environmental sciences proceedings

MDPI

Proceeding Paper

BIM Applications in Waste and Demolition Management in Circular Economy Concept †

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† Presented at the 3rd Built Environment Research Forum, Sydney, Australia, 1 December 2021.

Abstract: Although BIM has been used for many different purposes in construction, there are still some areas that can be improved by extending the application of BIM. One of the emerging concepts in the literature is the circular economy (CE). The CE aims to minimize waste, recover resources and reduce pollution and emissions, generally by reusing, sharing, repairing, and recycling input resources. However, the increasing amount of construction waste reflects that CE is not well adopted in the construction field yet. The study aims to investigate how BIM enables circularity in the construction sector, mainly focusing on the trend for BIM applications in the implementation of the CE concept including waste and demolition management in the construction context.

Keywords: building information modelling (BIM); waste and demolition management; circular economy (CE); life circle assessment (LCA)

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Citation: Hai, Y.; Yang, L.; Sepasgozar, S. BIM Applications in Waste and Demolition Management in Circular Economy Concept. *Environ. Sci. Proc.* **2021**, *12*, 13. https://doi.org/10.3390/environsciproc2021012013

Academic Editor: Luciano Cardellicchio

Published: 24 February 2022

1. Introduction

Information and Communications Technology (ICT) has been widely adopted in the construction field. Building information modelling (BIM) has an important role in the process of adoption. Meanwhile, the circular economy (CE) has increasingly developed in recent years in the sector, known as an economic system that aims to minimize waste, recover resources and reduce pollution and emissions, generally by reusing, sharing, repairing, and recycling input resources. However, the construction industry is known as one of the main waste producers across the world. This reflects that the CE is not well adopted in the construction field yet. The study will study how BIM can enable circularity in the construction sector, mainly focusing on the trend for BIM applications in waste and demolition management, and the extent of circular economy (CE) adoption, to enhance its practice in the construction field and facilitate environmental benefits.

The study will conduct a careful intensive review analysis of the literature using a set of keywords such as BIM, waste and demolition management, and CE, collecting relevant keywords from each and developing comprehensive lists of keywords. After that, systematic research is conducted and data analysis implemented. The study will provide the potential directions of CE implementation of BIM applications in waste and demolition management.

2. Research Methodology

Figure 1 shows the flowchart of the research project. To review the implementation of BIM applications, Scopus was selected for the thesis research, which is a comprehensive and authoritative database providing abstract and citation of literature, as well as access to data via analytical tools.

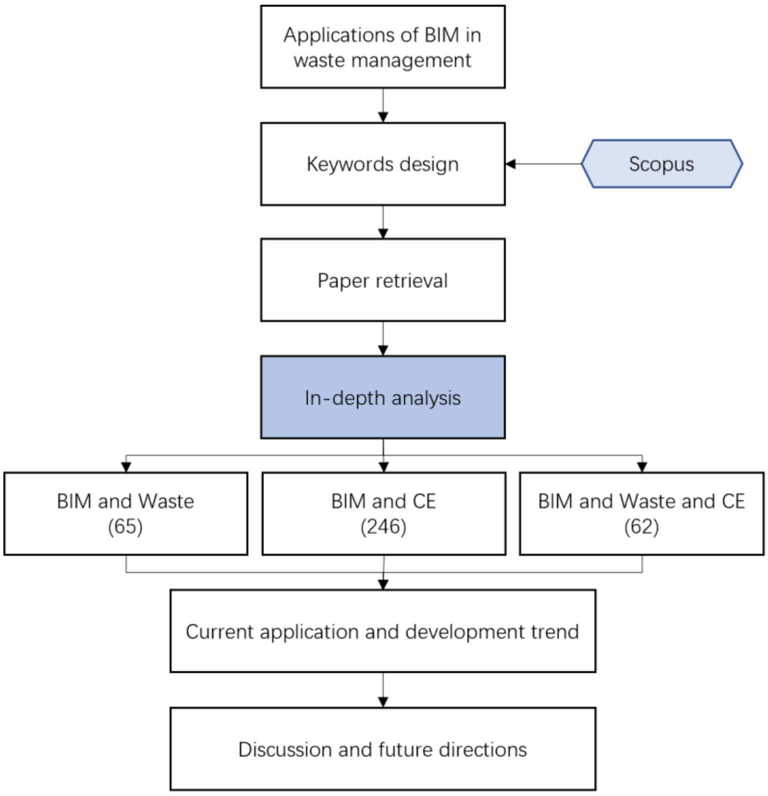

Figure 1. Research flowchart.

