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A Bibliometric Analysis on Life Cycle Assessment of Bricks

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Abstract

Conventional production methods used in the production process of bricks as a building material causes several impacts on the environment and climate change due to greenhouse gas emissions and waste generation. The life cycle assessment (LCA) methodology is used to determine a material's carbon footprint from cradle to grave, including all production processes from the extraction of raw materials to the disposal of waste materials or re-use of recycled materials. It is important to examine the energy and material flow of the product using the LCA methodology to develop sustainable solutions in the production processes of brick material. This preliminary study aims to review existing LCA approaches about bricks, obtain bibliometric data from the published papers that include the analysis of the life cycle of bricks, and form a basis for the main study by analyzing literature data. Within the scope of this study, the bibliometric analysis method is used to examine available literature about the LCA of bricks, research gaps are investigated, and bibliometric mapping is implemented using several co-occurrences such as authorship, publication years, countries, keywords, etc. Web of Science and Scopus databases are used for bibliometric mapping. The results of the study show that it is an emerging research topic mostly studied in the context of environmental sciences, engineering, and technology that needs further research, especially in Turkey. Also, this topic is generally covered with and related to building materials, sustainability, waste management, biosolids, carbon emission, environmental impacts, recycling, and circular economy.

Keywords

life cycle assessment, building materials, brick, bibliometric analysis, bibliometric mapping

1 Introduction

The increase in the world population and migration from villages to towns caused the crowding of cities. For this reason, the construction sector has grown rapidly, and accordingly, the building materials that provide the built environment have increased considerably in terms of variety and quantity. Production of all building materials, especially cement and iron, needs high amounts of energy input in production processes, and a certain amount of waste were generated at the end of each production process. Therefore, the production of all building materials has many negative impacts on the environment, such as greenhouse gas emissions, climate change, global warming, environmental pollution, ecosystem degradation, and biodiversity loss.

In general, buildings are responsible for 30–40% of total primary energy use, and 40–50% of greenhouse gas emissions (Ramesh et al., 2010). Walls are the main determining component of a building in terms of indoor energy consumption, and life cycle environmental impacts, because of their functional use in the building's envelope (Atmaca, 2016; Monteiro and Freire, 2012, Talang and Sirivithayapakorn, 2018). Brick is one of the most commonly used building materials for the construction of walls, which are used to separate interior and exterior spaces in buildings or to separate spaces with different functions in the building. For this reason, it is important to determine and reduce the negative environmental impacts caused by the production of bricks. Life Cycle Assessment (LCA) methodology enables the calculation of overall emissions that result from all stages of the production processes of materials. Various environmental impacts and emissions occur during the life stages of a product such as the extraction of raw materials, production, transportation, use, and disposal or recycling.

The life cycle of a product is defined as "consecutive or interlinked stages of a product system, from the raw material acquisition or generation from natural resources to final

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disposal" (ISO 14040:2006, 2006:p.1). Also, the LCA is defined as "the compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040:2006, 2006:p.1; ISO 14044:2006, 2006:p.1). LCA is an objective process from cradle to grave, used to quantitatively evaluate the environmental burdens associated with a product, process, or activity throughout its entire life cycle. The environment is often thought of as a cradle because it is the primary source of all materials. These materials are processed in various industrial stages and processes called gates. The final location of the disposal of the material as waste is generally referred to as the grave. Thus, the environment is both the cradle and the grave (Striebig et al., 2015).

The life cycle of brick consists of the extraction of raw material, transportation to the production facility, extrusion, shaping, drying, cooking, storage, packaging, transportation to the construction site, and recycling/reusing/disposal after the end of service life. All of these stages have different environmental impacts. Clay mining (65.8%), brick molding (24.8%), and brick roasting (9.4%) are found to have the highest environmental impacting stages of brick production (Ncube et al., 2021). Calculating the environmental impacts associated with all of these stages makes it enable to make necessary revisions to reduce important negative environmental impacts associated with either one of these stages. LCA methodology is useful in this manner, for the calculation of environmental impacts and supports decision making.

The purpose of this preliminary study is to investigate previous work and available literature on the topic of life cycle assessment of bricks in order to prepare a base for calculating environmental impacts associated with the production of bricks and reducing them by developing environmentally friendly solutions. Hence, a bibliometric analysis approach is used in this study, and literature data were analyzed.

The bibliometric analysis method is effective for determining appearances and linkages between publications in the literature, based on quantitative data gathered from various scientific databases. WOS and Scopus databases were used as sources of bibliometric data which consist of authors, countries, organizations, keywords, citations, etc. The VOSviewer software tool is used to analyze the data and interpret the results.

The results of the study show that the LCA of building materials and building components, particularly bricks within the concept of this study, is an emerging research topic in environmental sciences, engineering and technology, and energy that draws the attention of many researchers in recent years. Researchers from China, Australia, Italy, and Spain show more interest on the subject. Universities such as Royal Melbourne Institute of Technology, Curtin University, Chinese Academy of Sciences, and ETH Zurich lead the research on this topic. "LCA" and "brick" keywords generally appear with keywords like building materials, sustainability, waste management, biosolids, carbon emission, environmental impacts, recycling, and circular economy in the literature.

