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The Journal *Buildings*: A Bibliometric Analysis (2011–2021)

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Abstract: The journal *Buildings* was launched in 2011 and is dedicated to promoting advancements in building science, building engineering and architecture. Motivated by its 10th anniversary in 2021, this study aims to develop a bibliometric analysis of the publications of the journal between April 2011 and October 2021. This work analyzes bibliometric performance indicators, such as publication and citation structures, the most cited articles and the leading authors, institutions and countries/regions. Science mappings based on indicators such as the most commonly used keywords, citation and co-citation, and collaboration are also developed for further analysis. In doing so, the work uses the Scopus database to collect data and Bibliometrix to conduct the research. The results show the strong growth of *Buildings* over time and that researchers from all over the world are attracted by the journal.

Keywords: bibliometrics; science mapping; Scopus; Bibliometrix

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1. Introduction

Buildings is an international journal in the fields of building science, building engineering and architecture. Prof. Chimay J. Anumba, the founding editor, created the journal in 2011 [1]. Between 2011 and 2018, *Buildings* was published as a quarterly journal. In 2017, Prof. David Arditi became the editor-in-chief and in the next year, the journal increased the number of issues and began to publish every month. Today, the journal is well recognized in the scientific community. It is indexed in Scopus (Elsevier) and the Science Citation Index Expanded (SCIE) of Web of Science (Clarivate Analytics). According to the Journal Citation Reports (JCR) of the Web of Science, the journal's 2020 impact factor was 2.648, ranking 32nd of 66 journals in the category of Construction & Building Technology and 61st of 136 in Engineering, Civil. This was the first time that *Buildings* received an impact factor.

Recently, *Buildings* is celebrating its 10th anniversary. Inspired by this event, the main aim of this paper is to provide a thorough bibliometric analysis of the journal from the last ten years. A bibliometric performance analysis of *Buildings* is carried out based on key factors, such as the publication and citation structures, the most cited papers, and the leading authors, institutions and countries/regions. To map the bibliographic data graphically, this work uses a wide range of indicators including bibliographic coupling [2], co-citation [3], co-occurrence of keywords and collaboration. To this end, this work uses the Scopus database and Bibliometrix [4] to collect and analyze the bibliographic material.

Note that in the literature, it has become the norm to develop bibliometric research since it provides scholars with realistic and objective statistics and analysis, enabling researchers to build a comprehensive knowledge and understanding of the research field. The different application fields of bibliometric analysis include civil engineering and management [5], automation in construction [6], energy [7], road and bridge engineering [8],

transport [9], etc. Particularly, it is interesting to publish special issues or papers to celebrate the significant anniversary of a journal. A key example is that in 2015, *Knowledge-Based Systems* published a bibliometric analysis of its scientific content to celebrate its 25th birthday [10]. Many other journals have published special issues or papers to celebrate their anniversaries, such as *International Journal of Systems Science* [11] and *Information Sciences* [12].

This paper is organized as follows: Section 2 presents the bibliometric methods used in this paper. Section 3 provides the bibliometric performance analysis. The science mapping analysis of *Buildings* is carried out in Section 4. Finally, Section 5 gives a short description of the main findings and conclusions of the paper.

2. Bibliometric Methods

The term bibliometrics was first created by Paul Otlet [13] in 1934 and further defined by Broadus [14] as "the quantitative study of physical published units, or of bibliographic units, or of the surrogates for either". Bibliometrics is valued as an important and useful approach to analyze academic research outputs and deal with overwhelming volumes of information [15]. Several decades ago, it was difficult for researchers to collect and classify complex bibliometric data due to the lack of efficient technology or software. However, thanks to the rapid development of science and technology, different bibliometric tools and software are available now to assist scholars in conducting their research [16].

In this paper, the bibliometric data come from Scopus, one of the world's leading academic databases. Scopus covers more than 80 million documents and 17 million author profiles. The search covered the period from April 2011 to October 2021 using "Buildings" as the source title. Note that there was another journal with the same name between 1996 and 2002 and it is not included within the scope of this research. A total of 1466 articles shown as the results were considered (1542 articles have been published in *Buildings* so far, but the other 76 documents were omitted since they were not directly available in Scopus).

The authors used Bibliometrix to collect and analyze the dataset and develop the graphical visualization. This unique tool was developed in R language by Aria and Cuccurullo [4] in 2017. To conduct this study using a bibliometric method, several bibliometric indicators from different perspectives were considered. As for bibliometric performance analysis, we analyzed the journal's annual publications, citation structure and the most cited papers, as well as the leading authors, institutions and countries/regions. As for science mapping analysis in Section 4, we analyzed the keywords of the articles published in *Buildings* and describe studies based on citations, co-citations and collaborations. The whole process of bibliometric analysis of the journal is illustrated in Figure 1.

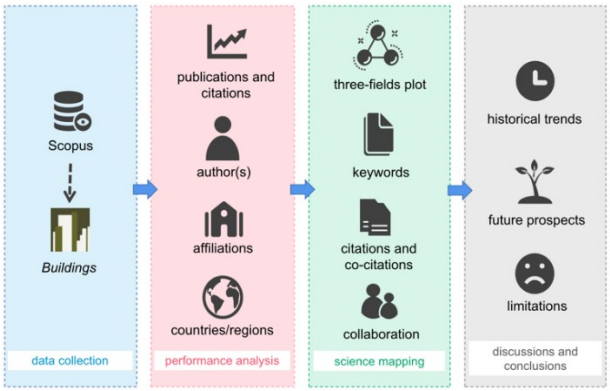

Figure 1. The process of bibliometric analysis.

3. Bibliometric Performance Analysis of *Buildings*

In this section, several performance indicators including the publication and citation structure, the most cited papers and the leading authors, institutions and countries/regions are used.

3.1. Structure of Publications and Citations

Buildings published its first volume with one issue in 2011 and expanded to contain four issues in the next year. In 2018, the journal adopted a monthly publication schedule and since then it has published 12 issues per year. The distribution of publications and citations up to October 2021 is shown in Table 1. Additionally, several citation thresholds are included to provide a better overview.

Table 1. Annual publication and citation structure.

