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Review Article

Demolition wastes in the global construction industry: An overview of research perspective from 2001 to 2020

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ABSTRACT

Construction Demolition and Renovation Wastes (CDRW) are produced in large amounts in many countries, with the construction industry serving as a primary catalyst for both infrastructure development and socioeconomic progress. Global calls for action have been sparked by the threats that CDRWs represent to human health, safety, and the environment. The objectives of this review are to provide a bibliometric analysis and a thorough literature assessment of DWC-related publications, key players, and scientific advancements using data from the Scopus database. The analysis shows a 20-year rise in publications of 1725%, with significant improvements in CDWR treatment, disposal, management, and valorization. These highlight how crucial sustainable practices are to the construction industry and offer a pathway for further study. Practical applications of these results include the development of more effective recycling programs and the creation of policies aimed at reducing construction waste. The findings will be useful to researchers to guide future research towards inventive approaches as well as policymakers and stakeholders to promote sustainable practices for waste management and valorization.

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INTRODUCTION

The construction industry is a significant contributor to the socio-economic growth and infrastructural development of nations around the globe [1, 2]. The industry provides millions of people with direct and indirect jobs, critical public infrastructure, and social amenities among other benefits [3, 4]. However, the industry generates large volumes of greenhouse gases (particularly Carbon dioxide through the use of cement) [5, 6], solid wastes, and liquid effluents [7, 8] during the construction of building structures. Over the years, the volumes of waste streams generated by the construction industry have increased exponentially due to the high demand for building structures ranging from residential housing to critical social infrastructure [9]. One of the most prominent waste streams generated by the global construction industry is construction and demolition wastes (CDW) [10, 11] also known as construction, demolition, and renovation wastes (CDRW) [12]. In theory, CDW is a generic term for all the waste derived from engineering works, pulling down, and structural development in the construction industry. Typically, CDW is largely comprised of 80% excavated soils and stone, along with waste plastics, bricks, concrete, metals, tiles, glass, and wooden debris [13].

Various studies in the literature have estimated that CDW accounts for 30% – 40% of all solid wastes generated in China [14]. In the European Union, the proportion of CDW in the total waste stream is estimated at 33% (or one-third), which makes it the most significant single waste stream in the region [13]. Depending on the materials used for construction, the resulting CDW could pose significant treatment, disposal, and management (TDM) challenges for the construction firms and the industry at large. Similarly, the composition of CDW could result in human health, safety, and environmental problems if poorly treated, disposed of, or managed. For example, the poor handling of CDW from lead-based building components, asbestos, asbestos-containing materials (ACM), plastics, and composite materials could severely endanger the health and safety of humans, living organisms, and the environment [15, 16]. Studies have shown that exposure to lead-containing materials and ACMs in quantities above 1% causes cancers, respiratory illnesses (e.g., asthma), and other cardiovascular diseases [15, 17, 18].

Current strategies for the disposal of CDW include landfilling, dumpsite deposition, open burning of combustible components, or incineration are unsustainable from the social, economic, and environmental perspectives. To address these challenges, numerous policies, technologies, and strategies have been proposed, designed, and developed for the effective treatment, disposal, and management (TDM) of CDW around the world. One of the most widely researched and reported approaches for the TDM of CDW is the conversion into geopolymers, recycled aggregates, and other composite-based concrete [19-21]. Due to the numerous studies on the area, there is an urgent need to examine the research landscape and scientific developments on concrete and demolition wastes in the construction industry (hereafter termed DWC). The research landscape in any given area of research provides a detailed analysis of the key players (publications, authors, affiliation, funding organizations, and countries). On the other hand, the scientific developments are an overview of the major milestones accomplished by the stakeholders along with the prospects, challenges, and recommendations for future studies.

Various tools and methods have been proposed over the years to methodologically identify, screen, and analyze the research landscape and scientific developments of various fields. Some of the most commonly used approaches are the bibliometric analysis technique (BAT), scientific meta-analysis (SMA), systematic literature review (SLR), and the combined SLR-SMA approach called PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). According to Donthu and Kumar [22], the BAT is commonly used to explore and analyze large sets of scientific data to examine and highlight the stepwise progression and peculiar subtleties of any scientific field or research area. Thus, a major advantage of (BAT) is that it aids in analyzing large volumes of literature, particularly for benchmarking and performance measurement to support strategic decisions and facilitate collaboration. The concept of BAT also provides mathematical and statistical tools to identify, screen, and analyze the publication trends as well as the major stakeholders actively participating in any area of research [23, 24]. The approach has been successfully used to examine the research landscape, scientific growth, and technological developments in many areas of research such as energy [25, 26], waste management [27, 28], climate change [29, 30], greenhouse gas emissions [30, 31], among others in the literature.

Therefore, this study offers a thorough bibliometric analysis and a systematic literature evaluation spanning between 2001 to 2020 from published documents retrieved from the Elsevier Scopus database. This provides a novel contribution to the field of demolition wastes in construction (DWC). In contrast to previous research, the study identifies important key industry players and scientific advancements. This method offers new perspectives on sustainable practices and cutting-edge technologies in demolition waste management. It is envisaged that the critical analysis of the DWC will also address the following questions;

i. Who are the major stakeholders actively participating in the research and development of DWC research?
ii. What are the current status and scientific impact of DWC research in the global construction industry?
iii. How will the growth of innovative technologies and the development of strategic policies affect the treatment, disposal, and management of DWC?

METHODOLOGY

This paper seeks to examine the research landscape and scientific progress on the management of demolition wastes in the construction industry worldwide. Figure 1 shows the schematic flowchart of the methodology used in this study. The chart outlines the main steps of the study process. The initial step involves the identification and retrieval of relevant papers from the Scopus database, with emphasis on publications related to DWC from 2001 to 2020. Next, publication trends are mapped by performing bibliometric analysis to identify influential researchers and institutions and analyze the impact of various studies. This was followed by a systematic literature review to assess the role of innovative technologies and policies in DWC management. To draw a meaningful conclusion and offer recommendations for additional research, the last stage involved compiling and assessing the data.

Therefore, a search query based on the keywords "demolition wastes" and "construction" was designed to identify, screen, and analyze all the publications on the topic in the scientific literature. Consequently, the search for the keywords was executed within the TITLE-ABS-KEY of publications in the Elsevier Scopus database from 2001 to 2020. The search recovered 2,222 documents with the keywords. However, it was discovered that most recovered documents were unrelated to the topic, thus warranting screening. Subsequently, the recovered documents were screened using the TITLE-only search to limit the results to only related documents on demolition wastes in construction (DWC). The final resulting documents were subjected to bibliometric analysis using the VOS viewer software (Version 1.6.11) to examine the co-author, keyword co-occurrence, and citation relationships between the published documents on DWC.

RESULTS AND DISCUSSION

Publication Trends

Figure 2 shows publication trends on DWC research from 2001 to 2020. The results show that interest in the field has gradually increased over the twenty years under examination in this study.

As observed, the number of publications increased from 8 to 146 between 2001 and 2020. The marked percentage 1725% increase in publications could be ascribed to the growing calls for the adoption of sustainable practices in the construction industry. Studies have shown that the construction industry is one the largest emitters of greenhouse gases (GHGs) and solid wastes such as demolition wastes (DW) annually [32, 33]. Therefore, the sustainable disposal and management of DW could be a key driver for

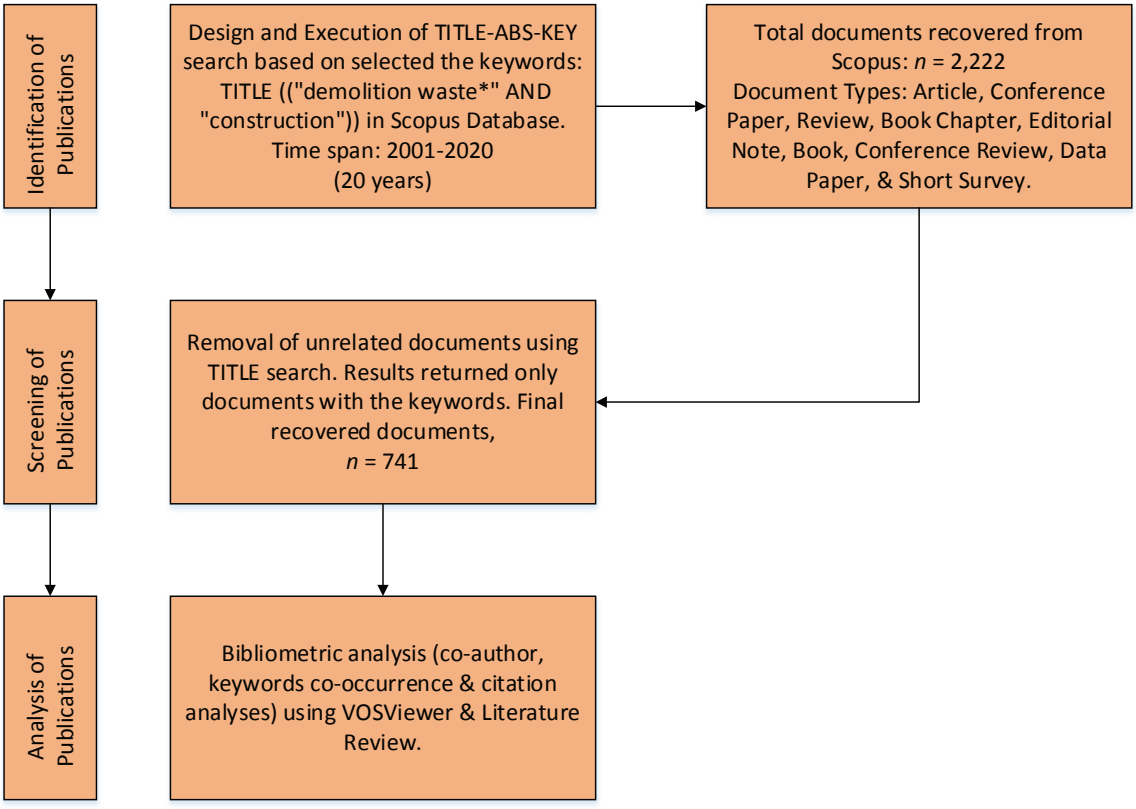

Figure 1. Flowchart of the study methodology.