2 Methodology

The aim of this study is to investigate available literature data based on publications related to the LCA of bricks. With the help of Web of Science (WOS) and Scopus databases the tendency to shape the trend of research about the subject has been revealed (WOS, 2022).

The bibliometric analysis method was used in this study. This method is known as an effective way of showing up the progression of relevant research with a historical approach and paving the way for future studies on a specific research topic. There are various novel studies that use the bibliometric analysis method to assess information regarding LCA (Furness et al., 2021, Moghayedi et al., 2022; Norouzi et al., 2021; Ohene et al., 2022; Yu and Chen, 2022). The bibliometric analysis method is useful for investigating the growth of research topics, finding relationships between logical progresses, applying modifications to the common approach, and identifying expanding interdisciplinary alliances. This method provides detailed quantitative and statistical scientific information regarding the processes of making decisions (Varshabi et al., 2022). VOSviewer software tool was used to analyze bibliometric data, create bibliometric coupling, and generate the bibliometric mapping (Van Eck and Waltman, online).

In WOS and Scopus databases, the keywords "life cycle assessment" and "brick" were used to gather bibliometric data. A total of 298 publications were found in the WOS database, and 4,150 publications were found in the Scopus database when the search is done in "all fields" with no limitations were applied.

Since these results reveal a high number of publications with which some of them were less related or not directly related to the subject of the study, the search results were needed to be refined to serve the purpose of the study. Therefore, different refinements were done based on the author's opinion and experience in two different databases. Results and procedure may differ due author's judgment and are open to interpretation.

WOS database consists of publications after 1999. Out of 298 publications, 277 were published after 2012 including 2012. Therefore, the search was limited to cover the years 2012 and forth, and 93% of all publications were covered (WOS, 2022).

The type of documents were articles, proceeding papers, review articles, early access, and book chapters. 41 proceeding papers and 2 book chapters were excluded from the results to further increase the quality of the content with a consideration that journal articles will be more developed versions of various proceeding papers, and includes more results rather than preliminary findings. After this extraction, a total of 234 publications were left.

The search results were categorized into 34 different WOS categories. In order to reach the most relevant content, some of these categories were eliminated with considering the relevance of the category with the research idea in mind. The eliminated categories are; toxicology, polymer science, mineralogy, meteorology atmospheric sciences, materials science paper wood, materials science coating films, forestry, computer science hardware architecture, chemistry applied, biochemistry molecular biology, and chemistry multidisciplinary. A total of 224 publications have remained.

There were 22 different publishers in the WOS database. The widely known publishers, namely Elsevier, Multidisciplinary Digital Publishing Institute (MDPI), Springer Nature, Taylor & Francis, Wiley, American Society of Civil Engineers (ASCE), and Emerald Group Publishing were selected and others were excluded. These widely known publishers cover 206 out of 224 publications, a rate of 92% (ASCE, 2022; Elsevier, 2022; Emerald Gruop Publishing, 2022; MDPI, 2022; Springer Nature, 2022; Taylor & Francis, 2022; Wiley Online Library, 2022; WOS, 2022).

After these refinements, 206 publications were left for further analysis. No interventions were done in refinement options such as authors, affiliations, publication titles, funding agencies, open access categories, research areas, and countries/regions. The language of all 206 publications was English, therefore no further refinement was needed. The results of the search were imported as "tab-delimited file" format for bibliometric analysis and mapping.

Scopus database gave 4,150 document results after searching for the keywords "life cycle assessment" and "brick" in all fields. Since this many number of documents is not practical for the bibliometric analysis method, and the capacity of VOSviewer software is limited to 2,000 documents, it is decided to search the keywords in "article title, abstract, keyword" instead of "all fields". A reasonable amount of publications appeared for analysis after this modification, a total of 280 documents (Scopus, 2022).

Scopus database gives results of the documents published after 2001. Out of 280 publications, 258 were published after 2012 including 2012. 92% of the publications were covered by this limitation. The year 2012 was also selected to ensure consistency and comparability of the analysis between WOS and Scopus databases.

The results were filtered according to their subject area category. There were 20 different subject areas. The subject areas considered to be least relevant were excluded from the results. These are pharmacology, toxicology, and pharmaceutics; medicine; decision sciences; chemistry; biochemistry, genetics, and molecular biology; chemical engineering; mathematics; economics, econometrics, and finance; arts and humanities; computer science; and physics and astronomy. 220 documents were left after this refinement.

The document types in the Scopus database were article, conference paper, book chapter, review, and conference review. Conference papers, book chapters, and conference reviews were excluded from the results with the same logic that was explained previously for the WOS database. 164 documents were left after this refinement.

2 documents written in Spanish, 1 in Chinese, and 1 in Russian were excluded from the search results as these languages were not known by the authors. A total of 160 documents were left for analysis (Scopus, 2022).

