Shaping circular economy in the built environment in Africa. A bibliometric analysis

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Abstract

Purpose – This paper aims to explore the intellectual structure shaping the circular economy (CE) discourse within the built environment in Africa.

Design/methodology/approach – The study adopted a bibliometric analysis approach to explore the intellectual structure of CE in the built environment in Africa. The authors collected 31 papers published between 2005 and 2021 from the Scopus database and used VOSviewer for data analysis.

Findings – The findings show that there are six clusters shaping the intellectual structure: demolition, material recovery and reuse; waste as a resource; cellulose and agro-based materials; resilience and low-carbon footprint; recycling materials; and the fourth industrial revolution. The two most cited scholars had three publications each, while the top journal was *Resources*, *Conservation and Recycling*. The dominant concepts included CE, sustainability, alternative materials, waste management, lifecycle, demolition and climate change. The study concludes that there is low CE research output in Africa, which implies that the concept is either novel or facing resistance.

Research limitations/implications – The data were drawn from one database, Scopus; hence, adoption of alternative databases such as Web of Science, Google Scholar and Dimensions could potentially

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

Supplementary materials: Appendix A1: Literature overview of the extracted 31 articles representing the CE in the construction industry in Africa. *Appendix A2*: A list of all the co-cited authors based on the co-citation analysis network.

Institutional review board statement: The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed consent statement: Not applicable.

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have yielded a higher number of articles for analysis which potentially would result in different conclusions on the subject understudy.

Originality/value – This study made a significant contribution by articulating the CE intellectual structure in the built environment, identified prominent scholars and academic platforms responsible for promoting circularity in Africa.

Keywords Africa, Sustainability, Construction industry, Circular economy, Bibliometric analysis, Built environment

Paper type Literature review

1. Introduction

Circularity and sustainability have become buzzwords within the construction industry. The realisation that construction activities are largely dominated by linear practices of extract, make and dispose that deplete natural resources and emit toxic gases has given the circular economy (CE) its impetus in the construction industry (Benachio *et al.*, 2020; Patwa *et al.*, 2021). The Ellen MacArthur Foundation (EMF) has, in the recent past, been a leading voice in advocating for circularity and defines CE as a system that is both regenerative and recuperative by design (Ellen MacArthur Foundation, 2013). The underpinning standpoint of the EMF and other circularity proponents is that the linear model is unsustainable. For that reason, the CE has been widely regarded as a concept that operationalises sustainability (Galvao *et al.*, 2018). The CE practices are anchored on the principles of reduce, reuse and recycle (Mahanty *et al.*, 2021). In the construction industry, principles such as designing out waste, biomimicry, material selection and flow analysis, designing for deconstruction or disassembly have also emerged (Rahla *et al.*, 2021). All these practices are the industry's contribution to advancing circularity and sustainability.

Several scholars have extensively reviewed the CE practices adopted in the construction industry. Since 2016, there has been a steep increase in research output on the CE within the construction industry, accounting for approximately 21% annually across the globe (Norouzi *et al.*, 2021). Contrary to the academic growth, a systematic review from Akhimien *et al.* (2021) on the application of CE principles in buildings concludes that the level of awareness of the concept in Africa remains low (Bilal *et al.*, 2020). The authors attributed the low awareness level to scant research output from Africa (approximately 1.6%). Furthermore, material selection is an important CE practice determining how the construction industry contributes to circularity. Rahla *et al.* (2021) examined the issue based on articles published from 2015 to 2020 and revealed that Africa only contributed 2% of the publications. Evidently, these are worrisome statistics, particularly in advancing the CE knowledge within the African context. Similarly, Desmond and Asamba (2019), as well as Rweyendela and Kombe (2021), also claim that circularity remains vague in Africa and conclude that the CE has yet to yield tangible actions in most countries. For that reason, examining CE concepts within the African construction industry is likely to give an indication of emerging practices and platforms where these concepts are being discussed and would potentially inform future researchers on how to venture into the scholarly debate. To date, to the knowledge of the researchers, no studies have exclusively looked at the emerging circularity concepts, clusters and authors from the African continent using a bibliometric analysis approach.

This study uses a bibliometric analysis of circular construction in Africa to respond to the following research questions:

RQ1. What is the current intellectual structure of the CE in the construction industry in Africa?

RQ2. Who are the most cited authors?

RQ3. Which are the top journals or conferences publishing the most cited articles?

RQ4. What are the dominant practices and concepts that are shaping the current CE trends in Africa?

By answering these research questions, this study seeks to identify the concepts that are shaping circular construction on the African continent while showing the circularity practices that can be adopted by the various construction stakeholders, such as governments, professionals and contractors.

2. Literature review

2.1 Transition from linearity to circularity in the construction industry

The construction industry has, for a long time, been characterised by a linear model. A linear approach involves a sequential exploitation of natural resources through extraction, use and disposal (Benachio *et al.*, 2020). The concept does not consider any form of recycling or reuse, which subsequently leads to immense waste generation and pollution (Akhimien *et al.*, 2021; Ranjbari *et al.*, 2021). In response to these findings, Pearce and Turner (1990; p. 35) coined the term "circular economy" in addressing the necessity to extend the useful life of resources to reduce the burden for extracting virgin raw materials. For that reason, the CE is anchored on three fundamental principles: reduce, reuse and recycle (Mahanty *et al.*, 2021; Kirchherr *et al.*, 2017; Anastasiades *et al.*, 2021; Leising *et al.*, 2017). However, Potting *et al.* (2016) identified 10 Rs: recover, recycle, repurpose, remanufacture, refurbish, repair, reuse, reduce, rethink and refuse, which further gives an in-depth perspective on the circularity approach. Recently, Cimen (2021) coined an eleventh R, called "Replace". The replace principle seeks to pursue total eradication of unsustainable materials within the construction industry while advocating for the adoption of alternative biodegradable materials. For instance, the environmental issues caused by the production of Portland cement have seen advancement in its replacement by waste materials such as fly ash, which is more economical and safer for the environment (Asa *et al.*, 2020). The ultimate goal of these principles and practices is for the industry to rethink the design, operational and waste management strategies. Spreafico (2022) suggests various design strategies that are essential in advancing the circularity agenda. More so, the scholar seems to favour quantitative measures in determining the environmental sustainability resulting from circularity practices in contrast to the widely adopted qualitative approaches. To that end, since the concept of circularity in construction is evolving as practitioners and advocates push for a transition from linearity to circularity, there are a wide variety of both established and emerging practices available for industry to consider in this process.

Regardless of the nobility of the cause of transitioning from linearity to circularity, it appears that the construction industry faces a number of hurdles. Kooter *et al.* (2021) argued that chief among the hindrances of the transition is the unwillingness of the business owners to change their way of doing business. It is in the same vein that Ghisellini *et al.* (2016) and Górecki *et al.* (2018) postulated that business models determined how the companies were likely to adopt circularity. It is apparent that the transformation of the construction industry's business models, which have been mainly characterised by linear practices, would perhaps leapfrog the sector towards circularity. Munaro and Tavares (2021) noted that material passports and government incentives such as subsidies were crucial in leading the construction industry to embrace circular practices. Other barriers include lack of collaboration among stakeholders, limited technology adoption, archaic building codes and unclear financial benefits (Vincevica-Gaile *et al.*, 2021; Mhatre *et al.*, 2021; Hart *et al.*, 2019;

Antwi-Afari *et al.*, 2021; Çetin *et al.*, 2021; Zami, 2020; Spreafico and Spreafico, 2021). On the other hand, construction professionals such as architects, engineers and quantity surveyors have a large role to play (Al Hosni *et al.*, 2020; Minunno *et al.*, 2020). Central to the role of these professionals is convincing clients to adopt new sustainable means of construction even though the associated costs could be higher compared to the conventional approach at the project inception phase (Lovrenčić Butković *et al.*, 2021; Agyemang *et al.*, 2019). Despite the challenges that could be encountered in the construction industry's transition to circular practices, it is evident that any sustainable future relies mainly on how construction activities pay attention to the sustainability agenda.

