A bibliometric and scientometric analysis-based review of environmental health and safety research in the construction industry

Juliet Owusu-Boadi
Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Ernest Kissi
Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa

Ivy Maame Abu, Cecilia Dapaah Owusu and Bernard Baiden
Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Caleb Debrah
Department of Building and Real Estate (BRE), The Hong Kong Polytechnic University, Hung Hom, China

Abstract

Purpose – The construction business is widely recognised for its inherent complexity and dynamic nature, which stems from the nature of the job involved. The industry is often regarded as one of the most challenging industries globally in terms of implementing environmental, health and safety (EHS) practices. However, in the absence of EHS, the construction industry cannot be considered sustainable. Therefore, this study aims to identify the trends, knowledge gaps and implications of EHS research to enhance construction activities and knowledge.

Design/methodology/approach – The study adopted a science mapping approach involving bibliometric and scientometric analysis of 407 construction EHS publications from the Scopus database with the VOSviewer software. The study is based on journal articles from the Scopus database without restriction to any time range.

Findings – The main focus of construction EHS research identified in the study includes sustainability-related studies, risk-related, environmental issues, EHS management, integrated management systems studies, health and safety related and EHS in the construction process. Some emerging areas also identified include productivity, design, culture, social sustainability and machine learning. The most influential and productive publication sources, countries/regions and EHS publications with the highest impact were also determined.

Research limitations/implications – Documents published in the Scopus database were considered for analysis because of the wider coverage of the database. Journal articles written in English language represent the inclusion criteria, whereas other documents were excluded from the analysis. The study also limited the search to articles with the engineering subject area.
Practical implications – The research findings will enlighten stakeholders and practitioners on the focal knowledge areas in the EHS research domain, which are vital for enhancing EHS in the industry.

Originality/value – To the best of the authors’ knowledge, this review-based study is the first attempt to internationally conduct a science mapping on extant literature in the EHS research domain through bibliometric and scientometric assessments.

Keywords Environmental, health and safety (EHS), Bibliometric, Scientometric, Construction industry

Paper type Literature review

1. Introduction

More than 10% of the global gross domestic product is generated by the building industry, which in turn stimulates national economies (Bawane, 2017; Sánchez et al., 2017). Despite its economic and social importance, the construction industry is one of the most dangerous in the world, responsible for numerous workplace deaths and negative environmental impacts (Health and Safety Executive, 2018; Agyekum et al., 2021a, 2021b, 2021c). Every 10 min, at least one person is killed in a construction accident somewhere in the world (Mubita et al., 2019). The adverse environmental effects, such as abiotic depletion and global warming, are estimated to be between 20% and 35% due to construction operations and activities (Opoku, 2019). In the contemporary age characterised by a liberalised market and rapid technological progress, enterprises are compelled to maintain high levels of productivity to contend with their counterparts effectively. Nevertheless, it is worth mentioning that there is a positive correlation between a company’s production level and the occurrence of work accidents (Afroh and Basaria, 2023). Owing to the interconnected nature of construction safety and environmental concerns, improving construction safety may also result in better environmental management (Zutshi and Creed, 2015; Asah-Kissiedu et al., 2021).

EHS, or environmental health and safety, has evolved into an integral part of modern business. Companies around the world use the term interchangeably with occupational health and safety (OHS; Sharma and Mishra, 2021). The protection of the well-being of employees in their different workplaces is a primary focus of safety, health and environmental concerns (Shamsuddin et al., 2015). According to Hamid et al. (2004), the four fundamental pillars of an effective management system are safety, health, environment and quality. The effective management and implementation of appropriate environmental health and safety (EHS) measures are crucial in attaining organisational goals and enhancing business productivity.

The construction business is widely recognised for its inherent complexity and dynamic nature, which stems from the nature of the job involved. The building process encompasses various stages, including viability assessment, design development, planning, execution, decommissioning, demolition and clearing (Hassan, 2012). According to Lazarevic and Perry (2004), contractors frequently engage in the practice of replacing their staff. This practice, combined with the open environment in which the workers operate, increases their susceptibility to infections. The construction industry is often regarded as one of the most challenging industries globally in terms of implementing EHS practices, as indicated by Eurostat in 2008. Construction projects are commonly confronted with a multitude of intricate and varied OHS and environmental (OHSE) hazards (Sui et al., 2020; Ruuska et al., 2011; Zou et al., 2007). If the right management of these risks is not implemented, it will adversely affect the OHS of workers and the environment (Kim et al., 2019). However, many companies perceive EHS issues as a financial burden that might increase production costs (Hassan, 2012).
EHS has attracted researchers from developed and developing nations, leading to several initiatives to better EHS. Several studies have significantly contributed to EHS construction research (Asah-Kissiedu, 2019; Asah-Kissiedu et al., 2021; Soltanzadeh et al., 2022). However, review papers on the subject remain necessary (Jin et al., 2019), as Kunisch et al. (2018) showed that reviews can shed light on the nature of a field’s research by highlighting its dominating research foci, knowledge gaps and emerging trends. Therefore, this study reviewed EHS research works in construction using the science mapping approach through bibliometric and scientometric analysis. The subject of what new knowledge areas are emerging in the EHS research field was addressed by this study through a mapping of existing studies, which can be used for future research and bringing it to the attention of practitioners. The study also presents the most influential countries, articles with the highest impact on EHS research, the most dominating publication sources and the most focused areas in EHS research.