Year	TP	TC	≥50	≥20	≥10	≥5	≥1
2011	2	13	0	0	1	1	1
2012	27	764	4	12	15	21	27
2013	39	407	1	6	14	26	38
2014	47	551	1	9	18	28	43
2015	75	1124	3	20	38	55	72
2016	51	500	0	5	22	39	49
2017	121	1695	4	31	64	96	121
2018	187	1638	2	18	61	110	177
2019	237	1684	1	14	66	121	224
2020	246	731	0	0	14	55	205
2021	434	307	0	0	2	6	154
Total	1466	9414	16	115	315	558	1111
%	100.00%		1.09%	7.84%	21.49%	38.06%	75.78%

Abbreviations: TP and TC = Total papers and citations; ≥50, ≥20, ≥10, ≥5, ≥1 = Number of papers with equal or more than 50, 20, 10, 5 and 1 citation(s).

Until 2016, the journal published a small number of papers per year. In 2017, more than twice as many articles as the previous year were published. This change reflects the growing popularity of *Buildings* in the scientific community. In 2020, the journal published its 1000th paper, which marked a new milestone. Between 2011 and 2016, the pattern of citations received per year was variable, reaching peaks of 1124 citations in 2015. Then, the number of citations remained around 1600 from 2017 to 2019 and decreased significantly after 2019. This phenomenon in the two last years (2020 and 2021) may be caused by the citation time-window [11], so citations may pick up in the following years. Note that 1.09% of papers receive more than 50 citations and 7.84% more than 20. A proportion of 38.06% of documents have more than five citations and 75.78% get at least one citation. It can be observed that once articles are a few years old, there are very few uncited articles in *Buildings*. This result shows that *Buildings* is a high-quality and widely recognized journal. Next, let us consider the most cited papers published in the journal. Note that research articles and review articles are divided and the results are summarized in Tables 2 and 3, respectively.

Table 2. Most cited papers (research articles).

R	TC	Title	Author/s	Year	C/Y
1	181	Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector	Akadiri, P.O.; Chinyio, E.A.; Olomolaiye, P.O.	2012	18.10
2	94	A Comparative Cradle-to-Gate Life Cycle Assessment of Mid-Rise Office Building Construction Alternatives: Laminated Timber or Reinforced Concrete	Robertson, A.B.; Lam, F.C.F.; Cole, R.J.	2012	9.40
3	65	Fatigue-Prone Details in Steel Bridges	Haghani, R.; Al-Emrani, M.; Heshmati, M.	2012	6.50
4	63	Rethinking Design and Urban Planning for the Cities of the Future	Saaty, T.L.; De Paola, P.	2017	12.60
5	60	A Thermal Simulation Tool for Building and Its Interoperability through the Building Information Modeling (BIM) Platform	Bahar, Y.N.; Pere, C.; Landrieu, J.; Nicolle, C.	2013	6.67

Table 2. *Cont.*

R	TC	Title	Author/s	Year	C/Y
6	55	Rocking and Kinematic Approaches for Rigid Block Analysis of Masonry Walls: State of the Art and Recent Developments	Casapulla, C.; Giresini, L.; Lourenço, P.B.	2017	11.00
7	54	Adaptive Thermal Comfort in Japanese Houses during the Summer Season: Behavioral Adaptation and the Effect of Humidity	Rijal, H.B.; Humphreys, M.; Nicol, F.	2015	7.71
8	52	A Production Model for Construction: A Theoretical Framework	Antunes, R.; Gonzalez, V.	2015	7.43
9	50	Strategies for Applying the Circular Economy to Prefabricated Buildings	Minunno, R.; O'Grady, T.; Morrison, G.M.; Gruner, R.L.	2018	12.50
10	49	Seismic Analysis of Historic Masonry Buildings: The Vicarious Palace in Pescia (Italy)	Betti, M.; Galano, L.	2012	4.90
11	48	Daylight Design of Office Buildings: Optimisation of External Solar Shadings by Using Combined Simulation Methods	González, J.; Fiorito, F.	2015	6.86
12	48	Building Information Modelling for Smart Built Environments	Zhang, J.; Seet, B.-C.; Lie, T.T.	2015	6.86
13	47	Life Cycle Assessment (LCA) of Different Kinds of Concrete Containing Waste for Sustainable Construction	Colangelo, F.; Forcina, A.; Farina, I.; Petrillo, A.	2018	11.75
14	46	Material Efficiency of Building Construction	Ruuska, A.; Häkkinen, T.	2014	5.75
15	43	Economic-Environmental Indicators to Support Investment Decisions: A Focus on the Buildings' End-of-Life Stage	Fregonara, E.; Giordano, R.; Ferrando, D.G.; Pattono, S.	2017	8.60
16	43	BIM Guidelines Inform Facilities Management Databases: A Case Study over Time	Kensek, K.	2015	6.14
17	42	Integrating Simplified and Full Life Cycle Approaches in Decision Making for Building Energy Refurbishment: Benefits and Barriers	Oregi, X.; Hernandez, P.; Gazulla, C.; Isasa, M.	2015	6.00
18	41	Rooftop PV Potential in the Residential Sector of the Kingdom of Saudi Arabia	Khan, M.M.A.; Asif, M.; Stach, E.	2017	8.20
19	41	Using Genetic Algorithms for Real Estate Appraisals	Del Giudice, V.; De Paola, P.; Forte, F.	2017	8.20
20	39	Energy and Economic Evaluation of Green Roofs for Residential Buildings in Hot-Humid Climates	Mahmoud, A.S.; Asif, M.; Hassanain, M.A.; Babsail, M.O.; Sanni-Anibire, M.O.	2017	7.80

Table 3. Most cited papers (review articles).

R	TC	Title	Author/s	Year	C/Y
1	98	A Review of Seismic Isolation for Buildings: Historical Development and Research Needs	Warn, G.P.; Ryan, K.L.	2012	9.80
2	89	Self-Centering Seismic Lateral Force Resisting Systems: High Performance Structures for the City of Tomorrow	Chancellor, N.B.; Eatherton, M.R.; Roke, D.A.; Akbaş, T.	2014	11.16
3	83	The Vertical Farm: A Review of Developments and Implications for the Vertical City	Al-Kodmany, K.	2018	20.75
4	65	A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design	Gillis, K.; Gatersleben, B.	2015	9.29
5	60	Performance Review of Prefabricated Building Systems and Future Research in Australia	Navaratnam, S.; Ngo, T.; Gunawardena, T.; Henderson, D.	2019	20.00
6	58	Estimation and Minimization of Embodied Carbon of Buildings: A Review	Akbarnezhad, A.; Xiao, J.	2017	11.60
7	51	PCMs for Residential Building Applications: A Short Review Focused on Disadvantages and Proposals for Future Development	Bland, A.; Khzouz, M.; Statheros, T.; Gkanas, E.I.	2017	10.20
8	49	Recent Progress in Daytime Radiative Cooling: Is It the Air Conditioner of the Future?	Santamouris, M.; Feng, J.	2018	12.25
9	32	A Scientometric Review and Metasynthesis of Building Information Modelling (BIM) Research in Africa	Saka, A.B.; Chan, D.W.M.	2019	10.67
10	32	Blockchain and Building Information Modeling (BIM): Review and Applications in Post-Disaster Recovery	Nawari, N.O.; Ravindran, S.	2019	10.67