2.2 Circular economy in the construction industry: emerging concepts, practices and trends

Of late, scholars across the world have been seized with a growing research interest of the CE paradigm. The interest has been largely hinged on the fact that the concept serves as an alternative to the linear model, which is deemed unsustainable (Benachio *et al.*, 2020). Buttressing that observation, Norouzi *et al.* (2021) and Akhimien *et al.* (2021) noted that between 2016 and 2017, CE studies skyrocketed as academicians pursued the sustainability agenda. As a result, several CE concepts and trends have arisen. Goyal *et al.* (2020) identified some of the leading CE concepts as measurement strategies and models, CE and sustainability, level of adoption (company, country and regional), 3R model (reduce, reuse and recycle) and the role played by project design. Furthermore, the study concludes that CE research has been characterised by interdisciplinary collaborations because of how its practices permeate across economic sectors.

On the other hand, Norouzi *et al.* (2021) and Mhatre *et al.* (2021) identified the emerging concepts in the construction industry as energy efficiency, waste management, enablers and drivers, end-of-life management, alternative construction materials and circular business models. They recommended that smart or green cities and industry 4.0 be the future trends of the industry. Consequently, Owusu-Manu *et al.* (2021) identified eight parameters that indicate the greenness of cities; air quality, water, sanitation, land use, health and safety, transportation, energy and building and construction. Therefore, the construction industry has a significant role in shaping smart cities. In tandem with that, Tsai *et al.* (2020) added that incineration, separation and sorting construction solid waste have also gained focus. Contrariwise, Cimen (2021) argued that incineration produces toxic gases that, in turn, deter the circularity agenda. Rahla *et al.* (2021) augment the findings of Cimen (2021) by suggesting that instead of thinking about incineration and recycling, the industry should explore eco-friendly materials that are biodegradable. Nevertheless, Akhimien *et al.* (2021) noted that an increase in scholarly publications had demonstrated heightened awareness of the concept. Despite these practices, Cimen (2021) argued that the construction industry still struggles to implement CE. The fragmentation of the industry has perhaps contributed to this situation. As a result, the concept continues to be explored and new practices are emerging and, at the same time, raising a question about whether the industry would ever become fully circular.

Furthermore, some innovative ways of transforming the construction industry to fully adopt circularity continue to emerge. According to de Azevedo *et al.* (2021), the use of glass waste to form roof tiles has been developed. Arguably, the approach does address the issue of viewing waste as a resource within the construction sector. The CE concepts have also seen the advancement of alternative materials, particularly to reduce the use of carbon-rich products such as cement and lime. For that reason, Marvila *et al.* (2021) study on the substitution of lime with waste marble and clay residue mined from rocks proved to be a commendable alternative as long as the mixing proportions were adequately applied. It is clear that the CE appears to provide a solution for how to deal with the waste materials, which are a significant by-product of conventional construction activities (Galvao *et al.*, 2018; Goyal *et al.*, 2020). The CE concepts are in a rapid state of flux, which requires innovative ways to enable a transforming of the traditionally technology-averse construction industry.

2.3 Circular economy practices in the African construction industry: opportunities and challenges

The construction industry has, for a long time, been lagging in adopting new concepts and technologies. Recently, Cimen (2021) reviewed the 2017–2020 articles and concluded that the construction industry is struggling to implement CE principles. Such a position could have been necessitated by the multiplicity of stakeholders in the supply chain. Mahanty *et al.* (2021) observed a structural shift from 2014 to 2015 in CE studies as more attention was being directed towards the social pillar of sustainability. Arguably, such a shift in research was imperative as it considered problems that bedevilled emerging economies such as Africa. Furthermore, Ranjbari *et al.* (2021) linked waste management attributes with CE and concluded that, with construction industry's generation of enormous waste, CE might prove a game changer in enhancing sustainability. Charef and Lu (2021) argue that business models and supply chain integration provide the basis for the transition towards adopting CE practices in the construction industry. On the other hand, Tsai *et al.* (2020), as well as Norouzi *et al.* (2021), in a 2005–2020 bibliometrics analysis using both Web of Science (WoS) and Scopus databases lament that although CE is receiving much scholarly attention, the African continent is being left behind. Delgado and Oyedele (2020) also argue that the limited use of the building information modelling (BIM) during the operational phase of the buildings has possibly hindered the construction industry transitioning towards circularity. The study further argues that the use of BIM has the potential of enhancing the whole lifecycle perspective among stakeholders of the buildings, thus aiding the circularity trajectory. Since the construction industry is still emerging in Africa, ignoring circularity principles could potentially have detrimental effects on the continent's contribution to the sustainable development goals (SDGs).

The policy direction of the nation informs the direction of the practices within a country. In most cases, policies are informed by research. Contextually, Rademaekers *et al.* (2020) in their study entitled "Circular Economy in Africa-EU cooperation Continental Report" observe that approximately 96% of the African countries have incorporated at least one CE practice in their policies. For that reason, it is clear that there is growing traction of the concept within the African continent, which perhaps is informed by research in the area spearheaded by collaborations. With regard to collaborative initiatives, Türkeli *et al.* (2018) focused on CE scientific knowledge in the European Union and China and concluded that for the CE agenda to be permeated globally, there might be a need for collaboration among scholars. Therefore, a series of EU–African collaborative studies were conducted across Africa, and the findings indicated the following key CE practices.

Table 1 illustrates a detailed summary of the practices that are applied by some of the African nations considered to be leaders in the circularity agenda. Evidently, African countries have adopted CE practices at different levels. Nonetheless, some of these practices are fairly new, which has hindered scholars' attempts to ascertain their effectiveness (Mahmoud *et al.*, 2020). These practices, apart from the innovative brick manufacturing, arguably seem to leave much work to be done by the construction industry in terms of fully embracing circularity. For instance, the banning of plastics, importation of materials, revision of building codes and green building certification stem mostly from government

Country	CE practices	References	Application and significance
Egypt	Green economy strategy, recycling, resource efficiency, use of local sandstone, use of secondary materials	Mahmoud *et al.* (2020)	The recycling of materials will limit the amount of raw material extraction, and the use of locally available materials reduces the carbon footprint of the transportation of materials. Use of local resources requires innovation and disruptive adaptation (Lekan *et al.*, 2021)
Ghana	Green public procurement, recovery of materials at demolition stage, sustainable sourced materials, local inspired architecture, energy efficiency, renewable energy, green building and efficient lighting	Hemkhaus *et al.* (2020)	The adoption of green procurement enables contractors to detail how they will deal with the environment in their practices. Such practices allow clients to reduce their negative environmental impact
Kenya	Banning of single-use plastics, sustainable waste management, reduction of material importation, recycling of materials, use of interlocking stabilised soil blocks (ISSB) made from crushed glass, shredded plastic waste and agro-based residues	Karcher *et al.* (2020)	The banning of materials that are not bio-degradable allows the construction industry to reduce its impact on the environment (Schmidt *et al.* 2020; Caschera *et al.* 2020; Ghosh, 2020). While the use of ISSB enables the sector to reuse demolished or waste materials to produce future construction materials (Edike *et al.*, 2020)
Morocco	End-of-life waste management, low cost and natural building materials, value addition of local eco-friendly materials	Diaco *et al.* (2020)	End-of-life thinking allows designers to suggest materials with the end in mind. The approach addresses the question: What will become of the material at the end of the building life?
Nigeria	Informal waste management, waste minimisation	Rajput *et al.* (2020)	The construction industry produces a vast amount of waste which requires management. Therefore, the adoption of waste management allows the sector to dispose of waste in a responsible manner (Schmidt *et al.*, 2020)
Rwanda	Use of sustainable materials and recycled materials, energy efficiency, environmental performance (green building rating systems), renewable energy, urban forests (green spaces)	Whyte *et al.* (2020)	The use of recycled materials has not been widely adopted in most countries due to various reasons, such as "negative attitude towards waste" and lack of standardisation (Potting *et al.*, 2016). However, Rwanda has shown that the use of these materials reduces a strain on virgin natural resources. Furthermore, reclaiming green spaces allows the cities to restore the ecosystem (Pearlmutter *et al.*, 2020)

(*continued*)

Table 1.
Dominant CE practices in the construction industry in Africa available in literature

