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Mapping the Dynamics of Emerging Technologies Research Trends in Africa vis-à-vis Built Environment-Related Studies

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Abstract
Compared to the conventional ones, emerging technologies (ETs) offer numerous benefits and potentials in the health and safety, digitalization, and sustainability of the construction industry (CI). To mitigate the adverse impacts of conventional materials and technologies on the human and natural environment, ETs are perceived as a panacea, especially in this fourth industrial revolution (4IR) era. However, the global research and development (R&D) focus and discourse on the subject of ETs is pioneered and is continually dominated by the developed or western countries. On the African continent, the uptake, implementation, and utilization of ETs remain in their infancy despite their potential in aiding the transition of the CI to a sustainable and 4IR-compliant sector. Hence, this study is aimed at analyzing and visualizing ET research publication outputs in Africa. A quantitative method was used to analyze the 60 bibliometric datasets extracted from the Scopus database. The datasets are ET research publication outputs from 1990 to 2022. The findings presented the trend, citations, document sources, co-occurring keywords, and most-cited ET research in Africa. The study recommends that African research and higher education (HE) institutions should embrace and commit to research, teaching, and learning on ETs to bridge the knowledge gap between Africa and the rest of the world.

Keywords
Construction Industry, Emerging Technology, Fourth Industrial Revolution (4IR), Africa, Sustainability.

1. Introduction

As indicated by Beach et al. (2013), the construction industry (CI) involves multiple professions and stakeholders making it data-intensive and highly fragmented. The complex nature of the sector and stakeholders' resistance to change is also responsible for its slow-paced transition from conventional construction practices to sustainable and innovative ones. In this present era of the fourth industrial revolution (4IR), it is believed that the infusion and implementation of innovative/emerging technologies (ETs) into the CI should top global priority. However, these technologies are characterized by some impediments and complexities. As indicated by Abdirad and Dossick (2016), these technologies are potentially costly, evolving, complex, and require extensive managerial and technical skills for their effective implementation. The study of Aghimien et al. (2020) also noted lack of training, high cost of training, high cost of technologies, and lack of digital culture as other impediments. Despite the obvious and numerous drawbacks of ETs, Day and Shoemaker (2000) posited their potential to create market opportunities and remake entirely the CI remains too attractive to discard. With the domineering and widespread influence of the 4IR on all sectors of the economy, the CI is left with no choice but to align with the trend.

The previous three industrial revolutions are instrumental and fundamental to the economic productivity and technological advances of the current 4IR (Oke & Fernandes, 2020). Despite the emergence of numerous technologies in the third revolution era, the 4IR give rise to an era of disruptive and high-level automation. Globally, the 4IR promises immensurable benefits and potential for the architecture, engineering, and construction (AEC) sector among others (Aghimien et al., 2020). The era has seen improvements in the efficiency and effectiveness of ETs and the birth of new ones. The area of application of these ETs now cut across all sectors ranging from education, defense, medical sciences, and most especially the AEC industry. To therefore maximize the potential of ETs to transform the CI,

creating awareness and their integration into the built environment (BE) education and training are imperative (Keogh & Smallwood, 2021).

According to Veletsianos (2011), the utilization of ETs in any field provides opportunities for meaningful and relevant transformation. However, it is important to note that the realization of new/ETs evolves from existing technologies (Gupta & Jha, 2015). While these ETs dominate the face of the 4IR era, it is important to note that they will likewise define the influence and nature of the coming industry 5.0 on all sectors of the economy. Notable ETs defining the 4IR era include virtual reality (VR), augmented reality (AR), robotics, internet of things (IoT), artificial intelligence (AI), blockchain/distributed ledger technology, 5th generation (5G) networks, serverless computing, biometrics, vactrain, hoverbike, jetpack, personal rapid transit, autonomous rail rapid transit, self-driving car, genetic engineering, cryonics, quantum computing, mobile collaboration, 3-dimensional printing, unmanned aerial vehicles, artificial photosynthesis, wireless energy transfer, powered exoskeleton, sonic weapon, and concentrated solar power amongst numerous others (Maull et al., 2017; Wohlgenannt et al., 2020; Abdi et al., 2021; Ahmad et al., 2021; Dein, 2021; Xiong et al., 2021). The application of these ETs can be found in entertainment, energy, electronics, materials, textile science, optoelectronics, finance, agriculture, aerospace, medical sciences, space, transport, robotics, information technology (IT) and communications, and most especially the AEC industry (Kirkwood & Price, 2013; Gros, 2016; Kumar et al., 2019). Despite the disadvantages and ills associated with the use and implementation of some of these ETs, numerous research has established that their potentials are far-reaching while calling for massive R&D into ways of effectively and efficiently optimizing the ETs in circulation.