2. Literature review

2.1 Empirical studies on EHS

Globally, the performance of OHSE management of the construction industry is deemed poor. This is evident in Health and Safety Executive (2021) and ILO (2018), which indicated a disproportionality in accident rates compared to the workforce and other industries. Other previous studies, such as Shen and Tam (2002), Asah-Kissiedu et al. (2021) and Opoku (2019), have also stated the contribution of construction activities to environmental pollution in terms of air, water, noise, traffic, landscape, energy, waste, etc. Hence, Uher (1999) posited that construction activities, including off-site, onsite and operational activities, substantially influence the environment. The construction industry is continually faced with challenges in terms of environmental health and safety risk factors and other risk factors (Soltanzadeh et al., 2022). Therefore, Rowlinson and Jia (2015) and Kim et al. (2019) mentioned the various risk factors in construction, including personal risks, environmental risks (unsafe conditions), occupational risks, unsafe acts and managerial/organisational factors. In a case study, Peckitt and Coppin (2005) also suggested that the limitations in EHS management of construction projects are usually caused by factors such as Crown immunity, focus on cost and time, traditional procurement practices and political influence to deliver projects on time. Previous studies also report on the EHS practices implemented on construction sites: green construction, lean construction, sustainable construction, safety training, accident reporting, risk assessment, proper use of PPEs and clothing, provision and execution of EHS management plans, inspections, audits, permit to work, toolbox talks, etc. (Hassan, 2012; Windapo and Jegede, 2013; Umeokafor, 2015; Vyas and Jha, 2016; Zang et al., 2022; Samsudin et al., 2022). Owing to the severity of losses and damages caused by construction projects, most nations have made the establishment of a suitable risk management process a national priority to reduce accidents (Sousa et al., 2014). In EHS management, Peckitt and Coppin (2005) indicated that the design process for construction could be enhanced by placing greater emphasis on EHS risk assessment, sharing best practices, standardisation and waste reduction. Moreover, Kibert and Coble (1995) suggested integrating construction safety and environmental regulations, such as some EPA and OSHA functions, will enhance efficiency while minimising conflicting guidance from agencies and improving the quality of workers’ safety and environmental protection. The integration of these functions would need management systems (MS) in various firms for effective implementation (Koehn and Datta, 2003). Hence, the systematic approach developed to handle EHS issues for projects is documented in EHSMS (Vandermolen and Cella, 1999; Remmen et al., 2007), which follows specific standards, ISO 14001 and Occupational Health Safety Assessment Series.
Asah-Kissiedu et al. (2021) asserted the need for organisational capability for effective EHSMS implementation in construction firms in terms of strategy, process, people, resources and information. Using the Modified Waterfall Model with IT experts, Leyesa et al. (2022) developed a decision support system in EHS to aid the implementation of an effective integrated management system (IMS) regarding the easier storage, retrieval and update of pertinent documents, whereas Gangolells et al. (2013) developed a model which focused on the sub-systems for on-site environmental impacts and health and safety risks to enhance MS in construction firms.

Owing to the relevance of EHS, the subject has gained popularity in various fields of study and industries, including the health sector, manufacturing, engineering, environmental sector, agriculture, construction, etc. For instance, with studies related to the health sector, Kaplan et al. (2009) investigated ways to advance EHS for patients and workers, whereas Polivka assessed the EHS hazards experienced by home health-care providers. Saranga and Rajini (2013) also investigated the factors affecting EHS in the health sector. Acheampong and Kemp (2022) also reviewed the regulations and outcomes of EHS in the offshore oil and gas industry. In contrast, Ak et al. (2022) assessed the textile production industry’s occupational health, safety and environmental risks. Some previous studies have identified the EHS practices in the construction industry. For example, Hassan (2012) and Alhanouti and Farrell (2021) investigated the environmental, health and safety practices in the construction sector of specific countries. Asah-Kissiedu et al. (2021), Gangolells et al. (2011) and Tepaskoualos and Chountalas (2017) are studies conducted to assess the integration of EHSMS in the construction industry. Regarding MS, various studies have been done for either health and safety MS (HSMS/OHSMS) (Ligade and Thalange, 2013; Yiu et al., 2018; Yiu et al., 2019; Kineber et al., 2023) or environmental management system (Ofori et al., 2002; Owolana and Booth, 2016; Campos et al., 2016; Farouq et al., 2017) in construction.

Although the studies mentioned above have made noteworthy advancements in construction EHS research, review papers remain necessary (Jin et al., 2019). While there is a dearth of reviews in the area of EHS, there are several reviews on OHS research. For instance, in EHS research, Sharma and Mishra (2021) reviewed the research trends in OHS concerning safety culture and environmental management using a thematic structure analysis, although it is not construction-specific. Safety is one of the major reasons for technological advancement in the construction industry. Hence, Thibaud et al. (2018) reviewed studies which have investigated the application of Internet of Things in high-risk environments, health and safety industries, which include the construction sector, while Dobruca et al. (2023) reviewed the digital technologies used in construction health and safety. Studies such as Pu et al. (2023) and Guo et al. (2017) are susceptible to bias (subjectivity) due to the adoption of traditional systematic approach. Researchers in diverse domains of construction management have started to embrace intelligent methodologies, including scientometric and bibliometric analysis, building information modelling and advanced creative approaches such as causal layered analysis (Inayatullah, 2019), to tackle intricate topics and enhance performance (Adebowale and Agumba, 2022), which has become crucial to adopt these methods in the field of EHS to improve performance. Umeokafor et al. (2022) also critically reviewed construction health and safety research in developing countries using the bibliometric and scientometric analysis-based approach. Literature reviews are useful tools for gaining a broad perspective on a particular field. Bibliometric indicators have become indispensable within the scientific community to assess the current status of a particular topic and identify emerging areas of knowledge within a specific discipline (Mooghi et al., 2012; Belter, 2015). These findings create an avenue for future research and practical considerations and implications, hence its adoption for this study.
2.2 Concept of environmental health and safety

Concern for the safety of employees dates to the earliest days of the British industrial revolution. However, as production increased in the 1950s and 1960s, additional safety problems were identified beyond the traditional focus on preventing trips, falls and other similar incidents (Ashton and Crawley, 2002). It was also acknowledged that OHS issues and the working environment have become linked to environmental issues and that proper EHS conditions provide workplaces that are injury- and incident-free for all employees, visitors and contractors and improve the well-being of its workforce and local communities. As this is the case, EHS has been singled out as a critical area of study (Saranga and Rajini, 2013).

The initial voluntary formal approach to EHS management can be traced back to 1985. This development emerged due to collaborative efforts by chemical manufacturers who spearheaded the Responsible Care initiative programme. The chemical industry is the brains behind the Responsible Care project (Albareda, 2013). Many businesses and organisations have adopted and refined their EHS strategies since the 1990s. OHSAS 18001, developed through multinational collaborations, provided additional guidance that bolstered this and EHS management practices worldwide. Since the turn of the millennium, the EHS has become an interdependent aspect of businesses' sustainability efforts (Sharma and Mishra, 2021).

EHS is an academic subject and specialised field that encompasses the practical aspects of safeguarding the environment and ensuring occupational safety in the workplace. In basic terms, it is what organisations must do to ensure that their activities do not harm (Thibaud et al., 2018). Without EHS, the construction industry cannot be considered sustainable (Hassan, 2012). Integrating EHS practices effectively enhances individuals' well-being and safety while managing and mitigating the potential effects on the surrounding environment. Additionally, Stevens (2010a, 2010b) has noted that the implementation of an effective EHS programme aims to mitigate the adverse impact of an organization's operations, activities, goods and services on the environment (Saranga and Rajini, 2013).