No interventions were done in refinement options such as open access categories, author name, source title, keyword, affiliation, funding sponsor, and country/territory. The results of the search were imported as "comma separated values (CSV)" format including citation information, bibliographic information, abstract and keyword, funding details, and other information available for bibliometric analysis and mapping.

To sum up, bibliometric data were gathered for 206 publications from the WOS database and 160 publications from the Scopus database. These data were used in the VOSviewer software tool, and the analysis and results of the data were discussed in Section 3 (Scopus, 2022; WOS, 2022).

3 Results and discussion

In Section 3, the gathered bibliometric data were analyzed, results were presented, and the findings were discussed taking into account various considerations such as publication years, research areas, authorships, countries of publications, sources of publications, affiliations, and co-occurrences of keywords.

3.1 Publication years

The publication years of the documents from the results of the bibliometric data were interpreted in Fig. 1 from WOS data, and in Fig. 2 from Scopus data. Both figures show the data after 2012.

From the results of the publication years data, it can be concluded that studies about the LCA of bricks are a trending topic amongst various researchers. It is becoming more popular, and the subject is an up-to-date research concern that has the potential to get a high chance of success to be noticed and benefited by other researchers.

The main words in the title start with capital letter, articles, and conjunctions with lowercase letters.

3.2 Research areas

According to the results of the research subject, environmental sciences were found to have mostly appeared as research areas in both WOS and Scopus databases in common. Since the subject areas were named differently in WOS and Scopus, a one-to-one comparison cannot be done, and they will be evaluated separately (Scopus, 2022; WOS, 2022).

In WOS research area categories, the most appearances occurred in environmental sciences, engineering environmental, and green sustainable science technology (Table 1). The percentages do not sum to 100%, because publications may appear in more than one research area in the WOS database (WOS, 2022).

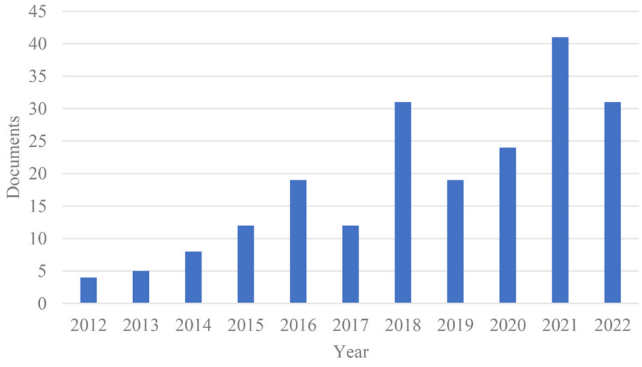

Fig. 1 Number of publications by years (WOS, 2022)

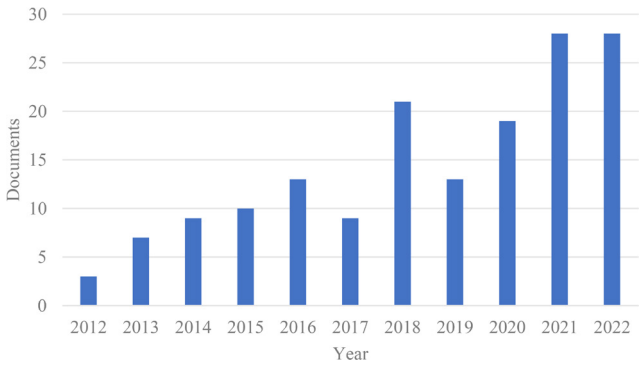

Fig. 2 Number of publications by years (Scopus, 2022)

Table 1 Research area categories (WOS, 2022)

WOS research area categories	Record count	Percentage
Environmental Sciences	111	53.9%
Engineering Environmental	87	42.2%
Green Sustainable Science Technology	78	37.8%
Construction Building Technology	58	28.2%
Engineering Civil	54	26.2%
Energy Fuels	35	17%
Materials Science Multidisciplinary	31	15%
Environmental Studies	19	9.2%
Others	44	17.5%

In Scopus research area categories, most appearances occurred in environmental sciences, engineering, and energy. These three categories represent more than 70% of the related studies (Table 2).

From the results of the research areas that appeared from bibliometric data, it can be concluded that the LCA of bricks is basically a subject of environmental science, engineering, science and technology, and energy. There is also a lesser number of multidisciplinary studies, and studies in the fields of social sciences, management, and economy.

3.3 Authorship

The authorship was analyzed according to the number of publications by various researchers. The up-front authors are given in Fig. 3 from the WOS database, and in Fig. 4 from the Scopus database.