Note that in the case of a tie in the number of citations, the youngest paper appears first. The most cited research article was published by Akadiri, P.O., Chinyio, E.A. and Olomolaiye, P.O. in 2012, with 181 citations. This paper proposed a framework based on the sustainable triple bottom line principle, including resource conservation, cost efficiency and design for human adaptation [17]. This paper is the only one that has received more than one hundred citations. Considering the indicator of citations per year, it can be found that Al-Kodmany, K. comes first. Prof. Al-Kodmany delivered a review on a vertical farm and analyzed its developments and implications for a vertical city [18]. Although this research was published only three years ago, it has received more than 70 citations, indicating the widespread interest in vertical farms.

3.2. Leading Authors, Institutions and Countries/Regions

This section reviews the most contributing authors, originating institutions and countries/regions based on published papers in *Buildings*.

First, the 20 most productive authors are shown in Table 4. To provide a better overview, several other bibliometric indicators including author Scopus ID, countries/regions, the number of citations and the cites per paper ratio are also considered. The table ranks the data based on the number of publications and, in the case of a tie, according to the number of citations. We can highlight that Dr. Sepasgozar, Prof. Al-Kodmany, Prof. Bedon and Dr. Zhang are the most productive authors in the journal. Dr. Sepasgozar published 14 scholarly papers in *Buildings* concerning digital technology applications, such as three-dimensional printing [19], digital twin [20] and additive manufacturing applications [21]. Prof. Al-Kodmany conducted research mainly on the sustainability of tall buildings [22–24], vertical farms [18] and vertical cities [25]. Note that Prof. Al-Kodmany and Bedon were the winners of the "*Buildings* 2018 Best Paper Awards" and "*Buildings* 2020 Young Investigator Awards", respectively. As Prof. Bedon and Dr. Zhang have only started publishing papers in *Buildings* in recent years, their citations are relatively low compared to other leading authors.

Table 4. Most productive authors.

R	Author	Scopus ID	Country/Region	TP	TC	TC/TP
1	Sepasgozar, S.M.E.	55924332100	Australia	14	224	16.00
2	Al-Kodmany, K.	6603005886	USA	9	191	21.22
3	Bedon, C.	57217221032	Italy	9	54	6.00
4	Zhang, X.	57209625490	Sweden	9	24	2.67
5	Iannace, G.	6506458238	Italy	8	93	11.63
6	Kvande, T.	6504559094	Norway	8	63	7.88
7	Lafhaj, Z.	6508004741	France	8	31	3.88
8	de Brito, J.	7003285554	Portugal	8	21	2.63
9	Blanchet, P.	7102260600	Canada	8	20	2.50
10	Trematerra, A.	56016998400	Italy	7	58	8.29
11	Wang, C.C.	57194027095	Australia	7	24	3.43
12	Silva, A.	25959361900	Portugal	7	11	1.57
13	de Paola, P.	56433637200	Italy	6	162	27.00
14	Lourenço, P.B.	7004615647	Portugal	6	101	16.83
15	Shirowzhan, S.	55923557900	Australia	6	66	11.00
16	Mojtahedi, M.	57211244906	Australia	6	59	9.83
17	Sassu, M.	6508376589	Italy	6	56	9.33
18	Ciaburro, G.	55459296100	Italy	6	47	7.83
19	Edwards, D.J.	7404086765	United Kingdom	6	27	4.50
20	Hammad, A.W.A.	56430620200	Australia	6	15	2.50

Another interesting issue to analyze is the most productive affiliations of the journal. For this purpose, Table 5 presents the 20 most productive affiliations. As in the previous table, other indicators are also included to provide a better overview. The University of New South Wales clearly obtains the first position with 46 articles, followed by the

University of Naples Federico II and the Norwegian University of Science and Technology. It is interesting to note that even though the University of Naples Federico II has published only about half as many articles as the University of New South Wales, it has a higher citation rate. Furthermore, the University of Naples Federico II and Norwegian University of Science and Technology have published almost the same number of papers, but the former has the leading number of citations.

Table 5. Most productive affiliations.

R	Affiliations	Country/Region	TP	TC	TC/TP
1	University of New South Wales	Australia	46	345	7.50
2	University of Naples Federico II	Italy	24	364	15.17
3	Norwegian University of Science and Technology	Norway	23	142	6.17
4	University of Minho	Portugal	20	175	8.75
5	Sapienza University of Rome	Italy	17	138	8.12
6	Curtin University	Australia	15	137	9.13
7	University of Pisa	Italy	14	185	13.21
8	Tongji University	China	13	124	9.54
9	The University of Melbourne	Australia	13	113	8.69
10	The University of Sydney	Australia	13	107	8.23
11	Ryerson University	Canada	13	98	7.54
12	The Hong Kong Polytechnic University	China	13	75	5.77
13	Rzeszow University of Technology	Poland	13	55	4.23
14	Deakin University	Australia	13	27	2.08
15	Lund University	Sweden	12	87	7.25
16	Aalto University	Finland	12	69	5.75
17	Delft University of Technology	The Netherlands	12	46	3.83
18	University of Florida	USA	11	102	9.27
19	University of Trieste	Italy	11	68	6.18
20	Polytechnic University of Bari	Italy	11	61	5.55

Finally, the most productive countries/regions are shown as follows in Table 6 and Figure 2. Globally, Italy dominates the list with nearly twice the number of papers than the USA, which is in second place. Australia comes in third, with 105 total papers. Note that in Tables 2 and 3, the majority of productive authors and institutions are from Italy and Australia, so there is no doubt that these countries rank high. Furthermore, Italy is the only country that has published more than 200 papers and has more than 2000 citations. From the indicator of MCP/MRP, we can conclude that countries such as Italy, Australia and United Kingdom have a strong willingness to cooperate with other countries/regions.

Table 6. Most productive countries/regions.