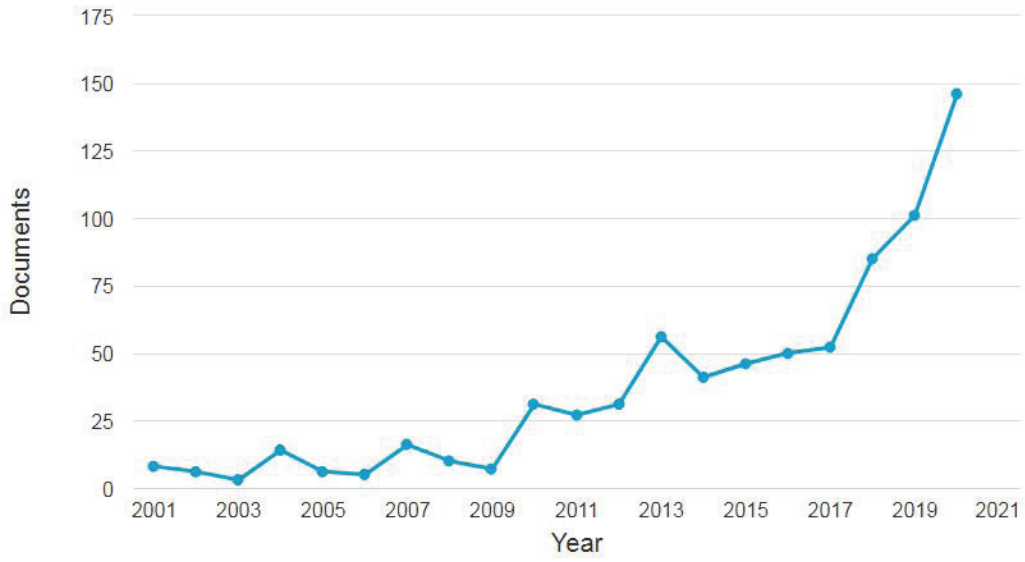

Figure 2. Publication trends on DWC Research.

the transition to low emissions in the construction industry. In response to the calls, numerous researchers have examined various strategies for the realization of low emissions and effective solid waste management in the construction industry. The studies have resulted in various types of published documents such as articles, reviews, and books, among others. The distribution analysis of document types, as shown in Figure 3, shows that DWC Research is published in a wide range of articles, conference papers, reviews, book chapters, editorials, notes, books, conference reviews, data papers, and short surveys. Further analysis shows that the top 3 most preferred mediums are articles (503), conference papers (153), and reviews (39).

The result shows a clear preference by researchers and academics in the field for articles. This inclination for disseminating DWC research findings in articles may be either due to the prestigious nature or the financial rewards for journal articles over other forms of publication types in academia. Therefore, researchers tend to lean towards the publication of their scientific findings in journals, which accounts for the 67.0% share of articles when compared to conference papers (20.6%) and reviews (5.3%). Consequently, the analysis of the most commonly used publication outlets for DWC research was examined, as shown in Figure 4.

The journals that have published the most documents on DWC research over the years are the Journal of Cleaner

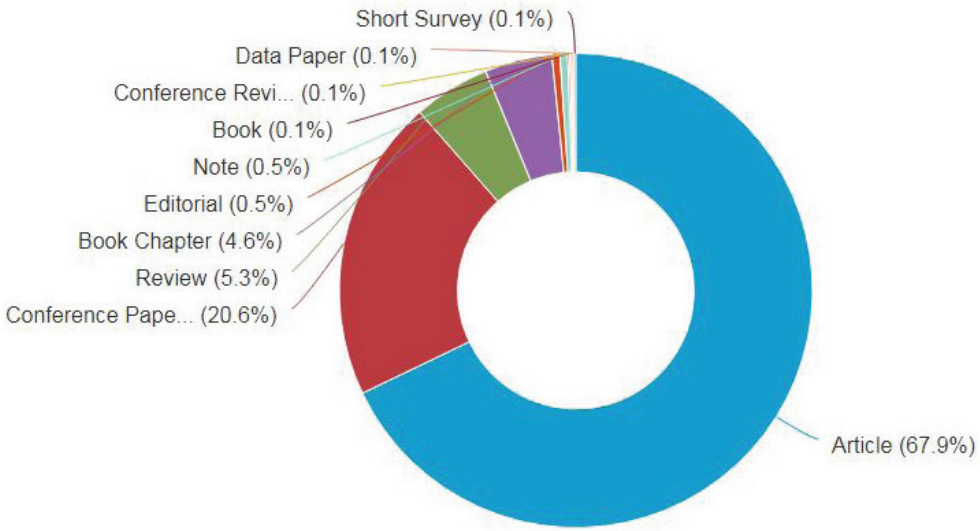

Figure 3. Document type distribution analysis for DWC Research.

Figure 4. Distribution of most common journals for DWC Research publications.

Production (58), Construction & Building Materials (49), Waste Management (48), Waste Management & Research (31), and Resources Conservation & Recycling (26). Further analysis shows that 4 out of 5 of the top journals are published by one of the world's most prestigious publishers Elsevier BV, whereas Waste Management & Research is published by Sage. The five journals have impact factors ranging from 3.549 (Waste Management & Research) to Resources, Conservation & Recycling (10.204), and hence termed high impact or prestigious journals. Studies have shown that researchers who publish their works in prominent journals gain not only rapid career advancements but also significant academic awards, financial incentives, and global fame. Hence, it can be reasonably inferred that the authors/researcher's predilection for articles by researchers on DWC is based on these reasons.

Figure 5 presents an overview of the most published researchers in the field of DWC research in the literature based on several publications over the 20 years. As observed, the top ten authors in the field have published between 8 and 16 publications (or 10.5 on average) over the period under investigation in this study. Further analysis showed that the top ten authors with the most publications account for 14.17% or 105 publications out of the total publications recovered on the topic. However, the top three authors with the most published works on DWC Research in the

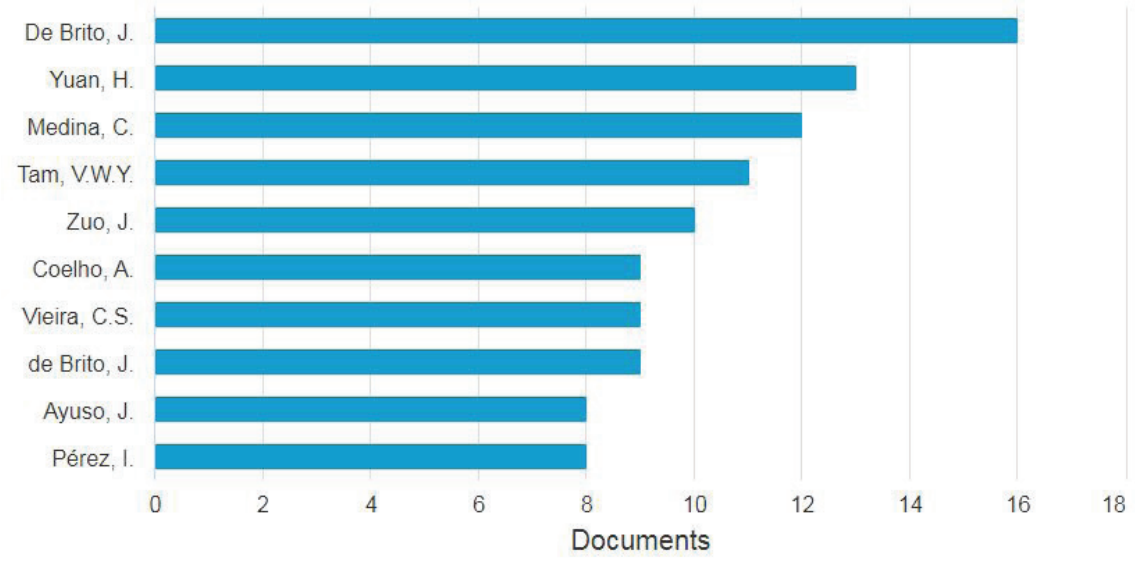

Figure 5. Most published authors on DWC Research.

scientific literature are Jorge De Brito (16), Hongping Yuan (13), and Cesar Medina (12), who are based at the Instituto Superior Técnico (Portugal), Guangzhou University (China), and Universidad de Extremadura (Spain), respectively. Next, the productivity of the top author affiliations on DWC research was examined to determine the impact of the institutions on the topic.