While there has been a massive drive and trend in the adoption, and utilization of ETs in developed countries, the continent of Africa and most developing nations lag due to numerous reasons. Hence, the need for a study that presents the present state and trend of ET awareness, adoption, and application in Africa, focusing on the AEC niche. The present study sought to ascertain the trend and development of research studies on ETs in Africa covering the period from 1990 to 2022. The literature search was conducted on February 28, 2022. To better characterize and grasp the pattern of Africa's research contributions and outputs on ETs with a focus on the built environment, a bibliometric analysis was conducted.

2. Research Methodology

The objective of this study is to ascertain the trend and cogent areas of concentration in research publications on ETs within the BE-related fields. Science mapping, which is a quantitative method was used in the study. According to Moral-Muñoz et al. (2019), science mapping is a bibliometric instrument for mining and analysis of scientific and scholarly outputs, productivity, and quality. Science mapping can help in presenting scientific and scholarly works in a format that can be used to aid the description, interpretation, or evaluation of the development and state of scientific and scholarly knowledge and practices (Chen et al., 2014). The cardinal composition of science mapping consists of scientific literature, scientometric, and visual analytic instruments and indicators for identifying cogent patterns for piloting the exploration of visualized intellectual structures (Chen et al., 2017). The terms "Emerging Technology" OR "Emerging Technologies" were used to search and retrieve the bibliometric dataset from the Scopus database. Scopus database was used due to its popularity, richness, and description as a top choice for literature search globally (Aghimien et al., 2019). It is also important to know that the Scopus database by Elsevier is highly subscribed to by most research and higher education institutions across Africa. Due to its simplicity and ease of use, the VOSviewer was used to visualize and present the bibliometric networks for this study. Depending on the choice and proficiency level of the user or researcher, there are other tools such as SciMAT, BibExcel, CiteSpace II, and CitNetExplorer which can perform the same function as VOSviewer.

The search for relevant research publications was focused on published conference proceedings, journal articles, book chapters, and books within the BE-related fields. The key search words adopted were "Emerging Technology" OR "Emerging Technologies". The subject area for the search was limited to engineering, energy, materials science, environmental science, and chemical engineering. The English language was adopted as the language selection because it is the predominant language for disseminating research publications in Africa. Search countries were limited only to the continent of Africa thereby excluding other continents/countries. The time component for this study was the period from 1990 to 2022. The decision to focus on this timeframe was to understand the historical trajectory and trend of ETs in Africa and the built environment. With the key search words used, an initial search result of 37,272 (consisting of results from every continent of the world) results was obtained for the search conducted on 28 February 2022. However, based on the refinements, exclusions, and limitations adopted in the search, a total of 60 publications were exported and adopted as the dataset for this study. The refinements, exclusions, and limitations include the following: the choice of English language as the language selection, subject area limited to BE-related fields, and most

importantly the exclusion of countries from other continents except for Africa. Results are presented based on the number of publications per year, the number of publications and citations per country, publications per document source title, most cited publications, and research focuses based on co-occurring keywords. A pictorial representation of the research framework employed in this study is shown in Figure 1.