According to these results, it has been found that most of the authors have less than 5 publications on the subject of LCA of bricks. Cerny R. has the highest number of publications on the subject with a score of 6. Therefore, it can be concluded that important authors are working on the subject to be followed for the preparation of the main study, but there isn't any specific author that has been a pioneer on this subject. So, a more detailed investigation of

Table 2 Research area categories (Scopus, 2022)

Scopus research area categories	Record count	Percentage
Environmental Science	107	30.5%
Engineering	89	25.4%
Energy	63	17.9%
Business, Management, and Accounting	36	10.3%
Social Sciences	30	8.5%
Materials Science	19	5.4%
Others	7	2%

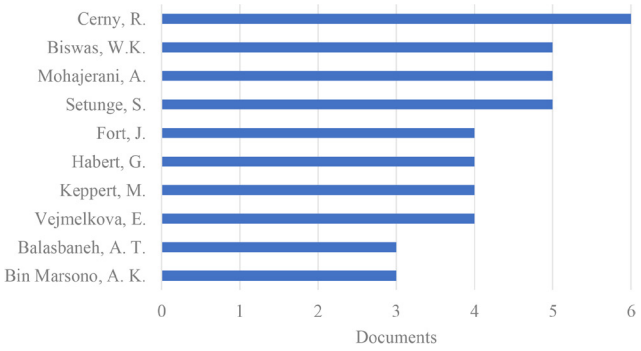

Fig. 3 Authors by number of publications (WOS, 2022)

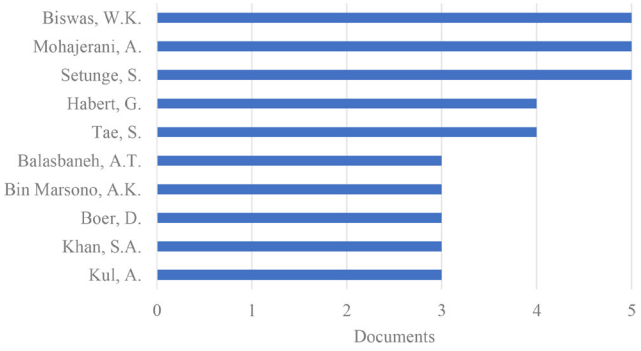

Fig. 4 Authors by number of publications (Scopus, 2022)

the publications from various authors is needed in order to reach the most relevant and inspiring people on the subject.

From the WOS data, co-authorship analysis was done, and the results were presented in Fig. 5. The minimum number of documents of an author was selected to be at least 2, and among 213 authors 12 met the threshold. The co-authorship links with other authors were calculated for each of the 12 authors. 6 of them were found to be connected among 15 authors. These are found to be, de Souza D. M., Chappert B., Lafontaine M., Lima L., Charro-Doucet F., and Duarte F. These results show that out of 213 authors, only 6 of them are linked, and this can be interpreted as a weak link between several authors (WOS, 2022).

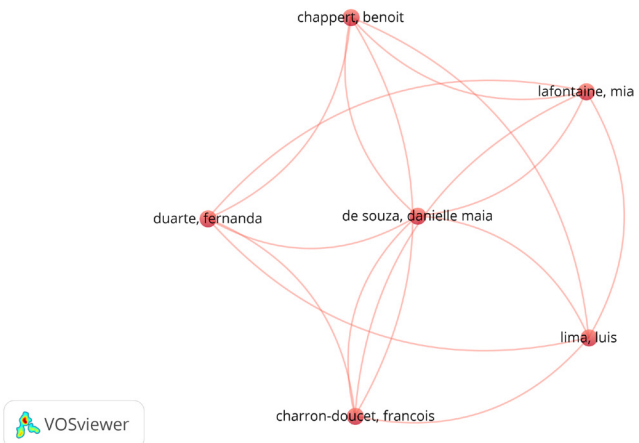

Fig. 5 Analysis results for co-authorship (WOS, 2022)

The co-authorship analysis results from the Scopus data are presented in Fig 6. Again, the minimum number of documents of an author was selected to be at least 2, and among 596 authors 52 met the threshold. The co-authorship links with other authors were calculated for each of the 52 authors. Some of the 52 authors were found to be not connected to each other. The largest set of connected authors consists of 6 authors. The results appear to be totally different than the WOS database.

Bibliographic coupling of authors' analysis was only available with Scopus data. The minimum number of documents of an author was selected as 2, and out of 596 authors, 52 met the threshold. The bibliographic coupling of these 52 authors is presented in Fig. 7.

3.4 Countries of publications

The countries which the related content was published from are illustrated in Fig. 8 for the WOS database, and in Fig. 9 for the Scopus database. The results of both databases highly match each other. According to the results, China, Australia, Italy, and Spain have the greatest number

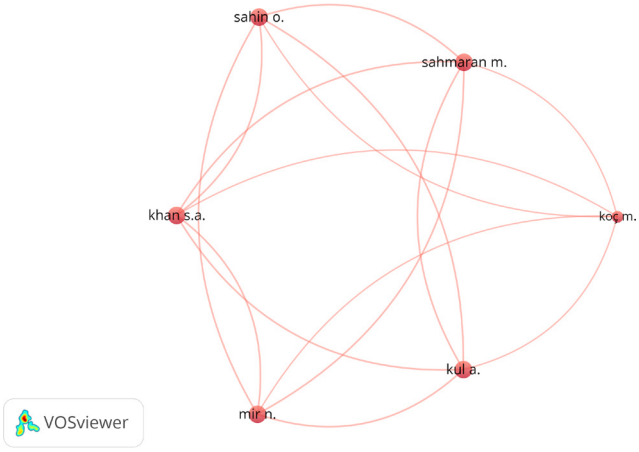

Fig. 6 Analysis results for co-authorship (Scopus, 2022)