Figure 6 shows the top ten author affiliations for DWC research between 2001 and 2020. Table 1 presents an overview of the top affiliations and their details.

The top ten affiliations have produced 10 or above publications, i.e., between 13 and 31 (or 20 on average), with the combined output accounting for 26.99% of all publications on the topic in the literature. Furthermore, the total publications by the authors have been cited 9365 times in the literature, which reflects their significant research impact on the field over the years. The most prolific institutions based on the total publications (TP) are; Instituto Superior Técnico (IST, Portugal) with 31 publications, along with the Hong Kong Polytechnic University (HKPU, China), and Universidade de Lisboa (UdL, Portugal) each with 25 publications. However, the analysis of the ratio of total citations to total publications (TC/TP) shows that the Hong Kong Polytechnic University (China) with a TC/TP of 74.44 exerts the highest research impact. However, this is closely followed by Instituto Superior Técnico (IST) and Universidade de Lisboa (UdL) who have a combined TC/TP of 137.41, which shows the dominance of the Portuguese affiliations. Typically, the scientific productivity and research impact of institutions is ascribed to various factors such as national policy, financial support, knowledge centers, and technical infrastructure among others.

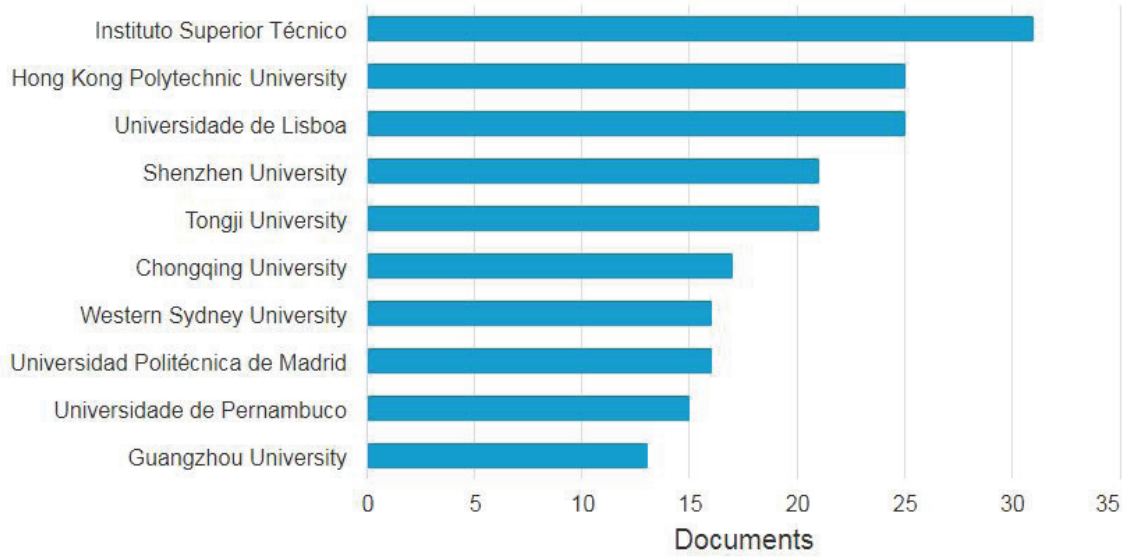

Figure 6. Top ten author affiliations for DWC Research.

Table 1. Overview of top ten affiliations on DWC Research

Affiliation	TP	%TP	TC	TC/TP	Country	Continent
Instituto Superior *Técnico*	31	4.18	2257	72.81	Portugal	Europe
Hong Kong Polytechnic University	25	3.37	1861	74.44	China	Asia
Universidade de Lisboa	25	3.37	1615	64.60	Portugal	Europe
Shenzhen University	21	2.83	896	42.67	China	Asia
Tongji University	21	2.83	602	28.67	China	Asia
Chongqing University	17	2.29	818	48.12	China	Asia
Western Sydney University	16	2.16	265	16.56	Australia	Oceania/Asia
Universidad Politécnica de Madrid	16	2.16	470	29.38	Spain	Europe
Universidade de Pernambuco	15	2.02	96	6.40	Brazil	South America
Guangzhou University	13	1.75	485	37.31	China	Asia

**Total publications (TP); Total citations (TC); Ratio of total citations to total publications (TC/TP); Percentage of TP (%TP)*

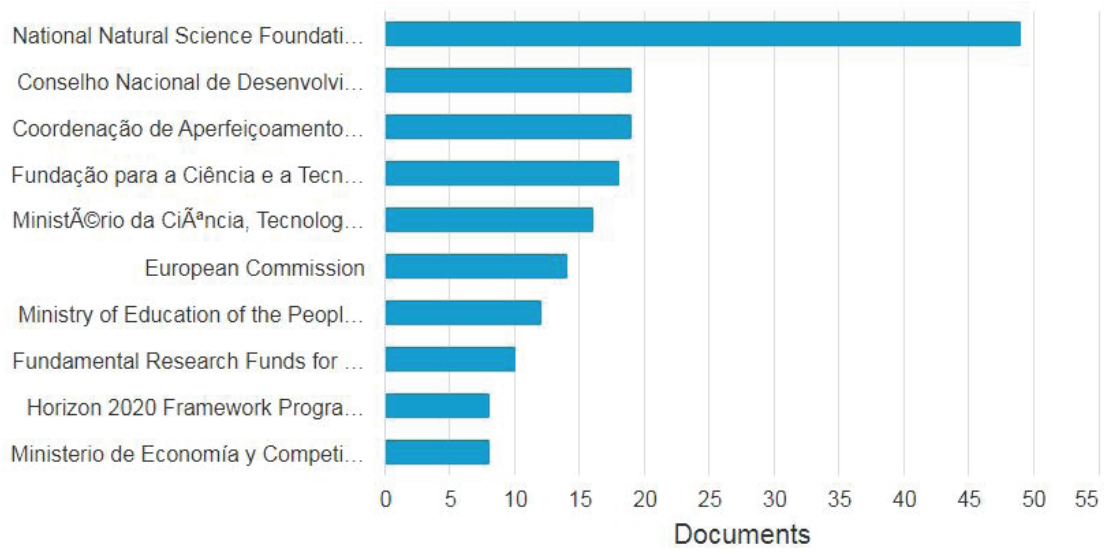

Figure 7. Top ten funding agencies for DWC Research.

One of the most critical factors is the availability of funding agencies that typically provide human, capital, and material resources for the nature and nurture of scientific ideas and innovative research. Therefore, the analysis of the funding agencies for DWC Research was examined to determine their role in supporting researchers in the field over the years. Figure 7 shows the top ten funders of DWC Research worldwide.

The results indicate that the top ten funding agencies for DWC research have financially supported the publication of between 8 and 49 documents (or 17.3 on average). The top three agencies with the most funded publications are the National Natural Science Foundation (NNSF, China), with 49 documents during the period under examination. This trend is followed by the agencies Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) both based in Brazil with 19 publications each. Other notable funders include the Fundamental Research Funds for the Central Universities (10) and the European Commission through various funding schemes such as the Horizon 2020 Framework Programme with (22) published documents over the years. It is important to state that the funding provided by the NNSF, CNPq, and CAPES reflects the dominance of China and Brazil on DWC research, as also shown in Figure 8.

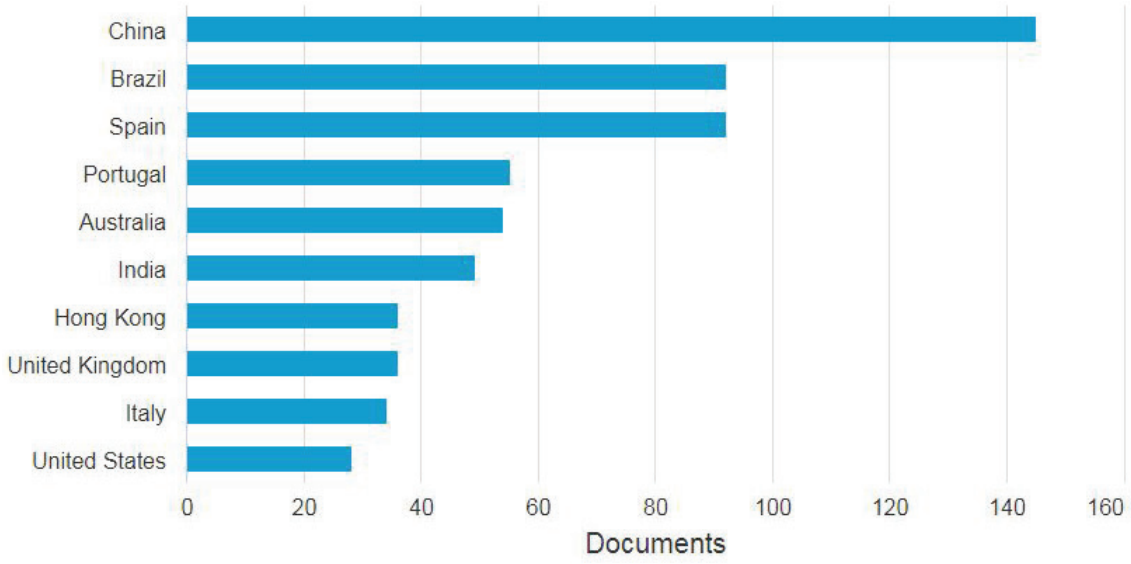

Figure 8. Top ten countries for DWC Research.