3. Research methodology

The study adopted the bibliometric and scientometric approaches to examine and summarise studies on environmental health and safety in the construction industry. The bibliometric and scientometric research steps were followed based on various studies (Dobrucali et al., 2023; Adebowale and Agumba, 2022; Akinlolu et al., 2022; Debrah et al., 2022). Pritchard (1969) first presented the notion of bibliometric evaluation and analysis, positing that employing quantitative analysis of patterns and boundaries can offer valuable insights into research within a certain discipline. Bibliometric analysis identifies the concepts, terms and theories presented in books, articles and other sources pertinent to a specific subject by comprehensively examining their contents. The principal objective of bibliographic analysis is to furnish an exhaustive comprehension of a subject by reviewing the existing literature. Scientometric measures the performance and usefulness of various research methodologies and scientific practices. This strategy aims to evaluate the precision, correctness and validity of the underlying scientific procedures. To quantify the significance of scientific studies and spot patterns in the scholarly literature, the field of scientometrics uses techniques such as citation analysis (Aftabi, 2023). The bibliometric analysis uses science mapping techniques to visually represent the tangible characteristics of scientific research and domains and to elucidate the structure of their respective disciplines (Van Eck and Waltman, 2010; Akram et al., 2019; Akinlolu et al., 2022). Because it converts qualitative information to numerical data, it benefits researchers, journal editors and referees (Baraibar-Diez et al., 2020; Wallin, 2005).
Therefore, bibliometric analysis yields more objective and scientific findings than manual reviews (Wang et al., 2021). Hence, both bibliometric and scientometric analyses were adopted for this study.

3.1 Search for publications

The first step in conducting bibliometric research is to identify the data source. According to Pranckuté (2021), while considering various data sources, it is asserted that Web of Science and Scopus, which are multidisciplinary and selective bibliographic databases, are regarded as the most reliable and valid options. Nonetheless, this study obtained data from the Scopus database due to its larger collection of construction-related publications compared to the Web of Science database (Adebowale and Agumba, 2022; Ahmad et al., 2021; Akinlolu and Haupt, 2020; Akinlolu et al., 2020; Hosseini et al., 2018; Olawumi et al., 2018; Vigneshkumar and Salve, 2020; Yi and Chan, 2014). The keywords “Environmental” and “Health” and “Safety” were used for publications search, which resulted in 39,310 document results, as indicated in Figure 1. The search terms were used because they returned EHS articles that were more pertinent to the study’s objective. However, to provide a more

![Figure 1. Research process](image)

Source: Author’s own creation
confined and comprehensive results, “search within” field of “Title, Abstract Keywords” the in the Scopus database was explored. The search was limited to publications specific to the construction industry. The restriction resulted in 2,184 papers as of 21 June 2023. Figure 1 demonstrates the research process used for the study.

3.2 Exclusion and inclusion criteria
Second, the database was further subjected to a filtering procedure. The inclusion criteria were initially based on the language “English” and document type “article” of the publications. Thus, the search was limited to documents written in English language and articles. The inclusion criteria were restricted to scholarly articles, as these documents generally exhibit higher quality than other forms of publications, such as conference papers, owing to their rigorous peer-review procedure (Debrah et al., 2022). This yielded 1,205 papers as a result. The results were further limited to a specific subject area, “Engineering” since construction is a major domain in engineering, which reduced the outcome to 407 publications. A thorough study was also conducted on the titles and abstracts of the documents to evaluate the pertinence of the research topics exported from the Scopus database in a CSV format for further analysis.

3.3 Bibliometric analysis
Like other bibliometric studies, the VOSviewer (version 1.6.19) was used to analyse the study. The Excel data was subsequently transferred to VOSViewer software (version 1.6.19), where the necessary analysis was performed. The VOSviewer software, namely, version 1.6.19, was created by Van Eck and Waltman in 2023. VOSviewer is a software tool that offers visual representations of bibliometric networks based on distance measurements, allowing for the identification of relationships between different elements (Van Eck and Waltman, 2014). The distance between two items or nodes in a network generated by VOSviewer software inform the proximity of the element of analysis to each other. Some construction research works have adopted the VOSviewer for the purpose of reviewing the literature. For instance, it has been applied in construction labour productivity (Adebowale and Agumba, 2022), green financing (Debrah et al., 2022), construction safety management technologies (Akinlolu et al., 2022) and construction safety (Jin et al., 2019). To visualise, compute and analyse the effects of keywords, sources of papers and active regions in the field of EHS research, this study used VOSviewer for scientometric analysis. The bibliometric and scientometric analysis will form the basis for the qualitative discussions of the existing literature.

This review-based study is the first attempt to internationally conduct a science mapping on extant literature in the EHS research domain through bibliometric and scientometric assessments.

4. Data presentation and analysis
4.1 Year of publications
Researchers can assess the amount of interest in a certain subject area through the analysis of annual publications. Figure 2 presents the trend of EHS publications from 1993 to 2023, which also indicates that there are more published articles in the 21st century (2001–2023) than in the 20th century (1993–2000), indicating an upward trajectory or a rise in the interest of the subject area. The data set shows that the initial EHS study was published in 1993 (Koehn, 1993) “Infrastructure construction: Effects of social and environmental regulations”. The highest number of publications on EHS was recorded in 2022, which published 25 articles, representing 23% of the total. This was followed by 2021, where 18 published...
articles on EHS were retrieved, representing 16%. No firm conclusions can be made on the 2023 article output as of this report’s writing. Yet, its current representation shows that 15 published articles are present, representing 14% of the total. The number of publications on EHS became steady from 2017 to 2020, publishing seven to eight articles yearly. There were also some inconsistencies in the number of publications from 2005 to 2016. The minimum number of publications on EHS in the construction industry was experienced in earlier years (1993–2003); the highest number of publications recorded was two. However, a forecast of about three periods indicates the likelihood of a continuous increase in EHS publications, as depicted by the trendline in Figure 2.

4.2 Network of journal sources
Bibliometric analysis involves examining the direct citations from journals in a certain field of study, which provides insights into the significant and expanding journals within that subject (Hosseini et al., 2018). According to Darko et al. (2020), analysing academic journals across many scientific disciplines is crucial for readers and authors to identify the most reliable sources of information and choose the most suitable publication venues. Additionally, such analysis enables journal editors to make appropriate modifications to align with the objectives of their respective journals. Institutions and libraries can also derive advantages from optimising their investment in periodicals. The VOSviewer software was used for the analysis, with the chosen type of analysis being citation analysis. The unit of analysis in this study was sources. To get an ideal network, the parameters for the minimum number of documents from a source and the minimum number of citations were established at three. Of the 170 publication sources identified by the VOSviewer software, 32 met the thresholds.