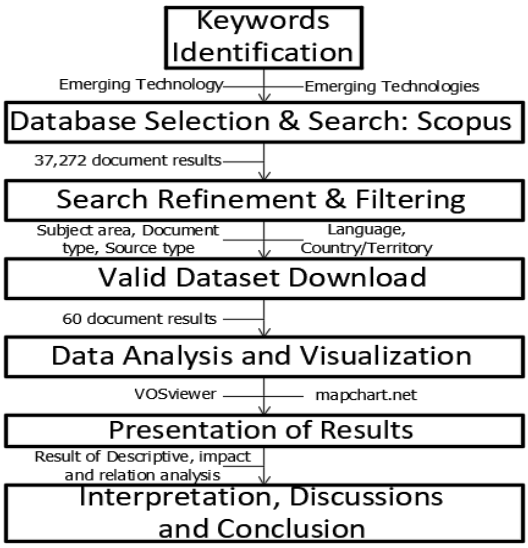

Fig. 45. Pictorial chart of the research framework

3. Results and Discussions

Trend in BE-related research publications on ETs from 1990 to 2022

A total of 60 research publications were extracted after the refinement and filtering process of the database search. Out of the 60 research publications extracted, seven (7) are book chapters, 21 are journal articles and 32 are conference articles. The number of yearly research publications on ETs in Africa from 1990 to 2022 (as of 28 February) is presented in Figure 2. Based on the result, there is no record that Africa produced any research publication on ET that is BE-related in 1990 while the period 1991 to 1994 and 1999 to 2004 recorded zero publication output as well. Compared to the rest of the world, especially the developed nations, the extremely low ET research publication output that is BE-related across Africa is a clear indication that Africa is far behind in the awareness, R&D, adoption, and implementation of ETs. According to Kissi et al. (2022), stakeholders in the BE face numerous challenges that prevent the adoption and implementation of ETs. A few of these barriers hindering the uptake of ETs are lack of awareness, paucity of ETs, lack of technical capacity on ETs, and most especially resistance to change on the part of stakeholders. It is therefore indicative that as the wave of digitalization sweeps across the global BE, Africa will be left with little or no choice but to embrace and align with the trend.

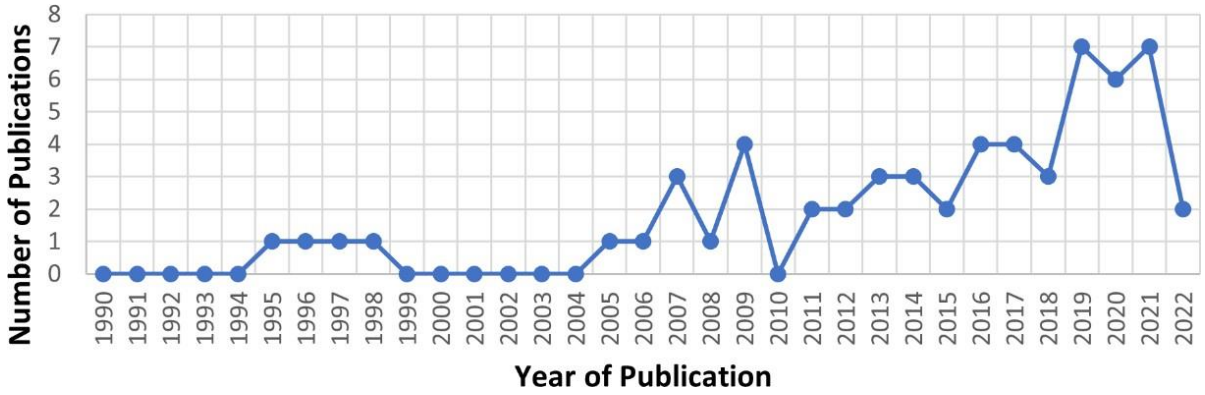

Fig. 2. Number of ET publications per year

Trend in BE-related research publications and citations on ETs per country

A total of 12 countries are found to have contributed to ET research publications that are BE-related across the continent of Africa. This result is based on the search criteria specifying only countries (owing to the low number of countries revealed in the result) with at least one ET research publication from 1990 to 2022. While most of these publications originated from one country, there are some affiliated with research and higher education institutions from other African countries and the rest of the world. Figure 3 presents the trend in research publications and citations on ETs that are BE-related per country. Based on the result, South Africa tops the chart (23 publications and 105 citations). This is followed by Egypt (9 publications and 153 citations), Tunisia (7 publications and 86 citations), Morocco (7 publications and 23 citations), Algeria (3 publications and 18 citations), Nigeria (3 publications and 1 citation), Mozambique (2 publications and 5 citations), Ethiopia (1 publication and 12 citations), and Zambia (1 publication and 2 citations). Benin, Sudan, and Zimbabwe all contribute one ET research publication with zero citations within the years in review. However, it is not surprising to see South Africa and Egypt topping the chart as both countries are at the forefront concerning R&D while they are also home to the top 10 best higher education institutions in Africa according to world university rankings.