R	Country/Region	TP	SCP/SRP	MCP/MRP	TC	TC/TP
1	Italy	209	172	37	2085	9.98
2	USA	114	89	25	1118	9.81
3	Australia	105	71	34	741	7.06
4	United Kingdom	98	70	28	907	9.26
5	Poland	79	72	7	252	3.19
6	China	73	48	25	153	2.10
7	Portugal	53	45	8	287	5.42
8	Sweden	50	40	10	316	6.32
9	Canada	48	37	11	351	7.31
10	Spain	42	33	9	191	4.55

Table 6. *Cont.*

R	Country/Region	TP	SCP/SRP	MCP/MRP	TC	TC/TP
11	New Zealand	29	25	4	249	8.59
12	Finland	28	19	9	166	5.93
13	Germany	27	16	11	166	6.15
14	Japan	24	17	7	138	5.75
15	France	22	13	9	204	9.27
16	Korea	22	20	2	24	1.09
17	Norway	22	19	3	108	4.91
18	Saudi Arabia	21	16	5	154	7.33
19	Greece	18	16	2	63	3.50
20	Indonesia	17	13	4	138	8.12

Abbreviations: SCP/SRP = Single Country Production/Single Region Production; MCP/MRP = Multiple Country Production/Multiple Region Production.

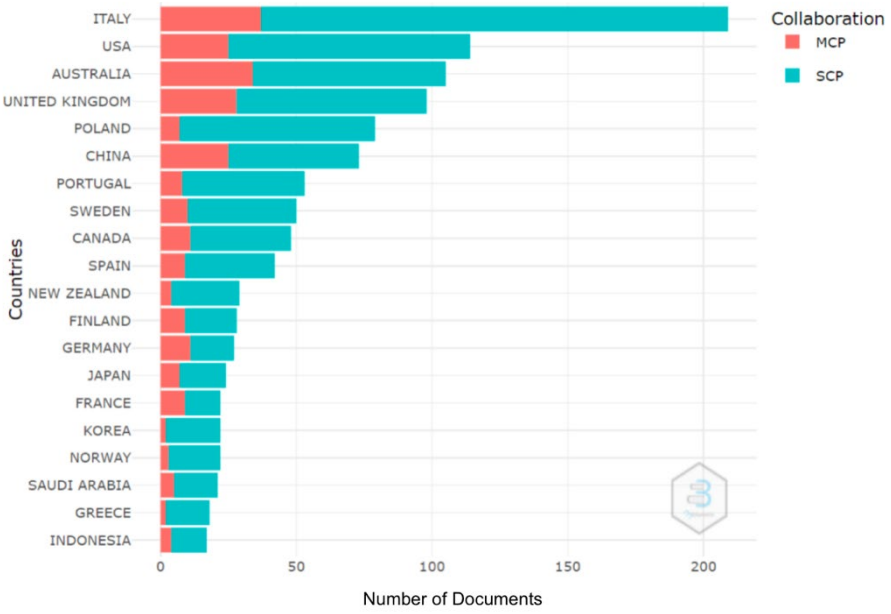

Figure 2. Most productive countries/regions.

4. Science Mapping Analysis of *Buildings*

This section developed a science mapping based on key factors including keywords, citation/co-citation and collaboration.

4.1. Analysis of Keywords

To begin with, we analyzed the author keywords occurring in the journal and their frequency, thematic map, growths, trends, and thematic evolution. Note that author keywords sum up the issues involved in an article and author preferences [26].

Figure 3 depicts a word cloud to show the 50 most frequent author keywords in papers in *Buildings*. The size of words demonstrates the word's frequency of occurrence. It is not surprising to find that the keyword "sustainability" is in the center of the graph, followed by "energy efficiency" and "thermal comfort". "Buildings", "bim" (Building Information Modeling) and "construction" also show their importance. "Climate change" has been a hot topic in recent years, especially in fields such as architecture and the environment. Other building performance parameters, such as "durability" and "natural ventilation", are also commonly utilized.

Figure 3. Word cloud of keywords.

Then, to get further understanding, Figure 4 depicts a thematic map of author keywords. A thematic map allows the visualization of four different typologies of themes based on two dimensions, i.e., density and centrality. Density is the strength of internal ties among all the keywords that are used to describe the research theme, while centrality is the strength of external ties to other themes by exploiting the authors' keyword field [27]. The upper-right quadrant called motor themes has clusters that are vital and well-developed in *Buildings*. In this quadrant, Cluster 1 includes "lean construction", "refurbishment", "embodied energy", "project management" and "case study". The position of Cluster 1 indicates its highest density among these keywords and its above-average importance. The upper-left quadrant called niche themes has clusters that are well-developed but not vital for the domain. From this quadrant, Cluster 1 includes "reinforced concrete", "cultural heritage", "pushover analysis", "seismic assessment" and "masonry", while Cluster 2 includes "durability", "concrete", "building envelope", "compressive strength" and "fly ash", and the third one includes "facility management" and "machine learning". Due to the close position of Cluster 1 and Cluster 2, we can argue that both of them are well developed but not the most vital for the domain. It is evident that Cluster 3 indicates its lowest importance in this map. The lower-left quadrant called emerging or declining themes has clusters with lower centrality as well as density in *Buildings*. The only cluster in this quadrant includes "optimization", "residential buildings", "energy performance" and "genetic algorithm". Finally, the lower-right quadrant called basic themes has clusters that are crucial for the domain but not well-developed or clusters that are cornerstones of the domain. In this quadrant, Cluster 1 includes "buildings", "climate change", "energy", "comfort" and "energy saving" and the second one includes "building information modeling", "construction", "productivity" and "retrofitting". It is obvious that some of them are basic concepts, such as "buildings", "construction" and so on. Some others, such as "climate change" and "energy saving", are important and need more attention.

Another interesting issue to consider is the annual growth of the top 10 keywords. Figure 5 demonstrates the evolution clearly from 2011 to 2021. On the whole, every keyword increased yearly, and this phenomenon also shows the sustained and steady development of *Buildings*. From the details, it is striking that "energy efficiency", "thermal comfort" and "sustainability" have remained the top three occurrences in the past decade. "Buildings", with a sharp increase in the curve, has emerged as the fourth most common occurrence since 2016. "BIM" has maintained a high growth rate since 2018; it emerged as the sixth most common keyword in 2021 while its occurrence was very low before 2018. Although "durability" consistently had the fewest occurrences, it has seen a significant increase after 2019, and we can assume that it will continue to grow in the future.