The results also show that the top 10 agencies account for 23.35% (or 173 publications) of the total publications on DWC research. However, the top three are based in China, Brazil, and Spain, which makes them the most dominant funders of research in the field. Other notable countries are Portugal and Australia, with 55 and 54 publications, respectively. The success of Jorge De Brito along with institutions such as IST and UdL, may be due to funding from CNPq, and CAPES based on collaborations with their peers in Brazil. The level of collaboration among authors, affiliations, funding organizations and nations is an indicator of research impact on any given area. Hence, the network of these stakeholders will be examined through bibliometric analysis as presented in section 3.2 of the paper.

Bibliometric Analyses

Bibliometric analysis is a comprehensive mathematical and statistical technique typically used to identify and analyze large data sets in any scientific field of study. Over the years, the method has been used to explore the growth trajectory of various areas of science to highlight the current and potentially new areas [22]. Various research groups have adopted the technique to examine various fields in the literature. In this study, the technique has been adopted to examine the research landscape and scientific developments on demolition wastes generated in the global construction industry within the timespan from 2001 to 2020. Consequently, the co-authorship, keyword occurrence, and citation analyses on the topic are presented herewith.

Co-authorship analysis

Figure 9 shows the network visualization map for DWC research based on the data retrieved from the Elsevier Scopus database. The data analysis is based on a minimum of three documents per author, which resulted in 168 items and 54 connections. Consequently, the total number of clusters generated from the connected items is 8, with each cluster containing 5 – 10 items or authors with a total link strength of 254. As observed, the largest cluster comprises the works of Chen Y. (as well as Liu J., Huang B., among others), whereas the smallest (brown cluster) contains the works of Gao X among others. The results indicated that the red cluster is the most connected due to collaborations with their peers such as Zhao Y. (brown cluster), Zhang F. (purple cluster), Hao J. (turquoise blue), Tam V.W.Y. (dark blue), Li X (green), and Wang J. (orange). The strong links between the red cluster and others show the wide extent of both national and international collaborations among the authors. According to various studies, the level of collaboration between authors is an important measure of the research impact of any given area of science. Hence, it can be reasonably inferred that DWC research has an immense impact on academics and researchers worldwide. The plausible reason for this could be the importance of the construction industry to the socio-economic growth and infrastructural development of many nations around the world. Furthermore, the research impact of the DWC topic may be due to the growing calls for sustainable practices during construction owing to the huge health, occupational safety, and environmental burden placed on humans by the industry over the years. Hence, analysts have called for

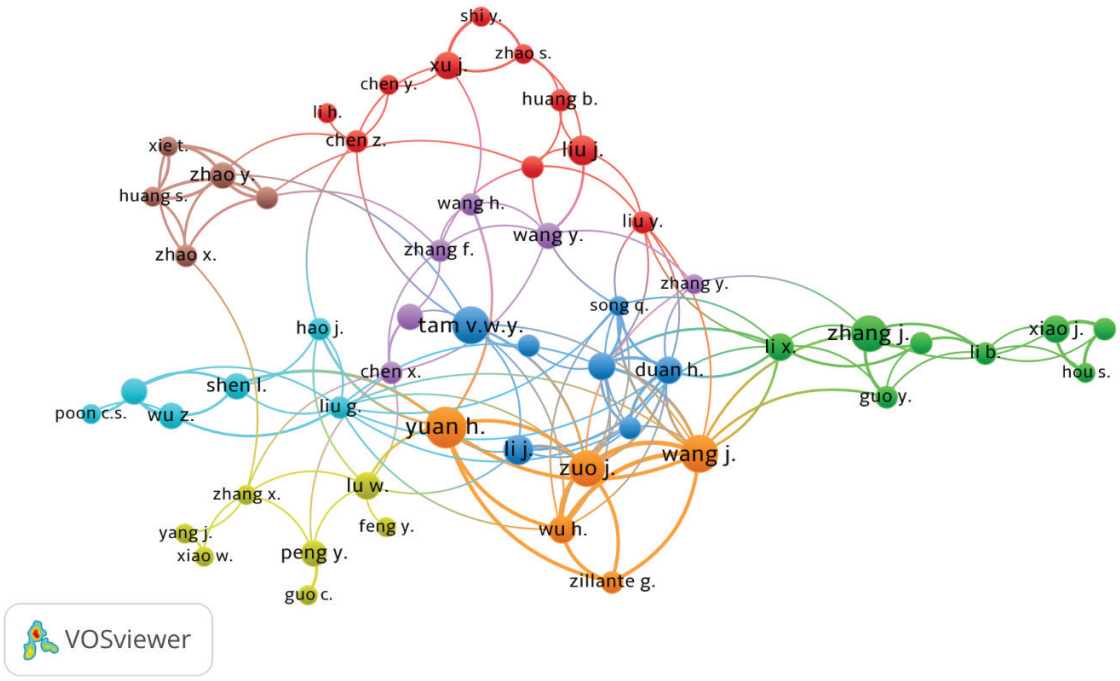

Figure 9. Network visualization map for DWC Research.

concerted efforts to address the waste burden of the construction industry to promote sustainable construction and safeguard human health, safety, and the environment.

The organizations (typically comprising universities, research institutes, and knowledge centers) working on any given area of research are critical to the growth, development, and research impact of the field. Hence, the network of organizations working on DWC research worldwide was also examined using VOSviewer. Figure 10 presents the network visualization map for organizations actively working on DWC Research. The analysis was based on organizations that have produced a minimum of 2 documents, which resulted in 7 connected items and 3 clusters.

As observed, the results show that the network of organizations working on DWC research is somewhat limited. The observed trend could be due to limited collaborations between organizations in the area. The results further indicate that although the overall publications output, co-authorship, or research productivity on DWC research is significant, inter-organizational collaborations, particularly at the intra-country level, are limited. To further examine this trend, the inter-country collaboration trend for DWC research was examined. The analysis of the inter-country collaborations was based on a minimum of 3 documents, of which 44 countries fulfilled the requirements. The network visualization map of the countries working and collaborating on DWC Research is shown in Figure 11.

As observed, numerous countries are working and actively collaborating on DWC research worldwide. The VOSviewer analysis showed that 35 of these countries are interconnected resulting in 10 clusters (each with 2 – 7 items) with 94 links and a full link strength link of 229. The

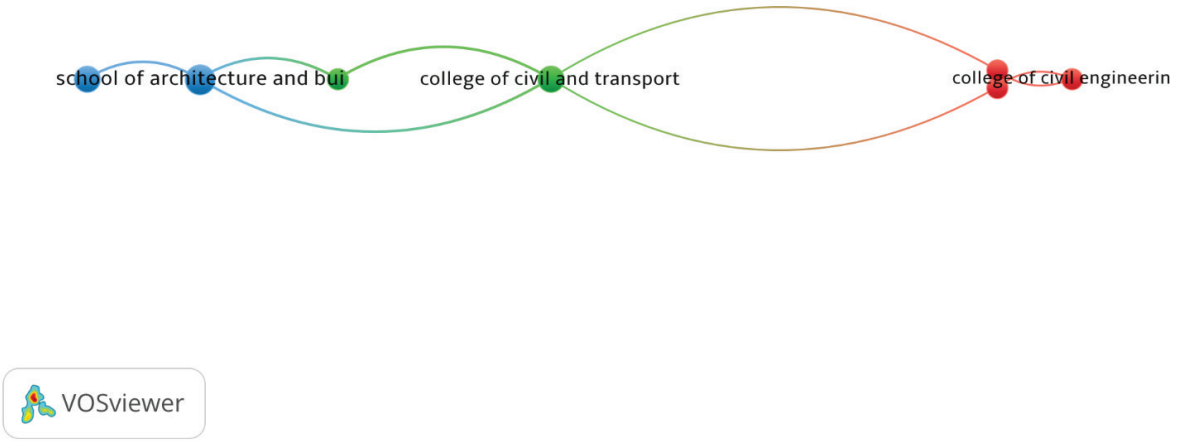

Figure 10. Network visualization map of Organisations working on DWC Research.