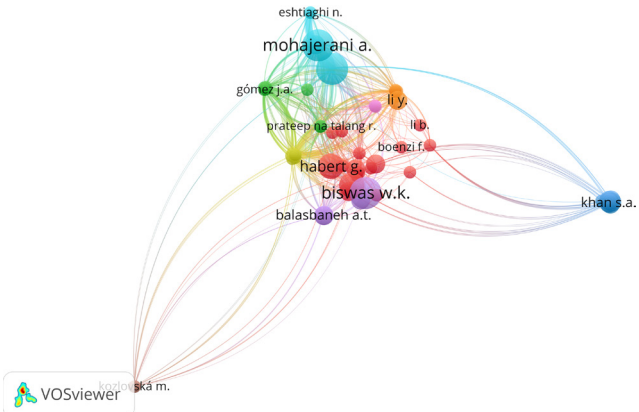

Fig. 7 Analysis results for bibliographic coupling of authors (Scopus, 2022)

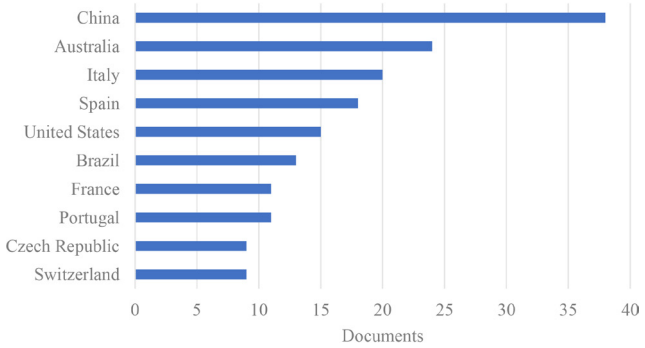

Fig. 8 Countries by number of publications (WOS, 2022)

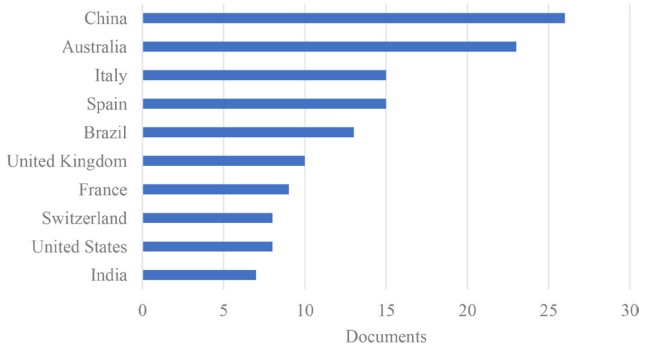

Fig. 9 Countries by number of publications (Scopus, 2022)

of publications accordingly. The alignment differs between these countries in WOS and Scopus databases (Scopus, 2022; WOS, 2022).

Also, the number of publications differs according to the database. In the WOS database; China has 38 publications, Australia has 24 publications, Italy has 20 publications, and Spain has 18 publications. In the Scopus database; China has 26 publications, Australia has 23 publications, Italy has 15 publications, and Spain has 15 publications (Scopus, 2022; WOS, 2022).

From WOS data, co-authorship of the countries was analyzed. 29 different countries were occurred from the search results, and when the minimum number of documents of a country is selected as 2, 17 countries met the threshold. For each of the 17 countries, the total strength of the co-authorship links with other countries was calculated. 13 countries among 17 were found to be connected to each other. The results were presented in Fig. 10. According to the results, there are stronger links between Australia and China, and Russia (blue); between Italy, Spain, France, and Germany (red); between Brazil and Portugal (yellow); between Canada and Sweden (purple); between Switzerland, Colombia, and United Kingdom (green) (WOS, 2022).

The co-authorship data of countries from the Scopus database is given in Fig. 11. The results were narrowed such that out of 14 countries 13 of them met the criteria to

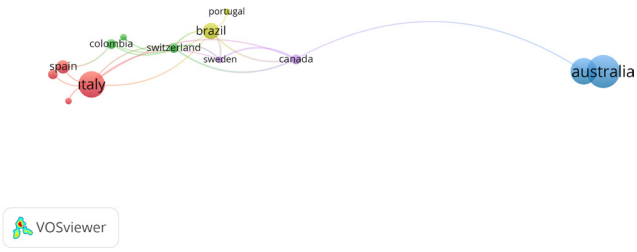

Fig. 10 Analysis results for co-authorships from different countries (WOS, 2022)