However, the total link strength of each link was calculated using the software by which the sources with the greatest total link strength were chosen. The network generated produced a total of 28 items with 71 links. The total link strength for the network was 125.83. Within the network, the items represent the journals, while the links between the items or nodes represent the relationship between the journals. A link can exist between only two items (Van Eck and Waltman, 2023). This means every link within the network represents the relationship between the journals it connects. The relatedness of the journals can be informed by the closeness (distance) between them and the thickness of the link/line; hence, the higher the link strength, the more closely related the journals are. From the network diagram of the sources displayed in Figure 3, the maximum link strength between...
Safety Science and Journal of Cleaner Production with a link strength of 14.50. The journals are categorised into seven distinct clusters, each visually represented by different colours in the network. The node size and font also define the number of documents/publications of a particular journal and citations. Therefore, journals with a higher number of publications and citations are represented by larger items or nodes (Van Eck and Waltman, 2023).

Based on this information, a line graph was plotted with MS Excel, indicating the six most influential journals with a minimum of ten publications, as shown in Figure 4. These include Safety Science (45), Journal of Cleaner Production (41), Sustainability (Switzerland) (16), Journal of Construction Engineering and Management (14), Journal of Safety Research (14) and Building and Environment (11). The findings are consistent with Sharma and Mishra (2021) as the study similarly identified Safety Science as the highest publication source for research works on safety culture and environmental management. The incomplete presentation of journal names in Figure 3 can be attributed to the limitations imposed by using VOSViewer software for analysis.
4.3 Most active regions/countries
VOSviewer network was created to ascertain countries exerting the most influence in EHS research and establish collaboration. “Co-authorship” was selected as the type of analysis, the “unit of analysis” was “countries” and “full counting” was the method of counting adopted. The number of citations and the documents cited were broken down by country. The VOSviewer analytical tool collected the citations and a total number of documents, with a threshold of five publications per country, to achieve an optimal network. Out of the 81 countries identified, 31 met the threshold represented in the network. The network was attributed with 31 items and 101 links, with a total link strength of 152.

Table 1 presents the VOSviewer citation analysis of the most influential countries in EHS research, visualised in Figure 5. The countries were ranked based on the number of publications/documents published. The USA, China and the UK were discovered to be the most influential countries in this EHS collaboration network, with the USA emerging as the largest contributor to the field. The USA contributed the highest number of publications (75) and citations (2738). This was followed by the documents from China (44) and the UK (39). Australia and Malaysia both contributed 28 documents each. However, the countries were...

<table>
<thead>
<tr>
<th>Label</th>
<th>Citations</th>
<th>Avg. pub. year</th>
<th>Documents</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>2738</td>
<td>2013</td>
<td>75</td>
<td>1st</td>
</tr>
<tr>
<td>China</td>
<td>1471</td>
<td>2019</td>
<td>44</td>
<td>2nd</td>
</tr>
<tr>
<td>UK</td>
<td>846</td>
<td>2016</td>
<td>39</td>
<td>3rd</td>
</tr>
<tr>
<td>Australia</td>
<td>652</td>
<td>2017</td>
<td>28</td>
<td>4th</td>
</tr>
<tr>
<td>Malaysia</td>
<td>186</td>
<td>2020</td>
<td>28</td>
<td>5th</td>
</tr>
<tr>
<td>India</td>
<td>758</td>
<td>2019</td>
<td>27</td>
<td>6th</td>
</tr>
<tr>
<td>Iran</td>
<td>401</td>
<td>2020</td>
<td>23</td>
<td>7th</td>
</tr>
<tr>
<td>Canada</td>
<td>573</td>
<td>2016</td>
<td>18</td>
<td>8th</td>
</tr>
<tr>
<td>Turkey</td>
<td>357</td>
<td>2019</td>
<td>17</td>
<td>9th</td>
</tr>
<tr>
<td>Italy</td>
<td>312</td>
<td>2019</td>
<td>15</td>
<td>10th</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>569</td>
<td>2017</td>
<td>14</td>
<td>11th</td>
</tr>
<tr>
<td>Norway</td>
<td>446</td>
<td>2014</td>
<td>11</td>
<td>12th</td>
</tr>
<tr>
<td>Spain</td>
<td>320</td>
<td>2017</td>
<td>11</td>
<td>13th</td>
</tr>
<tr>
<td>Germany</td>
<td>335</td>
<td>2017</td>
<td>9</td>
<td>14th</td>
</tr>
<tr>
<td>Brazil</td>
<td>304</td>
<td>2018</td>
<td>9</td>
<td>15th</td>
</tr>
<tr>
<td>South Korea</td>
<td>242</td>
<td>2019</td>
<td>9</td>
<td>16th</td>
</tr>
<tr>
<td>Indonesia</td>
<td>70</td>
<td>2019</td>
<td>9</td>
<td>17th</td>
</tr>
<tr>
<td>South Africa</td>
<td>49</td>
<td>2020</td>
<td>8</td>
<td>18th</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>512</td>
<td>2018</td>
<td>7</td>
<td>19th</td>
</tr>
<tr>
<td>France</td>
<td>352</td>
<td>2015</td>
<td>7</td>
<td>20th</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>257</td>
<td>2013</td>
<td>7</td>
<td>21st</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>248</td>
<td>2021</td>
<td>7</td>
<td>22nd</td>
</tr>
<tr>
<td>Japan</td>
<td>170</td>
<td>2019</td>
<td>7</td>
<td>23rd</td>
</tr>
<tr>
<td>Egypt</td>
<td>84</td>
<td>2020</td>
<td>7</td>
<td>24th</td>
</tr>
<tr>
<td>Pakistan</td>
<td>243</td>
<td>2017</td>
<td>6</td>
<td>25th</td>
</tr>
<tr>
<td>Portugal</td>
<td>512</td>
<td>2018</td>
<td>5</td>
<td>26th</td>
</tr>
<tr>
<td>Sweden</td>
<td>217</td>
<td>2017</td>
<td>5</td>
<td>27th</td>
</tr>
<tr>
<td>Poland</td>
<td>100</td>
<td>2020</td>
<td>5</td>
<td>28th</td>
</tr>
<tr>
<td>New Zealand</td>
<td>86</td>
<td>2017</td>
<td>5</td>
<td>29th</td>
</tr>
<tr>
<td>Nigeria</td>
<td>22</td>
<td>2020</td>
<td>5</td>
<td>30th</td>
</tr>
<tr>
<td>Ghana</td>
<td>14</td>
<td>2022</td>
<td>5</td>
<td>31st</td>
</tr>
</tbody>
</table>

Table 1. Active regions/countries of EHS research

Source: Authors’ own work
ranked in such situations based on the number of citations. The continents represented in
the network include North America, Asia, Europe, South America, Africa and Australia.