The research of the thesis is organized via PRISMA method, which is a data collection method for systematic research. It includes four steps, in terms of identification, screening, eligibility, and inclusion of the research records. Different sets of keywords are used to search for relevant papers. Then the identified papers are screened via certain criteria, after which the in-depth analysis is conducted. The analysis process is expected to include three aspects, namely, BIM and waste, BIM and CE, BIM and waste and CE. In this way, a review of BIM applications in the waste and demolition area is developed, followed by the discussion of findings and future directions.

2.1. Identification

After selecting Scopus, we identified search keywords. To cover as many relevant articles as possible on the topic of this research, the most interchangeable keywords related to BIM and highly relevant terminologies about waste and the circular economy were used for the search (see Figure 1 for details of the search keywords involved).

2.2. Screening

The screening was carried out based on publications LIMIT-TO (language. "English"), LIMIT-TO (source type, "article" and "conference paper") and LIMIT-TO (publication year, "2017–2021").

2.3. Eligibility

In this step, the abstract of each publication was assessed to remove the papers with low matching degree. Some 65, 246 and 62 publications remained after rigorous study.

2.4. Inclusion

In this step, the final resultant papers were recorded and analyzed for science mapping, to develop a comprehensive network among the factors that illustrate relations between each of them.

Figure 2 shows the flowchart of study selection, including search keywords and the filtering process and the outcomes.

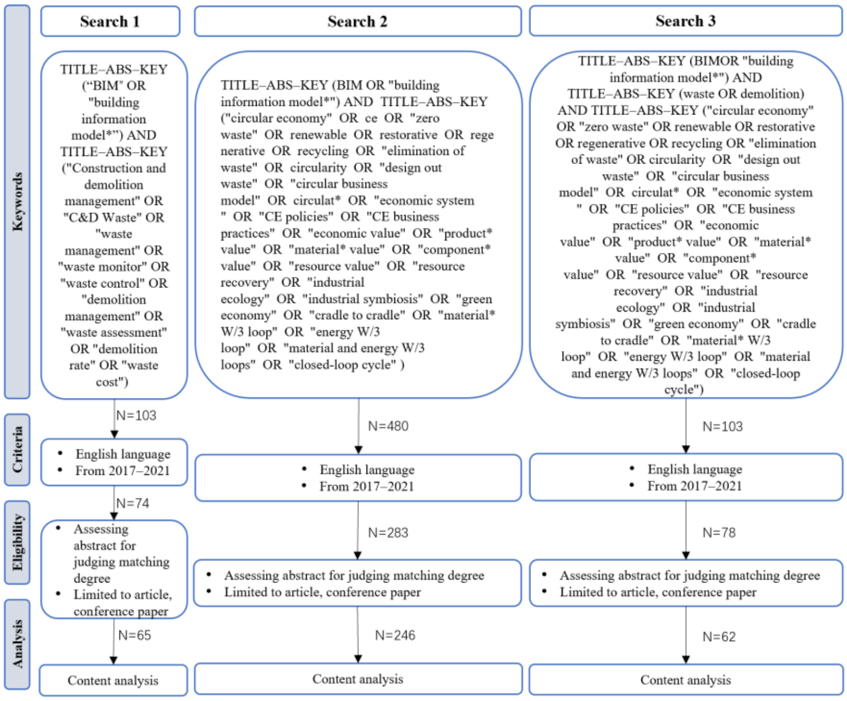

Figure 2. The flowchart of study selection, including search keywords and filtering process.

3. Content Analysis and Critical Analysis

This chapter presents the outcome of the examination of current practices and the relevant literature in the field. The first section presents the outcome of scientometric analysis of the bibliography of three searches in the Scopus Database. The second section presents the content analysis outcome of three searches.

3.1. Scientometric Analysis

In this section, we conducted four scientometric steps, regions network, co-authorship network and keyword evolution. This part aims to reflect the emerging trends and the collaboration of BIM applications in waste and demolition management, and the circular economy.