Country	CE practices	References	Application and significance
Senegal	Building using compressed earth bricks (CEB), eco-construction, revision of building codes, construction waste management, recycling	Bonnaire *et al.* (2020)	Earth bricks are an innovative way of combatting the carbon footprint associated with cement bricks (Meek *et al.*, 2021; Migliore *et al.*, 2018). Furthermore, Edike *et al.* (2020) note that eco-friendly brick production has increased in Africa The revision of building codes, on the other hand, allows the sector to move with the times and address the sustainability and climate change challenges (Zami, 2020)
South Africa	Regulation of indoor environment (Tebogo Home), waste management, recycling of plastics, green building certification	Potgieter *et al.* (2020)	The recognition of the impact that the construction sector has on the environment is a significant step towards addressing circularity issues. It allows the industry to think in a holistic manner whenever constructing a building (Hossain and Ng, 2019). Therefore, the certification of buildings in view of their impact on the environment has great benefits
Zambia	Using copper tailings as partial replacement of sand in concrete production	Muleya *et al.* (2021)	The study found out that 30% of sand replacement with copper tailings was the maximum replacement amount to produce optimum compressive strength values from both mixes. With the abundance of copper tailings in Zambia, their use in concrete could increase circularity within the construction industry

Source: Adapted from Circular economy in Africa-EU cooperation country reports (2020) and Muleya *et al.* (2021)

Table 1.

policies (Babalola and Harinarain, 2021; Bassi *et al.*, 2021; UNEP, 2018). These practices do agree with the assertion made by Rademaekers *et al.* (2020) that in their study, a majority of African countries had put policies in place to address issues of circularity. The African continent continues to face both opportunities and challenges in light of adopting CE practices. Some of these opportunities include employment creation, reduction of importing materials, locally available natural resources, agricultural waste materials, construction of low-cost housing, reducing carbon dioxide (CO_2) emissions, minimising waste disposal, combatting climate change, cultural conservation, new professions, reclaiming biodiversity and designing out waste (Diaco *et al.*, 2020; Rajput *et al.*, 2020; Pearlmutter, 2020; Meek *et al.*, 2021; Al-Hamrani *et al.*, 2021; Schmidt *et al.*, 2021). Vijaya Prasad *et al.* (2022) argue that efforts are being made to develop sustainable concrete materials to satisfy the present need of the construction sector, which presents some emerging opportunities within the industry. The study further identifies geopolymer concrete (GPC) as one of the materials being investigated (Asa *et al.*, 2020). GPC uses alternative binders such as fly ash instead of cement. Therefore, with concrete as a major construction material, sustainable options such as GPC could potentially boost designing for the climate. On the other hand, Muleya *et al.* (2021) notes that in Zambia due to the abundance of waste copper tailings, there is advanced investigations of replacing sand in concrete aggregates. The opportunities are an indication that the CE within the construction industry is there to enhance the livelihoods of construction stakeholders.

To a greater extent, these practices allow the nation to address the issues of climate change as it limits its reliance on virgin materials (Mahmoud *et al.*, 2020). On the other hand, challenges include inconsistent policies, CE skills deficits, sprouting landfills, misalignment of awareness and implementation (closely linked to policy inconsistency, the industry's failure to embrace the practices as they are not aware of the benefits that accrue due to circularity), archaic building standards void of CE practices (dated building codes that are devoid of recent research output with regard to innovative circular practices), lack of secondary markets (including the establishment of the markets that manufacture and sell recycled materials, which are deemed second-hand materials), informal settlements, low research and development and limited continental standards and assessment indicators (Mahmoud *et al.*, 2020; Hemkhaus *et al.*, 2020). In a bid to address circularity assessment problems, Abadi and Sammuneh (2020) postulated a lifecycle circularity assessment framework. The authors argued that central to the failure of the full adoption of the CE were the lack of a unified industry-wide measurement criterion. Nonetheless, it appears that the stance of both local and central governments in fostering a transition towards circularity cannot be overemphasized (Bolger and Doyon, 2019). Therefore, central government policy inconsistency creates a problem that culminates in the lack of standardisation within the industry. On the other hand, the CE seems to require industry professionals to upskill themselves so that they adopt circular practices within their professions (Edike *et al.*, 2021; Dokter *et al.*, 2021). The retooling of construction professionals calls on both academic and professional regulatory bodies to consider offering learning platforms to raise awareness of these CE practices. Furthermore, in Africa, landfills are a significant problem because of the perception that they are a cheaper way of disposing of waste (UNEP, 2018). For that reason, contractors tend to adopt landfills as a waste disposal strategy even though their ecological challenges are well documented. At the same time, clients seem to possess limited interest in the environmental impact caused by landfill disposal of construction wastes (UNEP, 2018; Tunji-Olayeni *et al.*, 2020). Contextually, these opportunities and challenges inform the direction of future research in the ongoing CE debates that are worth exploring.

3. Materials and methods

The study adopted a quantitative research method, namely, the bibliometrics approach. The bibliometric analysis method is a useful statistical technique that determines the knowledge base of a scientific area of study (Garfield, 1979). More so, the author further notes that the main assumption of the method is that to ascertain any intellectual structure of a topic of interest, publication citations are a true representation of the ongoing discourse in that study area. Nonetheless, Culnan (1986) argued that the use of citation counts to measure publications' impact in shaping a knowledge structure is dependent on their availability, which potentially limits the effectiveness of the technique. However, in addition to citation counts, van Eck and Waltman (2014) complemented that the method statistically analyses published articles and establishes networks based on co-citations, bibliographic coupling, co-authorship and keyword co-occurrences. The study used the citations, co-citations and co-occurrence options to address its aim.

The study sampled data from the Scopus database. Mongeon and Paul-Hus (2015) suggested that WoS and Scopus are the most popular databases and have a wider global coverage. However, Nobre and Tavares (2017) argued that Scopus has the largest collection of abstracts and citations. For that reason, the researchers used Scopus and followed five steps in data collection and analysis, as shown in Figure 1.

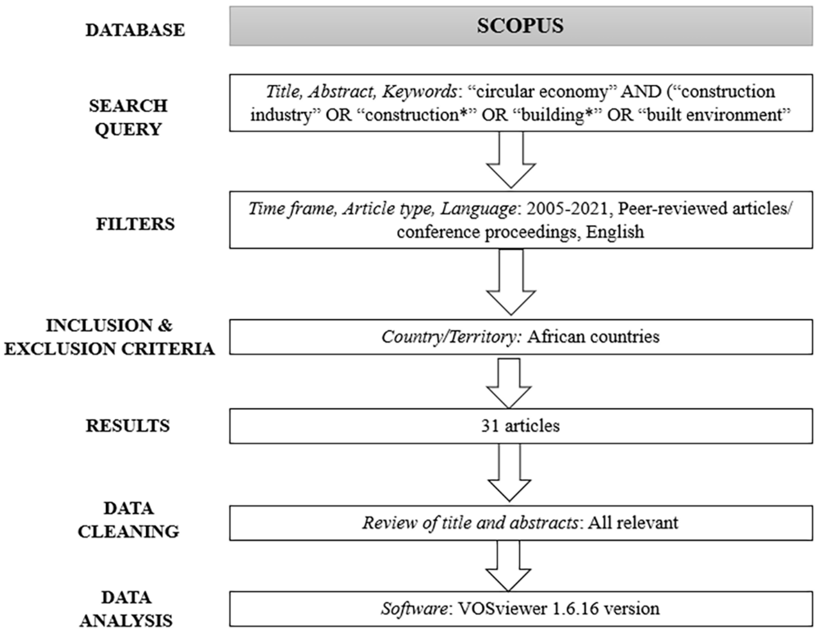

Figure 1.
Overview of the data mining procedure

Firstly, the search query was comprised of keywords "circular economy" AND ("construction industry" OR "construction*" OR "building*" OR "built environment") on the topic (Title, Abstract, Keywords). Secondly, the authors limited their search to peer-reviewed articles and conference proceedings published between 2005 and 30 August 2021. Thirdly, the results were further filtered to include African countries only. Fourthly, the researcher read the abstracts to ascertain the relevance of each article. Finally, relevant data were exported to VOSviewer version 1.6.16 for analysis (VOSviewer, 2020). The VOSviewer software is a mapping tool that allows for visualisation of the networks that exist between the articles (van Eck and Waltman, 2010).