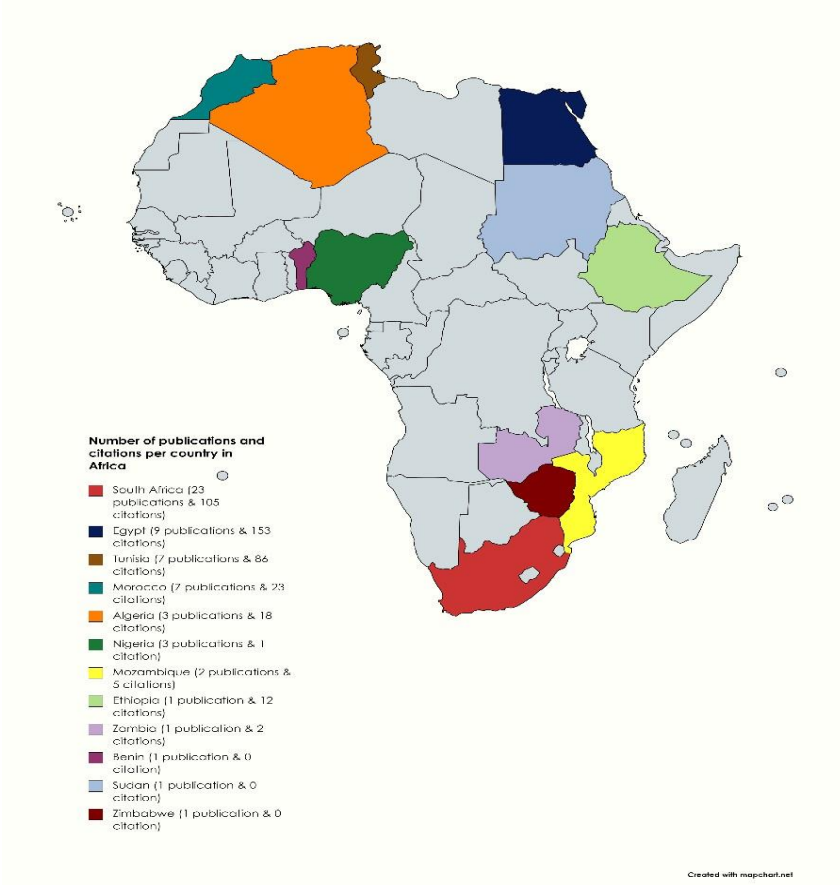

Fig. 3. Number of ET publications and citations per country

Trend in BE-related research publications on ETs per document source

This section presents the trend in BE-related research publications on ETs per document source. The dataset used in the study contains 60 research publications that are published in 54 different books, journals, and conference proceeding sources. Table 1 presents the result based on the search with document sources with at least two (2) BE-related research publications on ETs. Based on this criterion, three (3) document sources were revealed. Lecture Notes in Electrical Engineering topped the list with four (4) publications and six (6) citations. This result is not surprising as the subject area of this document source is industrial and manufacturing engineering published by Springer Nature.

Second on the chart is Materials Today: Proceedings (3 publications and 10 citations), and lastly Journal of Communications (2 publications and 11 citations).

Table 36. Number of ET publications per document source

Source title	Documents	Citations
Lecture notes in Electrical Engineering	4	6
Materials Today: Proceedings	3	10
Journal of Communications	2	11

Most cited BE-related research publications on ET

According to Zhao et al. (2020), the number of times a manuscript is cited is one of the yardsticks for judging its impact. Hence, the imperativeness of analyzing the dataset to identify the most cited BE-research publication output on ET. Table 2 presents the result showing the titles and authors of ET research publications with at least 10 citations. Out of the 60 publications that make up the dataset, only 12 have been cited for a minimum of 10 times as seen in Table 2. The publication titled "The living walls as an approach for a healthy urban environment" and authored by Sheweka and Magdy (2011) is the most cited BE-related research publication on ETs in Africa. The open-access article has 56 citations and is published in Energy Procedia by Elsevier. The study indicated that green vertical surfaces as one of the ETs have the potential to benefit the BE sustainably by directly addressing energy and climate change challenges. The study further states that the adoption and implementation of ETs can offer sustainable strategies for greening the urban environment. With the global call for sustainability especially in the AEC industry, ETs must be maximally embraced and implemented for a speedy transition of the industry to a sustainable one.