However, it is evident in Table 1 that most of the developed countries from these
continents have dominated in the EHS research domain compared to the developing
countries, especially in Africa. Egypt, Nigeria and Ghana recorded very low numbers of
EHS publications. Therefore, there is a need for developing countries to improve on their
current contribution towards the research and development of the EHS domain.

4.4 Authors’ keywords co-occurrence analysis
Using keywords, researchers can narrow their focus to the most relevant articles and topics
in their field of study (Su and Lee, 2010; Vigneshkumar and Salve, 2020). Although
individual researchers may have their interpretations of certain phrases, the context in
which those keywords are used might shed light on their true meaning (Isenberg et al., 2016).

Darko et al. (2019) assert that the utilisation of keyword analysis facilitates the discernment
of pivotal study domains. The VOSviewer programme was used to generate a co-occurrence
network of keywords. A total of 1,515 keywords were retrieved from the EHS data set using
the “full counting” method, of which 36 keywords satisfied the threshold criteria. To
incorporate a certain keyword into the network, we establish a requirement of requiring a
minimum of four occurrences of the keyword. Figure 6 displays the network of 36 keywords
that have met the predetermined threshold with 113 links.

The connection lines establish the relationship between two terms (Akinlolu and Haput,
2020; Akinlolu et al., 2020). The clustering of keywords is visually represented in the figure
provided by Vigneshkumar and Salve (2020), where a distinct node colour indicates each
cluster. The nodes exhibit distinct colours, indicating the presence of four detectable
clusters. Each cluster comprises keywords that possess internal links inside their respective
clusters. According to Van Eck et al. (2017), the degree of relatedness among clusters in
terms of citations increases as their proximity increases.
Conversely, as the distance between clusters increases, their level of closeness and relatedness decreases. Cluster 1 had the highest number of items (14), presented in red nodes; Cluster 2 and Cluster 3 both covered eight items each, presented in green nodes and blue nodes, respectively. Cluster 4, which covered the minimum number of items (6), was presented in yellow nodes. Some common keywords such as environment, safety, health and safety, OHS, construction industry and health may be similar to the study’s objective but may not be focused on in the discussion of the clusters. The colour of a point in the cluster density visualisation is determined by blending the colours of many clusters. The weighting assigned to the colour of a specific cluster is determined by the number of items within the cluster present within a specified location, as depicted in Figure 8. Similar to the item density visualisation, the object’s weight is also considered (Van Eck and Waltman, 2023).

Figure 6 presents common keywords such as construction industry, OHS, health, safety, environmental management, environment, construction safety. These common keywords were excluded to achieve the emerging areas in EHS research in construction. As a result, following their removal from the list, a subsequent analysis was performed using VOSviewer, as shown in Figure 7. Figure 7 shows that some research interests, such as sustainability, sustainable development, integrated MS (IMS), risk assessment, safety management and construction management, have garnered significant attention in EHS research. However, certain key research areas that seem to be lacking extensive investigation and are rather isolated include culture, productivity, ergonomics, contractor selection (CS) and social sustainability. Nonetheless, this provides promising grounds for future research in EHS, especially in productivity, ergonomics and social sustainability research, which considers the diversity of workers.

4.4.1 Keywords network discussion. Babaii and Taase (2013) highlight the roles of keywords in articles, such as how they convey the substance of the topic under consideration in the documents. Analysing the implications reveals the areas of concentration of existing studies and can provide supplementary support for research. Figure 6 shows that culture closely relates to health, environmental and safety. This is
Environmental health and safety research

**Figure 7.**
Filtered keywords

**Source:** Author’s own creation

**Figure 8.**
Cluster density visualisation of keywords

**Source:** Author’s own creation
explained by Cummings et al. (2013) who asserted that individual characteristics mostly influenced by culture influence EHS perceptions. From an organisational perspective, Liu et al. (2023) explained that a multicultural workplace or environment will likely influence workers’ mental health and well-being. It also indicates the relatedness of construction safety, safety performance and productivity. This is evidenced by Hamidi et al. (2012), who showed an established relationship between the implementation of integrated safety systems such as EHSMS and productivity, whereas Lu et al. (2016) based their study on some human and environmental factors to investigate safety performance which can eventually affect productivity. Additionally, Figure 6 demonstrates a close relationship with sustainability, environment and health and safety, which is evidenced in studies such as Mapar et al. (2020), Brum et al. (2021) and Samsudin et al. (2022). Sustainability is also linked with risk and risk assessment, as in Guo et al. (2022). However, Figure 6 also shows a distant relationship between the construction industry, construction safety, safety management and environmental management, which has been the case as presented by most studies (Vasudha et al., 2019; Ershadi et al., 2020; Demirkesen, 2021; Asah-Kissiedu et al., 2021; Khan et al., 2022).

Also, Figure 6 suggests some knowledge gaps based on the link length or the distance between connecting items. For instance, the distance between IMS and the construction industry suggests limited research on the role of IMS in the industry. This is similar to the relatedness of construction safety and environmental management. Although previous studies affirm a direct relationship between construction safety and environmental concerns (Zutshi and Creed, 2015; Asah-Kissiedu et al., 2021), Figure 6 shows limited research. The keywords network further indicated a level of relatedness between CS and construction safety, CS and OHS. However, the link length proves the need for more research concerns in considering construction safety/OHS in CS, as Abdul Razak et al. (2021) studied in considering H&S as prequalification criteria in CS. It also indicates limited cultural and OHS research.

4.5 Publications with the highest impact
Information regarding the most cited or construction EHS publications with the highest impact informs practitioners and researchers on vital information sources in the domain. The citation count for research in EHS is promising, except for a limited number of papers specifically focused on the construction industry. The analysis of citation information was conducted on the 407 documents to identify the most frequently cited works in the field of EHS. The minimum number of citations specific to each document was set at 30. Hence, 102 documents meet the threshold. Table 2 presents the top 17 documents with the highest impact in the area of EHS in construction, depicting the presence of early development and extensive expansion within the field of research. DeJoy et al. (2004) assessed the role of safety climate by identifying the factors that determine a safety climate to achieve safety-related outcomes.