In similar studies, Charef and Lu (2021) used the search query "circular economy" AND ("building" OR "construction industry" OR "built environment") AND "business model" OR "supply chain integration", while Mhatre *et al.* (2021) adopted "circular economy" AND "construction", "circular economy" AND "built environment" and Norouzi *et al.* (2021) adopted "circular econom*" AND "building OR construction". Although the keywords from the previous studies were almost identical to those in the current study, the researchers differentiated this study by limiting it to African countries to address the existing gap. Unlike, Charef and Lu (2021), who focused mostly on factors, Mhatre *et al.* (2021) and Norouzi *et al.* (2021) paid attention on the CE practices in the building sector, and they both included articles published from Africa. Nonetheless, in their analyses, these scholars concentrated more on publications with high publications and citations indices, which obscured the focus of African scholars. Furthermore, both these studies identified some of the influential scholars in Africa as Akinade O.O, Bilal M. and Clinton A.O.

4. Results

The data set was comprised of a total of 31 peer-reviewed articles (27 journal articles and four conference proceedings). The data was drawn from eight African countries, namely, Morocco, Egypt, Nigeria, South Africa, Tunisia, Malawi, Kenya and Ghana (as shown in Figure 2).

Upon the retrieval of 31 peer-reviewed articles shaping the CE discourse in the African construction industry, the authors generated a bibliographic coupling network to demonstrate the most influential authors and those that are closely related together. With a bibliographic coupling network, the size of the circle indicates the number of publications that the authors have in the subject area (van Eck and Waltman, 2014). Consequently, those with large circles have published extensively on the subject. The bibliographic coupling network was generated using the documents as a unit of analysis. To further ascertain the level of progression of the CE discourse in the African construction industry, the authors ensured that the year of article's publication was also included in the analysis. The study findings are shown in Figure 3. Additionally, Table 2 highlights the top 10 most influential documents that address the CE within the construction industry in Africa. The full list of the 31 documents can be consulted in Appendix A1 in the Supplementary Materials.

The concept of the CE has experienced exponential growth in the recent past. CE has permeated different industrial sectors, and it was necessary to demonstrate how the same principle has fared within the construction industry between 2005 and 2021. To determine the level of growth of CE, particularly within the construction industry, the authors sorted the 31 articles based on their year of publication. The results are as shown in Figure 4. From the findings, it is apparent that the African construction industry is also experiencing growth in the subject. The first article to be published in the African context was in 2016, while in 2017, there was no activity. Afterwards, from the year 2018 to 30 August 2021, there was a steady growth, which indicates that the concept is gaining momentum among scholars.

The CE is relatively in its infancy within the construction industry. For that reason, knowledge generation continues to evolve. However, to date, there are a number of scholars that have contributed immensely to the current CE discourse in the construction industry

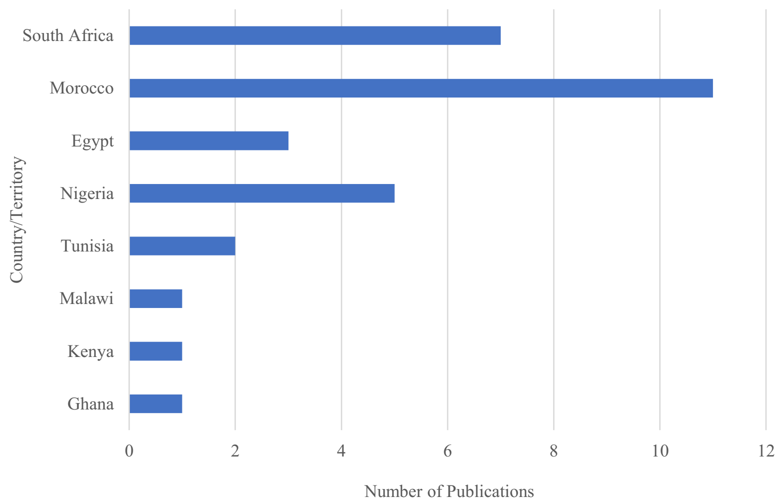

Figure 2.
The summary of the CE in construction industry publications in Africa (2005-2021)

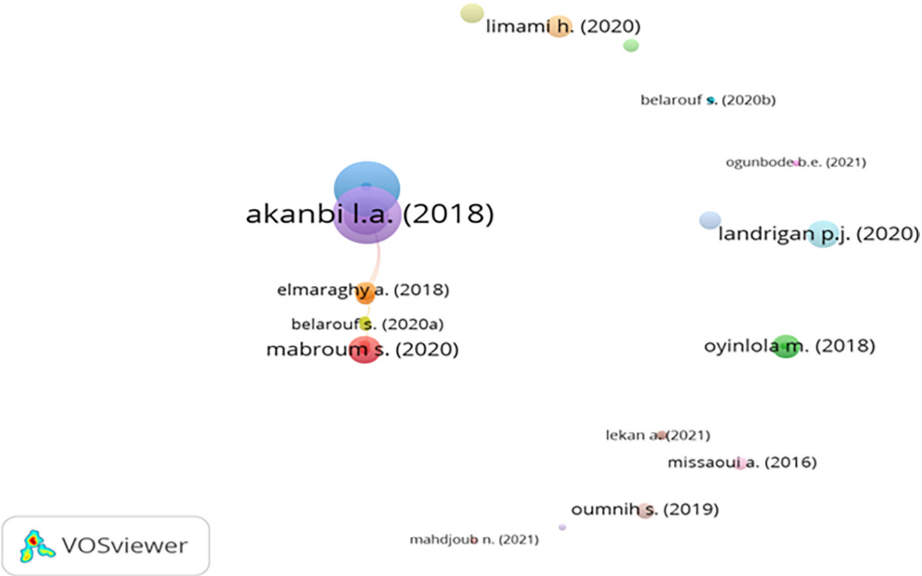

Figure 3. The bibliographic coupling network of CE publications in the construction in Africa (2005-2021)

Author(s)	Title	Source
Akanbi *et al.* (2018)	Salvaging building materials in a circular economy: A BIM-based whole-life performance estimator	*Resources, Conservation and Recycling*
Ibn-Mohammed *et al.* (2021)	A critical review of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies	*Resources, Conservation and Recycling*
Mabroum *et al.* (2020)	Elaboration of geopolymers based on clays by-products from phosphate mines for construction applications	*Journal of Cleaner Production*
Landrigan *et al.* (2020)	Human Health and Ocean Pollution	*Annals of Global Health*
Limami *et al.* (2020)	Study of the suitability of unfired clay bricks with polymeric HDPE\& PET wastes additives as a construction material	*Journal of Building Engineering*
Oyinlola *et al.* (2018)	Bottle house: A case study of transdisciplinary research for tackling global challenges	*Habitat International*
Oumnih *et al.* (2019)	Phosphogypsum waste as additives to lime stabilization of bentonite	*Sustainable Environment Research*
Hossain *et al.* (2020)	The impact of 4IR digital technologies and circular thinking on the United Nations sustainable development goals	*Sustainability*
Elmaraghy *et al.* (2018)	An exploration of BIM and lean interaction in optimizing demolition projects	*IGLC 2018—Proceedings of the 26th Annual Conference of the International Group For Lean Construction*
Missaoui *et al.* (2016)	Laboratory study on recycling of sediments in paving blocks	*Environmental Geotechnics*

Table 2. Top 10 most influential articles addressing CE in the construction industry in Africa (2005–2021)