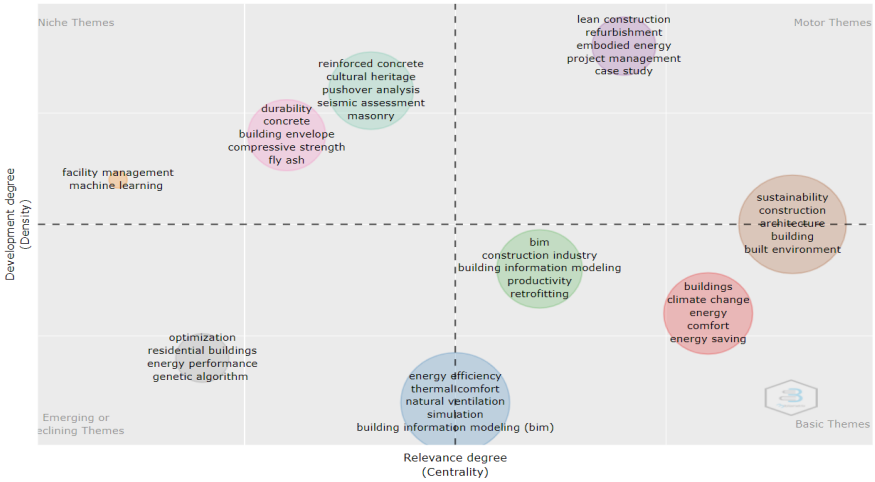

Figure 4. Thematic map of keywords.

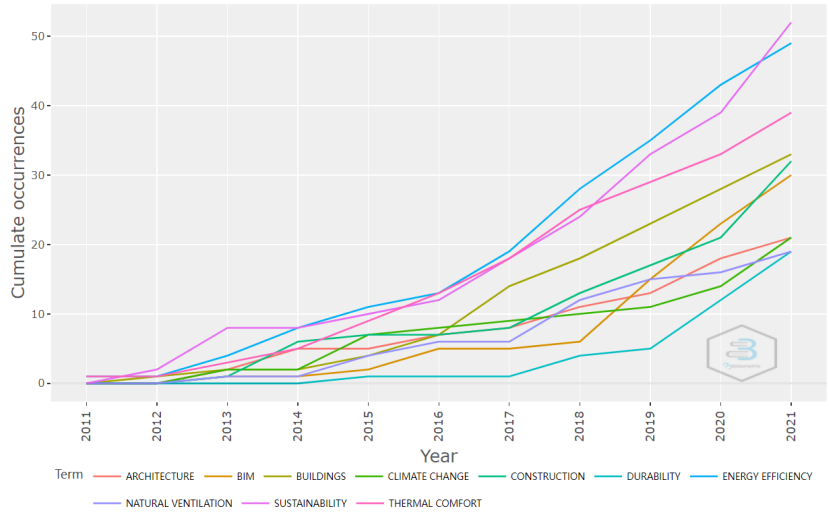

Figure 5. Growth of the top 10 keywords.

A further interesting issue is to analyze the trending topics in *Buildings*. Figure 6 depicts the top topics based on the keyword occurrences that have been continuously studied since 2011. As noted, on the right side of the figure, the topic frequency from 10 to 50 is demonstrated by the blue-filled circle, and the larger the circle, the higher the frequency. The topic "energy" was the only popular topic in the early years of *Buildings*. Then, in 2016 and 2017, some other topics such as "climate change", "simulation" and "energy efficiency" began to receive scholars' attention in *Buildings*. In 2016, "simulation" attracted more attention than "energy". Next, in 2017, "optimization", "sustainability" and "buildings" appeared in the trending topics list and continued to maintain scholars' attention. It is noticeable that "sustainability" and "construction" became the most two significant topics in 2019 and surpassed "energy efficiency" and "thermal comfort", which were most popular in 2018. However, from 2020 to 2021, "concrete", "cultural heritage", "durability" and "construction industry" have been focal points. Moreover, we can predict that these newly popular topics will continue to receive more attention in *Buildings*.

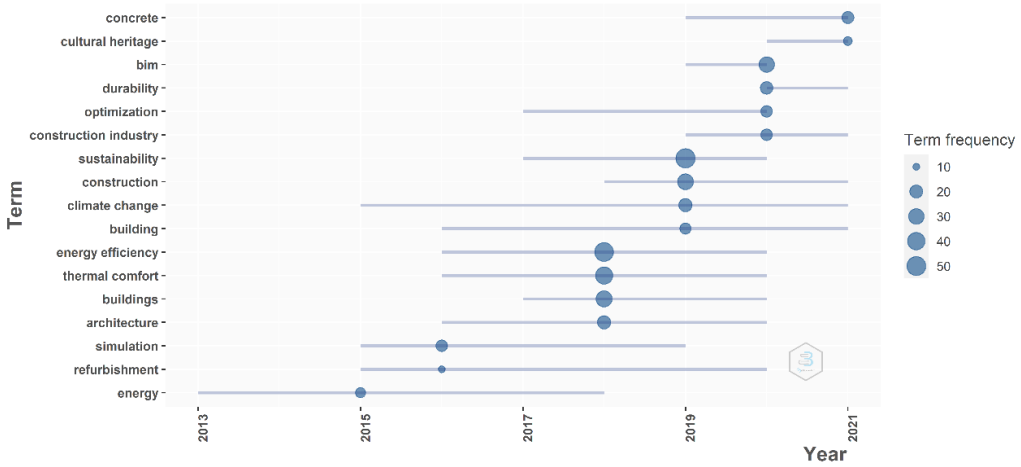

Figure 6. Trending topics.

Last but not least, in order to analyze the thematic evolution of the journal, we developed a Sankey diagram, shown in Figure 7. A Sankey diagram is used to show how different themes are connected and have developed in the past [28]. Each box in the map denotes a theme, and the size of boxes is proportional to the frequency of the theme's occurrences [29]. The flows connect each box showing the evolution traces of the theme, and the thicker the connecting line, the higher the linkage of the two themes.