The factors include environmental conditions, safety-related policies and general organisational climate. In DeJoy et al. (2004), demographic variables were controlled and the study adopted a quantitative method using a questionnaire as a data collection instrument. Zheng et al. (2012) assumed the second position as one of the most highly impacted publications with 308 citations. The study was considered due to its holistic nature in terms of industries, as it evaluated the hot and humid working environments and how they affect productivity and safety outcomes. Zeng et al. (2007) investigated using IMS while considering quality, environment, health and safety MS. The study identified certain challenges with IMS and the factors that influence the implementation of IMS (external and internal). The findings
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Title</th>
<th>Journal</th>
<th>Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>DeJoy et al.</td>
<td>2004</td>
<td>Creating safer workplaces: Assessing the determinants and role of safety climate</td>
<td><em>Journal of Safety Research</em></td>
<td>321</td>
</tr>
<tr>
<td>Zeng et al.</td>
<td>2007</td>
<td>A synergetic model for implementing an integrated management system: an empirical study in China</td>
<td><em>Journal of Cleaner Production</em></td>
<td>239</td>
</tr>
<tr>
<td>Choudhry</td>
<td>2014</td>
<td>Behaviour-based safety on construction sites: a case study</td>
<td><em>Accident analysis and prevention</em></td>
<td>187</td>
</tr>
<tr>
<td>Santos et al.</td>
<td>2011</td>
<td>Certification and integration of management systems: the experience of Portuguese small and medium enterprises</td>
<td><em>Journal of Cleaner Production</em></td>
<td>171</td>
</tr>
<tr>
<td>Lund and Aarø</td>
<td>2004</td>
<td>Accident prevention. presentation of a model placing emphasis on human, structural and cultural factors</td>
<td><em>Safety science</em></td>
<td>165</td>
</tr>
<tr>
<td>Nahmens and Ikuma</td>
<td>2012</td>
<td>Effects of lean construction on the sustainability of modular homebuilding</td>
<td><em>Journal of Architectural Engineering</em></td>
<td>145</td>
</tr>
<tr>
<td>Disfani et al.</td>
<td>2012</td>
<td>Environmental risks of using recycled crushed glass in road applications</td>
<td><em>Journal of Cleaner Production</em></td>
<td>124</td>
</tr>
<tr>
<td>Toole and Gambatese</td>
<td>2008</td>
<td>The trajectories of prevention through design in construction</td>
<td><em>Journal of Safety Research</em></td>
<td>118</td>
</tr>
<tr>
<td>Tsang et al.</td>
<td>2018</td>
<td>An Internet of Things (IoT)-based risk monitoring system for managing cold supply chain risks</td>
<td><em>Industrial management and data systems</em></td>
<td>116</td>
</tr>
<tr>
<td>DeJoy</td>
<td>1996</td>
<td>Theoretical Models of health behaviour and Workplace Self-protective behaviour</td>
<td><em>Journal of Safety Research</em></td>
<td>116</td>
</tr>
<tr>
<td>Choudhry et al.</td>
<td>2008</td>
<td>Safety management in construction: best practices in Hong Kong</td>
<td><em>Journal of professional issues in engineering education and practice</em></td>
<td>110</td>
</tr>
<tr>
<td>Karasan et al.</td>
<td>2018</td>
<td>A new risk assessment approach: safety and critical effect analysis (SCEA) and its extension with Pythagorean fuzzy sets</td>
<td><em>Safety science</em></td>
<td>107</td>
</tr>
<tr>
<td>Yi et al.</td>
<td>2016</td>
<td>Development of an early-warning system for site work in hot and humid environments: a case study</td>
<td><em>Automation in construction</em></td>
<td>99</td>
</tr>
<tr>
<td>De Oliveira</td>
<td>2013</td>
<td>Guidelines for the integration of certifiable management systems in industrial companies</td>
<td><em>Journal of Cleaner Production</em></td>
<td>99</td>
</tr>
<tr>
<td>Rajendran et al.</td>
<td>2009</td>
<td>Impact of green building design and construction on worker safety and health</td>
<td><em>Journal of construction engineering and management</em></td>
<td>93</td>
</tr>
<tr>
<td>Hwang and Lee</td>
<td>2017</td>
<td>Wristband-type wearable health devices to measure construction workers’ physical demands</td>
<td><em>Automation in construction</em></td>
<td>91</td>
</tr>
</tbody>
</table>

**Source:** Authors’ own work

*Environmental health and safety research*

**Table 2.** Publications with the highest impact
of the study identified four major factors, each for both internal (understanding and perception, human resources, organisational structure and company culture) and external factors (technical guidance, certification bodies, stakeholders and clients and institutional environment). These are key factors that affect EHS.

Additionally, the study proposed a multi-level synergy model (strategic synergy, organisational structural-resource-cultural synergy and documentation synergy) for implementing IMS effectively. Out of the 102 document results, the least cited publications based on the limitation include Teukken et al. (2021) and Chinda (2016), which had 30 citations each. All the highly impacted documents were published in the 21st century except DeJoy (1996), which examined the theoretical models of health behaviour and workplace self-protective behaviour, with 116 citations.

4.6 Cluster discussion
As presented in Figure 6, Cluster 1 constituted 14 items, including the following keywords: sustainability, risk, risk assessment, safety, culture, environment, health and safety, CS, environmental issues, OHS, construction, construction management, ergonomics and health. Cluster 1 comprises a lot of projected items/nodes. However, the keyword with the largest circle or node is sustainability, indicating the highest number of occurrences (36). Sustainability had a total link strength of 27, with 15 links to other items. Cluster 1 has the maximum weight due to the number of items it contains; hence, the denser its colour.

Sustainability is a broad concept that refers to satisfying current needs without compromising those of future generations (Lin et al., 2021). The idea of incorporating sustainability into construction projects is not novel in the global construction sector (Babatunde et al., 2022). The concept of sustainable development in building design and construction can be described as a dynamic procedure aimed at improving and safeguarding the environmental health and well-being of the building’s occupants, construction workers, the general public and future generations (Karakhan and Gambatese, 2017). This is achieved through efficient resources and methodologies (Marjaba and Chidiac, 2016). Hence, its application in building construction is usually measured by the level of certification attained (e.g. LEED and BREEAM) to promote EHS in the construction industry.