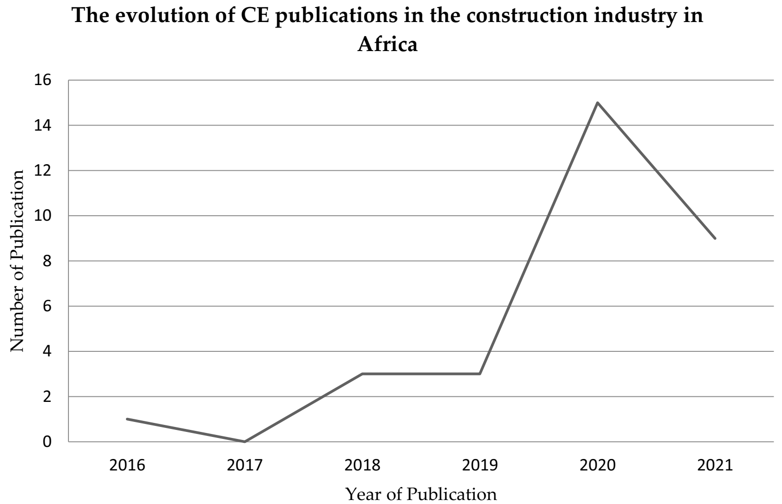

Figure 4.
The evolution of CE publications in the construction industry in Africa (2005–2021)

such that they have shaped the intellectual structure. To show the current intellectual structure of CE in the construction industry in Africa, the authors selected the co-citation option. The co-citation analysis demonstrates how two publications are simultaneously cited by a single document (Norouzi *et al.*, 2021). The analysis indicated how documents are related through sharing a common subject. In doing so, the co-citation analysis signifies the intellectual structure within the subject area. To generate the co-citation analysis, the authors adopted the co-citation and cited authors as a unit of analysis. The threshold was set at a minimum number of three citations per author. One hundred and seventy-one authors met the threshold (see Appendix A2 in Supplementary Materials). The results yielded the diagram as shown in Figure 5 together with the associated clusters.

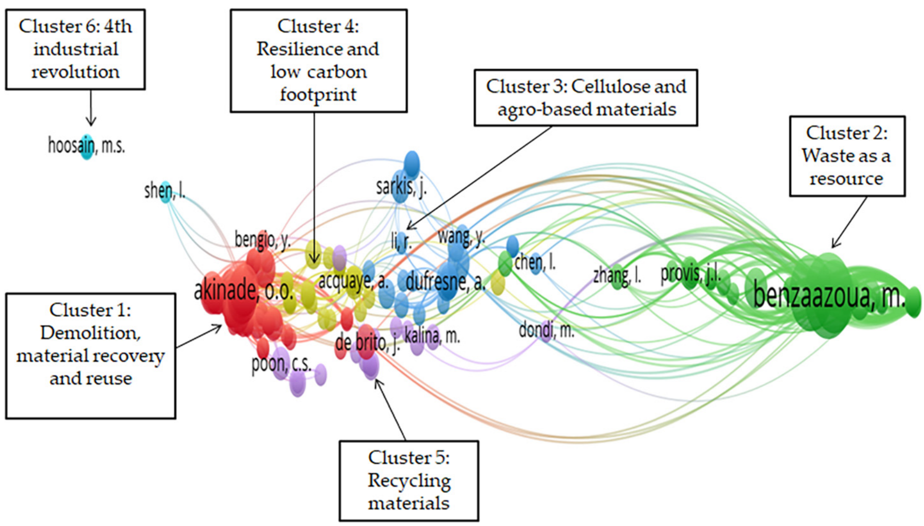

Figure 5.
The co-citation and authors network showing the intellectual structure of the CE in the construction industry in Africa (2005–2021)

To demonstrate the most-cited scholars in CE in the construction industry in Africa, Table 3 was generated using the following VOSviewer commands: type of analysis: citations; unit of analysis: authors. The minimum number of documents was set at two and the minimum number of citations at ten. The authors set at two the minimum number of documents so that they show authors who had made some scholarly contribution in the field through repeated publication on the same topic. Mhatre *et al.* (2021) set their minimum at three publications. Again, the citations were set at 10 as per the authors' discretion seeing that Norouzi *et al.* (2021) study identified the most influential authors through a minimum citation of at least 100. Therefore, to cater for the possibility of an emerging concept, the authors had to set theirs at a minimum of 10.

Table 3 shows the top ten most cited authors in Africa. Akanbi and Oyedele both had three TP, respectively. The most cited authors per publication (56) were Ajayi, Akinade and Bilal, who published two articles each. The other crucial component is that the area is still in its infancy, as evidenced by the total number of publications from the 10 authors, which cements the positions of Norouzi *et al.* (2021) and Cimen (2021) that there was more to be done within the CE in construction. The study identifies the contemporary voices in Africa who are shaping circular building. These authors play a critical role in spreading the concept throughout the industry.

To highlight the top journals or conferences that published the most-cited articles in CE in the construction industry in Africa, the authors used the following VOSviewer commands: type of analysis: citations; unit of analysis: sources. The threshold was set at a minimum of one publication. Table 4 highlights the top 10 journals or conferences.

Table 4 highlights the top 10 journals and conferences that cited the most articles. Contrary to the findings by Norouzi *et al.* (2021) that the *Journal of Cleaner Production* was the most productive journal in Africa, the leading journal in terms of number of citations is *Resources, Conservation and Recycling*. This perhaps informs the reason why recycling and reuse have gained more traction than other circularity principles (Diaco *et al.*, 2020). It is also interesting to note that circularity in the construction industry has also permeated other disciplines, such as health. Again, conferences in Africa seem to be shaping the discussion of CE within construction, as evidenced by the IGLC 2018, which linked CE with lean construction. Conferences provide a platform for convergence of both researchers and practitioners to debate emerging concepts. *Cellulose* is another journal that is worth noting because it seems that more agro-based materials from waste are now being explored in Africa.

Author	TP	TC	CPP
Akanbi, L.A.	3	121	30.25
Oyedele, L.O.	3	121	30.25
Ajayi, A.O.	2	112	56
Akinade, O.O.	2	112	56
Bilal, M.	2	112	56
Benzaazoua, M.	4	22	5.5
Hakkou, R.	4	22	5.5
Mabroum, S.	3	22	7.33
Taha, Y.	4	22	5.5
Elmaraghy, A.	2	14	7

Notes: TP: total publications; TC: total citations; CPP: citations per publication

Table 3. Most cited authors regarding the CE in the construction industry in Africa (2005–2021)

There are various practices and concepts that drive the CE within the construction industry. These trends, in turn, highlight the focal points to which both the construction stakeholders and researchers should pay close attention to enable the attainment of circular construction. Although some of the CE practices and concepts are generic, to some extent, there are certain concepts that are contextualised. Premised on that, to identify the CE concepts and practices, the authors adopted the co-occurrence network based on all the keywords. The network mainly addressed the *RQ4*: *What are the dominant practices and concepts that are shaping the current CE trends in Africa*? The authors used the following VOSviewer commands: type of analysis: co-occurrence; unit of analysis: all keywords, while the threshold was set at a minimum number of two occurrences of a keyword (see Figure 6). Table 5 provides a list of all the keywords, divided into five clusters based on their co-occurrence.

5. Discussion

Of the publications retrieved, as shown in Figure 4, the oldest article was published in 2016 by Missaoui and colleagues. Although there was no publication in 2017, the data revealed a

Table 4.
Top journals or conferences that published most cited articles in CE in construction industry in Africa (2005–2021)

Journal/conference	No. of publications	No. of citations
Resources, Conservation and Recycling	2	150
Journal of Cleaner Production	4	62
Annals of Global Health	1	18
Habitat International	1	13
Journal of Building Engineering	1	12
Environmental Research	1	9
IGLC 2018—Proceedings of the 26th Annual Conference of the International Group for Lean Construction	1	8
Cellulose	1	8
Sustainable Environment Research	1	8
Lean Construction	1	6

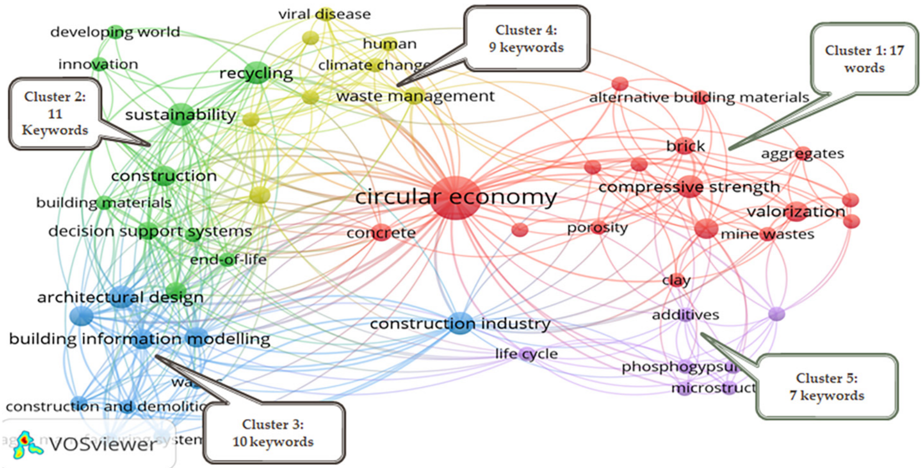

Figure 6.
The map based on the co-occurrence of all the keywords (2005–2021)