3.1.1. Co-Author Analysis

Collaboration among researchers helps us to understand the status of research and identify influential authors. Figure 3 shows seven major author communities, indicating that strong collaborative relationships have been built up between theses authors. Each node refers to an author and the edges represent collaborative years from 2017 to 2021. The largest networks were the community of I. Kovacic which included M. Honic, H. Rechberger, B. Liang, and Y. Wang.

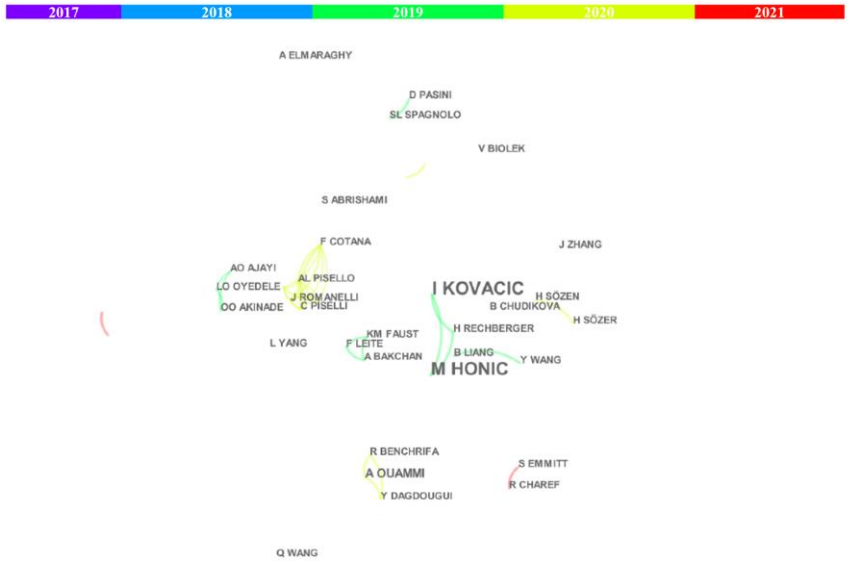

Figure 3. Co-authorship network.

3.1.2. A Network of Regions

This research generated a network visualization of co-authorship countries to identify the spatial distribution of publications based on BIM applications in waste and demolition management, and the circular economy. Figure 4 contains 82 nodes and 100 links. The size of a node refers to the publication number in the country. In Figure 4, the United Kingdom (26 papers), China (24 papers), United States (23 papers), Italy (20 papers) and Germany (13 papers) top the list, which illustrates that these countries are at the world forefront in the study of BIM applications in waste and demolition management and the circular economy.

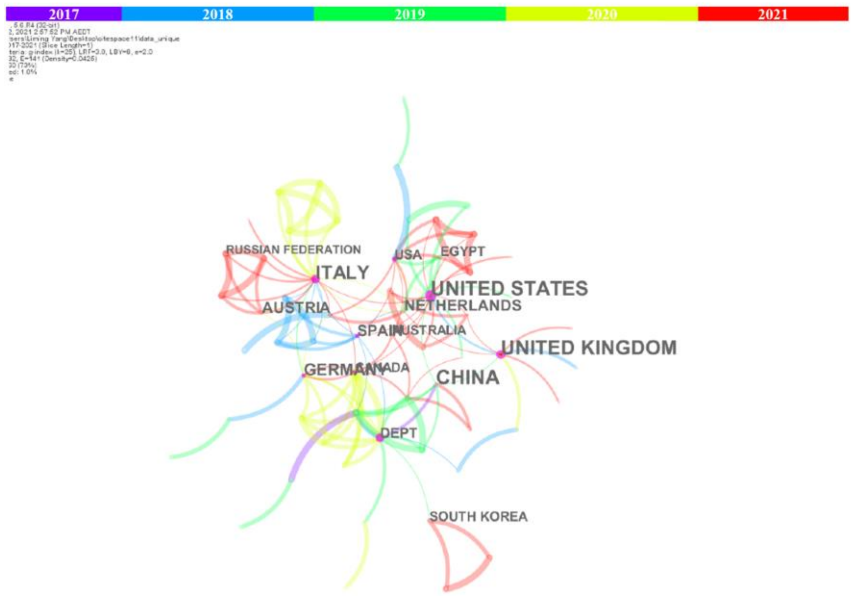

Figure 4. A network of regions.