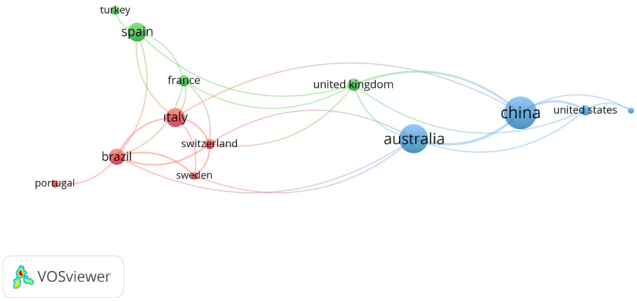

Fig. 11 Analysis results for co-authorships from different countries (Scopus, 2022)

have at least 5 publications. For each of the 13 countries, the total strength of the co-authorship links with other countries was calculated. The clustering appeared between China, Australia, USA and the South Korea (blue); Spain, United Kingdom, France, and Turkey (green); and Italy, Brazil, Switzerland, Sweden, and Portugal (red). As it may have been noticed, the countries and the clusters of countries differ in different databases for countries such as Italy, Brazil, and Switzerland (Scopus, 2022).

The citation links between countries were analyzed and interpreted in Fig. 12. Out of 47 countries, 14 of them met the criteria to have at least 5 publications. For each of the 14 countries, the total strength of the citation links with other countries was calculated. According to the results, clusters between Australia, Portugal, USA, France, and South Korea (red); between China, Italy, Brazil, United Kingdom,

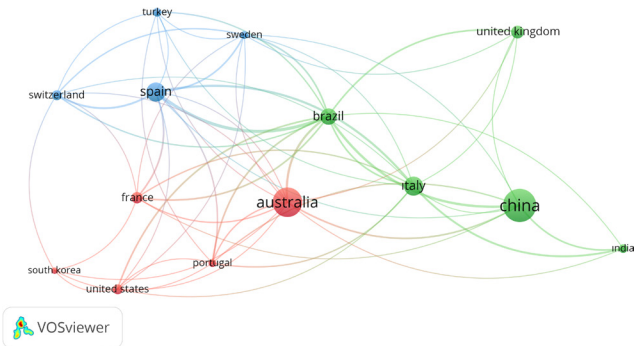

Fig. 12 Analysis results for citation links between countries (Scopus, 2022)

and India (green); between Spain, Turkey, Switzerland, and Sweden (blue) have occurred (Scopus, 2022).

The bibliographic coupling of countries was also analyzed using Scopus data (Fig. 13). Out of 47 countries, 14 of them met the criteria to have at least 5 publications. For each of the 14 countries, the total strength of the bibliographic coupling links with other countries was calculated. According to the results, China, Australia, USA, and South Korea form a cluster; United Kingdom and France form another cluster, whereas Italy, Spain, Brazil, Portugal, Sweden, Switzerland, Turkey, and India form another cluster.

3.5 Sources of publications

The sources of publications or the title of the journals that they have been published are given in Table 3 and Table 4 for WOS and Scopus databases respectively. There were various journal names, and the top ten journal titles were demonstrated according to the number of publications they involve. Journal of Cleaner Production, International Journal of Life Cycle Assessment, Building and Environment,

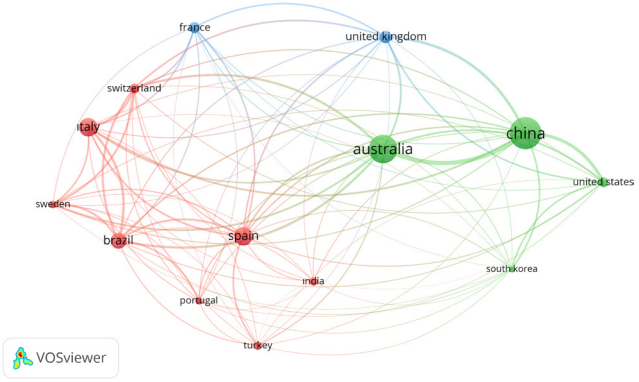

Fig. 13 Analysis results for bibliographic coupling of countries (Scopus, 2022)

Table 3 Top ten journals according to the number of publications (WOS, 2022)

Journal titles (WOS database)	Count
Journal of Cleaner Production	46
Construction and Building Materials	16
Sustainability	14
International Journal of Life Cycle Assessment	13
Energy and Buildings	12
Building and Environment	10
Journal of Building Engineering	7
Waste Management	6
Journal of Environmental Management	5
Materials	5
Others	43

Table 4 Top ten journals according to the number of publications (Scopus, 2022)

Journal Titles (Scopus database)	Count
Journal of Cleaner Production	36
International Journal of Life Cycle Assessment	11
Sustainability Switzerland	10
Building and Environment	9
Energy and Buildings	6
Construction and Building Materials	5
Journal of Building Engineering	5
Science of the Total Environment	5
Environmental Impact Assessment Review	4
Waste Management	4
Others	64

Journal of Building Engineering, and Waste Management have appeared commonly in both databases.