Furthermore, the discipline of ergonomics, which examines the dynamics between individuals and their surroundings, particularly within occupational settings, has the potential to contribute to the advancement of societal sustainability (Lin et al., 2021). Therefore, Lin et al. (2021) identified two major indicators of social sustainability in the field of ergonomics (environmental concerns and workers’ health and safety). Specific keywords such as risk and culture cannot be overlooked. The construction industry is filled with a culturally heterogeneous workforce (Desimone and Harris, 1998; Starren et al., 2013) such that its composition is full of people from different countries and backgrounds (race, ethnicity, values, beliefs, religions, languages, habits, etc.) (Liu et al., 2023). A study by Liu et al. (2021) revealed that a culturally diverse construction environment causes cultural stressors that influence workers’ mental health. Also, it has been recognised that culture influences not only behaviour and interactions (Leung et al., 2006) but also the team and team outcomes (Earley and Mosakowski, 2000), and thus may have distinct effects which include its impact on EHS (Ellis et al., 2019). The construction industry is well-recognised as one of the most dangerous and accident-prone in the world due to the inherent dangers of the work (Zhou et al., 2019). Historically, the construction sector has been plagued by health, safety and environmental (HSE) risks (Soltanzadeh et al., 2022). In project management, the process includes risk management planning, risk identification, risk analysis (qualitative
and quantitative), risk response planning and risk monitoring and control. Quantified risk assessment offers a systematic structure for prioritising risk mitigation strategies based on their quantifiable success, measured by the achieved decrease in risk (Aneziris et al., 2008). Examining incidents within construction projects reveals that inadequate risk management processes have been a significant contributing factor to substantial challenges in these projects (Soltanzadeh et al., 2022). As a result, incorporating EHS activities into contracting procedures or processes such as prequalification and CS can help boost EHS performance (Abdul-Razak et al., 2021; Umeokafor et al., 2020).

Cluster 2, as indicated in Figure 6, comprises eight items. These items include the construction industry, productivity, construction safety, safety performance, safety management, machine learning, occupational safety and structural health monitoring. As part of the recent technological advancement in the construction industry, various technologies have been adopted to improve the construction environment's health, safety, and activities and different software used by construction professionals. Additionally, owing to the hazardous nature of construction activities and the numerous construction fatalities, Zhu et al. (2023) assert the use of predictive models to predict construction fatality features, as it can be used to predict workplace injury severity based on factors such as the presence or absence of certain tools, the nature of the incident and the surrounding environment (Luo et al., 2023). Previous studies have justified the relationship between work environmental conditions, safety and productivity (Hamidi et al., 2012; Mapar et al., 2020). Safety management ensures safety performance and is also a key area under EHS.

Cluster 3 presented 8 items: injury, COVID-19, sustainable development, social sustainability, green buildings, project management, design and occupational health. Within Cluster 3, sustainable development acquired the maximum number of occurrences (10) and links (8) with a total link strength of 10. Designing is one of the early activities within the construction process and construction professionals responsible for designs, especially architects, must have an in-depth understanding of prevention through design (PtD). Although this is considered one of the proactive EHS measures or interventions, it is understudied, justifying its node size and font in the network. This is confirmed by Khalil et al. (2022). Green building adoption is another measure to ensure environmental protection and the reduction of carbon emissions through construction (Zhang et al., 2022; Vyasa and Jha, 2016). In the context of sustainable development goals, there is a parallel challenge between EHS sustainability (Cunningham et al., 2010). It is also evident that health, safety and environmental issues of sustainability are inextricably linked and should be regarded as a necessary infrastructure on the social dimension of sustainability (Atanda, 2019a, 2019b; Cunningham et al., 2010) and the economic one (Mapar et al., 2020; Molamohamadi and Ismail, 2014; Ozer, 2013). Organisations can better use their resources by incorporating EHS concerns related to sustainability into a single programme instead of treating them separately (Molamohamadi and Ismail, 2014; Ozer, 2013).

Cluster 4 constituted six items: environmental management, IMS, lean construction, ISO 14001, OHSAS 18001 and construction process. IMS assumed the highest occurring keyword (12) in this cluster with a total link strength of 17 and 7 links. The construction process must ensure that environmental health and safety standards are never compromised while trying to achieve project objectives (Kantová, 2021). Implementing IMS such as environmental health and safety MS in construction companies can provide solutions to the above (Gangoellels and Casals, 2012). There has been a rise in the number of construction companies using multiple MS at once during the past two decades (Tepaskovalos and Chountalas, 2017). Many businesses have combined multiple systems into one due to their structural similarities despite the different application areas between
OHSAS 18001 and ISO 14001 (environmental management and OHS, respectively). The established linkages between environmental impacts and health and safety concerns on construction sites (Gangolells et al., 2009; Gangolells et al., 2010; Ganga) are very compatible with the operational control standards that are mentioned in ISO 14001:2004 and OHSAS 18001:2007.

4.7 Key areas of EHS research in the construction industry

Drawing from Figure 6, the focus of environmental health and safety research has been presented as follows. The information regarding the corresponding studies was extracted from the bibliometric analysis data (consisting of 407 papers) that was imported into VOSviewer.

4.7.1 Sustainability related. Achieving sustainability in the construction industry and its activities has become an extremely crucial assignment. Sustainability in construction cannot be fully achieved if the environment is not protected and the health and safety of people are ignored, with the construction industry accounting for numerous accidents, diseases, deaths and environmental pollution, which disturbs sustainability and its development. As such, EHS research has extensively focused on how sustainability can be achieved through interventions and certain practices (Babatunde et al., 2022; Pradhananga et al., 2021) which protect the environment and people.

4.7.2 Integrated management systems. Over the years, most construction companies with MS have separate systems, which have been rendered ineffective due to the higher cost of operations and the repetitive nature of handling separate MS. Hence, the introduction of IMS to counter these setbacks in construction companies ensures that EHS is effectively and efficiently implemented, thereby making IMS an extensively researched area, as depicted in Figure 6, constituting certain relevant studies such as implementing integrated EHSMS in construction.

4.7.3 Environmental related. The construction industry is known for its impact on the environment (both positive and negative). With the overwhelming adverse environmental effects created through construction activities, the industry is bent on providing lasting solutions to these challenges. Hence, construction researchers focused on environmental issues, an aspect of EHS. Most studies examined how construction contributes to noise pollution building carbonation, as studied by Ning et al. (2019), Mir et al. (2022) and Muñoz et al. (2023). Construction activities also demand workers to mostly work under harsh environmental conditions, which can cause heat stress and other health concerns. However, the construction industry currently seeks to alleviate environmental pollution through innovations such as smart cities and AI (Liu et al., 2021). Moreover, certain construction raw materials such as cement and steel bars contain nanoparticles, which may be detrimental to EHS, hence the adoption of nanotechnology innovations (Nandekar and Rautdesai, 2019).