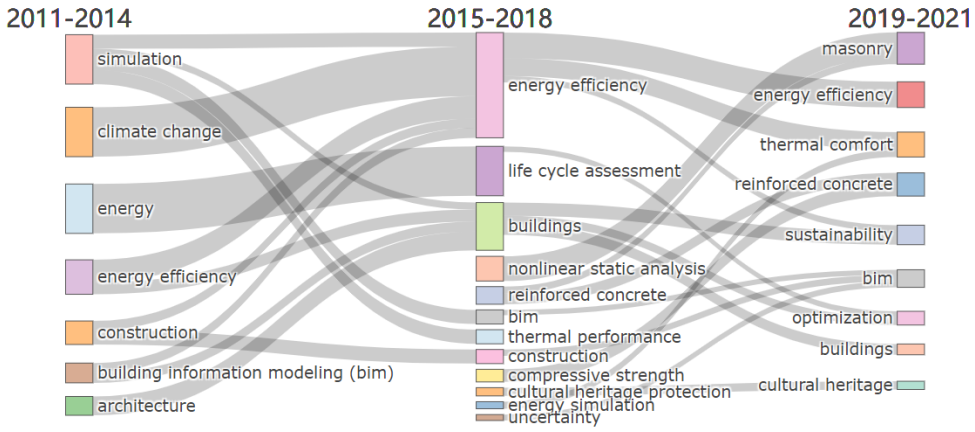

Figure 7. Thematic evolution.

From an overall perspective, it can be found that as time goes by, themes in *Buildings* are becoming increasingly diverse, probably because more and more scholars from different fields are attracted to the journal. It is noticeable that "energy efficiency" first appeared in 2011–2014, was further developed in the following four years, and continued to draw attention in the final time zone 2019–2021. Furthermore, this topic was the most popular one between 2015 and 2018. Some objective indicators, such as "optimization", "sustainability" and "thermal comfort", have only started to flourish in recent years. This result reflects the state-of-the-art of the journal.

4.2. Analysis of Three-Fields Plot

The three-fields plot embedded in the Bibliometrix tool allows us to understand the complete bibliometric research in one figure and exhibit proportionality among the content [27]. Figure 8 shows the most active 15 countries/regions in *Buildings* in the left field, keywords that these countries/regions are using in the middle field, and the main journal sources in the right field. From the middle field, we find that the scholars in *Buildings* focus more on "energy efficiency", "thermal comfort", "sustainability", "buildings" and

"construction". This field reveals hot topics that scholars should pay closer attention to. These results are the same as in Figure 3. Note that "energy efficiency" and "thermal comfort" are prevalent in *Energy and Buildings*, whereas "thermal comfort" is more prevalent in *Build and Environment*. Furthermore, it is obvious from the right field that *Energy and Buildings* and *Building and Environment* are playing the most significant roles as major sources in *Buildings*. From the left field, it is noticed that the United Kingdom, Italy, the USA and Australia have the largest number of publications in *Buildings* and cover most research areas, and this result is consistent with our previous analyses.

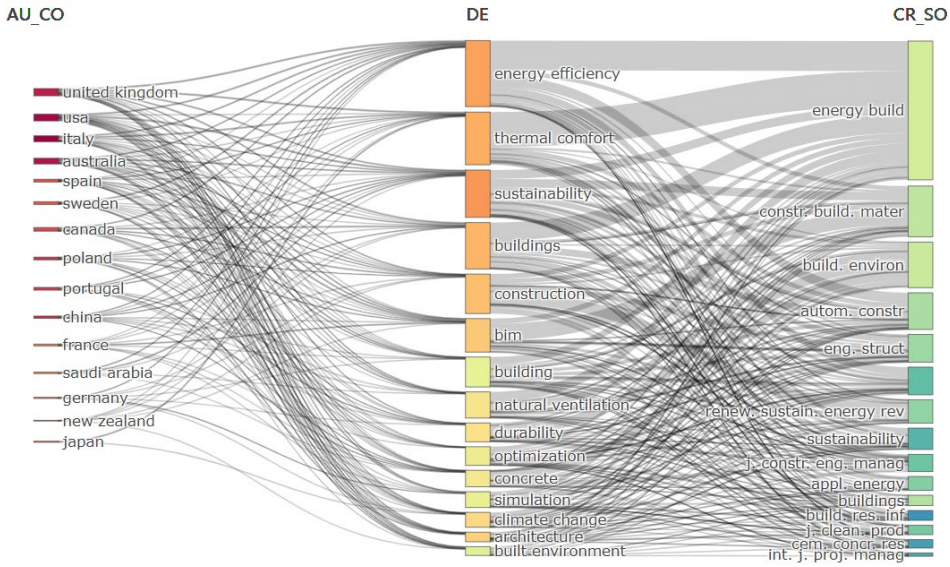

Figure 8. Three-fields plot.

4.3. Analysis of Citations and Co-Citations

We next created a historiograph of *Buildings*. Figure 9 shows the chronological map based on the most relevant citations. Each flow in the same color identifies a direct citation and signifies a concept and its historical development. The nodes in the flows are core documents with high citations (both local citations and global citations are taken into account). The largest citation stream is in blue, starting with the research of Vinokurov, M. in 2018 [30] and 2019 [31]. This path provides several new insights on the efficiency, economy and climate implications of the energy solutions. Note that as the most cited author in this figure, Fargnoli, M. is also marked in blue. He proposed two novel methods based on Preliminary Human Safety Assessment (PHSA) [32] and BIM [33] in order to enhance occupational safety in the construction industry. The second largest citation stream is in red, starting in 2019 and further developing in 2021. These papers in red provide insights into and analysis of seismic vulnerability [34], seismic assessment [35] and nonlinear static procedures [36]. Other citation streams all contain only a few nodes. From the diversity of colors in this map, we can conclude that *Buildings* covers a wide range of research topics and applications.

Then, we looked into the co-citations of journals regarding documents published in *Buildings*. A co-citation of journals occurs when two documents from different journals receive a citation from the same third document [3]. Fifty journals are shown in Figure 10. The colored circles and lines represent the journals and their co-linkages with other journals, respectively. At the same time, the size of the circle represents the citation weight [37]. We can intuitively see that this map is divided into three clusters with different colors. It is obvious that the three biggest circles in this colorful map are *Energy and Buildings* in green, *Building and Environment* in green and *Buildings* in blue. Therefore, these three journals have the largest number of citations and the broadest network. The blue *Buildings* circle links with journals such as *Sustainability* and *Automation in Construction*, and they form a

blue cluster together. As for the green cluster, *Energy and Buildings* has co-citations with *Automation in Construction, Energies* and other green circles. Similarly, the formation of the red cluster is based on the same theory. However, the red cluster has fewer citations and linkages than the other two clusters.