3.1.3. Keywords Evolution

Hot topics and research priorities are intuitively identified through the analysis of the keywords. In this research, we generated a network of co-occurring keywords based on time span with CiteSpace, containing 253 nodes and 1126 links, as shown in Figure 5. The node size represents the frequency of the keyword in the bibliometric record. The top 10 keywords are "architectural design" (frequency = 112), "construction industry" (frequency = 46), "building information modelling" (frequency = 45), "life cycle" (frequency = 36), "sustainable development" (frequency = 36), "circular economy" (frequency = 32), "recycling" (frequency = 27), "environmental impact" (frequency = 24), "sustainability" (frequency = 24), "energy efficiency" (frequency = 23).

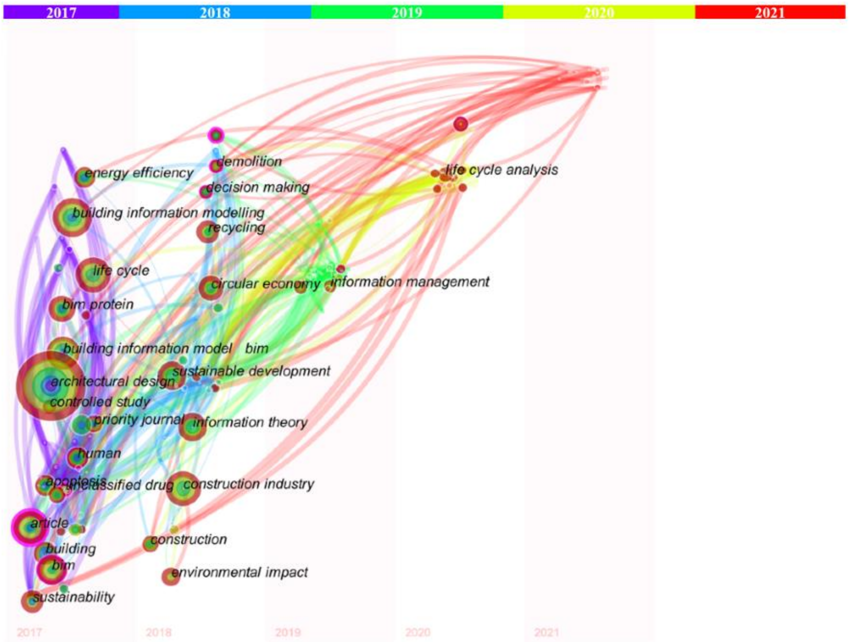

Figure 5. A timeline view of keyword co-occurrence network.

3.2. Content Analysis

This section presents the outcome of the content analysis of the bibliography of three searches for BIM applications for adopting CE in W&D management concept in the construction sector.

Papers with a Review document type have been full-text reviewed. The results illustrate that BIM applications have significantly enabled the circularity of CE adoption in the construction sector (Table A1). One of the BIM applications refers to its implementation as a digital tool in life circle assessment (LCA), which has ensured the reliability and accuracy of the assessment results. Benefiting from the technology, LCA tends to focus less on the its estimation, shifting the focus to emerging area such as CE [1].

The shifted focus further contributes to the width of CE practice in construction sectors. However, there are studies that illustrate that the BIM is still in the early stages to manage waste and demolition [2], and this may hinder the transformation. The main reason for this is related to the lack of a global framework. Since there are different local policies and criteria globally, the path to developing a global framework for LCA seems tough to achieve, especially in the end-of-lifecycle (EoL) stage [3], which is the pre-stage to the disposal of construction waste. In another words, the waste is finally generated after the EoL stage. The lack of global framework is likely to result in unreasonable disposal of waste, which leads to environmental impacts that are opposite to the CE concept. Despite this, BIM applications in the EoL stage have already benefited construction projects by changing the linear system to CE.

