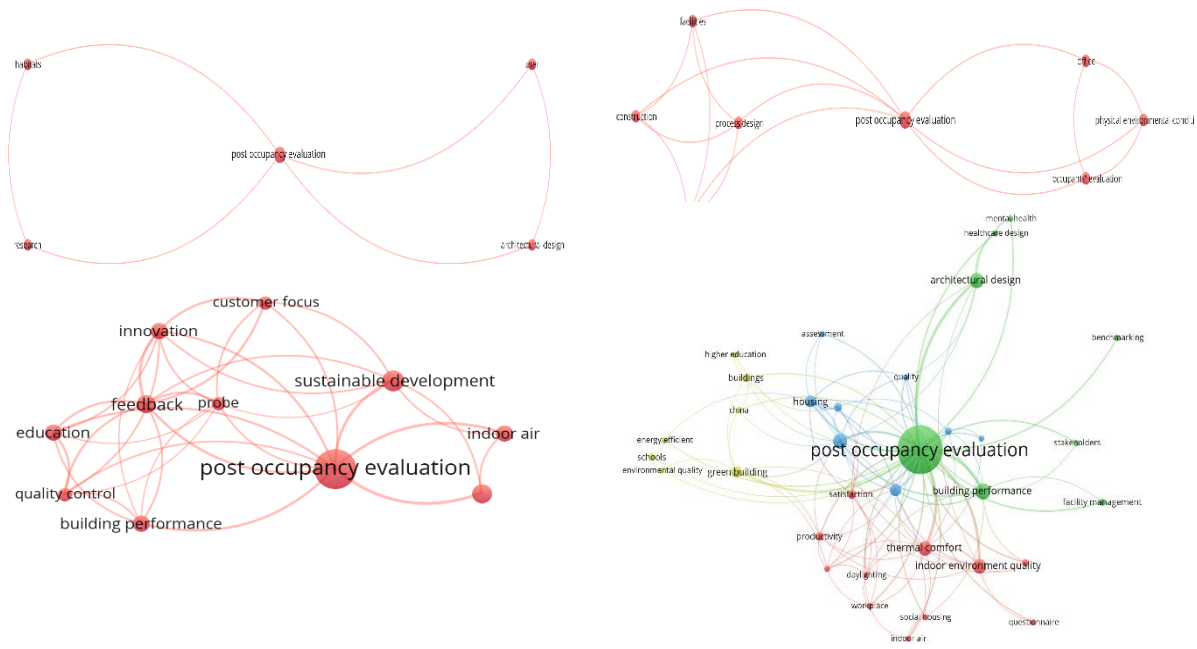

Fig. 8 - Phase co-occurrences networks: (a) 1979–1989; (b) 1990-1999; (c) 2000–2009; (d) 2010–2020

4. Discussion and Conclusions

Using "Scopus" as a data source, this research examined global trends in POE publications from 1979 to 2020. The results of the bibliometric review will be discussed further, with possible explanations and future study suggestions.

First, since around 2001, the number of POE publications has increased slightly year-on-year, and this trend continues into 2019. However, few reviews exist on these topics. The result is a comprehensive review of all previous research efforts. Three hundred eighty-one publications from 159 authors and source titles, 51 countries, and 160 institutions were identified and visualised. POE publications also have many distinct source types and subject areas, indicating the multidisciplinary nature of POE research. Yet, POE research is primarily concerned with engineering (37.93%). The journal source type contributed more than 63.52% of all publications in this field, and 96.34% used English. Based on the distribution of countries by continent, Asia leads in publications (27.23%); however, the United States, located in North America, made the most significant contribution to this field (19.68%).

The United Kingdom has the highest number of citations (1480) and h-index (18). A considerable proportion of POE publications (33.07%) were not (yet) cited by others, while just a tiny proportion (4.20 %) were cited 50 times or more. The most cited article relates to the application of POEs for building performance. The factor may be that performance has been studied extensively in both fundamental and practical theories. The King Fahd University of Petroleum and Minerals, Saudi Arabia, is the most influential institution. Because the publishing institutions are based in Saudi Arabia, the active authors Hassanain are also from the King Fahd University of Petroleum.

Second, the bibliometric analysis revealed a lot of collaborative research in POE, with multi-authored articles accounting for roughly 78.74% of all publications in the POE domain. However, the co-authorship and co-citation analysis network visual representation is quite limited. International relations are not universal. Generally, more international relationships in POE are required to connect existing clusters to extensive research network areas and strengthen research in the future.

Third, keyword co-occurrence revealed several POE technologies developed and researched over 40 years. Furthermore, five distinct research clusters in the domain of POE have been found based on keyword linkages that could be used to highlight POE research themes: (a) POE for comfort; (b) POE for sustainability; (c) POE for performance; (d) POE for design; (e) Criteria POE. The hotspots of recent research related to POE optimization are building performance, architectural design, and sustainable development environment.

POE studies involve various building typologies. Despite this, historical buildings received far less attention based on keyword occurrences. There is not enough attention to evaluating heritage buildings as separate countries and regions globally. There is no interconnection between existing research and approaches. On the other hand, a broader

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POE is necessary for historic buildings to ensure they are in good condition throughout their life cycle.

Aksah et al. (2019) mentioned that possessing POE on historical buildings enhances the user's well-being while ensuring future sustainable building rehabilitation. In addition, other performance criteria should also be evaluated, like technical (Ikediashi et al. 2020) and thermal comfort (Martinez-Molina et al. 2018). Tam and Hao (2018) mentioned that adaptive reuse of heritage buildings reduces waste and is environmentally friendly, and at the same time can benefit environmental sustainability. Therefore, future research, more impactful POE systems, and regulatory requirements on historical building performance are required to monitor the effectiveness of heritage building performance continuously.

The quality of the data collected strongly influences bibliometric studies. This article has attempted to include all relevant POE research documents. An absolute involvement from all records in this field is complex because of the limit of logical operators and keyword choices. Any database error will likely impact our findings, especially POE research trends. For the most intriguing research questions, a thorough literature review is advised.

Despite extensive bibliometric analysis, future research could improve data quality. The first thing to consider is the initial search key phrase. Future studies may even use synonymous keywords such assessment," "appraisal," or "analysis" in place of evaluation and may extend beyond the title of the article.

Furthermore, no search query can capture all scholarly works in this field. As a result, undesirable outcomes are likely. A search term can include Scopus, Web of Science, and Google Scholar to index scholarly articles holistically, among other databases. The search will yield more fruitful and insightful results if it is run across all academic publications databases.

Finally, despite limitations, this study provides a POE research pattern through 2020. This paper presents an analysis of recent POE developments in a method bibliometric. This study offers architects, engineers, conservators, and scholars valuable information and insights. Next, the study's findings can also be used to build future POEs research.

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