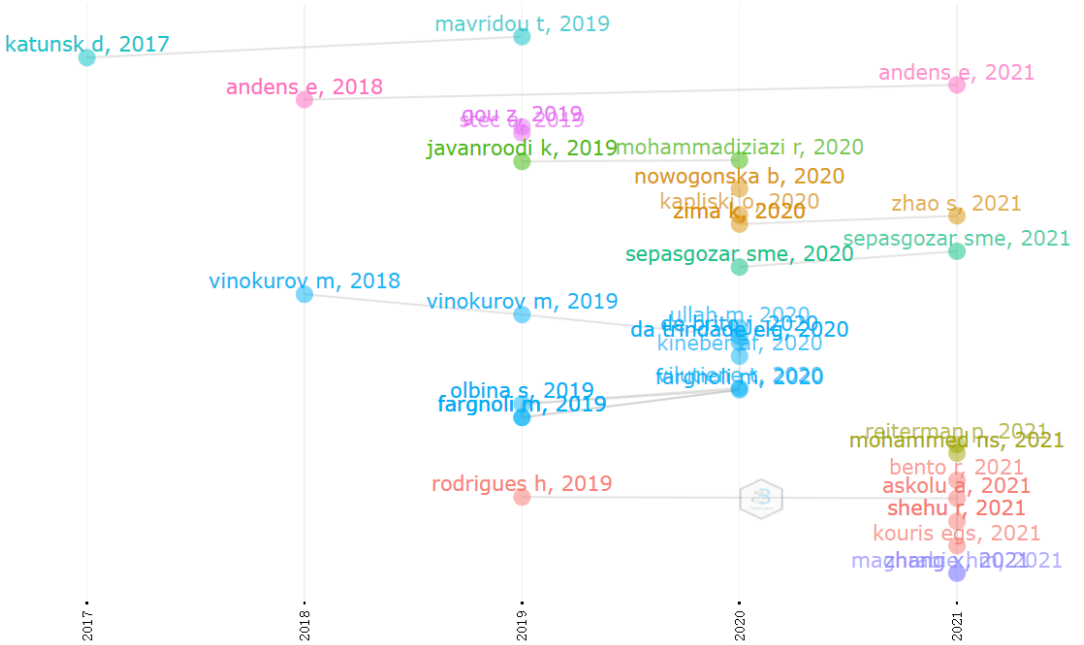

Figure 9. Historical direct citation network.

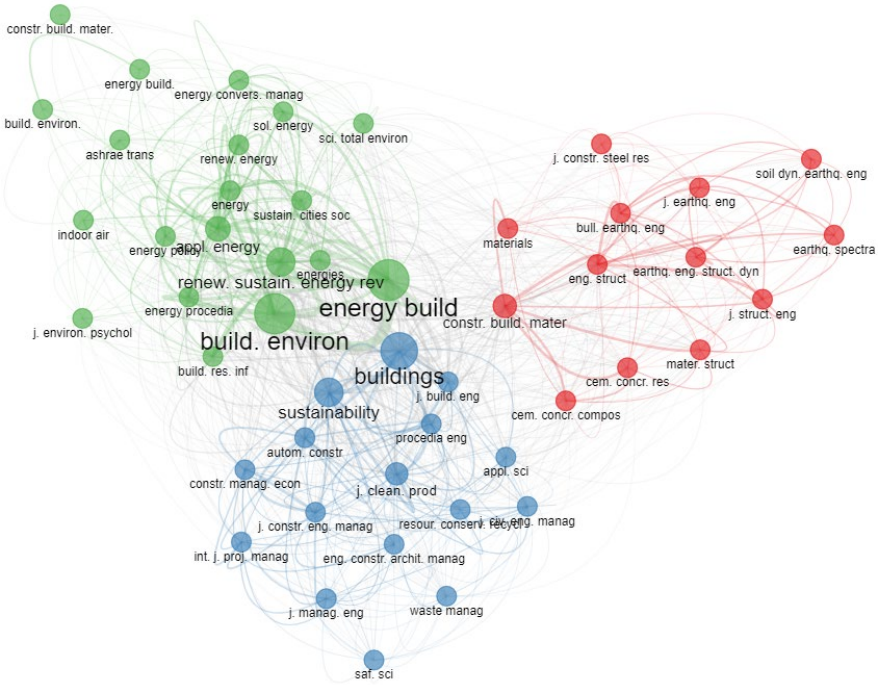

Figure 10. Co-citation network of journals.

4.4. Analysis of Collaboration

Figure 11 depicts the collaboration network of institutions in *Buildings*. The colored circles and lines represent the institutions and their collaborations with other institutions, respectively. This map is divided into seven clusters with different colors. By querying the

countries or regions where these institutions belong, it is not difficult to find that almost all the institutions in the same cluster come from the same country or region. For instance, Moscow Automobile and Road Construction University, Far Eastern Federal University, Belgorod State Technological University and Peter the Great Saint-Petersburg Polytechnic University are all located in Russia. Similarly, the institutions in the red cluster come from Australia, the pink from France, the yellow from Canada and the blue from Italy. However, the green cluster contains the University of New South Wales from Australia and Universidade Federal do Rio de Janeiro from Brazil, and the brown cluster contains the Central University of Technology from South Africa and Leeds Beckett University from the United Kingdom.

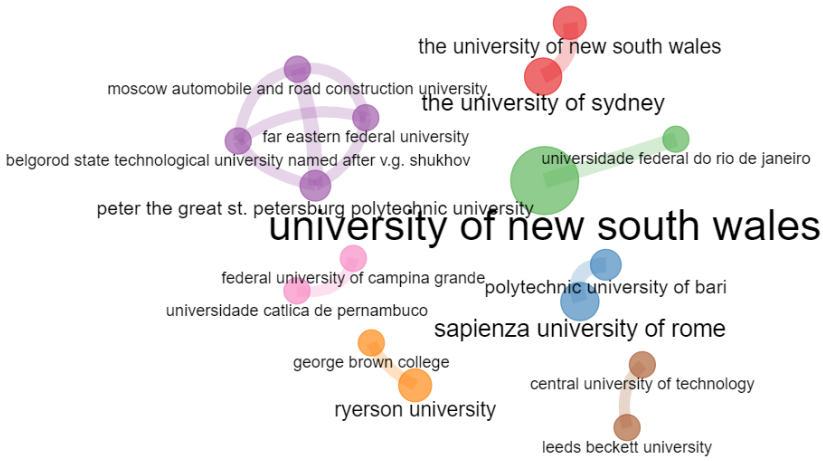

Figure 11. Collaboration network of institutions.