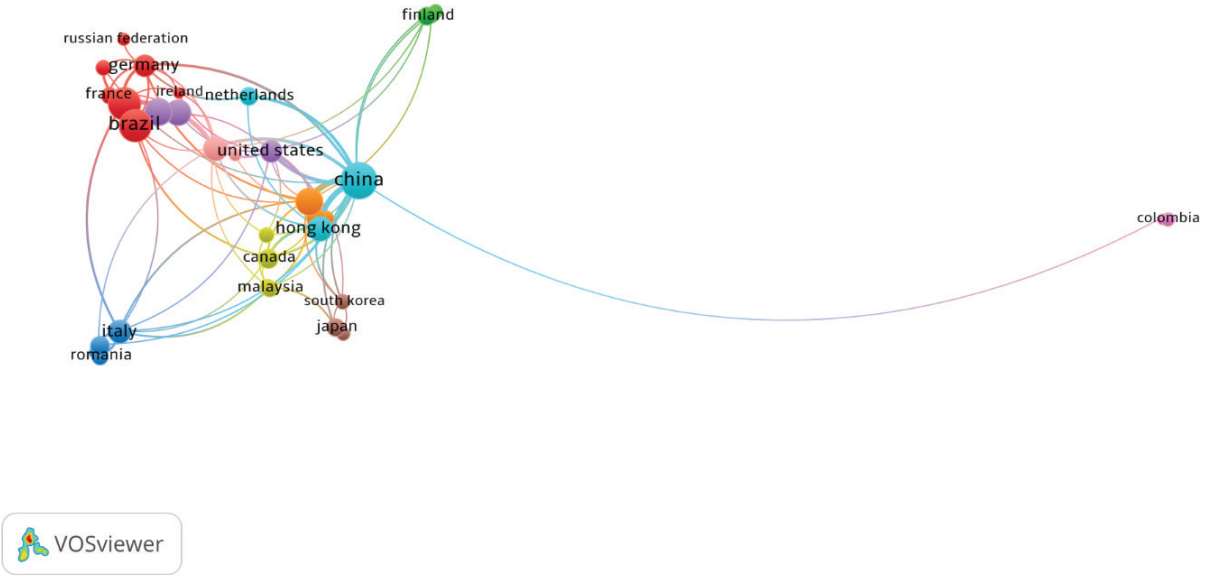

Figure 11. Network visualization of countries involved in DWC Research.

red cluster comprising Brazil, Germany, France, and Russia has the higher total link strength and connections, which indicate these countries are the most prolific, collaborating, and active on DWC research. The observed trend could be due to the availability of strategic national policies, knowledge centers and or research funding for DWC Research. As earlier shown in Figure 8, the DWC research in Brazil is highly prioritized with significant results from agencies and organizations such as CNPq and CAPES. Similarly, the research climate for DWC research in China is characterized by high research output owing to funding from the NNSF among others in the country. Consequently, China and Brazil have a wide network of collaborations through co-authored publications with other nations, as illustrated in Figure 11.

Keywords co-occurrence analysis

Co-occurrence analysis is a concept typically used to examine the frequency and interactions between the selected terms or subjects in any given area of research. It is also an indicator of the research impact of the given subject since it denotes the level of importance of such terms or subjects. In bibliometric analysis, the co-occurrence of keywords is an indication of the level of interaction between related keywords on any given subject of research. Consequently, the co-occurrence of author and index keywords was examined, as shown in Figures 12 and 13.

The results indicate the DWC research is characterized by numerous keywords designed by either the authors or by publishers during indexing. As observed, the most frequently occurring author keywords are "construction and demolition wastes", whereas the most observed for the index keywords is "demolition". Furthermore, the author and index keywords each generated 15 clusters based on the occurrence of a keyword at least 3 times in the search. The total links and total link strength of the author keywords were 1,012 and 1,772, respectively, whereas it was 33,557 and 76,175 for the index keywords. The results indicate that the index keywords have a higher occurrence or frequency compared to the author keywords, which is to be expected. This is because the indexing of publications in various databases such as Scopus involves multiple keywords, which are typically higher than those defined or designed by the authors in published documents.

Other notable keywords deduced from the author's keywords in Figures 12 and 13 are; cement, building materials, sustainable materials, recycled aggregates, heavy metals, circular economy, recycled powder, composites, plastics, material recovery, environmental impact, environmental sustainability, fly ash, and chemical composition. The

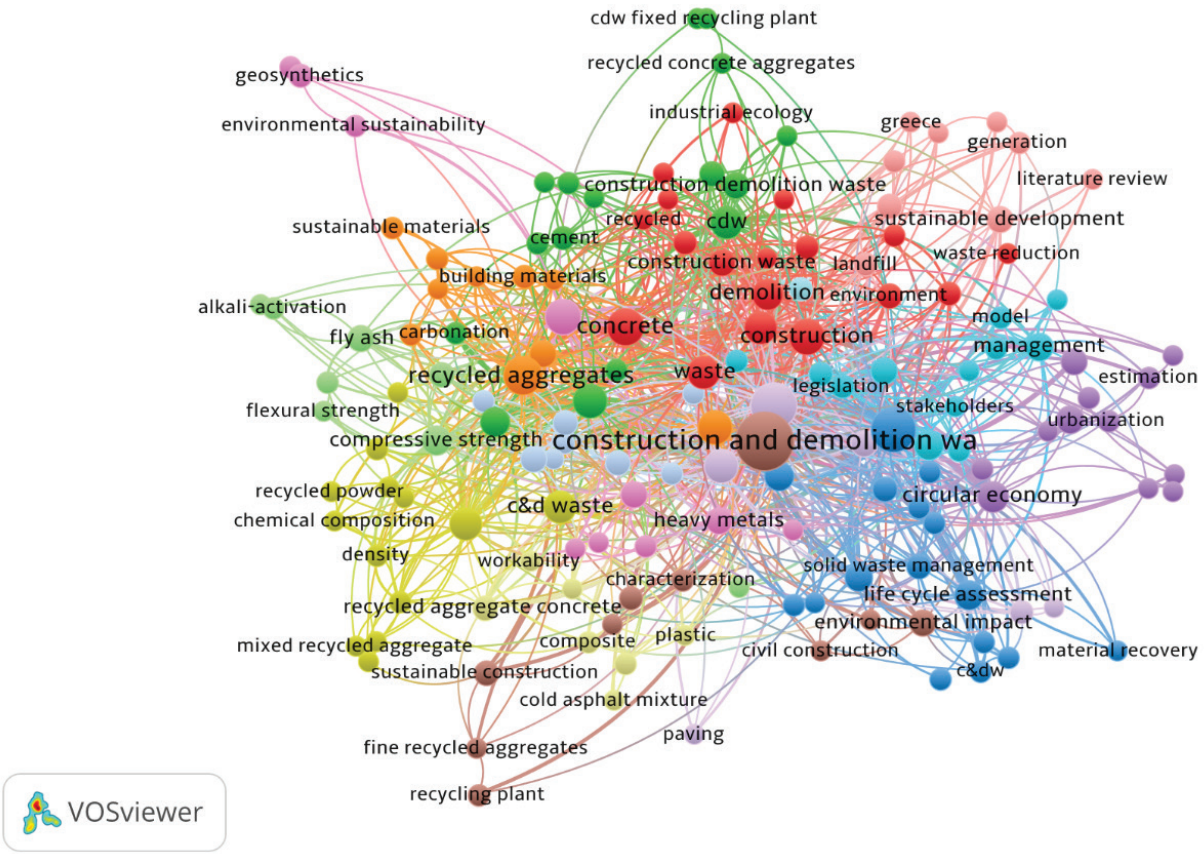

Figure 12. Author Keyword Map for DWC Research.