Table 5. List of key concepts in the CE in the construction industry in Africa, divided into five clusters based on their co-occurrence (2005–2021)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Circular economy	Building materials	Architectural design	Climate change	Additives
Aggregates	Construction	Building information modelling (BIM)	Economic aspect	Lifecycle
Alternative building materials	Construction material	Construction and demolition	Economics	Microstructure
Bottle bricks	Decision support systems	Construction industry	Environmental protection	Phosphogypsum
Brick	Developing world	Demolition	Human	Clay
Bulk density	End of lives	Industrial economics	Supply chain management	Mixtures
Compressive strength	End-of-life	Wastes	Sustainable development	Fourier transform infrared spectroscopy
Concrete	Information theory	Decommissioning	Viral disease	
Lithology	Innovation	Agile manufacturing systems	Waste management	
Mine wastes	Recycling	Building management		
Waste	Sustainability			
Phosphate mines				
Recycled aggregates				
Valorisation				
Waster absorption				
Porosity				
Mining				

steady growth between the years 2018 and 2019. In 2020 a total of 15 articles were published, which represents approximately 49% of the data set. Furthermore, as a build-up to the publication momentum gained in the year 2020, nine articles were already published by 30 August 2021. The findings buttress the studies by Norouzi *et al.* (2021) and Akhimien *et al.* (2021), which noted an exponential growth of studies in the area since 2016.

Akanbi *et al.* (2018), as one of the leading authors in the CE in Africa, address issues that relate to the role of BIM being used in the process of enabling the salvaging of waste materials. BIM as a system allows construction professionals to have a virtual view of the lifecycle of buildings (Elmaraghy *et al.*, 2018). Delgado and Oyedele (2020) outlined the extent to which BIM could potentially be a gamechanger in the circularity transition within the construction industry. Potting *et al.* (2016) noted that the main challenge faced by the construction sector in salvaging materials at the end-of-life is attributed to a reduced appetite by the clients to use second-hand materials. Recycling of materials seems to be taking centre stage in Africa. Interestingly, one of the first authors on the CE in African construction, Missaoui *et al.* (2016) investigated how to recycle pavers for reuse. The study corroborates the views of various scholars that recycling of construction materials is perceived as the best alternative to extracting raw materials for new buildings (Ranjbari *et al.*, 2021; Cimen, 2021; Mahmoud *et al.*, 2020; Diaco *et al.*, 2020). Demolition, alternative materials and the challenge of the COVID-19 pandemic are part of the issues addressed by CE scholars considering the African continent (Ibn-Mohammed *et al.*, 2021; Limami, 2020; Oumnih, 2019). CE practices appear to be a game changer in addressing a plethora of longstanding challenges within the construction industry, such as waste generation, pollution, material extraction and climate change. Notably, central to the advancement is the employment creation within its value chain, such as waste management and recycling (Edike *et al.*, 2021). Circularity seems to offer opportunities within the construction industry.

However, despite the potential of the concept, the findings also show that CE in the African construction industry is still in its infancy and evolving. Cimen (2021) notes that although the concept is still novel, the main challenge with the construction industry is that it has been a technological laggard (Marvila *et al.*, 2021). However, the current intellectual structure of the CE in the construction industry in Africa, as shown in Figure 2, demonstrates that the sector has been forthcoming in this area. Arguably, these findings indicate that the policies put in place, as highlighted by Rademaekers *et al.* (2020), are bearing fruit, although the growth is marginal.

Interestingly, Figure 5 shows that there are six common clusters that are shaping African research in the CE based on the co-citation network, and they have been included in: Cluster 1 – red colour – "demolition, material recovery and reuse". That is the most dominant cluster, with 52 authors and the leading African scholars included, Oyedele, Akanbi and Akinade (Akanbi *et al.*, 2018). Some of the themes include decommission, disassembly, simulation, performance assessment and salvaging (Akanbi *et al.*, 2018, 2019). Notably, Hemkhaus *et al.* (2020) and Ranjbari *et al.* (2021) contended that the construction industry in Africa is contributing to a sizeable amount of demolition waste, and yet there is little reuse of materials. Although it seems that there is activity in the research area on material recovery, Mahmoud *et al.* (2020) argued that, particularly in Egypt, the CE policies with regard to demolition and waste management are new and have yet to yield any results. Such a situation makes it difficult to ascertain the level of their success. A problem that is likely to inform future studies.

Cluster 2 – green colour – called "waste as a resource", which includes themes such as zero waste, alternative materials, residual phosphorous (Taha *et al.*, 2021), flint use, valorisation (El Machi *et al.*, 2021) and environmental protection (Drif *et al.*, 2021). The concept hinges on the beliefs held by the EMF (2013) and Goyal *et al.* (2020) that CE should be incorporated within the design stage. However, it seems that in most African countries, waste management is still informal, which deters its use and establishment of secondary markets (Rajput *et al.*, 2020; Potgieter *et al.*, 2020). Such a reality demonstrates an opportunity for reconfiguration of the perceptions of individuals about waste through community engagement and workshops with stakeholders. Cluster 3 – blue colour – "cellulose and agro-based materials" includes green manufacturing, waste treatment, nanocomposite cellulose (Caschera *et al.*, 2020), cross-laminated secondary timber (Rose *et al.*,2018), Kenaf fibres, biofibres and biodegradable materials (Ogunbode *et al.*, 2021). These authors seem to be tapping into the knowledge that Africa is largely agro-based, which presents a potential for innovative agro-based construction materials (Caschera *et al.*, 2020). Augmenting these agro-based materials, Schmidt *et al.* (2020) note that Africa has the potential of optimising its natural agro-based resources through converting them into construction materials (Schmidt *et al.*, 2021). For a continent that is predominantly agro-based, such innovations are likely to enhance circularity. Furthermore, Bonnaire *et al.* (2020) and Whyte *et al.* (2020) agree that in Africa, the development of alternative materials from agricultural waste, such as polysaccharides should be explored.

Cluster 4 – yellow, called "resilience and low carbon footprint", includes sustainability, supply chain resilience, air quality, carbon footprint, transportation and coronavirus disease 2019, popularly known as COVID-19 pandemic (Ibn-Mohammed *et al.*, 2021). The carbon footprint is a significant contributor of climate change (Agyemang *et al.*, 2019). Therefore, a study in this direction is a commendable approach in the attainment of SDGs. Additionally, Mahanty *et al.* (2021) perceived that although CE has gained traction, environmental sustainability has not been given much attention in the discourse. This observation corroborates the findings of Spreafico (2022), who appears to promote the need for a link between CE and environmental sustainability. Therefore, this shows a potential gap that can be further explored within the construction industry. Cluster 5 – purple "recycling materials" (Edike *et al.*, 2021; Oyinlola *et al.*, 2018; Mahdjoub *et al.*, 2021). The recycling process has gained traction. However, Norouzi *et al.* (2021) and Mhatre *et al.* (2021) are of the view that it is an inferior method to reusing because of the energy consumed during the recycling process. The study revealed that in Africa recycling is on the rise, but there seem to be limited standards of the end products, which deter its use. Cluster 6 – turquoise colour is called the "4th industrial revolution (4IR)" (Hoosain *et al.*, 2020; Turner *et al.*, 2021). Finally, technology is the central part of CE transition. The findings seem to contradict the study by Cimen (2021), who claimed that construction was technology-averse. Nonetheless, Lekan *et al.* (2021) recommend that the construction sector move towards Construction 4.0 (C4.0) to complement the 4IR. These six clusters demonstrate that Africa is contributing to the CE debate within the construction industry context.