4.7.4 EHS management. Previous studies have opined that construction activities continually face EHS risks and other risk factors. As such, there is a need for proper management of EHS to enhance project success. EHS management must be an integral strategy and program in construction project management. For EHS management to be effective, Kibert and Coble (1995) suggest establishing and implementing EHS regulations. Other studies also suggest using PPEs and other smart wearable safety devices to enhance effective EHS through real-time monitoring of workers (Hwang and Lee, 2017; Nnaji et al., 2021; Ibrahim et al., 2023).

4.7.5 Health and safety related. Owing to the risky nature of construction activities, construction safety has received much attention empirically and practically. Various dimensions of H&S have been studied, which is essential for EHS research. Here, studies
such as safety informatics under the area of safety science (Wang and Wu, 2020), accident causation (Demirkesen, 2021; Rostamzadeh et al., 2023), safety standards (Raheem and Hinze, 2014), preventive and safety measures, health and safety management (Vasudha et al., 2019; Shaik and Siva Kishore, 2017) and others.

4.7.6 Risk-related studies. Construction comes with several risks. As evidenced in Figure 6, several studies have probed into this aspect in EHS research. EHS risk factors include human factors, biological factors, environmental factors, thermal factors, etc. An effective management of these EHS risks in construction requires certain activities such as a risk management plan, risk identification, risk assessment or analysis and risk reduction strategies, as mentioned in Aneziris et al. (2008), Soltanzadeh et al. (2022) and Khan et al. (2023).

4.7.7 Construction process. As crucial as EHS is, it is believed that EHS must be considered throughout the construction process. A firm consideration of EHS in the pre-construction (design and procurement), for instance, how PtD can help achieve the sustainable aspect of safety, construction stage and post-construction (operation, maintenance and demolition) creates sustainable construction and development as suggested by Shen and Walker (2001), Karakhan and Gambatese (2017) and Alshamrani et al. (2023).

5. Conclusion
The study reviewed existing literature on EHS in construction and identified gaps that can be explored for further studies. This review-based study adopted the bibliometric and scientometric analysis for its science mapping, which used 407 documents in the field of EHS in construction. Scopus database was used for publication search. The findings revealed that EHS research published and indexed in the Scopus database was conducted from 1993 till date. However, a majority of identified publications were published in the 21st century.

Theoretically, the study identified the major areas of study and emerging areas in EHS research in the construction industry. The more focused regions include sustainability, IMS, EHS management, environmental-related, health and safety-related studies, EHS risk-related and EHS in the construction process. Despite experiencing consistent growth in recent years, EHS remains an embryonic research field that necessitates renewed attention from the academic community, particularly within the construction industry, as evidenced by the findings. Emerging areas in construction EHS research that serve knowledge gaps identified include productivity, design, culture, social sustainability and machine learning. Practitioners and policymakers may use the results to assess their degree of development in relation to EHS practices. Additionally, these findings can be used to identify areas for improvement in enhancing EHS standards within the construction sector.

6. Implications of study
Overall, the study has shown that there is a need for researchers and practitioners to give more attention to EHS in construction activities. The study has also demonstrated the relatedness among these constructs, environment, health and safety in construction. In terms of theory, the study has largely contributed to expanding the frontiers while delving into existing EHS studies. Plausibly, it is believed that this research will be the basis for further research that will critically examine EHS, especially in the construction sector. This research serves as a greater call to practitioners to consider and identify the common good of EHS as a relatedness concept and give it greater prominence to enhance successful project delivery. Thus, the applicability of one is dependent on the other. Finally, the study identified emerging areas key to the construction of EHS research for further examination.
7. Future study directions

Based on the qualitative assessment of the existing EHS research, the suggested directions for future studies include:

- Identifying the most influential or dominating countries in EHS research also suggested the underrepresentation of construction EHS research in most countries. With the number of countries in the world (about 195), only 81 countries were identified, indicating the need for the global promotion of construction EHS research. Hence, there is a gap to be filled by academics in various countries. Research work in EHS should focus on developing countries, especially African countries where the subject of EHS is understudied. Global promotion of construction EHS research will ensure that no country is left behind in environmental health and safety to enhance the achievement of more sustainable development goals.

- Though the keywords network showed a close relatedness of construction safety, safety performance and productivity, the sizes of each item indicate the need for more research. Since achieving an increase in productivity is an expected outcome of construction works, the role of EHS in construction productivity must be established while assessing the moderating and mediating factors.

- Identified emerging knowledge areas must further be explored in future studies. Areas such as social sustainability (e.g. diversity in construction), culture, machine learning (technology adoption) and ergonomics, which have many dimensions and their effects on EHS in construction, can further be studied. Much investigation in these areas will provide a deeper understanding to practitioners to enhance the effective implementation and management of EHS in the construction industry.

8. Limitations of study

Despite the study’s contributions, some limitations are still present, which must be considered in the interpretation of results. This study’s limitations include the inclusion criteria for bibliometric and scientometric analysis, which uses the number of publications as a metric and creates an inherent disadvantage for emerging researchers while favouring older counterparts in the field, as mentioned by previous studies (Belter, 2015). Additionally, in analysing the publications with the highest impact, it was observed that citation rates could not capture the real-life study impact, such as whether or not the work saved or improved any lives. Thus, it does not take into account alternative measures of academic influence. There is also a possibility of omission of relevant and impactful publications that have not been indexed in Scopus and other engines as specified by the VOSviewer software and, hence, are not included in the study.

Moreover, the study was limited by using documents which have been written in the English language. A choice of considering only peer-reviewed articles while not considering other document types, such as conference papers and proceedings, books, book chapters, also served as a limitation to the study. A restriction to engineering as the subject area for the extraction may also be considered a limitation of this research.

References


Aftabi, M. (2023), “Re: what is the difference between bibliometric and scientometric analyses?”, available at: www.researchgate.net/post/What_is_the_difference_between_Bibliometric_and_Scientometric_Analyses/642a73d980f2ea0b8b0e8d51/citation/download


Stevens, C. (2010b), “Are women the key to sustainable development?”.


Van Eck, N.J. and Waltman, L. (2023), “Crossref as a source of open bibliographic metadata”.


**Further reading**


**Corresponding author**
Juliet Owusu-Boadi can be contacted at: owusuboadi.j@gmail.com

For instructions on how to order reprints of this article, please visit our website: [www.emeraldgrouppublishing.com/licensing/reprints.htm](http://www.emeraldgrouppublishing.com/licensing/reprints.htm)
Or contact us for further details: permissions@emeraldinsight.com