Table 2. Number of ET publications per document source

Title	Source	Citations
The living walls as an approach for an approach for a healthy urban environment	Sheweka and Magdy (2011)	56
Adsorption of a textiledye "indanthrene Blue RS (CI Vat Blue 4)" from aqueous solutions onto smectite-rich clayey rock	Chaari et al. (2009)	52
Translocation and accumulation of Cr, Hg, As, Pb, Cu and Ni by Amaranthus dubius (Amaranthaceae) from contaminated sites	Mellem et al. (2009)	52
RASID: Robust WLAN device-free passive motion detection	Kosba et al. (2012)	35
Performance of cement-slag-titanate nanofibers composite immobilized radioactive waste solution through frost and flooding events	Saleh et al. (2019)	23
Chromium and nickel removal from industrial wastewater using Tunisian clay	Ghrab et al. (2014)	18
Ripple reduction in DTC drives by using a three-level NPC VSI	Messaïf et al. (2007)	16
Recent trends in the cleaning of diesel fuels via desulfurization processes	Hanafi and Mohamed (2011)	16
Studies of lead retention from aqueous solutions using iron-oxide-coated sorbents	Boujelben et al. (2009)	13
Phytoremediation of chromium from tannery wastewater using local plant species	Kassaye et al. (2017)	12
Sustainable development: a conceptual framework for the technology management field of knowledge and a departure for further research	Brent and Pretorious (2008)	12
An overview of smart grid cyber-security state of the art study	Dari and Essaaidi (2016)	11

Trend in BE-related research publications on ET per co-occurring keywords

Keywords and relations among sets of keywords constitute the networks of co-occurring keywords (Darko et al., 2020). Co-occurrence of keywords creates an understanding of the instances where two or more keywords occur together. According to Wuni et al. (2019), keywords are necessary for indexing articles in databases because they reflect the theme of such publications. The study of Aghimien et al. (2019) stated that a proper clustering of keywords into themes can help in explaining focus areas of previous studies on the subject. With the aid of VOSviewer software, a keywords co-occurrence network was developed. The unit of analysis is set to all keywords, the type of analysis is set to co-occurrence, the counting method is set to full counting, and a value of three (3) is set which is the minimum number of occurrences of a keyword accepted based on the dataset loaded into VOSviewer. The analysis showed a total of 785 keywords for all 60 research publications that make up the dataset. Out of these keywords, 17 met the threshold of three (3) co-occurrences which were further categorized into four (4) themes/clusters. Based on the number of occurrences, total link strength, and tabulated in descending order, the 17 co-occurring keywords are

presented in Table 3. According to Wuni et al. (2019), computing the Pearson product-moment correlation coefficient (r) between the number of occurrences and total link strength is an indication of a strong correlation between the indices. Therefore, the higher the occurrence of a keyword, the higher its chances of co-occurring with other frequently used keywords in ET research. The study of Zhang et al. (2020) amongst numerous other studies also subscribe and align with the same approach as used in this study.

Table 3. Number of co-occurring ET publications keywords

Keywords	Occurrences	Total link strength
Emerging technologies	26	28
Adsorption	3	17
Isotherm	3	17
Water treatment	3	17
Article	3	16
Chemicals removal (water treatment)	3	16
Solutions	3	15
Chromium	3	12
Wastewater	3	12
Wastewater treatment	3	9
Wireless sensor networks	4	6
Energy efficiency	3	5
Electric power transmission networks	3	3
Mobile telecommunication systems	3	3
Research	3	3
Wireless telecommunication system	3	3
Artificial intelligence	3	2

The network visualization map for co-occurring ET keywords is presented in Figure 4 as generated from VOSviewer. At the center of the map is the "emerging technologies" keyword to which all other keywords are linked. Cluster 1 (the green network of the map) contains 6 keywords namely artificial intelligence, electric power transmission networks, emerging technologies, energy efficiency, research, and wireless sensor networks. Cluster 2 (the red network of the map) also contains 6 keywords namely adsorption, article, chemicals removal (water treatment), isotherm, solutions, and water treatment. Cluster 3 (the blue network of the map) contains 3 keywords namely chromium, wastewater, and wastewater treatment. Cluster 4 (the yellow network of the map) contains 2 keywords namely mobile telecommunication systems and wireless telecommunication systems.