Evidently, CE in the construction industry can be perceived as an evolving concept that is characterised by new principles and practices. For instance, Mahanty *et al.* (2021) claim that the concept was for a long time characterized by the 3R model (reduce, recycle and reuse) until Potting *et al.* (2016) noted ten principles. Recently, Cimen (2021) coined the eleventh R called "Replace". Therefore, to ascertain the current trends and future areas to focus on in Africa, the study produced a co-occurrence map on all keywords. Five clusters emerged based on the number of keywords.

Cluster 1 – red: 17 keywords including CE, compressive strength, wastes and valorisation and alternative materials. The cluster confirmed the urgent call for the construction industry to think of alternative materials and waste management (Bonnaire *et al.*, 2020). However, in other continents, particularly Europe and Asia, alternative construction materials are being extensively explored (Marvila *et al.*, 2021). Such advances place Africa in the spotlight to pursue innovative construction materials. The future of construction in Africa seems to be hinging on how well the industry would adapt to innovative methods of construction and materials.

Cluster 2 – green: 11 keywords including end-of-life, recycling, sustainability and innovation. Galvao *et al.* (2018) view the CE and sustainability as complementary concepts. To put it another way, the CE exists to make sustainability a reality in the construction industry. Furthermore, as the CE is continually evolving, innovation appears to be its backbone. The innovativeness of the sector has seen the emergence of different types of materials being developed. Cimen is of the view that recycling coupled with end-of-life thinking has a great potential in advancing the circularity trajectory. Notably, other continents, such as Europe, are already advanced in the use of technologies that address both circularity and end-of-life thinking (Marvila *et al.*, 2021). The African continent cannot afford to remain behind.

Cluster 3 – blue: ten keywords including architectural design, construction and demolition and waste. CE principles appear to affect the entire lifecycle of the projects. Nonetheless, designing circular projects affords the concept a better chance of succeeding within construction (Goyal *et al.*, 2020). The design stage detects the nature of waste products. In other words, the designers have a key role to play in the movement of circularity. However, Dokter *et al.* (2021) note that the clients tend to be focused on the amount that is incurred during the construction, which determines their appetite for adopting circular practices. Studies do reveal that circular-based construction is expensive at inception, but the accrued benefits to both the economy and environment far outweigh conventional construction techniques (Patwa *et al.*, 2021; Galvao *et al.*, 2018).

Cluster 4 – yellow: nine keywords including climate change and human and viral disease. Due to lockdown restrictions imposed to curtail the COVID-19 pandemic, supply chains were allegedly disrupted, resulting in the utilisation of local products. The restrictions may have had a favourable impact on decreasing carbon emissions that contribute to climate change (Babalola and Harinarain, 2021; Hemkhaus *et al.*, 2020). Ibn-Mohammed *et al.* (2021) argue that COVID-19, although it affected the livelihood of humans across the globe, also presented the world with the opportunity to rethink how it affects the environment. With limited transport mobility due to lockdowns, cities arguably became "clean cities" (Owusu-Manu *et al.*, 2021). Some of the lessons from that experience which could be adopted in construction include the use of clean energies so that the industry contributes meaningfully to the climate change agenda.

Finally, Cluster 5 – purple: seven keywords including of additives, life cycle and phosphogypsum. There is an ongoing debate about how to replace concrete as a construction material because of its climate-changing impacts due to carbon dioxide emissions (Al-Hamrani *et al.*, 2021). The study suggests that Africa has also joined the discourse. However, contrary to Mahanty *et al.* (2021), who found a correlation between social sustainability and CE, such a link is lacking in Africa. Given the severity of Africa's social problems, it is critical to expand research in this area.

6. Conclusions

The CE in the construction industry remains inadequately explored in Africa. The study analysed 31 articles that were published from 2005 to 2021 and shows that the concept remains relatively new in Africa. Although that is the case, it seems that most African countries have incorporated CE principles in their policies. Nonetheless, these policies are still new for one to ascertain their effectiveness.

Furthermore, of the articles analysed, the six clusters, “demolition, material recovery and reuse”, “waste as a resource”, “cellulose and agro-based materials”, “resilience and low carbon footprint”, “recycling materials” and “4th industrial revolution” are shaping CE knowledge in the construction industry in Africa.

The most-cited authors in Africa include Akanbi, Oyedele, Ajayi, Akinade and Bilal. Although these authors were most cited, they had articles ranging between two and three. It should be noted that regardless of the low research output, these leading authors are making significant contributions to the ongoing circularity discourse from an African perspective. Having African contribution is of paramount importance in unravelling to the world how the continent addresses the transition from linearity to circular practices.

Evidently, the number of CE publications is quite low, ranging between two and four. This is, perhaps, a matter of concern, particularly in terms of furthering circularity. In theory, the study demonstrates that CE research output in the African construction sector is low, revealing possible gaps in the area that might be studied to expose circularity inclinations across the continent. In terms of practice, the study suggests circularity practices that might inform policy formulation and industry restructuring.

This study made a significant contribution by articulating the CE’s intellectual structure, identifying prominent scholars and highlighting platforms responsible for bringing Africa towards circularity, as well as providing concepts that will shape future trends. It should be noted that the current study used the Scopus database because of its enormous collection of abstracts and citations, which may have limited the number of articles reviewed. Finally, further study on CE in construction should be conducted using alternative databases such as WoS, Google Scholar and Dimensions to ensure a comprehensive bibliometric analysis and ascertaining of the implementation of the concept in Africa.

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Further reading

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Appendix 1

ID	Reference	Year	Title	Citations
1	Belarouf, S., Moufakkir, A., Samaouali, A., Rahier, H., and Gueraoui, K.	2021	Chemical-mineralogical characterization of concrete with recycled concrete aggregates	0
2	Drif, B., Taha, Y., Hakkou, R., and Benzaazoua, M.	2021	Integrated valorization of silver mine tailings through silver recovery and ceramic materials production	0
3	El Machi, A., Mabroum, S., Taha, Y., Tagnit-Hamou, A., Benzaazoua, M., and Hakkou, R.	2021	Use of flint from phosphate mine waste rocks as an alternative aggregates for concrete	2
4	Ibn-Mohammed, T., Mustapha, K. B., Godsell, J., Adamu, Z., Babatunde, K. A., Akintade, D. D., Acquaye, A., Fujii, H., Ndiaye, M. M., Yamoah, F. A., and Koh, S. C. L.	2021	A critical review of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies	72
5	Lekan, A., Clinton, A., and James, O.	2021	The disruptive adaptations of construction 4.0 and industry 4.0 as a pathway to a sustainable innovation and inclusive industrial technological development	2
6	Mahdjoub, N., Kalina, M., Augustine, A., and Tilley, E.	2021	Innovating traditional building materials in Chembe, Malawi: assessing post-consumer waste glass and burnt clay bricks for performance and circularity	0
7	Mukherjee, A. A., Singh, R. K., Mishra, R., and Bag, S.	2021	Application of blockchain technology for sustainability development in agricultural supply chain: justification framework	2
8	Edike, U. E., Aina, O., and Adeoye, A. B.	2021	Adoption of eco-bricks for housing: the case of Yelwa, Nigeria	0
9	Ogunbode, B. E., Nyakuma, B. B., Lawal, T. A., Yatim, J. M., Abdul, A., and Ayoosu, M. I.	2021	Morphological, microstructure, tensile and water-sorption characteristics of surface modified Kenaf fibre for sustainable biocomposite reinforcement	0
10	Windapo, A. O., and Moghayedi, A.	2020	Adoption of smart technologies and circular economy performance of buildings	11
11	Edike, U. E., Ameh, O. J., and Dada, M. O.	2020	Production and optimization of eco-bricks	4
12	Agyapong, D.	2020	Transition to circular economy: a strategic support for small and medium enterprises in the waste of electronic and electronic equipment sector	0
13	Akanbi, Lukman A, Oyedele, A. O., Oyedele, L. O., and Salami, R. O.	2020	Deep learning model for Demolition Waste Prediction in a circular economy	0

Table A1.
Literature overview

(*continued*)