The citations were analyzed according to the sources of publications using the Scopus database (Fig. 14). The minimum number of documents of a source is selected as 5, and 8 sources met the threshold out of 61 sources. For each of the 8 sources, the total strength of the citation links with other sources was calculated. 7 sources were found to be connected to each other. According to the results, a cluster between Sustainability and Journal of Building Engineering; between Journal of Cleaner Production, International Journal of Life Cycle Assessment, Building and Environment, and Energy and Buildings were found. Construction and Building Materials is linked with Journal of Cleaner Production, International Journal of Life Cycle Assessment, and Journal of Building Engineering; so, it is demonstrated as an individual cluster (Scopus, 2022).

The sources were also analyzed according to bibliographic coupling (Fig. 15). The minimum number of documents of a source is selected as 5, and 8 sources met the threshold out of 61 sources. For each of the 8 sources, the total strength of the bibliographic coupling links with other sources was calculated. According to the results, the Journal of Building Engineering and Science of Total Environment forms one

Fig. 14 Analysis results for citation links between sources (Scopus, 2022)

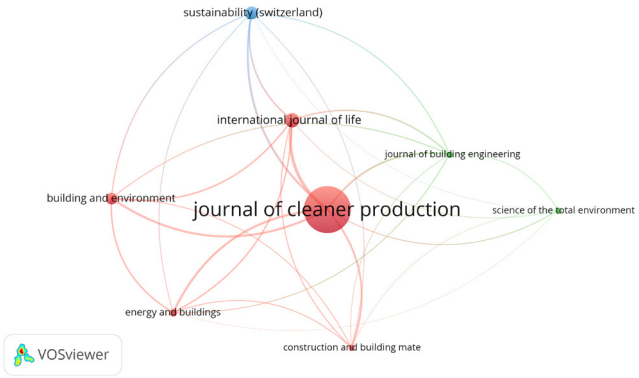

Fig. 15 Analysis results for bibliographic coupling of sources (Scopus, 2022)

cluster, and the others form another cluster. Sustainability Switzerland form an individual cluster by itself.

3.6 Affiliations

The affiliated higher education institutions which have publications related to LCA of bricks were analyzed, and the results were demonstrated in Fig. 16 and Fig. 17 for WOS and Scopus databases respectively. There were several different affiliations involved, therefore, the institutions with the higher number of publications were presented in Figs. 16 and 17. There are several small differences in the number of publications found in WOS and Scopus databases. Czech Technical University Prague is found to be at the top of the

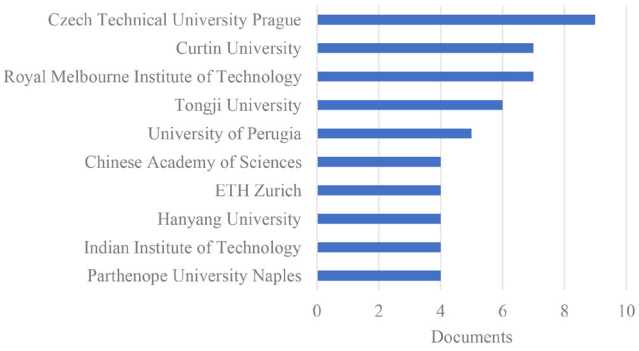

Fig. 16 Affiliations by number of publications (WOS, 2022)

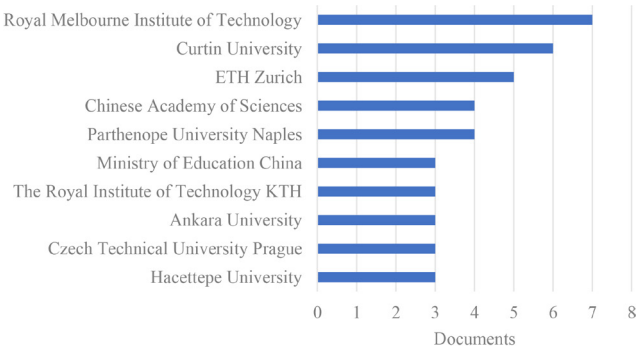

Fig. 17 Affiliations by number of publications (Scopus, 2022)

WOS database, but does not appear in the Scopus database. Royal Melbourne Institute of Technology, Curtin University, Chinese Academy of Sciences, and ETH Zurich are found to be the leading universities in this research topic. This information may help establish cooperation between universities and consider exchange programs for researchers.

3.7 Co-occurrence of keywords

The publications were also analyzed according to the co-occurrence of author keywords. In the WOS database, the minimum number of co-occurrences of a keyword is selected as 4, and 10 keywords met the threshold out of 191 keywords. For each of the 10 keywords, the total strength of the co-occurrence links with other keywords was calculated (Fig. 18). According to the results, life cycle assessment, building materials, brick, and sustainability form a cluster (red). Waste management and biosolids form another cluster (yellow). Circular economy and LCA form another couple (green). It should be noted that LCA is the abbreviation for life cycle assessment, so it is convenient to consider this cluster with the red group. Lastly, recycling and life cycle assessment (LCA) form another cluster (blue). Again, the same misspell error occurs here, and it is also convenient to consider this cluster with the red one. To sum up, it can be said that, waste management and biosolids form a separate cluster from other keywords.