Buildings has a massive international collaboration, which contributes to the global academic exchange. The international collaboration network identifies how countries and regions are related in the journal. Figure 12 shows results at the geographic level, and Figure 13 shows these in detail. In Figure 12, the shade of countries/regions and the thickness of lines represents the number and the proportion of their collaborations, respectively. Not surprisingly, the most active area is the European sector. We can observe that China and Australia demonstrate the strongest cooperative tie with each other. In Figure 13, the size of countries/regions represents the number of their collaborations, and the larger the circle, the more cooperative partners they have. The thickness of lines indicates the closeness of the collaboration of countries/regions. Italy has the widest range of cooperative partners, followed by the United Kingdom, Australia, the USA and China. These five countries are high-yield countries. Furthermore, it can be observed that China, the USA and Australia have a strong connection with each other, and their willingness to cooperate with each other is evident.

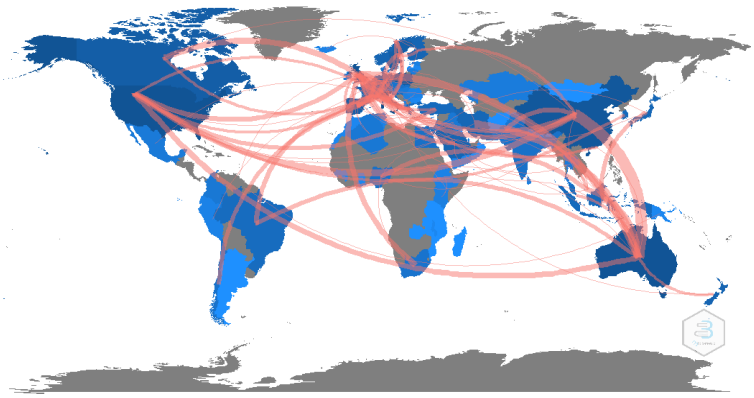

Figure 12. An overview of cooperation between countries/regions.

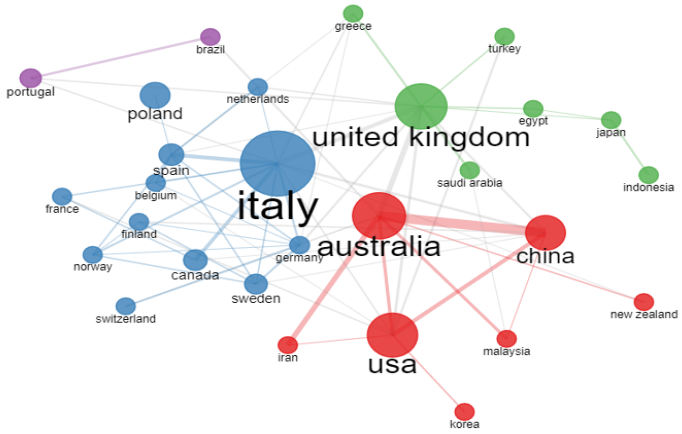

Figure 13. Collaboration network of countries/regions.

5. Discussions and Conclusions

Buildings was first published 10 years ago in 2011. Motivated by its 10th anniversary, this study presents a bibliometric analysis of publications in the journal between 2011 and 2021. This work adopts two bibliometric methods: performance analysis and science mapping [38].

Regarding performance analysis, the research first identified the publication and citation structure of the journal. The results show the strong growth of *Buildings* throughout time. Up to now, the journal has published more than one thousand documents and is widely acknowledged by scholars all over the world. The most cited paper, entitled "*Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector*", was written by Akadiri, P.O., Chinyio, E.A. and Olomolaiye, P.O. in 2012. Then, this work reviewed the leading authors, institutions and countries/regions. The results indicate that Italy is the most productive country in *Buildings*, well above the results of the USA, which appears at the second position. The University of New South Wales, located in Australia, has been the most productive affiliation over the past 10 years with 46 publications and 345 citations in total. Looking at the most cited authors, we recognize the contributions of Sepasgozar, S.M.E. from Australia, Al-Kodmany, K. from the USA, Bedon, C. from Italy and Zhang, X. from Sweden. In this sense, it is clear that the journal is becoming very popular worldwide.

In order to delve deeper into the results, this work used science mapping in Section 4. This approach provides a more comprehensive visualization of the results. We considered author keywords, three-fields plot of institutions, keywords and main journal sources, citations, co-citations and collaboration. From the analysis of author keywords, we can conclude that the journal published more on the topics of "sustainability", "energy efficiency" and "thermal comfort". Between 2011 and 2014, scholars in *Buildings* published papers mainly about simulation, climate change and energy. However, in the following four years, "energy efficiency" became the most popular topic, followed by "life cycle assessment" and "buildings". In the last three years, "masonry", "energy efficiency" and "reinforced concrete" have attracted more attention from researchers. This result provides us with the developing trends of topics of the journal.

This journal is closely connected to other leading journals in the field, such as *Energy and Buildings* and *Building and Environment*. As for the collaboration network in *Buildings*, this study provides a knowledge domain map that identifies collaborative networks of researchers between journals and countries/regions. The results show that institutions from the same country or region work more closely together. Italy has the widest range of cooperative partners, followed by the United Kingdom, Australia, the USA and China. These five countries are high-yield countries.

This study is useful to scholars, publishers or others interested in building science, building engineering and architecture. It provides people with a comprehensive overview

of *Buildings* from the past ten years using a bibliometric method and also forms a base for initiating further study in this area. For example, it is worth noting that hot topics such as energy efficiency, cultural heritage and climate change may continue to attract attention. Furthermore, through the previous analysis, we can predict that the journal will be acknowledged by more and more people over the world in the future. The number of publications and citations will likely continue to increase, and the research topics in the journal may become increasingly various and in-depth. There is no doubt that *Buildings* will continue to provide a platform for the expression and dissemination of ideas and strengthen cooperation among authors, institutions and countries/regions, as well as build a bridge between academia and industry.

Furthermore, there are some gaps the journal should pay attention to. For example, with the increase in publications, the diversity of research directions and fields has increased, too. The journal should maintain a quality/quantity balance and also emphasize on the depth and contribution of articles. Furthermore, *Buildings* runs special issues to create collections of papers on specific topics, but the classification of special issues can be further refined and become more innovative. It is also advisable for the journal to take some measures, such as organizing academic events, to encourage scholars and promote the development of academia.

This study provides a full description of *Buildings* but also presents some limitations. Since the data were collected from the Scopus database, the limitations of this database may also apply to this study. For instance, 76 documents are omitted since they are not directly available in Scopus, so some results may not be completely correct. Another limitation is that although the work uses a wide range of indicators in order to provide a comprehensive overview from different perspectives, we have to acknowledge that the work is not perfect and there are some missing perspectives we did not take into consideration. Future research should make improvements in these two directions to provide better research.

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