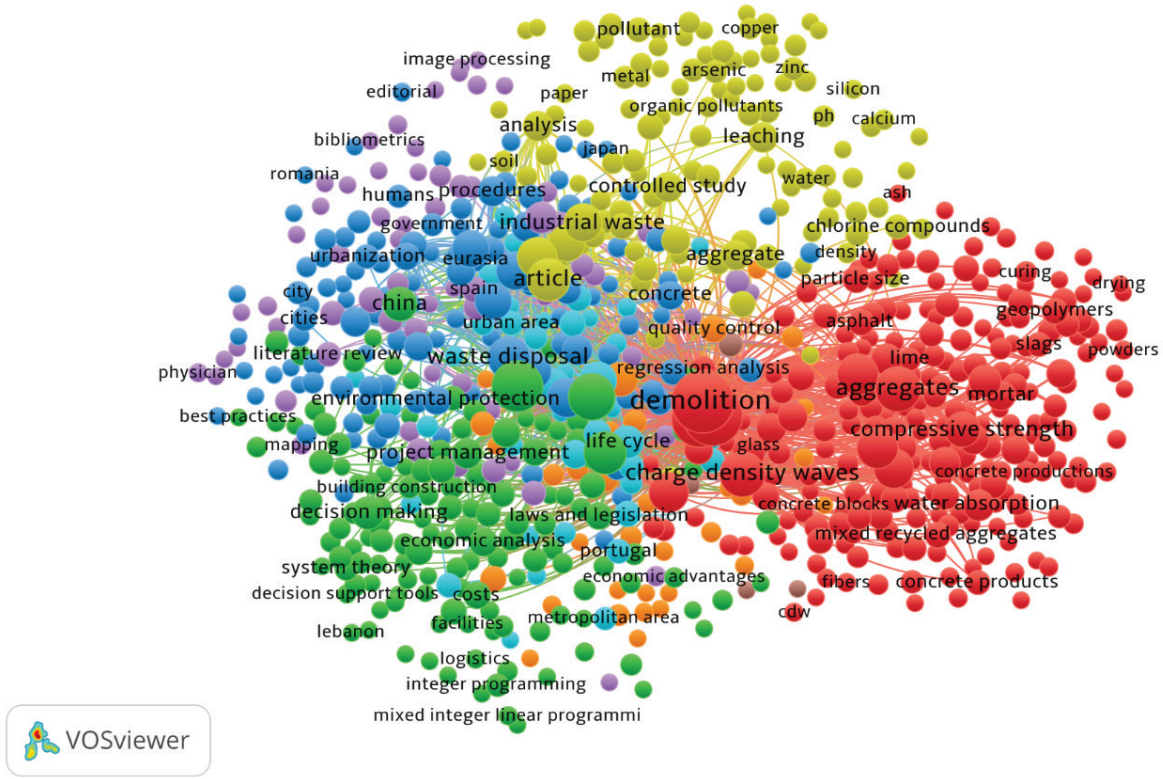

Figure 13. Indexed Keyword Map of DWC Research.

outlined keywords indicate the growing interest of global researchers in DWC as well as the concept of sustainability in the construction industry. The analysis of the studies reveals the growing interest in the use of alternative or sustainable or recycled building materials such as recycled aggregates or powders, plastics, or composites for construction. The long-term objective is to transition from the current regime of cement utilization in the construction industry. Many studies have shown that cement production and utilization is one of the most significant contributors to greenhouse gas emissions (GHG), accounting for 8% of global carbon dioxide (CO2) emitted into the environment. However, researchers believe the use of sustainable building materials could reduce the amount of cement utilized by the construction industry and thereby reduce GHG emissions. The use of agricultural wastes, fly ash, and other biomass-based ash residues as pozzolanic or supplementary cementitious materials could be an integral step in establishing a circular and material recovery economy for the future.

On the other hand, the most notable index keywords include industrial wastes, organic pollutants, compressive strength, water absorption, mixed recycled aggregates, economic analysis, building construction, environmental protection, leaching, logistics, decision support, best practices, and integer programming. The outlined keywords indicate that DWC research is broad and interdisciplinary, as observed in the varied selection of index keywords. For example, the terms industrial wastes, organic pollutants, leaching, and mixed recycled aggregates indicate the link between waste management, environmental protection, and materials utilization. Furthermore, the occurrence of compressive strength, water absorption, geopolymers, particle size, and charge density waves among others, denotes the role of materials science and engineering in the disposal and management of DW in the construction industry. Lastly, the keywords logistics, decision support, best practices, and integer programming denote the growing area of utilizing computer technology and information systems for the effective transport, disposal, and management of DW in the construction industry. Various studies in the literature have examined the use of various software such as GAMS which utilizes mathematical equations, algorithms, and programs such as multi or linear integer programming for waste management. These studies have garnered numerous citations and references for future studies. Next, the citation analysis of the publications was carried out to examine the impact of the various researchers and their affiliations on the topic of DWC research in the literature.

Citation analysis

Citation analysis presents insights into the research impact of authors, affiliations, and countries on any given area of research. In this study, the citation analysis of the various authors actively working on DWC research was based on a minimum of 3 documents and 5 citations. The results showed that 154 authors are connected, resulting in

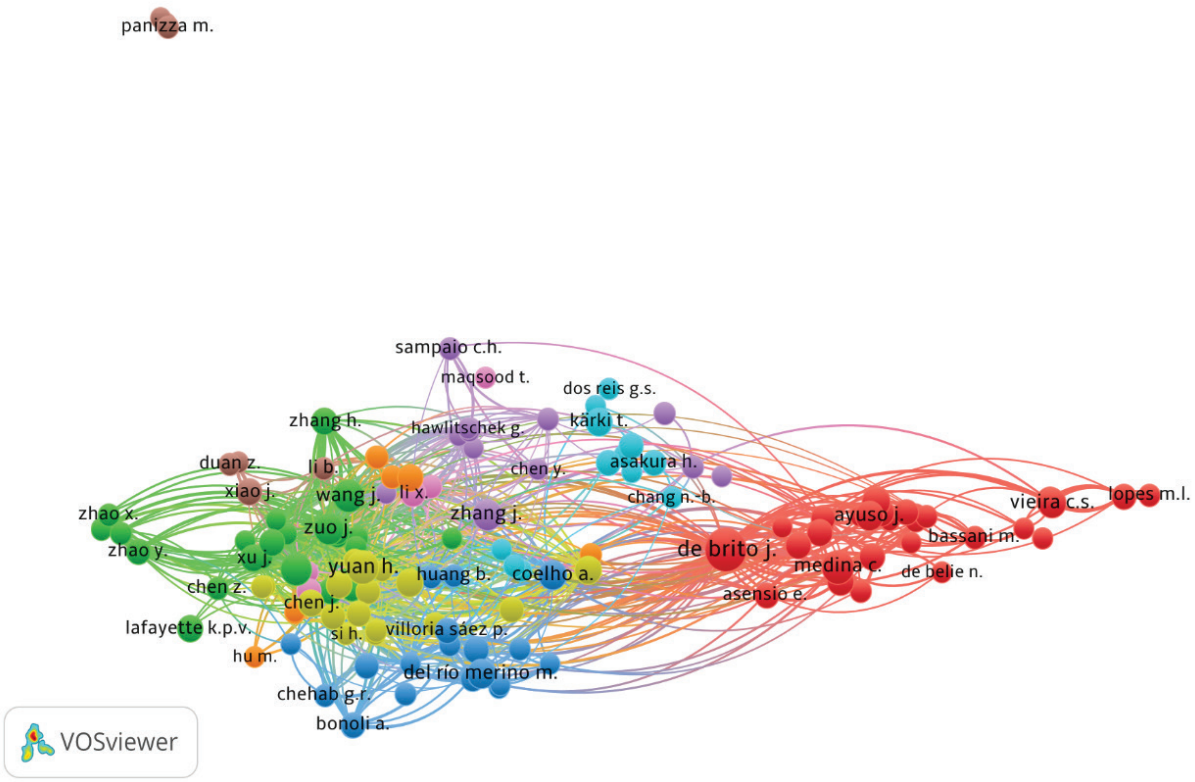

Figure 14. Citation map of the significant authors of DWC Research.

9 clusters (each with 6 – 36 authors), which have 2208 links and a total link strength of 4,661. The citation map of the significant authors on DWC research is presented in Figure 14.

The results indicate that the red cluster (comprising De Brito, Medina, Ayuso, and Viera is the most connected for researchers actively working in the area of DWC research. The results indicate that these authors have the highest number of citations of the authors, which is due to their high number of impactful publications and research productivity, as previously illustrated in Figure 5. The author Yuan who is the second most published author (Fig. 6), belongs to the yellow cluster, whereas Zuo. and Coelho, who belong to the green and blue clusters, are also among the authors with a high number of publications and citations on the topic. The results clearly show a clear correlation between high productivity (publications) and citations or research impact. The high number of citations observed for the authors may be due to some factors. Typically, the publication of studies in prestigious journals or publication sources, which are characterized by high impact factors, cite scores, and or h-indexes, attract higher citations compared to others. Hence, the high number of links (2208) and total link strength (4,661) observed for authors on the topic may also be due to publications in high-impact journals. Consequently, the citation analysis of the top journal sources on DWC research was examined. The analysis is based on a minimum of 3 documents and 5 citations observed for each source in the Elsevier Scopus database from 2001 to 2020. The results showed 296 sources of which 44 are connected generating 15 clusters (each with 1- 6 sources). The source network map for the sources is presented in Figure 15.

The results reveal that the most cited journals on DWC research are the Journal of Cleaner Production, Construction & Building Materials, Waste Management, Waste Management & Research, and Resources Conservation & Recycling, which are represented by the most prominent nodes in Figure 15. The observations are due to the high number of documents published by these journals over the years (Fig. 4). Similarly, the high citations of the sources may be due to the high number of benchmark papers, typically comprehensive reviews, published by such sources. As expected, researchers tend to cite papers from impact factors and prestigious journals in their area, which also has a ripple effect on their research, h-index, and careers.

