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Building life cycle assessment research: A review by bibliometric analysis

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ABSTRACT

This study aims to examine the literature related to the building life cycle assessment (LCA) that are published from 2000 to 2014 by means of bibliometric methods based on databases of the Science Citation Index and Social Science Citation Index. Of 2025 retrieved publications, 95% were journal articles. The patterns of these articles were investigated such as subject categories, journals, countries, institutions, hot topics and the most highly cited articles. The results showed a rapid growth of building LCA related publications with the USA being the leading country in terms of contributing to the largest number of articles and possessing the greatest influence. Norwegian University Science and Technology is the leading university in terms of building LCA research, which is followed by University of California at Berkeley. All the top 15 institutions possess a favorable cooperative relationship with other institutions. Most journal articles were associated with energy (521 articles), followed by material (388), sustainability (304), carbon (299) and technology with 180. According to the comprehensive analysis of the keywords, it can be concluded that subtopics such as energy, materials, environmental impacts and sustainable development will be prominent directions of future building LCA research, while life cycle costing and life cycle inventory will continue to be the common research methods. These findings help to identify hotspots in the building LCA research. Similarly, this study provides useful inputs for the decision making on the subtopic selection and publication strategy in the building LCA research.

1. Introduction

The last decades have witnessed a rapid growth of the construction industry arguably due to the social and economic development. The construction industry has significant impacts on the economy, environment and society. For instance, the construction industry is one of major consumers of resources especially the energy. Energy is the essential input during the entire life cycle of buildings not only during the operation stage but also during the manufacturing of building materials [1]. In China, buildings accounted for nearly 25% of the total primary energy consumption, and this proportion could be expanded to 35% by 2030 [2]. Particularly, with the consumption of 40% materials entering the global economy, the construction industry is responsible for 40–50% of the global output of greenhouse gases and the agents of acid rain [3].

Modern buildings are typically good-sized projects utilizing various kinds of building materials and large quantities of energy, resulting in significant influence on the environment. As a result, the last decades have witness a rapid growth of researches on the assessment of buildings across the entire life cycle. Life cycle assessment (LCA) provides a useful tool to serve this purpose by quantifying the environmental impacts and showing the practical reduction measures on assessing the sustainability performance of buildings [4–11]. Indeed, LCA has been widely employed in sustainable building related studies ([3,12,13]), especially for the energy consumption [14–16]. Some of these studies placed focuses on specific components of building [17]. This includes building materials [18], such as concrete ([19,20]), cement ([21,22]), steel [23], and wood [24,25]. Similarly, previous studies have attempted to examine the environmental impacts of the subsystems in buildings, such as heating and air conditioning systems [26], building integrated renewable energy systems ([27,28]), and electrical and thermal systems [29,30].

Therefore, it calls for a timely study to quantitatively evaluate the rapidly growing body of literature on building the LCA with the assistance of bibliometric techniques. This study aims to discover the characteristics of global building LCA literature from 2000 to 2014. Via the bibliometric method, the global trends in the building LCA research over the past 15 years are examined by analyzing the general patterns

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of publications, language, journals, subject category, country, institution, the most highly cited articles as well as hot topics. These findings provide useful inputs for the selection of subtopics in future research endeavor on the building LCA.

2. Methodology

Keywords were used to search the databases of science citation index and social science citation index in November 2014. Life cycle assessment and building were adopted as the core words. Similarly, various aspects of buildings are included such as: “building material”, “building HVAC system”, “building assembly” and so on. We also replaced “building” with “construction” or “architecture”. As a result, 2025 publications were retrieved from databases that are published during the period of 2000–2014. Study on these documents come down to document type, annual output, author, country output, citation frequency, hot topics classification, etc.

2.1. Bibliometric methods

Bibliometric is widely recognized as a well-established research method in the information science particularly for the evaluation of research performance of academics and universities. It adopts quantitative analysis and statistical methods to analyze the quantitative relation and content information in a given field; and further examine the detailed characteristics and patterns of the featured research field. The bibliometric analysis has been used in a variety of scientific fields, such as global groundwater [31], sustainable development [32], climate change [33], solar energy and carbon market [34,35] etc.

2.2. H-index and impact factor

In this paper, h-index and impact factor are adopted as measures of influence to examine the characteristics of publication statistics on countries, journals, institutions, languages, subjects, etc.