In the Scopus database, the minimum number of co-occurrences of a keyword is selected as 5, and 13 keywords met

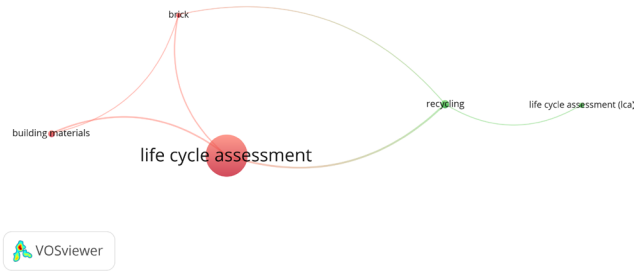

Fig. 18 Analysis results for co-occurrence of keywords (WOS, 2022)

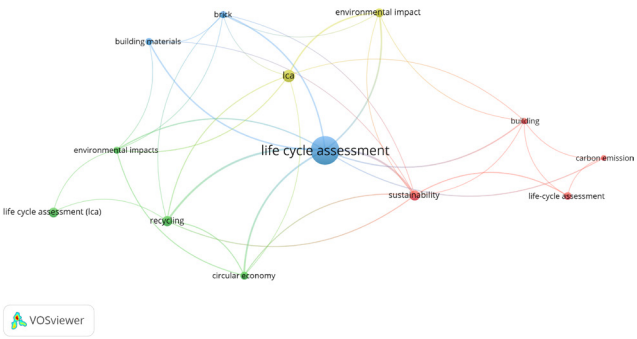

Fig. 19 Analysis results for co-occurrence of keywords (Scopus, 2022)

the threshold out of 496 keywords. For each of the 13 keywords, the total strength of the co-occurrence links with other keywords was calculated (Fig. 19). The same misspelling error occurs in the Scopus database too. "Life cycle assessment" keyword is clustered with brick and building materials (blue); "life-cycle assessment" is clustered with sustainability, building, and carbon emission (red); "life cycle assessment (LCA)" is clustered with environmental impacts, recycling, and circular economy (green); and "LCA" is clustered with brick and building materials (blue) (Scopus, 2022).

As a result, it is understood that it is necessary to determine the correct way of spelling the keywords and establish a linguistic unity among different publications. The most common occurrence of the keyword "life cycle assessment" is as the bigger dot in Fig. 18 and Fig. 19, and the authors of this study also agree on this spelling as "life cycle assessment", without any abbreviations or split lines. Care should be taken by journal referees and editors for such misspellings.

4 Conclusion

Bibliometric analysis of LCA of brick was done using the keywords "life cycle assessment" and "brick" in WOS and Scopus databases. 206 publications from the WOS database and 160 publications from the Scopus database were considered relevant for further analysis after several refinements were applied to search results. The VOSviewer software tool is used to analyze and interpret the data gathered. Bibliometric mapping and several linkages were presented with graphical visualization with various considerations such as publication years, research areas, authorships, countries of publications, sources of publications, affiliations, and co-occurrences of keywords.

The results of the study reveal that the LCA methodology applied to building materials such as bricks is gaining importance day by day. There is an increasing trend in the number of publications on this topic in recent years. This topic is generally studied in the fields of environmental sciences, engineering and technology, and energy, but is not limited to these research areas. Several authors study this topic, but according to the number of publications by authors, no author makes a significant outscoring. But in terms of distribution of the number of publications by countries, China, Australia, Italy, and Spain outscore other countries. The most common sources of publications on this topic are found to be Journal of Cleaner Production, International Journal of Life Cycle Assessment, Building and Environment, etc. Royal Melbourne Institute of Technology, Curtin University, Chinese Academy of Sciences, and ETH Zurich are found to be the leading universities in this research topic. Life cycle assessment and brick keywords generally appear to co-occur with keywords like building materials, sustainability, waste management, biosolids, carbon emission, environmental impacts, recycling, and circular economy.

The most important finding and obtainment of the study is that, it reveals out there is a fundamental research gap about the environmental impacts associated with one of the most important and widely used construction materials, namely bricks. According to the results of the bibliometric analysis, there is an increasing trend of interest in this subject, but detailed investigation of the sources of the impacts, and how to mitigate them is still a question that is worth investigating. LCA is a strong and widely used methodology for developing a solution. The most important feature of conducting life cycle assessment methodology applied on to bricks is that it is the most effective way to reveal out the environmental impacts associated with bricks step by step, with analyzing different LCA stages from cradle to grave. Thus, it will help practitioners, business owners, researchers, and academicians to identify the sustainability gaps in the production, maintenance and use stages of its whole life cycle.

These preliminary findings are considered to be helpful for future researchers working on the subject of LCA of building materials, particularly brick. The outcomes of this study can be used to shape the structure of the literature review and will save the researchers' time in finding correct literature sources, people, and institutions.

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