The results also show that conference procedia journals are also highly cited in the field of DWC research, which indicates that researchers in the area comprise industry, policymakers, as well as academics. The mix of various researchers, according to Lawrence Barker, indicates DWC research is broad, collaborative, and highly multidisciplinary, which presents a multidimensional perspective to problem-solving

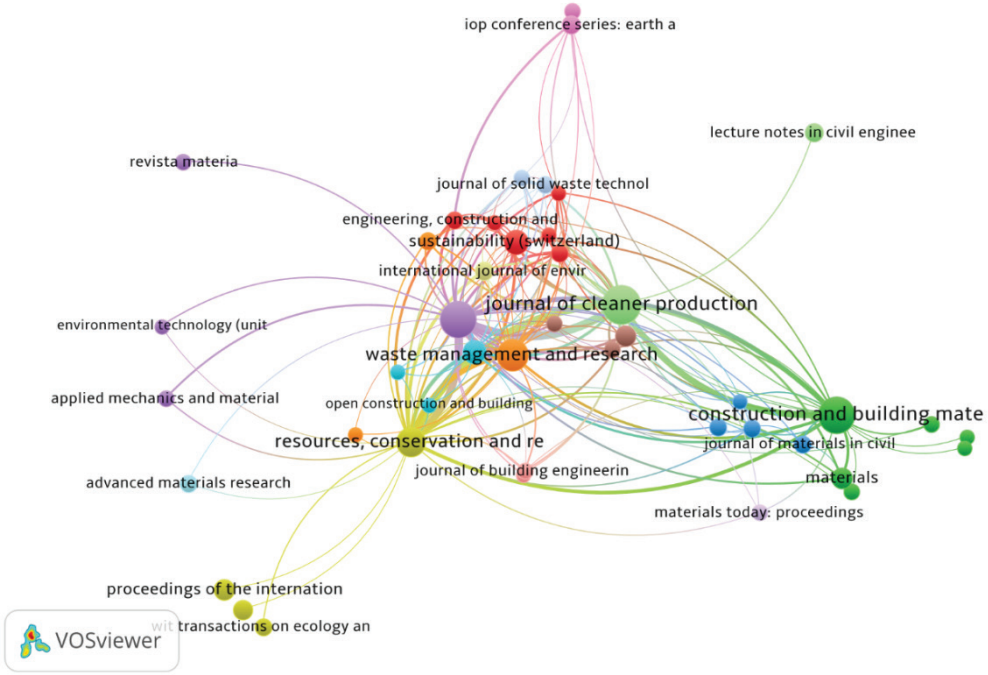

Figure 15. Citation Analysis of Journal Sources on DWC Research.

and solution delivery. The citation analysis of DWC research was also examined on a national level to identify the countries with the most research impact based on citations. The citation map for countries actively working in the area of DWC research is presented in Figure 16. The analysis is based on a minimum of 3 documents and 5 citations per country, which resulted in 41 connections 7 clusters each comprising 5 to 9 countries. The links and total link strength of the connections are 450 and 3488, respectively.

The largest (red) cluster of countries contained 9 countries with the largest nodes observed for Portugal, Spain, Brazil, and Italy, among others, whereas the smallest cluster contained 5 countries including Canada, Finland, and the United Arab Emirates among others. The largest cluster has characterized the works of researchers in Portugal such as Jorge De Brito (Instituto Superior Técnico), André D. Coelho of CERIS (Civil Engineering Research and Innovation for Sustainability), and Castorina S. Vieira (Universidade do Porto). In Spain, the works of Cesar Medina (Universidad de Extremadura), Ignacio Pérez Pérez (Universidade da Coruña), and Jesús Ayuso (Universidad de Córdoba) among others have garnered numerous citations nationally as well as internationally. The second-largest cluster comprising China, Australia, United States among others, has notable works, that have also been highly cited over the years. Worthy of note is the research works of Hongping Yuan (Guangzhou University) in China, whereas in Australia, the works of Jian Zuo (University of Adelaide) and Vivian W.Y. Tam (Western Sydney University) have been impactful in the area of DWC research over the years. Other nations such as India, Iran, South Korea, United Kingdom have also contributed immensely to the area producing benchmark papers with numerous citations. Section 3.3 will examine the most impactful papers on DWC research over the years based on citations.

Literature review

The review of the literature provides an overview of the recent developments in any given area of research. However, the vast amount of literature on DWC research limits this paper to reviewing the most cited publications on the top over the last 20 years. Table 2 presents an overview of the top ten most cited publications on DWC research. As observed, the top ten most cited publications on DWC have garnered between 187 and 515 citations (or 294.5 on average and over 2945 citations) over the period under investigation. Further analysis revealed that 8 out of the top ten most cited publications are articles, whereas 2 are reviews. In addition, the published documents have been published in 5 sources or journals; Resources, Conservation and Recycling (4), Waste Management (2), Journal of Cleaner Production (2), Construction and Building Materials (1), Clean Technology and Environmental Policy (CTEP). As observed in Table 2, the most cited publication on DWC research is the work of Silva et al. [34], which is a systematic review of the properties and composition of recycled aggregates from construction and demolition waste for utilization in the production of concrete. Rao and Jha [35], which is the second most cited published work on DWC research, examined the use of aggregates from recycled construction and demolition waste for the production of concrete (Table 2) [14, 35-43].

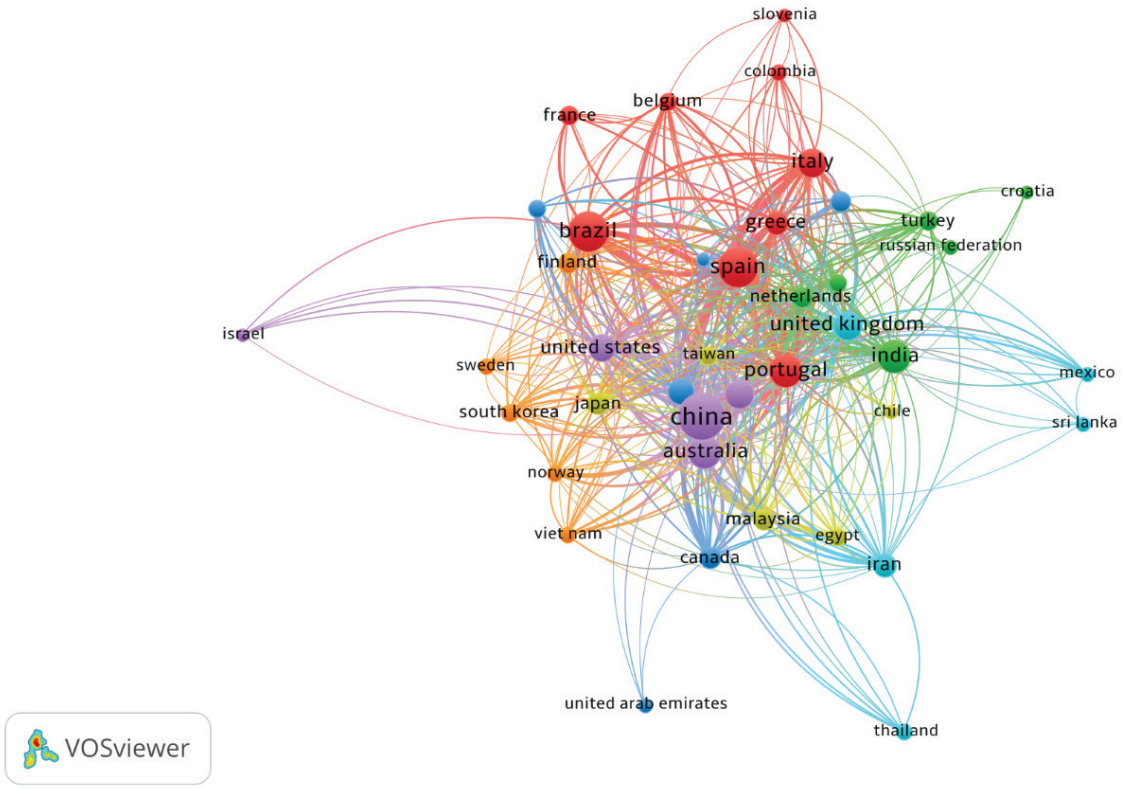

Figure 16. Citation analysis map for countries on DWC Research.