Another identified application of BIM is related to the digital-based tool to develop the component and material bank. Specifically, the bank requires detailed material information such as use records [4], which can be achieved through a BIM-based system, by extracting material information and managing the recycling of materials and direct reuse of components [5]. However, the existing material assessment tools lack solutions for material stocks [6]. In this way, the accuracy of building data assessment cannot be well guaranteed. To ensure more accurate and reliable material assessment results, it is necessary to generate a comprehensive framework which is able to take the following factors into account: (i) the feasibility, in practice, for projects to comply with current social factors and environment management [4]; (ii) waste disposal fees and waste volume adjustment factors [7]; (iii) the necessity to extract information about certain reusable and recycled materials that are not particularly useful in the project. Although there are still factors in BIM applications that might impede circularity, BIM has enabled CE for reaching high recycling rates via technological integration with other relatively mature techniques. Besides, the existing problems are likely to be addressed by the development of machine learning algorithms, recognizing typical building elements, assisting the assessment, analysis and prediction of the material flow [8]. In addition, it is argued that the integration of BIM and big data shows a positive future trend in waste generation management [9]. Big data is the technological recording of waste information, such as amount, date, and scenarios, while BIM can present a visible and dynamic mapping of waste generation via modelling.

4. Discussion and Conclusions

Overall, although a significant amount of construction waste may indicate that developed ICT such as BIM have not been best practiced in the field to achieve the CE concept, BIM applications in construction waste and demolition management enable circularity. The studies for BIM and CE mainly focus on LCA, BIM-based component and material banks, technological integration systems, and sustainable design. The implementation of these applications presents significant benefits of CE adoption in the construction sector including high recycling rates of construction materials, the increasing popularity of CE, potential realization of CE, and the shift from a linear system to CE.

There are still limitations for the practice of BIM in CE. The most important gap for implementation is the lack of framework on a global scale, which hinders current practice from being widely adopted. Additionally, some factors, which are likely to facilitate BIM application and CE adoption, have not been taken into consideration. Consequently, the future path could pay attention to these gaps between regions and creative integration of diverse technologies. One list of the research keywords is based on W&D management, while there might be another path for BIM application and CE adoption, further studies can also focus on other managing processes in construction projects.

Author Contributions: Conceptualization, Y.H., L.Y. and S.S.; methodology, Y.H., L.Y. and S.S.; software, L.Y.; validation, Y.H. and S.S.; formal analysis, S.S. and Y.H.; investigation, Y.H.; resources, S.S. and Y.H.; data curation, Y.H.; writing—original draft preparation, Y.H. and L.Y.; writing—review and editing, S.S.; visualization, L.Y.; supervision, S.S.; project administration, S.S.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. BIM applications on CE and benefits.

BIM Applications	Benefits on CE	Potential Directions or Limitations
LCA-contributing to more accurate and reliable LCA results	Shifting focus from estimation of the results to CE practice from the sector [1]	The potential negative impacts of construction materials within the adoption of CE might be analyzed and compared
Developing material bank-by extracting material information and managing recycled and reused materials components.	Quantification of waste and assessment of the design for deconstruction;Provide information of condition in reconstruction [7]	Waste disposal fees and waste volume adjustment factors might be acquired and added into the bank.
Providing detailed information about use records	Effective management on recycling of materials and direct reuse of components, further contributing to a more sustainable construction industry [4]	The application requires the construction projects to follow current social factors and comply with the environment management, which might be tough to achieve in practical projects
BIM to participate in asset End-of-Life phase	Changing linear system to CE [10]	It is necessary to pay attention to reuse and recycle components in design phase, enhancing the holistic construction process. this can be done through shifting architect attitudes.
Integrating BIM into the industry	Assisting CE to be widely applied in C&D management in the appropriate context [9]	The literature sample is limited to journals in English. Besides, it only focuses on research movement, which possibly have deviations with industry practice.
Providing information	Encouraging the CE to practice by value creation [8]	Whether and how certain reusable and recycled materials that are not particularly useful in the project can be extracted.
Providing visualization of the footprints about greenhouse gas emissions	Providing information to monitor and manage emissions [11]	Land use and transformation might be potentially estimated via further development of the resource footprints.
Basis tool of the generation of Material Passport (MP)	Enabling CE for reaching high recycling rates via the technological integration of BIM with laser scanning and ground penetrating radar (GPR) to capture data [8]	the development of Machine Learning algorithms for recognizing typical building elements, assisting the assessment, analysis and prediction of the material flow

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