Hirsch (h) index was introduced by Hirsch in 2005 which revolutionized scientometrics, and is considered as a quantitative method to evaluate the total effective output of a researcher with strengths of simplicity and immediate intuitive meaning [36]. According to Hirsch [36,37], h-index provides an unbiased evaluation and has a predictive value with one figure. Giving “an estimate of the importance, significance, and broad impact of a scientist's cumulative research contributions”, the index can be used for authors, journals and institutions as well [36]. In this research, based on the publications related to the building LCA, h-indexes of countries and journals were calculated to evaluate their performance, respectively. The impact factor (IF) is a traditional citation metric to measure the quality and influence of journals. IF is employed in this paper to assess the relative influence of journals related to the building LCA. The impact factor of a given journal is retrieved from the 2014 Journal Citation Reports.

2.3. Content analysis

As a common form of content analysis, word frequency analysis highlights the core content of literature as the research object. This can be utilized to unearth the development trends and changes in scientific research of a given field. In order to identify the hot topics in the building LCA field more completely and precisely, synonymous keywords and congeneric phrases are merged initially and consequently grouped into categories. For example, keywords associated with energy cover “renewable energy”, “embodied energy”, “operating energy”, “energy consumption”, “energy conservation”, “energy efficiency” and etc. Carbon management covers “greenhouse gas”, “CO_2 emissions”, “carbon footprint”, “carbon tax”, “carbon debt”, “carbon mitigation”, “global warming potential’, ”climate change” and etc. After initial mergence, keywords are ranked by mentioned times. Then those keywords with high occurrences are grouped into categories and listed in a table in order to further recognize hot topics in building LCA.

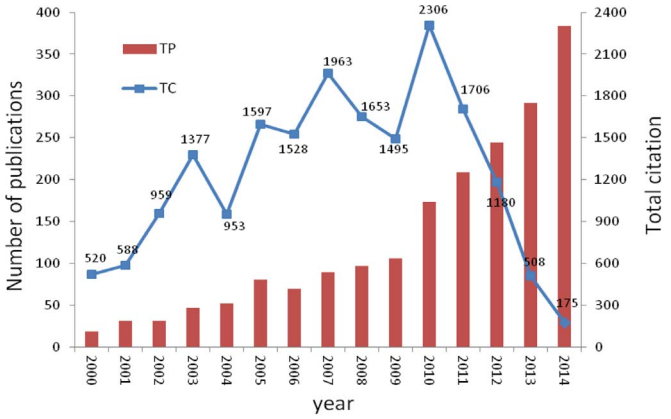

Fig. 1. TP and TC, from 2000 to 2014. Note: TP-total number of publications, TC-total citations.

3. Results

3.1. The general patterns

Of the 2025 publications retrieved from the databases, 1926 are articles followed by proceedings papers (4.64%), review (4.44%). Editorials, book chapters, software reviews and letters altogether accounted for as low as 0.52% of the total building LCA related publications. Therefore, only articles were further analyzed in this research. Articles related to the building LCA in SCI and SSCI involve 11 languages. Vast majority of these articles were written in English with 1855 records, accounting for 96.31%. This is followed by German (1.97%) and Spanish (1.14%). The other languages only occurred once or twice. This indicates that English is the predominant language in the field of building LCA research even in those non-English speaking countries such as Germany, China, Spain, and Japan.

As shown in Fig. 1, the number of publications related to the building LCA grew steadily during the past 15 years, and more rapidly since 2010. Total citation reached the peak in 2010 with a record of 2306 and then dropped gradually arguably due to the time required for the accumulated effects of new publications.

Table 1 shows the characteristics of the building LCA related publications during the period of 2000–2014. The analysis was conducted on the number of author (No. AU), the ratio of number of authors to number of publications (AU/TP), number of references (NR), and number of pages (PG). As shown in Table 1, there is a steady

Table 1
Characteristics of publication by year (2000–2014).

PY	TP	No. AU	AU/TP	NR	NR/TP	PG	PG/TP
2000	19	46	2.42	396	20.84	217	11.42
2001	31	95	3.06	574	18.52	308	9.94
2002	31	77	2.48	793	25.58	332	10.71
2003	47	136	2.89	1030	21.91	575	12.23
2004	52	176	3.38	1362	26.19	631	12.13
2005	81	246	3.04	2495	30.80	988	12.20
2006	70	213	3.04	2071	29.59	872	12.46
2007	90	288	3.20	2619	29.10	973	10.81
2008	97	303	3.12	2837	29.25	1066	10.99
2009	106	335	3.16	2930	27.64	1109	10.46
2010	173	523	3.02	5835	33.73	1919	11.09
2011	209	707	3.38	8041	38.47	2392	11.44
2012	244	811	3.32	9613	39.40	2799	11.47
2013	292	1016	3.48	11,610	39.76	3290	11.27
2014	384	1521	3.96	16,318	42.49	4242	11.05