Table 2. Top ten most cited papers on DWC Research

Authors	Title	Source title	Cited by
Huang et al. [14]	"Construction and demolition waste management in China through the 3R principle"	Resources, Conservation and Recycling	252
Rao et al. [35]	'Use of aggregates from recycled construction and demolition waste in concrete"	Resources, Conservation and Recycling	487
Aslam et al. [36]	"Review of construction and demolition waste management in China and USA."	Journal of environmental management.	362
Munaro et al. [37]	"Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment"	Journal of Cleaner Production	348
Oluleye et al. [38]	"Circular economy research on building construction and demolition waste: A review of current trends and future research directions"	Journal of Cleaner Production	106
Akhtar and Sarmah [39]	"Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective"	Journal of Cleaner Production	254
Yeheyis et al. [40]	"An overview of construction and demolition waste management in Canada: A lifecycle analysis approach to sustainability"	Clean Technologies and Environmental Policy	232
Bravo et al. [41]	"Mechanical performance of concrete made with aggregates from construction and demolition waste recycling plants"	Journal of Cleaner Production	224
Gálvez-Martos et al. [42]	"Construction and demolition waste best management practice in Europe"	Resources, Conservation and Recycling	224
Silva et al. [43]	"Use of recycled aggregates arising from construction and demolition waste in new construction applications."	Journal of Cleaner Production	281

Poon et al. [44] examined the sorting of DW and construction wastes. The results showed that the separation of wastes at the source is more efficient, cost-effective, and convenient, although construction firms are usually reluctant to perform such sorting activities onsite. Hence, the authors recommended that legislation and contractual provisions could assist in the implementation of on-site sorting and separation of wastes. In contrast, Rao et al. [35] proposed the sustainable valorisation of DW and construction wastes in concrete. The study demonstrated that construction and demolition wastes could be effectively treated and reused as recycled aggregates (RA) in concrete for low-level applications in the construction industry. However, the authors noted that numerous barriers currently hamper the application of RA such as poor awareness, zero government support, and absent provision of standard codes for their utilization in concrete.

Similarly, Silva et al. [45] examined the use of RA in concrete. Hence, the authors performed a comprehensive characterization of the constituents and features of RA for potential application in concrete. Bravo et al. [41] examined the mechanical properties (compressive strength, splitting tensile strength, elastic modulus, and abrasion resistance tests) of RA produced from five recycling plants that commercially recover construction and demolition wastes. It was observed that the addition of RA to concrete adversely affected the mechanical properties of the concrete such as density, although the abrasion resistance was improved. Overall, it can be reasonably surmised that the valorization of DW into RA for concrete production enhances the twin concepts of sustainable construction and circular economy. However, the use of RA from the mechanical, structural, and building perspectives leaves much to be desired.

The study by Huang et al. [14], and Gálvez-Martos et al. [42] identified the current challenges and proposed measures for more effective treatment, disposal, and management of DW in the construction industry. Thus, the lack of adequate integration of interdisciplinary approaches and the lack of standardized methods are some of the issues facing current DWC research [9]. Huang et al. [14] suggest that to effectively promote sustainable practices and make informed policy in the construction industry, a holistic approach must be adopted that ensures environmental, economic, and social dimensions of demolition waste management are integrated through robust analytical methods. The review of literature on DWC research revealed that current technologies, strategies, and practices are geared towards the valorization of construction and demolition wastes into recycled aggregates. However, the partial or complete utilization of RA in concrete fulfills the need for sustainable practices and circular economy requirements but does not meet the structural standards of concrete. Hence, further studies will need to focus on determining the optimal blends or mix of RA and cement for the production of sustainable yet structurally acceptable concrete for utilization in the global construction industry.

Additionally, the study by Xiao et al. [46] and Silva et al. [47] highlights the environmental impact of demolition waste as a significant concern that requires urgent attention. The study opined that improper management of demolition waste can lead to severe environmental degradation, affecting both natural ecosystems and human health for example demolition waste can cause soil contamination with heavy metals and other hazardous substances. Contaminants can leach into groundwater, posing risks to drinking water sources and aquatic life [48]. Moreover, airborne particles from demolition activities contribute to air pollution, impacting air quality and respiratory health such as asbestos and lead, while exposure to lead can result in neurological and developmental abnormalities, asbestos exposure can cause cancer and respiratory ailments [49-56]. Poon et al. [50] and Aljawad et al. [51] underscore the detrimental effects of improper waste management on ecosystems, including soil and water contamination. For example, the leaching of toxic substances from improperly disposed concrete and bricks can lead to elevated levels of pollutants in surrounding soils and water bodies. These pollutants can accumulate in the food chain, affecting flora and fauna and posing long-term ecological risks [52]. Sustainable practices such as recycling and waste valorization are crucial for reducing these impacts. Recycling demolition waste into new building materials, such as recycled aggregates and geopolymers, can significantly reduce the volume of waste sent to landfills and minimize resource extraction [53, 57].

Practical Implications and Future Research

The results of this study have important implications for environmental policy-making as well as the construction industry stakeholders and researchers. The status of DWC research from 2001 to 2020 has evolved significantly, with a marked increase in the number of articles published each year and with increasing emphasis on sustainable waste management practices. The 1725% rise reflects the growing recognition of the vital role that sustainable waste management practices play in the construction industry. The trend also indicates a broader engagement with environmental issues and a commitment to advancing scientific knowledge in this area. The results of the systematic literature review and bibliometric analysis offer a practical implication for the design of more efficient recycling programs and the formulation of construction waste reduction programs. The adoption of more environmentally friendly techniques, such as recycling demolition waste into geopolymers and recovered aggregates can have a lessening effect on the environment, thereby reducing the environmental footprint of the construction industry and advancing the circular economy.

As indicated by Yeheyis et al. [40], the use of advanced recycling technologies has significantly improved the efficiency of DWC management. The creation of innovative composite materials, chemical recycling techniques, and thermal treatment procedures are promising technologies

for the valorization of CDWR. Also, Scully and Moy [4] highlighted the role of policy frameworks in promoting sustainable practices and green technologies in the construction industry. The efficiency of existing laws and regulations in handling DWC varies across the world, while substantial progress is reported in regions with strong frameworks in sustainable waste management, many other regions still lack comprehensive policies. Additionally, the identification of significant stakeholders and publication patterns can facilitate industrial collaboration and innovation between academic institutions, industry players, and researchers. The United States, China, and European nations are leading the way in DWC research driven by strong research funding, robust policy frameworks, and active collaborations. Thus, collaborations promote innovation, sharing of knowledge and best practices as well as facilitating the development of creative solutions to tackle shared difficulties in DWC management. Additionally, it aids in the standardization of research methodology and fosters global dissemination of research findings.

Furthermore, future research can be directed toward innovative approaches to waste management and valorization. The identification of research gaps in the field of DWC is achieved through the examination of publication trends and scientific breakthroughs. Based on these results, future studies can investigate areas that have not received enough attention, such as the durability and long-term performance of recycled materials, the financial feasibility of sophisticated recycling technology, and the societal acceptance of environmentally friendly waste management techniques or researchers might focus on improving the technology used to recycle and remediate demolition waste. A basis for further research into novel approaches to improve the characteristics of recycled aggregates and geopolymers, including the application of nanomaterials and advanced composites. Environmental science, engineering, economics, and social sciences must all be included in interdisciplinary study due to the complexity of DWC management. This approach will effectively tackle the complex issues surrounding DWC, future research endeavors should follow a comprehensive methodology that balances technology progress with socio-economic and policy factors.

CONCLUSION

This paper presented a bibliometric survey and systematic literature review of stakeholders (authors, affiliations, journal sources, funders, and countries) actively researching the topic of Demolition Wastes in the Global Construction Industry. The scientific data for the study were retrieved from the Elsevier Scopus database using preselected keywords, which were subsequently executed using the TITLE-ABS-KEY search criteria. The recovered data were analyzed to determine the publication trends, followed by bibliometric analysis and literature review. The results showed that publications on the DWC research increased progressively over the years from 2001 to 2020, indicating increasing interest in the area. The marked increase in published documents on the topic is due to growing calls for the adoption and implementation of sustainable practices as well as the reduction of GHG emissions and solid demolition wastes in the construction industry. Further analysis revealed that the top researchers on DWC are primarily based in Portugal, China, Australia, and Brazil. The institutions and funding organizations in the outlined countries contribute significant resources in the form of research funding and knowledge resources, which has resulted in high publication output and scholarly citations over the years. The bibliometric analysis revealed that the topic of DWC is broad, multidisciplinary, and impactful, as evident in the vast networks of collaborations, collaborators, and funding across the world. The review of the literature showed that the vast majority of the research studies on DWC had been geared towards the valorization of construction and demolition wastes into recycled aggregates (RA) for utilization in concrete. These highlight the critical role of sustainable demolition waste management in the growing calls for environmental and sustainable practices in the global construction industry. Thus, industry stakeholders, policymakers, and researchers will benefit from this study by collectively promoting sustainable practices and furthering the global effort to mitigate the environmental impact of construction activities. Additionally, collaboration between industry stakeholders and researchers should be strengthened to facilitate the implementation of innovative solutions. Policymakers are encouraged to support research and development in this field through funding and legislative measures. However, this analysis is not without limitations, the study is constrained to the study period of 20 years from 2001 to 2020, which may leave out the most current developments made after 2021 or earlier fundamental research. Further studies could explore DWC beyond 2020, in addition, examine how digital technologies like IoT and AI can be integrated to enhance waste management procedures as well as exploring the economic and environmental benefits of these practices.

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AUTHORSHIP CONTRIBUTIONS

Abubakar Sadiq Mahmoud: Writing- Original draft preparation, Investigation and Editing. Mahmoud Hijab Abubakar: Conceptualization, Visualization. Jamilu Adamu Garkuwa: Methodology, Editing. Zulfikar Adamu: Supervision, Validation, and Reviewing.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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