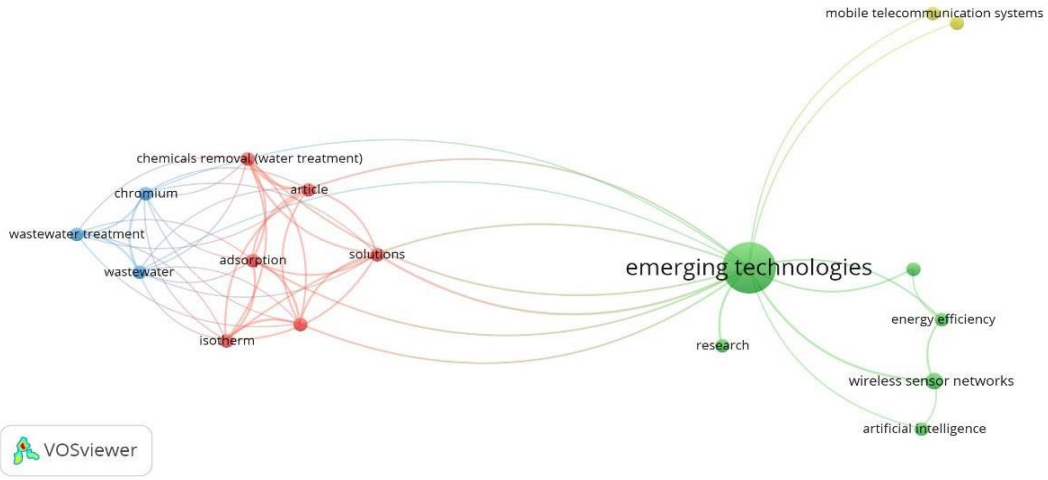

Fig. 4. Network visualization map for co-occurring ET keywords

4. Conclusion and Recommendations

This study sets out to identify the trend and research focus in BE-related ET research publication outputs using a bibliometric approach and with a focus on Africa. Based on the extracted dataset which are ET research publications indexed in the Scopus database between 1990 and 2022 (as of 28 February), the study has been able to understand the trend and key areas of concentration in ET-related research within the BE in Africa. Based on the findings, it can be concluded that the continent of Africa lags compared to the rest of the world with the R&D, adoption, and implementation of ETs. This is evident in the very low research publications on ET that are BE-related which emanated from Africa between 1990 and 2022. However, the highest number of publications of seven (7) recorded in 2019 and 2021 shows steady growth in the awareness level of ETs leading to the research output. With the current coronavirus (COVID-19) ravaging the world thereby forcing everyone to embrace technology and digitalization, it is believed that the AEC industry will be left with no choice but to massively embrace ETs for survival and to stay afloat. Out of the 54 countries that made up the continent of Africa, only 12 countries contributed to BE-related research publications on ET, namely South Africa, Egypt, Nigeria, Zambia, Zimbabwe, Mozambique, Tunisia, Morocco, Algeria, Ethiopia, Benin, and Sudan, representing 22.22%. This is extremely low if the African continent decisively intends to develop and thrive in this era of the 4IR.

While this study has been able to identify the state of ET adoption in the African BE, it is important and recommended that stakeholders in the industry alongside the African Union (AU), non-governmental organizations (NGOs), and other relevant governmental and inter-governmental agencies partner together to drive the digitalization of Africa. It is also recommended that further study is conducted to collect more data from other databases through web-scraping using text mining tools. This will ensure that BE-related ET research publications indexed in databases apart from Scopus are captured, extracted, and analyzed. Finally, it is recommended that massive investment should be directed towards the ET market, R&D, education and training, capacity development, awareness, and technology and knowledge transfer.

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