ID	Reference	Year	Title	Citations
14	Belarouf, S., Samaouali, A., Gueraoui, K., and Rahier, H.	2020	Mechanical properties of concrete with recycled concrete aggregates	0
15	Belarouf, S., Samaouali, A., Moufakkir, A., Gueraoui, K., and Rahier, H.	2020	Thermal behavior of concrete with recycled concrete aggregates on the effect of temperature and composition	0
16	Caschera, D., Toro, R. G., Federici, F., Montanari, R., de Caro, T., Al-Shemy, M. T., and Adel, A. M.	2020	Green approach for the fabrication of silver-oxidized cellulose nanocomposite with antibacterial properties	8
17	Chrispim, M. C., Scholz, M., and Nolasco, M. A.	2020	A framework for resource recovery from wastewater treatment plants in megacities of developing countries	9
18	El Machi, A., Mabroum, S., Taha, Y., Tagnit-Hamou, A., Benzaazoua, M., and Hakkou, R.	2020	Valorization of phosphate mine waste rocks as aggregates for concrete	2
19	Hoosain, M. S., Paul, B. S., and Ramakrishna, S.	2020	The impact of 4ir digital technologies and circular thinking on the united nations sustainable development goals	4
20	Lamptey, T., Owusu-Manu, D.-G., Acheampong, A., Adesi, M., and Ghansah, F. A.	2020	A framework for the adoption of green business models in the Ghanaian construction industry	2
21	Landrigan, P. J., Stegeman, J. J., Fleming, L. E., Allemand, D., Anderson, D. M., Backer, L. C., Brucker-Davis, F., Chevalier, N., Corra, L., Czerucka, D., Bottein, M.-Y. D., Demeneix, B., Depledge, M., Deheyn, D. D., Dorman, C. J., Fenichel, P., Fisher, S., Gaill, F., Galgani, F., . . . Rampal, P.	2020	Human Health and Ocean Pollution	18
22	Limami, H., Manssouri, I., Cherkaoui, K., and Khaldoun, A.	2020	Study of the suitability of unfired clay bricks with polymeric HDPE \& PET wastes additives as a construction material	12
23	Mabroum, S., Aboulayt, A., Taha, Y., Benzaazoua, M., Semlal, N., and Hakkou, R.	2020	Elaboration of geopolymers based on clays by-products from phosphate mines for construction applications	18
24	Sebbar, N., Lahmili, A., Bahi, L., and Ouadif, L.	2020	Treatment of clay soils with steel slag, in road engineering	0
25	Oumnih, S., Bekkouch, N., Gharibi, E. K., Fagel, N., Elhamouti, K., and El Ouahabi, M.	2019	Phosphogypsum waste as additives to lime stabilization of bentonite	6
26	Marzouk, M., Elmaraghy, A., and Voordijk, H.	2019	Lean deconstruction approach for buildings demolition processes using BIM	6
27	Akanbi, Lukman A, Oyedele, L. O., Omoteso, K., Bilal, M., Akinade, O. O., Ajayi, A. O., Delgado, J. M. D., and Owolabi, H. A.	2019	Disassembly and deconstruction analytics system (D-DAS) for construction in a circular economy	14

(*continued*)

Table A1.

ID	Reference	Year	Title	Citations
28	Akanbi, L A, Oyedele, L. O., Akinade, O. O., Ajayi, A. O., Davila Delgado, M., Bilal, M., and Bello, S. A.	2018	Salvaging building materials in a circular economy: a BIM-based whole-life performance estimator	78
29	Elmaraghy, A., Voordijk, H., and Marzouk, M.	2018	An exploration of BIM and lean interaction in optimizing demolition projects	8
30	Oyinlola, M., Whitehead, T., Abuzeinab, A., Adefila, A., Akinola, Y., Anafi, F., Farukh, F., Jegede, O., Kandan, K., Kim, B., and Mosugu, E.	2018	Bottle house: a case study of transdisciplinary research for tackling global challenges	13
31	Missaoui, A., Said, I., Lafhaj, Z., Daoued, S., and Ali, I. B. H.	2016	Laboratory study on recycling of sediments in paving blocks	4

Note: Search string: TITLE-ABS-KEY (“circular economy” AND (“construction industry” OR “construction*” OR “building*” OR “built environment”))

Table A1.

Appendix 2

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Demolition, waste recovery and reuse	*Waste as a resource*	*Cellulose and agro-based materials*	*Resilience and low carbon footprint*	*Recycling materials*	*4th industrial revolution*
Ahmad, T.	Aboulayt, A.	Adel, A.M.	Acquaye, A.	Abriak, N.E.	Hoosain, M.S.
Ajayi, A.O.	Adesanya, E.	Al-Shemy, M.T.	Barros, R.M.	Abuzeinab, A.	Paul, B.S.
Ajayi, S.O.	Amrani, M.	Caschera, D.	Belesova, K.	Adefila, A.	Ramakrishna, S.
Akanbi, L.A.	Argane, R.	Chen, L.	Chileshe, N.	Barna, T.	Shen, L.
Akinade, O.O.	Benarchid, Y.	Childe, S.J.	Chong, W.K.	Chan, D.	
Alaka, H.A.	Benzaazoua, M.	Dolgui, A.	Drechsel, P.	Creswell, J.W.	
Arayici, Y.	Bernal, S.A.	Dubey, R.	Feng, K.	Dondi, M.	
Bello, S.A.	Bouzahzah, H.	Dufresne, A.	Geissdoerfer, M.	Hoque, M.	
Bengio, Y.	Bussiere, B.	Dutta, R.K.	Hekkert, M.	Kalina, M.	
Bilal, M.	Daafi, Y.	Gunasekaran, A.	Hubacek, K.	Kansal, R.	
Cheng, J.C.P.	Elghali, A.	Huang, J.	Hultink, E.J.	Kuehr, R.	
Coates, P.	Fernandez-Jimenez, A.	Ivanov, D.	Ibn-Mohammed, T.	Lafhaj, Z.	
Davila Delgado, J.M.	Hakkou, R.	Kumar, S.	Kirchherr, J.	Li, J.	
Davison, B.	Illikainen, M.	Li, R.	Krajnik, P.	Meyer, C.	
De Brito, J.	Kchikach, A.	Li, T.	Macharis, C.	Muyen, Z.	
Eastman, C.	Khalil, A.	Liu, Y.	Ozawa-Meida, L.	Oteng-Ababio, M.	
Erdogmus, E.	Kinnunen, P.	Luthra, S.	Preston, F.	Oyinlola, M.	
Gencel, O.	Lemougna, P.N.	Mangla, S.K.	Rameezdeen, R.	Pakrashi, V.	
Guy, B.	Li, D.	Mohanty, B.	Rashid, A.	Poon, C.S.	
Kadiri, K.O.	Loutou, M.	Sarkis, J.	Savaget, P.	Rahman, M.E.	
Kagioglou, M.	Mabroum, S.	Shankar, S.	Stahel, W.R.	Rawat, A.S.	
Kibert, C.J.	Mansori, M.	Singh, S.K.	Verlinde, S.	Taaffe, J.	
Koskela, L.	Moukannaa, S.	Thomas, S.	Wang, P.	Tilley, E.	
Li, Z.	Nazari, A.	Wang, H.	Wang, X.	Wang, W.	
Liu, G.	Provis, J.L.	Wang, Y.	Yu, X.	Whitehead, T.	
Liu, I.	Rao, A.	Wu, X.	Zhang, Q.		
Lu, W.	Roning, J.	Zhang, S.	Zhang, Z.		
Martinez-Barrera, G.	Sanjayan, J.G.	Zhang, X			
O'reilly, K.	Semlal, N.				
Ofori, G.	Taha, Y.				

(*continued*)

Table A2. List of Co-Cited Authors

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Omoteso, K.	Tanskanen, P.				
Owen, R.	Van Deventer, J.S.				
Owolabi, H.A.	Yliniemi, J.				
Oyedele, L.O.	Zhang, L.				
Rentz, O.	Zhang, Y.				
Saa, A.					
Sacks, R.					
Schultmann, F.					
Succar, B.					
Tam, V.W.					
Tam, V.W.Y.					
Teicholz, P.					
Thaheem, M.J.					
Tingley, D.D.					
Usher, C.					
Volk, R.					
Wang, J.					
Won, J.					
Wu, W.					
Xie, M.					
Yuan, H.					
Zhang, C.					

Table A2.

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